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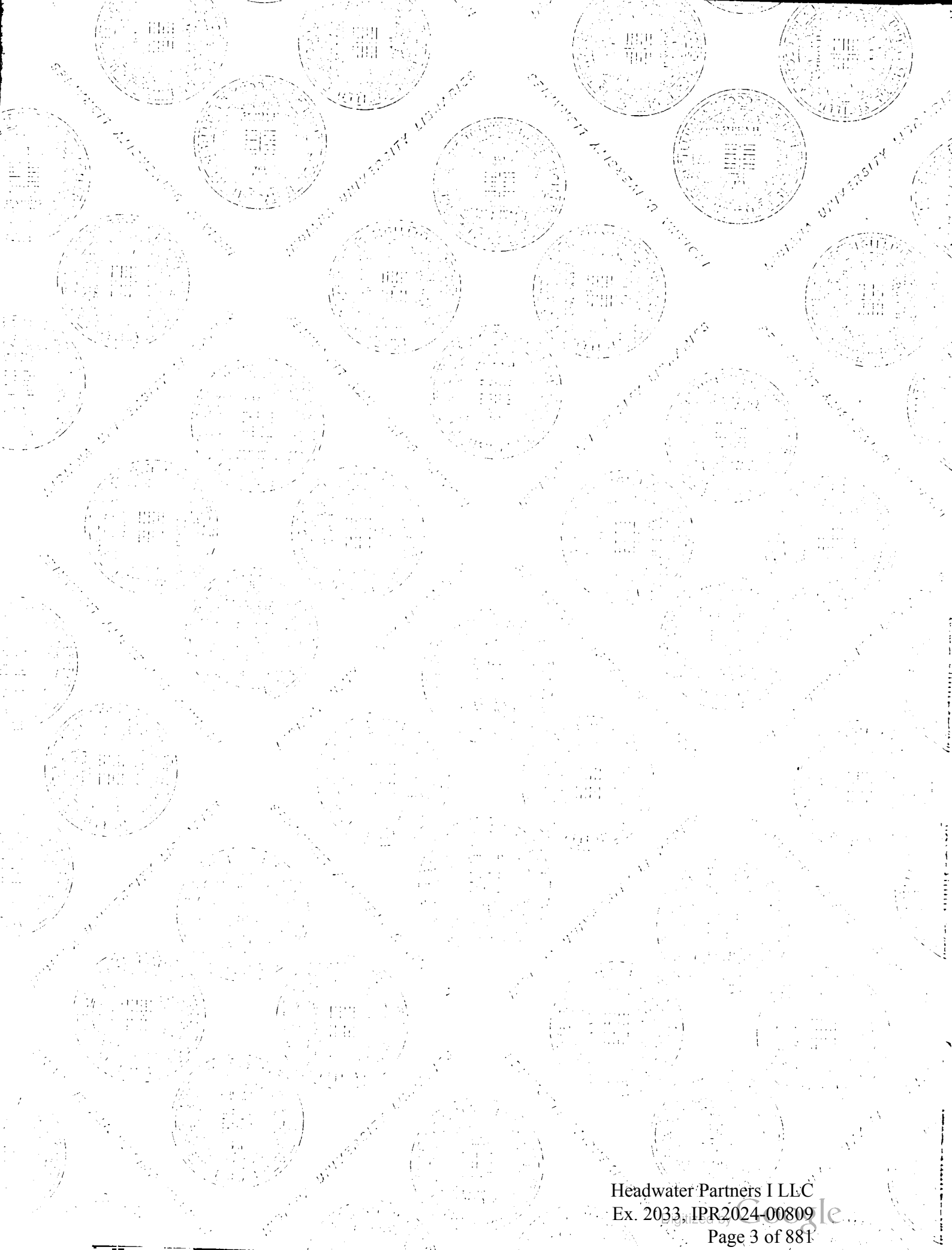
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A SURVEY OF TELECOMMUNICATIONS TECHNOLOGY PART 1

Eugene V. Rostow

President's Task Force on Communications Policy
Washington, D. C.

June 1969

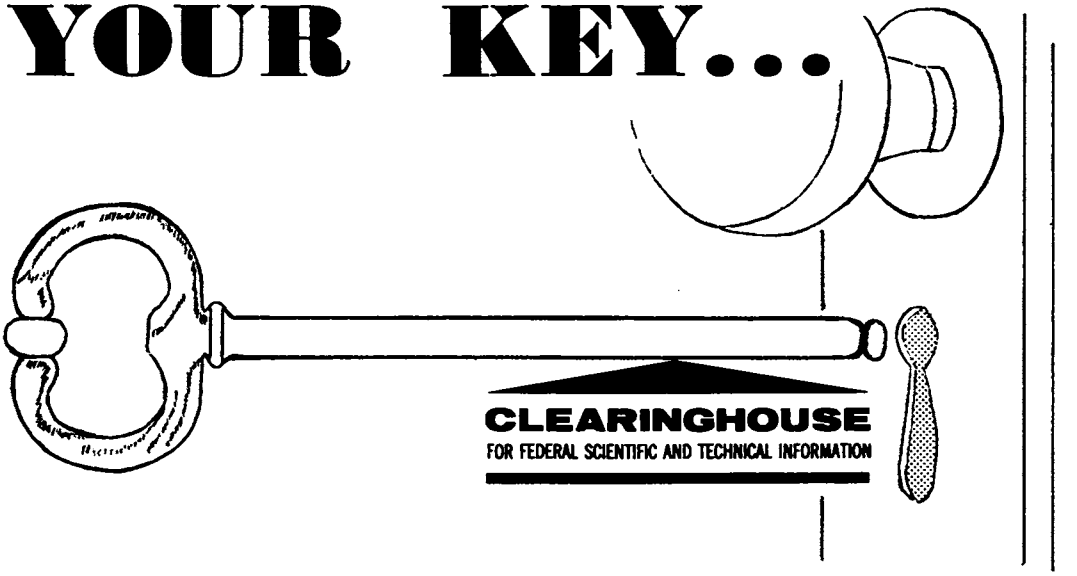
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PART 1

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STAFF PAPER ONE

A SURVEY OF TELECOMMUNICATIONS TECHNOLOGY

I. INTRODUCTION

In establishing this Task Force, President Johnson recognized that the technology of communication has entered a period of revolutionary change. New techniques for the electronic exchange of information, for the instantaneous transmission of pictures, numbers, and written material, have begun to appear at a constantly accelerating pace. These developments are expected to have a profound impact on our way of life. Some forecasts predict that communications will emerge in the last third of the 20th century as an institution comparable in importance to the automobile in the economy of the first two-thirds of the century.

At this early stage, it is vital to step back and assess the pace and direction of technological development. This paper will attempt to perform that task -- to survey the range of present and future innovations in communications techniques, to determine their costs, and to project the rate and manner in which they can realistically be expected to be deployed.

In the very limited time available to the Task Force it is, of course, impossible to undertake a study in depth of the vast range of technical developments that are currently being exploited or are on the horizon. Moreover, any projections through the next decade are necessarily subject to uncertainty, and there is disagreement among knowledgeable people. The purpose of this paper, therefore, is to provide the reader with a concise, but general, description of the prospects and problems of certain promising developments, as well as to provide the staff with a coherent use of working materials.

A. The Range of Opportunities

1. Expanding video services. In the past, television communications capacity has been limited to a few broadcast channels per community. More recently, broadband cables have been introduced to provide customers with as many as 20 television channels. Now in the planning stage are systems that would carry video technology much further. The Bell System is already operating a limited picturephone service which provides point-to-point,

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small-screen, video communications. Other potential developments include so-called "switched broadband" systems offering pictures comparable to commercial television in size and quality for point-to-point communications, shopping, or entertainment services of unlimited diversity. Making video communications as commonplace as voice communications is however a formidable task, as a single television channel requires as much information-carrying capacity as several hundred voice circuits.

2. Providing data processors with adequate communications services. In the past our communications system has served two primary functions: telephony and broadcasting. Recently a new phase has begun with automated data processing emerging as an important consumer of communications services. The data processing industry has found telecommunications increasingly attractive: It can economize by sharing large, centrally-located computers; retrieve information from computerized data banks; and permit computers to exchange programs and other data instantaneously.

There is little, however, that communications offers data processors which they cannot obtain in other ways. The

computer industry will use communications lines to share central processing and storage capacity (hardware), for example, only if the communications cost and terminal charges do not exceed the cost of duplicating processing and storage capacity. Non-electronic means of communication -- messenger services and the mails -- will also compete with teleprocessing. Therefore, the growth rate of teleprocessing will depend at least in part on the rate that telecommunication costs fall.

A related issue is the conflict between the characteristics and requirements of data communications -- the type of signal computers generate and the line speeds and error characteristics teleprocessors desire -- and the design of the present system, which is optimized for voice communications. Unless the system can be better adapted to data communications, the growth of teleprocessing may be hindered, with the teleprocessor seeking alternatives to the common-carrier communications network.

3. Producing terminal equipment which will provide access to computers for households and small businesses. The number of computer-related terminals attached to the common-carrier network is growing rapidly. Paper tape and

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card punching equipment, teletypewriters, and visual display terminals number about 200,000 today, and are likely to increase tenfold within a decade. Each of these terminals is many times as costly as a telephone handset. Businesses which exchange large amounts of data are able to bear this expense; but before a mass market of occasional users can develop for computer-based services (e.g., information-retrieval, shopping, banking) dramatic reductions will be required in the cost of data terminals.

Besides making new services such as video telephone and teleprocessing economically feasible, technological advances are enabling cost reductions also in services -- even in the face of inflation elsewhere in the economy. Besides the use of technical progress, the presence of pronounced economies of scale offer additional cost-reducing opportunities -- so long as population and national income continue to increase.

4. Cost reductions are essential in exploiting these opportunities. All the present challenges to communications technology could be met today for a customer who was indifferent to price. Every home could have a data terminal, a facsimile terminal, a video telephone, and

access to a switched broadband network offering a large medley of entertainment and shopping services. The task is to make these capabilities less costly so that they can be available on a wide scale. Thus, we have looked at the various functions performed by communications systems, with an eye to discovering opportunities for cost-reducing innovations and to appraising the impact these advances are likely to have on the overall costs of transferring information.

B. Prospects for Innovation

1. While the cost of sending large amounts of information long distances is falling rapidly, the outlook is less favorable for dramatic cost reductions elsewhere. A basic characteristic of communications technology is that the capacity of a long-haul transmission system can be enlarged without a proportionate increase in cost. Innovations in satellite, terrestrial microwave, and coaxial cable technology promise even greater economies of scale. As a result, the investment cost of adding a circuit mile of long-haul transmission facilities to the Bell System, which averages $11.00 today, will be about $1.50 in 10 years.

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But long-distance transmission represents a small fraction (about 17%) of the total cost of the telephone network, while switching (45%), terminals (23%), and local loops (15%) account for the rest. In these catagories, potential cost-reducing innovations are less apparent. Some reductions will be possible in switching; but except for special situations, the cost of local loops and terminals (particularly telephone handsets) appear quite stable.

These trends will have important consequences for services employing the common-carrier network: First, because long-haul transmission is the area of most rapid technical progress, consumers will find costs falling roughly in proportion to the distance over which they communicate. Long-haul leased lines will be in an especially favorable position for rate reductions, because they bypass local switching facilities. On the other hand, local telephone service which makes little use of long lines is unlikely to become much cheaper over the next decade. The best possibility is for some expansion in toll-free dialing.

Second, reductions in communications costs are unlikely to equal the rate at which the cost of computer

processing and storage capacity is falling. Data processing capacity has been falling in cost by 50% every 2 years; even the cost of leased long-haul circuits is not falling at a comparable rate. This comparative trend raises doubt about the ultimate prospects for bulk teleprocessing, which is economical only if additional terminal equipment is more expensive than using communications lines to share capacity. But a long-term trend to in-house data processing will not prevent growth in either the absolute volume of data communications or in its share of total communications traffic. Data processing is expanding rapidly; and for many computer users, a dramatic reversal in cost relationships would be required before ownership of their own data processing equipment would be economical.

Finally, cables used to distribute television signals locally share some characteristics of long-haul coaxial cables, and their costs are likely to fall. In the future, cable loops may also be efficient for some point-to-point communications. But such broadband services as picture telephone would require high-capacity switching plant and costly terminal equipment making them prohibitively expensive through

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the next decade except for a limited market of business customers.

2. A dedicated network for data processing may offer cheaper communications and greater flexibility. The present communications system is not ideally suited to teleprocessing. Data signals cannot pass directly into the network. They must be conditioned to assume the same form ("analog") as voice signals. Furthermore, the type of switching now used is inefficient for data signals, error characteristics are sometimes unsuitable, and data communicators cannot obtain the needed choice of bandwidths (the determinant of the speed at which information can be transferred). But teleprocessors have hesitated to establish their own, so-called "digital" system, because they would then lose the economies of scale from sharing transmission facilities with voice traffic.

In the 1970's, however, it may be practical to establish either a separate digital network or a sub-network for data customers within a shared system. On the same local distribution loops used by telephone customers, data signals could travel to local digital switches. From there they could enter directly dedicated channels on the system's

transmission lines, or a separate long-haul digital network -- perhaps provided via satellite -- by-passing the expensive multiplexing and routing facilities of the basic telephone network. A dedicated network of this kind could offer teleprocessors an increased choice of bandwidths, as well as cost savings of at least 50%. */

3. While data terminals will remain costly, the touchtone telephone instrument will offer occasional users direct access to computers. There will be some reductions in the cost of data terminals. Together with much greater reductions in computer hardware, they will make some new services such as computer-assisted instruction economically feasible during the next 10 years. But significant breakthroughs would be needed for every household to be outfitted with a teletypewriter or visual display unit. Nevertheless,

---

*/ Multiplexing involves conbining several individual channels into a single multiple-circuit channel. Digital switches can perform the multiplexing function without need for additional equipment. However, routing facilities will still be needed to steer messages through the digital network (even if satellites are used). Time-division multiplexing will be required which is expensive.

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as telephone companies install touchtone station sets throughout the country, subscribers will gain access to computers. Unlike earlier dial telephones, touchtone station sets generate pulses similar to the output of some AT&T dataphones. Of course, a touchtone handset, with no more than 12 buttons, is a less flexible data terminal than a teletypewriter; and to date output has been limited to audio responses. But combined with a television set serving as a visual display terminal, the touchtone telephone could make computerized information retrieval and shopping services available to a wide market.

C. Implications for Policy

1. Data communicators require a wide choice of services and the freedom to establish sub-networks as needed. Unlike telephone customers, teleprocessors have widely varying communications requirements. As a supplier of communications services, as well as facilities, the common carriers can satisfy these needs to a limited degree by offering a larger selection of bandwidths. But the requirement for customization among data communications is likely to exceed the diversity that franchised common carriers can provide. Therefore, teleprocessors should be free to

define their own level of service by channelizing common-carrier leased lines (dividing circuits into narrower customized channels) and connecting to common-carrier switching, multiplexing or terminal equipment provided by the customer or communications "freight forwarder." The FCC's allocation of the foreign attachments tariff is a step in this direction. Further progress would require elimination of restrictions on channelizing and line brokerage. Of course data customers should bear any added costs of adapting the network to their needs.

2. Depreciation keyed to economic life would permit investment decisions to take into account the impending availability of new technologies. Often the common-carriers must decide whether to delay construction of a switching or transmission system until a new technology, promising substantial cost reductions, becomes available. In many cases the decision turns on whether the carrier perceives a demand for expanded services that would be unsatisfied if the investment is delayed. But the level of estimated demand depends on the price that will be charged and therefore is affected by the depreciation method used. Accelerated, economic-life depreciation, which projects a

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larger share of equipment costs in the system's early years, is more likely to suggest a delay in construction until the new technology is available. It is also the preferable method in a period of technological change. Customers in the latter part of the system's life-in-use (after the new technology becomes available) should not have attributed to them amortization charges equal to those in earlier years, since they should be allowed to take advantage of the lower costs offered by the new technology.

3. Cost reductions are most needed in local loops and terminals. It appears that technical progress will continue to reduce the cost of transmission and switching while leaving local loop and terminal expenses relatively unaffected. Thus, the latter two elements of the network will represent a growing share of its costs, and significant overall cost reductions will depend on progress in these areas.

II. THE COMMON-CARRIER NETWORK

A. The Focus of Our Analysis Is the Four Elements of the Common-Carrier Network: Transmission and Switched Facilities, Local Loops and Terminals

Today most domestic communications traffic travels over the common-carrier telecommunications network -- a

maze of lines and switches permitting different users to share a common set of facilities. For analysis, we have found it useful to divide the network into four basic elements -- transmission facilities, switching facilities, local loops, and terminal -- each the subject of a separate section. Some services do not use all four elements. Mobile radio, for example, uses special terminals but no loops, and it may or may not be interconnected with switching and long-haul transmission facilities. Television distribution, involving primarily one-way transmission, uses a dedicated broadband switching plant separate from the network's main switching facilities. Nevertheless, we have found that focusing on the domestic, common-carrier switched network is the best way to illustrate the complexity of a communications system and the interaction of its component parts. Services such as mobile radio and television distribution that lie wholly or partly outside the network will be discussed, but within the context of our discussion of the common-carrier network. */

*/ We have excluded some areas as being too specialized to merit treatment in a paper aimed at a broad overview of communications technology. The most significant exclusions are radar, navigation, and meteorology -- all of which rely heavily on the same kinds of technology as the more traditional communications services and which are likely to benefit from and contribute to technological cross-fertilization.

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To understand how the network operates, it may be useful to trace a signal as it moves through it. The starting point of any network connection is a terminal device, including a modulator which transforms the voice or record signal to make it suitable for transmission over the network. The signal then passes over a local line (loop) to a switching center, known as the local exchange. The switching center selects, from numerous possible combinations of transmission lines, the path that the signal will follow. Typically, if it is a long-distance connection, the signal will pass through several intermediate switches where the long-haul transmission (trunk) lines that make up its route are interconnected. For efficient long-haul transmission, the signal will be combined with other signals (multiplexed) and will pass through repeaters which increase (amplify) its power to compensate for energy lost along the transmission path. Finally, the signal will go through a reverse process of demultiplexing, switching, and, in the recipient's terminal, demodulation until it emerges as intelligible information.

The system planner's job is not simply to find the cheapest way to perform each of the four functions in

isolation from the others. Opportunities exist for (a) substituting one function for another (e.g., using a direct transmission route between points, whose traffic was previously routed through an intermediate switching center) and (b) changing the cost of other network components by changing the way in which a function is performed. These trade-offs between switching and transmission, terminals and local distribution lines, etc., are central to the task of designing a communications network and planning its future development. In our discussion of individual network functions, we will attempt to conceptualize the most important trade-offs.

B. In Seeking to Decrease the Cost of Transferring Information, Planners Deal with Three Variables: Channel Bandwidth, Signal-to-Noise Ratio, and Coding Efficiency

In the most elementary terms, telecommunications involves transforming voice, picture, code, or symbol into information that can be carried by electromagnetic waves, traveling through space, over wire, or in enclosed tubes. It is the task of communications technology to discover the least-cost, reliable way of transferring information over the communications channels furnished by these electromagnetic waves. There are three technical determinants

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(1) Usable bandwidth -- the greater the range of frequencies which a channel can support, the more information it can carry;

(2) The amplitude (volume) of the received signal compared with the inherent background noise or interference on the channel. This relationship is commonly expressed as a signal-to-noise ratio (S/N) or signal-to-interference ratio (S/I). Success at raising these ratios may permit the communicator to dispense with bandwidth-consuming measures which might otherwise be required to preserve the signal's accuracy; it may permit use of wider bandwidths, previously ruled out by unacceptable background noise; or it may simply improve a signal's voice fidelity or accuracy of reproduction;

(3) The efficiency with which information is coded into a signal. Coding efficiency is measured by the bandwidth consumed in transmitting a given amount of information, the error rate, and the clarity of the received signal.

New technologies rarely affect only one of the three parameters. Often a trade-off exists between improvements in one factor and sacrifices in another. Digital transmission

techniques, for example, are inefficient users of bandwidth for voice communications; but they may be justified, nevertheless, by their very high resistance to noise and interference.

Cost, of course, is a factor cutting across all three parameters. Though a new technology may promise to increase usable bandwidth, signal-to-noise (or interference) ratio, or coding efficiency, if the market will not bear the cost of the additional capacity, or if it is cheaper to provide the extra capacity with existing techniques, then the technology will not be adopted.

C. The Rate of Innovation Is Limited by the Need to Adapt New Systems to Installed Equipment

Past investment decisions inhibit the introduction of new technologies into the common-carrier network. At any point in time the telecommunications grid contains several generations of equipment, all of which must be compatible. This retards innovation, because advances in switching or multiplexing technology, for example, may be incompatible with existing equipment in other parts of the system. Then either the new technique is discarded or an additional expense is incurred to preserve the system's compatibility.

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There are several methods of ensuring compatibility. The new technique can be adapted to the existing network; the network can be adapted to the new technique; or the innovation can simply be segregated from the rest of the system. Today we see examples of all three. Digital transmission facilities terminate in conversion equipment which restores the signals to analog form ("adapting the innovation"); the design of telephone handsets has been changed to permit installation of cheaper local loops ("adapting the system"); and there is in effect a separate network for long-distance transmission of television signals ("segregating the innovation"). But all these adaptive or insulating measures entail added costs, and often delay an innovation for a long time. For example, it would be technically feasible through solid state technology to provide micro-second circuit switching, useful for interconnecting real-time computer systems. But before the telephone company could install such facilities throughout the network, it would either have to replace the 100 million telephone handsets with terminals that could be rung by low-voltage signals, or more expensive line circuits would be required in the central office to insert high current ringing signals.

This added expense is likely to delay considerably the changeover to solid-state switching.

Another factor limiting the rate of innovation is the long useful lives and high ratio of fixed-to-operating cost characteristic of transmission, switching, and local distribution equipment. The annual amortization costs of a subterranean cable, for example, are four times as great as its maintenance and operating costs. These traits are less pronounced for other types of equipment, such as microwave systems. But on the whole, the major cost of a system has been incurred once the equipment has been installed; and for the remaining 15 or 20 years of the system's useful life, any innovation that would replace it in the network must demonstrate capital and operating costs that, between them, are less than the old equipment's relatively small operating costs.

III. TRANSMISSION

A. Terrestrial Microwave and Coaxial Cable Have Now Replaced Paired Wire as the Dominant Long-Haul Transmission Media

Morse's original transmission medium for telecommunications was open wire strung on poles. To accommodate large numbers of circuits for long-distance transmission,

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open wire was gradually replaced, before World War II, by twisted pairs of wire placed in large numbers inside a sheath of protective materials. As late as 1946, these two methods accounted for 97% of the telephone companies' long-distance transmission plant. But twisted pairs were characterized by interference between adjoining circuits (crosstalk), high losses, and an inability to transmit broadband signals. After World War II the common carriers began to substitute coaxial cables for twisted pairs. These offered much more usable bandwidth, with less signal degradation over long distances. At the same time the carriers introduced line-of-sight, wideband radio transmission links using the microwave portion of the electromagnetic spectrum.

Today, 93% of the long-distance telephone transmission plant consists of coaxial cable and microwave facilities. Twisted pairs of wire, however, are still the primary medium for the carriage of signals between local exchanges and telephone terminals. In the near future, the greatest challenge to microwave and coaxial cable for long-haul transmission will come from satellites, particularly for distribution services and variable-capacity routes.

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In the more distant future, newer facilities such as millimeter wave guides and laser systems may come into use where routes with densities of around 100,000 circuits are required.

B. Coaxial Cables: Free From Spectrum Limitations, Wire Transmission Media Promise Large Economies of Scale and Low Unit Costs

Wire or cable transmission has certain advantages over radio for fixed point-to-point services. Each cable can operate over a wide frequency bandwidth without encountering interference from similar frequencies in neighboring cables. The outer conductor shields the transmission path from external radiation. Microwave systems and satellites, on the other hand, can interfere with one another if they transmit over the same or neighboring frequencies on intersecting or closely adjacent paths.

Cables, however, have their own limitations. Signals are subject to power loss, especially in the higher frequencies, as they travel over the wire. Extremely high frequencies cannot pass over cables. Within a single cable, moreover, circuits operating on nearby frequencies can interfere with each other.

Since 1936, shielding technology has advanced far

enough to increase tenfold the number of coaxial lines (each containing many circuits) in a single underground tube. At the same time progress in extending the frequency range of cables has allowed greater bandwidth and, hence, more voice circuits to be carried by a coaxial line. */

Thus, the trend in overland cable design has been to achieve lower unit costs through economies of scale. **/ Ancillary developments in cable technology also link savings in circuit costs to large volumes. The millimeter wave guides, which in the 1980's may provide guided transmission in the range above 10 GHz ***/ are planned for routes

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*/ To accommodate these higher frequencies it has been necessary to shorten the spacing (from an average of 8 to 2 miles) between the repeaters which amplify dying signals along the cable's route. But the reductions in per circuit costs that come from increased cable capacity have more than offset this additional expense.

**/ From the L1 to the L3 to the L4 cable systems, voice circuit capacity has increased from 2,000 to 16,740 to 32,400 voice circuits, while annual costs per circuit mile have fallen from $3.00 to $1.50 to $.90. The L5 system, scheduled for introduction in the mid 1970's will provide 81,000 voice circuits at an annual cost of about $.35 per circuit mile.

***/Symbol for gigahertz, 1 billion cycles per second.

of 260,000 voice circuits. Meanwhile, there has been relatively modest progress in wire transmission techniques (as well as microwave systems, discussed later) for lighly traveled routes.

Ocean cables show the same trend toward economies of scale. The first voice-quality transoceanic cable was laid in 1956 with a capacity of 36 voice circuits; today's cables have 720 and those of 1975 should have 3,000. Costs per circuit mile will have decreased more than 90% from 1956 to 1970.

C. Spectrum Availability and Maintenance Cost Limit the Economies of Scale Achievable by Microwave Relay Systems

Microwaves -- extremely high-frequency radio waves in the 1-10 GHz region of the spectrum -- do not bend around obstacles or the earth's curvature but travel on a line-of-sight path. Relay towers, spaced at an average interval of 25 miles, are used to amplify microwave signals and send them on to the next tower. Like wire transmission methods, microwave is characterized by high fixed costs and large economies of scale. The newest add-on system, the TH-3, can double (12,000 to 23,000 voice circuits) the capacity of existing microwave installations

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at much less than the cost of duplication ($2.75 vs. $4.15 per circuit mile). These costs, however, are considerably above those projected for the highest capacity cable systems.

While cost reductions due to capacity increases have been significant, reductions in start-up and maintenance costs have been much more modest. The necessity of building roads to relay sites for installation, maintenance, and regular deliveries of fuel is a costly undertaking not likely to benefit from other technological developments in the communications field. Should the cost of small unattended nuclear power sources become competitive, it could become economically attractive in some locations (e.g., wild or mountainous terrain) to dispense with such road-building tasks through the use of helicopters for installation and maintenance.

Largely because of multiplex terminal costs and spectrum crowding, microwaves have not been used for short-haul transmission of telephone or television signals. Development is underway, however, on short-distance (e.g., 5-10 mile range) radio relay transmitters which operate in the above-10 GHz spectrum area -- at present, an electromagnetic no man's land. The initial market for these

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devices is likely to be CATV systems carrying television signals that require about 6 MHz per television channel. Transmitters operating in this part of the spectrum can distribute large numbers of these channels.

D. The Cost of Satellite Circuits Are Expected to Decline Sharply by the Mid-1970's.

Communication satellites provide another line-of-sight transmission medium: electromagnetic waves travel on a line-of-sight path between a ground-based transmitter or receiver and a satellite repeater, stationed about 23,000 miles above the equator in a geostationary orbit, can relay messages directly among many separate locations, whereas long chains of microwave relay links or cable facilities would be required to accomplish this function terrestrially. Several characteristics attend this single-node configuration.

1. Circuit costs are essentially independent of terrestrial distance within the coverage of a single satellite system. Terrestrial line-haul costs, by contrast, tend to be directly proportional to distance.

2. Dense routes in a satellite system have some advantage because earth station costs can be spread over a larger volume of traffic, but the total capacity of the

satellite system, serving any number of routes has a greater effect on cost. Figure 1 (from Appendix C) illustrates a model we have constructed of three satellite systems of different sizes. It demonstrates that a 24-circuit route in the largest system is less costly per circuit than a 600-circuit route in either of the other two.*/ In a terrestrial network, on the other hand, individual route size is the primary determinant of economies of scale.

3. A satellite system has the ability to reallocate capacity among the routes it serves. The capacity of terrestrial routes is fixed.

4. The entire capacity of a satellite repeater constitutes a single trunk group, permitting efficient utilization of circuit capacity (i.e., circuits are in use a large percentage of the time) without degrading service. Terrestrial media can achieve equivalent efficiency only through high-density routes and alternate routing capabilities.

5. Satellites are particularly suitable for distributing a single, wideband (e.g., television) signal

*/ The model compares the circuit costs of routes of varying density within the context of three different satellite systems -- served by satellite repeaters with total capacity of 6,750, 13,500, and 40,500 circuits, respectively. Appendix C contains a description of the model including its assumptions about the cost components.

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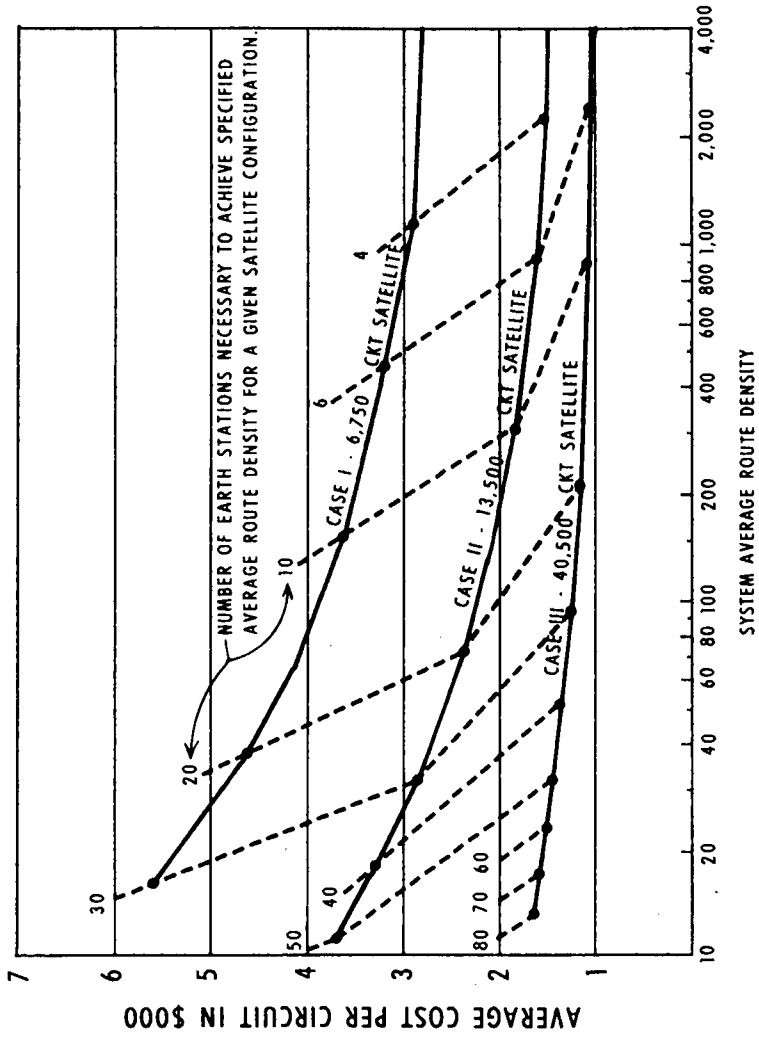


FIGURE 1. SATELLITE SYSTEMS COST TRENDS

simultaneously to many points. Except for construction cost in adding an extra reception point. Terrestrial systems generally provide wideband distribution by interconnecting a complex network of point-to-point transmission lines.

A major breakthrough in satellite technology came with the introduction, in 1963, of synchronous satellites which occupy fixed positions above the equator with respect to points on the earth. Previous random orbital satellites required costly ground stations employing tracking antennas. Since then, the principal trend has been to make improvements in the satellite which offer greater circuit capacity with existing or "standard" earth stations. One example is to increase the satellites' effective radiated power, so that ground stations can eliminate expensive "cooled-amplifier" receiver techniques and use smaller antennas.

The current generation of standard two-way INTELSAT earth stations cost between $4 and $6 million each.*/ During the 1970's, however, increased satellite power will permit

*/ These stations feature 85' diameter, tracking antennas and helium-cooled receivers providing a system noise temperature of 50 °Kelvin.

the introduction of earth stations with smaller (e.g., 30 ft.) non-tracking antennas and uncooled receiver amplifiers that will nevertheless provide the same number of circuits per unit bandwidth. Earth station costs are likely to drop to less than $500,000, i.e., by a factor of 10.

At present satellite transmission resembles broadcasting in that a signal is transmitted indiscriminately to all earth stations within the area covered by the satellite's antenna. Signals are separated out either by coding or by assigning a specified frequency channel to each pair of earth stations. The effective bandwidth available for satellite communication -- hence the net communications capacity -- would increase if different earth stations could operate on or re-use the same frequencies. This requires more directive satellite antennas, not yet in use but expected to be available in the early 1970's.*/

*/ The INTELSAT IV, now under contract for delivery by mid-1970, will employ two such directive antennas, though frequency re-use is not contemplated in the initial satellite.

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E. High-Frequency Is Plagued by Quality and Reliability Problems

In the competition among long-distance transmission modes, high-frequency (i.e., between 3 and 30 MHz) radio has suffered from quality and reliability problems, even on the long, thin routes where it is most competitive from the standpoint of cost. Appendix D describes some new techniques for HF radio which may well improve its competitive position, particularly for developing nations with very low circuit requirements. It is unclear, however, whether HF radio, even with these techniques, will support any significant traffic volume during the unfavorable part of the sunspot cycle or whether, even under favorable conditions, HF radio will be competitive with the anticipated marginal costs of adding circuits in a satellite system established for either domestic or international services.

F. Digital Transmission Techniques Offer Superior Signal Quality and Interference Protection, Particularly on Long Routes and for Radio Systems.

Almost all present facilities transmit signals in analog form: The signal imposed on the electromagnetic wave duplicates the configuration of the sound wave or data signal which entered the terminal. An alternative method,

known as digital transmission replaces analog signals with a series of binary or on-off pulses. When a voice signal enters a digital system, it is normally sampled and represented by these pulses as a multi-digit binary number (the presence of a pulse = 1; the absence of a pulse = 0). At the receiving end the pulse signal is decoded and restored to analog form. The most common version of this coding and decoding process is pulse code modulation (PCM).

For long-distance transmission, digital systems do not use the frequency division multiplexing (FDM) techniques characteristic of analog systems, where a group of narrowband signals is combined into a single wideband signal. In a digital system all signals are wideband to begin with; but through time division multiplexing (TDM), the entire long-distance channel is assigned to individual signals for brief time slots; so that each signal is received as a series of pulses, separated by pulses belonging to other signals. Thousands of digitized voice signals can be "interleaved" in time, in this fashion, without causing apparent interruptions in the ongoing conversations.

All signals, digital or analog, lose power as they pass through a transmission system and must be amplified

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at regular intervals to restore their strength. In the case of analog systems, there is no way for the repeater to separate the original signal from the "background noise" (e.g., random radiation or interference from other signals on nearby frequencies) it picks up along the way; and when it leaves the repeater, the new amplified signal contains all these extraneous elements. Digital signals, on the other hand, are relatively easy to recognize since background noise is much less likely to obscure the presence or absence of a pulse than the precise configuration of an analog signal. It is possible, therefore, for repeaters in a digital system to ignore the noise and to generate a clean signal at each relay point. Therefore, digital signal quality is superior to analog over long distances where many repeaters are used and promises higher quality long distance telephone service under these circumstances.

A digital system's offsetting disadvantage, compared to analog transmission, is the large amount of bandwidth it requires to reproduce analog signals. While data signals are inherently digital and can be efficiently transmitted over a digital system, reproducing an inherently analog voice signal in digital form requires up to 16 times

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as much bandwidth as the original voice signal itself. In the future, the bandwidth requirements of digital systems for some analog signals (e.g., video, picturephone and other wideband services) may be reduced by redundancy-removal equipment that identifies the continuing elements in a series of signals (e.g., the background of a television scene) and transmits only the signal characteristics that change over time. But today such equipment is either very expensive or else it degrades the quality of the signal.

Digital systems are presently able to overcome the disadvantage of large bandwidth requirement only (1) where the transmission medium is not bandwidth limited due to spectrum availability (e.g., cable, wire, or other guided transmission), (2) where new transmission facilities are prohibitively expensive, (3) where conventional analog methods of expanding circuit capacity or (4) where the built-in signalling capability of digital channels can be exploited. Thus far, the capability of digital signals to utilize existing cable pairs that are subject to cross-talk and voice, and the economy of built-in digital signalling, have been instrumental in promoting the use of

digital transmission in the local plant. With T-1 digital systems, Bell has been able to multiply by 12 the capacity of these existing routes.

G. For U.S. Domestic Services, Paired Wire is Likely to be the Dominant Mode on Fixed Capacity Routes of Fewer than 500 Circuits; Microwave Between 500 and 15,000; Coaxial Cable Between 15,000 and 80,000; and Wave Guides Above 80,000.

The dominant characteristic of transmission technology is the advantage of large trunk groups. First, there are strong economies of scale. As a rule of thumb, doubling the number of circuits on a terrestrial route involves an increase in total cost of about 60%. Large trunk groups also benefit from the same type of statistical efficiencies discussed in the previous section on satellite systems.

As the length and circuit density of trunk groups change, so do the relative costs of different transmission media. These shifting advantages are indicated in Figure 2. Nevertheless, there are extraneous factors that affect the choice of a transmission medium. Sometimes the trade-off is between length and channel density: Thus, paired cable is generally most attractive for trunk groups of fewer than 500 circuits, but because of paired cable's range limitations, it's greatest use is for routes of less than

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COST TRENDS IN TERRESTRIAL TRANSMISSION

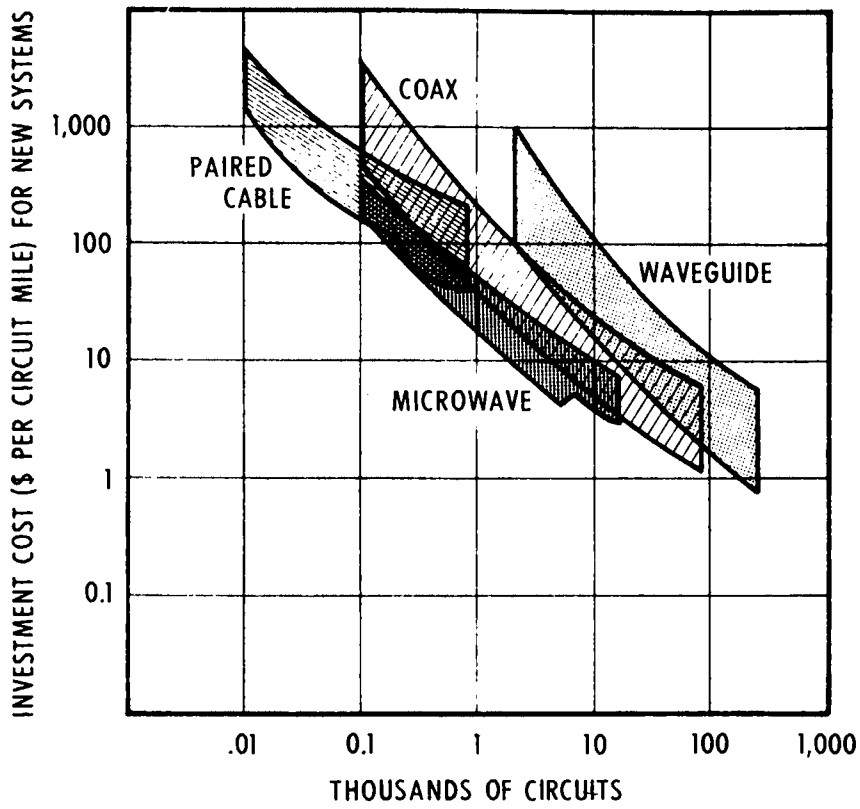


FIGURE 2

about 10 miles. Often spectrum space and terrain are important factors. The former constrains microwave, especially on approaches to cities; the latter affects primarily the capability to lay coaxial cable.

These factors aside, paired-wire cable generally dominates for fixed capacity routes of fewer than 500 circuits; microwave between 500 and 15,000; coaxial cable between 15,000 and 80,000;and wave guides above 80,000 circuits.

The expected growth in the volume of long-distance communications will allow the telephone companies to make greater use of economical, high-density transmission methods. Voice traffic is expected at least to triple by 1980. By the same time, the amount of information sent as "data," which now accounts for a very small share of long-haul transmission, may exceed that transmitted by voice.*/

Taking into account this growth in volume of traffic, Bell has predicted that by then 90% of its long-haul circuitry

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*/ Data transmission requires far less bandwidth per unit of information transmitted than does voice, thus transmission capacity required will still be determined primarily by the voice demands.

will be in coaxial cable, which means that only a small number of circuits will use relatively high-cost transmission media of fewer than 10,000 circuits. According to Bell, the average incremental line-haul investment costs per voice circuit mile will drop from $11 to about $1.40.

With respect to analog versus digital transmission methods, two technological breakthroughs expected in the 1970's promise expanded use of digital systems. Redundancy removal techniques may reduce bandwidth requirements for certain wideband services. In addition, large-scale, integrated circuitry promises to cut the costs of today's digital hardware significantly while increasing speed of operation and improving reliability. If both these advances occur, the entire telecommunications network may eventually be built around digital transmission. Until that time, however, we expect a parallel development of digital and analog technology, with the former principally used in low-grade cable and twisted-wire circuits in cities and in very long-distance circuits because of its ability to operate effectively on noisy links.

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H. Domestically, Communication Satellites Appear Most Economical for Wideband Distribution Services and for Specialized Networks Requiring Many Variable, Low-Capacity Routes

The distribution of one wideband signal to many dispersed points simultaneously via terrestrial facilities (cable or microwave relay) requires many long, interconnected routes, with attendant switching facilities. By contrast, this distribution service provided via satellite requires only a single satellite repeater which in effect "broadcasts" to a large number of receive-only earth stations, thereby avoiding the need for many intermediate relay and interconnection facilities. This should make satellites particularly attractive vis-a-vis terrestrial alternatives for distribution services.*/

*/ In various studies of domestic television distribution via satellite, it has been estimated that a receive-only television earth station will cost no more than $200,000 in the 1970's; comparable with the cost of a single radio relay terminal. Since one satellite transmission can reach hundreds of such terminals for TV distribution, the critical cost comparison will be between the satellite itself and the total of all intermediate radio relay points and interconnection (switching) facilities required to interconnect a particular network configuration. A direct satellite-to-home broadcasting system would dispense with receive-only ground stations and work directly with "augmented" household antennas. Its prospects are discussed in Section IX.

As a medium for two-way domestic communications, satellite prospects are best in providing specialized networks requiring relatively low-capacity, long-haul routes -- particularly where the satellite system's ability to vary individual route capacity to meet variations in demand can be effectively exploited. Applications where these capabilities appear particularly promising include variable information rate data networks, video-conferencing networks, computer-aided instructional networks, etc.; and of course all types of services for low traffic density, including the less developed areas of the world.

Figure 1 illustrates the unusual nature of economies of scale in satellite transmission. Total system capacity has a marked effect on per circuit costs, as indicated by the 3 separate curves for 6,750, 13,500, and 40,500 circuit-capacity satellites. On the other hand, individual route capacity, the major cost determinant for terrestrial media, is relatively unimportant in satellite systems.*/

In comparing satellite and terrestrial facilities for two-way services, it is thus apparent that neither individual route densities nor distances--nor any combination of these -- are adequate yardsticks. Meaningful comparisons can only be

*/The cost ratio between a 24-circuit route and a 600-circuit route is only 5:3, even in the lowest capacity system exhibiting the greatest variation with route density. By contrast, the equivalent ratio for terrestrial media is 10:1.

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made on the basis of total systems, with due consideration of the differences between fixed and variable capacity routes, interconnection (switching) costs, total system circuit capacity, etc.

I. On Intercontinental Routes, Communications Satellites Are Likely to Become the Dominant Mode by 1980

For intercontinental transoceanic transmission, the alternatives are HF radio, ocean cables and satellites. Despite recent improvements such as LINCOMPEX and CURTS, HF radio remains primarily suited to the very low traffic requirements and to services where high reliability and continuous availability are less important than low cost. For normal international telephony and data services, HF radio is unlikely to suffice except for the smallest, most isolated nations.

For routes where demand and the need for reliability is higher, the preferred choices will be ocean cables and satellites. The National Academy of Engineering's Committee on Telecommunications has made a cost and technology comparison of ocean cable and satellite systems for use in the Atlantic Basin through 1985. They state that:

> The technology that has been considered in this comparison is not very far from present technology. The 3,000-circuit SG cable used here is already under exploratory development,

> and its cost and performance are fairly predictable. The satellites are only minor modifications of INTELSAT-III and IV. Some minor improvements in power supplies and antenna systems have been possible. One result of these rather conservative technology forecasts, however, has been that the costs, particularly for research and development, that we have been able to use are quite low. So the cost per channel of the systems used in this comparison may well be reasonably correct for 1980, even though the actual technology used in that time period may be different from what we have projected.*/

The NAE comparison shows that, in the world area with the highest point-to-point demand -- the Atlantic Basin -- satellites are the least costly means of satisfying the demand. Cables, however, provide technical benefits which are not easily quantifiable, such as reliability, no use of radio spectrum, and better quality for some services.

IV. SWITCHING

Fundamentally, switching is a way of conserving communications lines. If there were no switches, every terminal would require a dedicated line to every other terminal. Thus, the present telephone network with 100 million terminals would need 100 million x 50 million, or 5×10^{15} separate lines. A single-node communications system, with all terminals

*/ Report of the NAE Panel on Satellites and Other Long-Haul Transmission Modes, Staff Paper Two, Appendix, pp. 19-20.

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directly connected to one centrally located switch, would reduce this figure to the minimum number of lines (i.e., 1 x 100 million or one link for every terminal). However, with the partial exception of satellites, this configuration is impractical for many reasons: the entire system would consist of costly single-circuit lines, the average length of each line would be inordinately large, and there would be no way for two nearby terminals to time-share a circuit to a distant point.*/ Therefore, a network configuration has evolved in which a group of terminals share a local switching center which, in turn, is connected via a multi-channel trunk route to a wider-area switching center, and so on through a hierarchy that currently includes five levels of switches.

A. There are Two Basic Switching Techniques: Circuit Switches Provide Continuous Connection Between Communicating Points; Store-and-Forward Switches Relay Messages After A Delay

In a network dominated by telephone service, with its requirement for uninterrupted conversation, circuit switch is

*/ In the case of satellites, once a signal has reached a transmitting earth station, every location within the area served by the satellite is directly accessible at the same line-haul transmission cost, and there is less need for intermediate consolidation and trunking, to achieve greater economies of scale. As noted previously, this mode of operation is rendered particularly attractive through the ability of a satellite system to provide variable-capacity rather than fixed-capacity routes.

the logical choice. Within this category, however, are alternative types of switches. Today space-division switching predominates; crosspoints establish a physical connection between terminals for the duration of the conversation. But an uninterrupted physical connection is not essential to circuit-switching. In a time-division circuit switch, each line entering the switch has a time slot during which its "gate" is opened, and information can pass through. The interval between these time slots must be sufficiently short to permit undistorted continuous transmission.*/ A third kind of circuit switching is called frequency division. As in a cable television system, all signals are assigned carrier frequencies within a common transmission channel, from which the recipient selects the signal he wants by switching to the assigned frequency.

Store-and-forward switching can also be performed by several methods of varying technological sophistication. On the simplest level, a telephone answering service performs the job of a store-and-forward switch. Another example is the Western Union torn-tape system, which concentrates messages at a central location where they are stored on punched tape

*/ Time-division circuit switching is distinguished from store-and-forward switching by the absence of a perceptible delay between transmission and reception.

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and relayed in batches. Today, high-speed computers can store and then forward messages. This switching mode is, therefore, expected to have its most rapid growth as an ancillary service to data processing.

B. Progress in Circuit Switching Has Brought Direct Distance and Automatic Dialing and Has Increased Switching Speed.

The inverse relationship between costs and traffic density, so important in transmission, is somewhat less significant for circuit switching.*/ Instead the key to switching economy is the elimination of operator assistance. Switching's share of total investment in the telephone system is relatively low (28%), but operator salaries raise its contribution to the cost of the average telephone call to 45% and, in the case of long distance calls alone, to 54%.

*/ Present-day space-division switch that can handle 10,000 terminals is about three times as costly as one accommodating 2,000 terminals. Time-division switching has scale efficiencies not present in space-division equipment; thus its projected savings through size may be much greater. Circuit switching also has scale economies at the toll exchange level. The cost per trunk of a 16,000 trunk switch is half that of a 3,000 trunk switch; in the future 50,000 trunk switches are expected to provide still lower costs per trunk.

The most successful innovation in reducing the role of operators in long-distance service has been direct distance dialing, made possible by the introduction of switching systems with relay computers. The earliest automatic switching systems (step-by-step and mechanical selector) followed a rigid, pre-established route in making a connection between two terminals. But long-distance telephone service is costly without flexible routing. If the main path between two switching centers is occupied, alternative routes must be explored. Because the step-by-step and mechanical selector switching systems could not undertake the logical operations necessary for alternate routing, long-distance switching remained manual long after switching had become automatic on local calls. Relay computers, on the other hand, can select an open route from among a large number of alternatives to the main path. Therefore, once relay computers were installed in large numbers, Bell was able to introduce direct distance dialing. The new ESS computers can even change the basic configuration of the network to meet changes in traffic patterns from day to night and on special occasions such as Christmas and Mothers Day.

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The new electronic switching systems (ESS) will allow switching centers to do jobs previously performed in other parts of the telecommunications system. Besides a temporary memory unit that stores the status of every subscriber line, the ESS has a semi-permanent memory that contains instructions for processing calls. This will allow the ESS to (a) assist in automatic dialing by maintaining a file of frequently called numbers for the subscriber (a function previously performed within a terminal), (b) route a call automatically to another terminal if the primary number is busy, and (c) set up conference calls. The advance from step-by-step to mechanical selectors to cross-bar switches to ESS has also brought with it a steady reduction in the time a switch requires to make a connection. The shorter this time period, of course, the more traffic a switch can handle.

C. A Digital Network, Using Time-Division Switches, May Reduce Modulation, Switching, and Multiplexing Costs for Data Communications.

The accompanying table based on technology expected to be available within 10 years, compares the investment costs for data users of an analog system (with space-division switching) and a digital communications system (with time-division switching).

There would be three principal sources of cost savings for data users employing a digital communications system.

(1) Users could dispense with the conversion equipment presently required on their terminals to adapt digital signals for transmission over an analog network.

(2) Both local and toll switching would be 1/3 to 1/2 as costly if time-division technology were used.

(3) Assuming reasonable ranges of demand (1,000,000 subscribers distributed over 100 cities), time-division multiplexing is expected to be between 1/10 and 1/3 as expensive as frequency-division multiplexing, required in an analog network.

TABLE 1

Network Cost Comparisons Per Customer

Function	Analog Network		Digital Sub Network Highest		Digital Sub Network Lowest
Conversion of digital signals	$500		$ 0		0
Local distribution	$256	(1-1/10)	$ 292		292
Local switching	$184	(1/2)	$ 92	(1/3)	37
Toll switching	$ 25	(1/2)	$ 12	(1/3)	5
Trunking (terminal)	$ 50	(1/3)	$ 17	(1/10)	5
(line-haul)	$ 50	(1-1/10)	$ 55		55
Total	$1065		$ 468		394

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The data in Table 1 may be considered conservative since they fail to take account of savings expected in some quarters from the use of large-scale integrated circuitry in digital systems. Nor do they account for savings which may result from integration of the toll switching and multiplexing functions implicit in time-division systems.

The principal obstacle to a digital, multi-purpose network, serving inherently analog (voice, TV, etc.) as well as inherently digital (data) customers, is the cost of converting analog signals into digital form for transmission over the network. Today the necessary equipment would cost about $1,500 per subscriber. Optimistic predictions for the mid-1970's, based on mass production of large-scale integrated circuits, place the cost at perhaps only $50 per subscriber. But even at the lower figure, the need to provide this capability for more than 100 million telephone handsets would represent a formidable deterrent to installing an all-digital system. Of course, with the present multi-purpose analog network, data users must convert their digital signals to analog form; but in the 1970's the number of data terminals on the network is not likely to exceed 2 million -- a small fraction of the number of telephone handsets.

Nevertheless, it may be possible to provide data users with a digital system, without either requiring analog users to adapt to a digital network or foregoing entirely the economies of joint usage between analog and digital communicators. The distribution lines of data customers could by-pass the local exchanges, which must receive signals in analog form, and enter a separate digital, time-division switch. Signals on this digital sub-network could also by-pass the frequency multiplexing facilities in the long-distance terminals since time-division switches can multiplex signals directly for long-distance transmission. Thus, digital signals could enter long-haul transmission facilities directly, whether these were dedicated channels on transmission facilities shared with the analog network, or a special digital long-haul network such as might be provided by a multiple-access satellite system.

Users of the digital sub-network would have to pay perhaps 10% more than analog customers for the distribution loops and transmission lines they would share. This surcharge would reflect the additional cost to the network of maintaining separate distribution cables for digital customers in the same trench or conduit as analog users. The preceding chart takes account of these additional costs and still suggests savings of greater than 50% from handling data subscribers on a special digital network.

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D. Computerized Store-and-Forward Switching Is More Costly Than Circuit Switching. Therefore, Message Systems Will Generally Store and Forward Only Messages for Which Circuit Switching Is Unsuitable.

As mentioned above, the defining characteristic of store-and-forward switching is that it dispenses with a continuous connection between two communicating terminals. Store-and-forward switching is preferable to circuit switching in several situations. If a customer wishes to transmit identical or similar information to numerous recipients, it is wasteful of his time and terminal facilities to make a separate connection and repeat the message for each recipient. It is advantageous to transmit the information once to a message-switching center which, in turn, relays the message to each terminal on his list. Store-and-forward switching also allows a customer to communicate with electronically incompatible terminals or to transmit a message when the receiving terminal is otherwise occupied, or in off-hours when there are no facilities at the other end to receive a message.

For telephone customers, these services have long been performed by answering services and secretaries. But it is inefficient to print-out computer data so that dispatching

personnel can forward it to another data terminal. Computerized store-and-forward switching has thus developed primarily as an ancillary service performed by data processing systems. The message is sent directly to the central data processing equipment which later forwards it to another terminal. While store-and-forward switching can exist as an independent function, the marginal addition of message switching to an existing data processing system offers significant economies in many applications. Today store-and-forward switching is, on the average, 5 to 10 times as expensive as circuit switching. Thus it is usually economic for firms requiring store-and-forward services to establish hybrid switching facilities. If the message requires processing or if the receiving terminal is occupied, a message is stored. Otherwise, a direct circuit-switched connection is established between the two terminals, and the message is relayed immediately. In most existing systems, a majority of messages can be circuit-switched. The fewer the messages that must be stored, the less costly the system will be.

Just as the time-sharing systems are most costly when they must accommodate a broad community of users, so do the costs of a message-switching installation grow in response to

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diversity, e.g., different data-speed, response-timing, and storage requirements. Moreover, when customers with incompatible terminal equipment share a single switching system and seek to communicate with one another, a larger share of their messages must be stored and forwarded, thereby generating cost increases.

V. LOCAL LOOPS (DISTRIBUTION)

Local loops perform the function of carrying signals between user terminals and the local exchanges. But despite the predominance of transmission costs in local loop expenses, technical progress has been slower in this area than in the telecommunications network as a whole: Most cost reductions that have accompained technological advance in high-density transmission methods have not affected the local loops that break up large trunk groups on their way to the user terminals. Also, increasing numbers of cities have been requiring the telephone company to lay its local distribution cables underground -- a procedure for which current technology offers few prospects of significant cost reductions.

A. Broadband Loops, Installed for Cable Television, Could Carry Point-to-Point Traffic as Well

Broadband cable is becoming increasingly attractive as a distribution mode. Although cable systems are substantially limited today to television distribution, they may be economic media for some point-to-point services, as well.

As a distribution loop, broadband cable represents a substitution of transmission for switching. While in a network configuration such as the message telephone system, signals are sent only to the terminal for which they are intended, a broadband cable distribution loop carries every signal to every terminal on the loop. The compensatory saving is in switching gear. A cable system uses frequency-division switching; a customer simply tunes in the frequency channel he wants to receive.

Once a decision is made to install cable for television distribution, it is relatively inexpensive to provide additional transmission capacity for other services through increased cable bandwidth.*/ This extra capacity could, in principle, be used for any communications service, including point-to-point voice traffic. Present cable television systems, however, lack the

*/ It has been estimated that the capacity of a 20-channel video cable could be expanded by 50% at an additional cost of only 20%. Those 10 extra video channels could provide the bandwith equivalent of 20,000 voice channels, exclusive of frequency spacing to prevent interference.

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signalling capability that point-to-point communications require. A cable television subscriber selects the signals he will receive after determining the channels on which they are to be transmitted from a program guide. But point-to-point services do not have the same regularity. Therefore, the broadband cable would have to include equipment permitting the sending party to inform the receiving party that a signal was arriving in a particular frequency time slot.

At least in the short-run, the cost of this signalling capability probably rules out broadband cables for point-to-point service between individual subscribers, few of whom generate enough traffic to occupy a circuit full-time. On the other hand, cables may be attractive to a few communicators who distribute a large amount of information among a wide local audience. These users could occupy one or more circuits or channels on the loop more or less full-time, and could spread the cost of signalling equipment over a large volume of traffic. This equipment would either indicate to the recipient that information was arriving in a particular frequency time slot, or else the information itself would be coded so that only a selected terminal would receive it. A video information retrieval system described in Section X, might use a channel or

a broadband loop in this fashion. The cable could also be adapted for voice or data communications, although given today's technologies, its comparative advantage is in providing broadband channels.

There has been some discussion of substituting a broadband loop -- equipped to carry digital rather than analog signals -- for the present local loop configuration.*/ While a conventional digital switching center (discussed in Section IV C) has time-synchronized gates which allow the appropriate signal to pass over a dedicated line to the user's terminal, this configuration would have no centralized switching or multiplexing. Instead all signals would be carried on a broadband loop which would have a dropline at each user's terminal. There a time-synchronized gate would open during the customer's assigned time slot and pass a signal between the terminal and the loop.

This system would have the full signalling capabilities of the present telephone network. But because the switching center would be replaced by a single gate to a long-distance trunk line and the individual terminal gates, switching costs might fall. Required transmission capacities would rise, but

*/ This concept is described more fully in Appendix G.

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the expectation is that the economies of scale of high density transmission methods might keep additional transmission costs below the savings on switching. The crux of this approach is its assumption that a large number of terminal gates, time-synchronized and capable of multiplexing and switching, would be cheaper than a single central switching office. Cost projections for this kind of system are necessarily speculative, because they depend so heavily on future trends in the cost of large-scale integrated circuits. Thus it is not clear whether savings in switching costs, intended to justify a larger transmission bill, will ever materialize. With such a digital loop configuration, it would also be more difficult to intermix network and leased-line services, particularly if the latter were to retain their present freedom to connect a large variety of foreign attachments to the network. Time-synchronization equipment at each terminal would be crucial, not only to the terminal's user but to every other customer on the loop; and therefore it might be impractical to let customers install their own terminal equipment. The fact that all conversations on a loop are available at each subscriber location on the loop would raise problems of

privacy, though these might be alleviated through various technical measures. There is, however, little likelihood that digital loop distribution systems will be installed before 1980.

VI. TRADE-OFFS AMONG TRANSMISSION SWITCHING AND LOCAL LOOPS

A. Because Transmission Costs Are Falling Faster than Switching Costs, Some Intermediate Switching Will Be Avoided by Creating More Direct Routes.

Transmission costs have been falling much more rapidly than switching costs. As this trend continues, it raises questions about the configuration of the network. Why route communications from point A to point C through an intermediate switching center (point B), if it becomes relatively more expensive to operate the switching center than to provide transmission routes directly from A to C?

As communications traffic increases, this movement away from switching to transmission is encouraged. For when the A-to-C volume becomes large enough, it will justify a direct high-density transmission line between the two points, exploiting economies of scale. This substitution has already been widely applied, and with increasing demand the process will continue.

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B. Economies of Scale in Transmission and Switching Will Lead to the Construction of Larger Switching Centers

The optimal size of a switching center -- or the number of local loops or long-distance trunks that should come together at a single node -- depends on a complicated calculation involving the relative costs or high- and low-density transmission lines and large and small switching centers.

If two switching centers are combined into one, several cost savings accrue. The number of switching centers is reduced. And because the trunk group leaving the switching center is larger, the new transmission medium is more economical (economies of scale) and capacity utilization is highe: (efficiencies of scale). On the other hand, the total numbe of switching crosspoints must rise; for the number varies geometrically with the number of trunks on a toll exchange, in order that each trunk has access to a crosspoint for ever other trunk. Finally, centralization requires signals to travel a longer distance on more costly, lower-density lines before they are collected at the consolidated switching cent

Basically, the choice depends on whether economies of scale in transmission and switching and the efficiencies of

large trunk groups can overcome the cost of additional crosspoints and longer, lower-density access trunks. Economies of scale in transmission have been predominant for many years; and recently large switching centers with many crosspoints have become more economically attractive. The per-trunk cost of a 50,000-trunk switch (a projected Bell development in the mid 1970's) is expected to be less than half the per-trunk cost of a 3,000-trunk switch. As a result there is a pronounced trend toward consolidating switching centers. Bell is considering dropping one of the upper levels in the switching hierarchy, so that trunk lines which previously came together only after passing through intermediate switching centers will now come together directly.

C. The Advent of Domestic Communication Satellites Will Alter the Trade-Off Between Transmission and Switching Significantly for Some Services.

As previously noted, communication satellite systems do not fit neatly into established concepts which treat transmission and switching as discrete and distinct functions. By inherently providing direct and variable capacity routes among dispersed locations at a relatively fixed cost irrespective of distance,

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satellites can avoid much of the intermediate switching and consolidation of transmission trunks required to realize economies of scale in conventional networks.

The full impact of these differences between satellite and terrestrial facilities on the provision of network services is uncertain, because operational and cost data are lacking. However, the prospects for satellites are best where they can replace both the transmission and switching functions of the terrestrial network, rather than as a direct substitute only for terrestrial transmission facilities. Thus, satellites are likely to find greater application in the provision of specialized long-haul networks for users with unique requirements, particularly where either the information rate or traffic loading on a given route is subject to wide variations over time.

VII. TERMINALS

Terminals convert signals for transmission over the network. A sound wave entering a telephone handset is converted into a corresponding electrical signal that carries it to the local switching center; for incoming signals the process is reversed. Data processing equipment on the telecommunications network generates digital signals which must also be converted

into appropriate form before they can be transmitted. These conversion processes are performed by modulation-demodulation devices or "modems."

A. Innovation Has Made the Telephone Handset a More Flexible Instrument, but Has Not Led to Substantial Cost Reductions.

Technical progress has given the telephone handset new capabilities such as automatic dialing and (through the introduction of the touchtone phone) the ability to generate a data signal. However, the cost of the terminal function has remained essentially constant. Today, station sets account for more than a fifth of total network costs; and as other elements of the network become cheaper and demands are placed on terminals for new services this fraction is likely to rise.

Labor expenses are a major portion of terminal costs. Although telephone instruments cost about $10 to build and are designed for a physical life of 10 to 15 years, these figures do not reflect the full extent of terminal costs. For every new terminal added to the network there are several connects or disconnects -- as customers move to new locations an average of once every 3 years. Under current procedures, a

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repairman visits the house every time the customer's location or telephone number changes or a new telephone is installed, and each of their visits costs as much as manufacturing a new instrument. In addition, terminal users are assessed the cost of maintaining station sets in working condition. It is notable that the reliability of the handset (one trouble call per 160 sets per year) is better than that of any other household electrical device.

One promising approach to cost reduction is to lessen the involvement of service personnel when customers move. If a handset were already installed at the new location, the telephone company could simply mail the customer an insert card with his new telephone number. Alternatively, all handsets could be of the portable extension variety operating with plug-in wall outlets, thereby permitting subscribers to take their handsets with them when they move and to obtain new handsets by mail as needed.

Another alternative is to have other parts of the system perform traditional terminal functions. This is being accomplished to a limited degree. ESS computers, for example, have semi-permanent memories which permit them to store a list of frequently called numbers and thereby remove from the

terminals the burden of providing automatic dialing. But the basic terminal function, modulation, can not be performed anywhere but at the terminal.

VIII. MOBILE RADIO

A. Spectrum Availability and Efficient Use Are the Key to the Expansion of Mobile Radio.

The growth of mobile land radio has been limited by two factors: the shortage of available spectrum, particularly in urban areas where use is heaviest, and the cost and size of portable receiver/transmitters. There is, of course, a trade-off between spectrum use and cost: The less stringent the constraints on bandwidth, frequency stability, antenna directivity, modulation, and other measures of spectrum use, the less costly the radio equipment can be. Also, just as large trunk groups make the most efficient use of circuit capability, a system of mobile radios with multi-channel capabilities uses less spectrum in achieving a given service level than a system of single channel sets. But again, multi-channel capabilities add to the cost of the receiver-transmitters.

The direction in technological advancement is to provide these spectrum-saving features at a cost comparable to available sets. Within the decade, receiver-transmitters that operate

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with narrower bandwidths and tighten frequency control are likely to be on the market, and 10-channel sets should cost little more than single-channel sets, and perhaps considerably less than today's single-channel sets.

In considering multi-channel mobile radios that could be carried from place to place, rather than installed in cars, weight becomes very important. The principal constraint on weight reduction has been battery power requirements. The development of solid state components and integrated circuitry, however, should make low-power sets practical.

IX. TELEVISION DISTRIBUTION

The least costly means of distributing TV signals is the existing method -- high-power transmitters and tall antenna towers. It is not discussed in detail for two reasons. First, little change is foreseen in local broadcasting technology over the next decade. Second, it does not appear possible to provide large numbers of TV channels (12 or more) to most viewers through normal over-the-air broadcasting means with the existing industry structure and the lack of available spectrum. Therefore, we have focused on alternative distribution methods that might increase the number of television channels.

However, cable is a very expensive means of reaching isolated viewers and is also an expensive system to install in major cities where streets must be dug up or where natural barriers (rivers, mountains) are involved. Either of the other technologies discussed subsequently might be used in conjunction with cable to reduce the overall system cost of providing multi-channel capability to each viewer.

B. Millimeter-Wave Radio Techniques May Provide Economical Multi-Channel Primary Distribution.

A system employing frequencies in the 18 GHz frequency range has been developed which will transmit the entire VHF television spectrum (12 channels) simultaneously over distances up to 6 miles, using a 100 MHz bandwidth. Its most attractive prospect is serving as an alternative to coaxial cable (1) in an urban environment with one transmitter using a fan beam transmitting to many receivers; (2) for reaching outlying surburban areas; and (3) in by-passing natural barriers such as rivers. Appendix E contains a more complete technical description of the system. At present the cost of such systems limit their potential use to interconnecting localized (e.g., block or neighborhood) cable distribution nets to a central distribution point. Whether receiver costs could be

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sufficiently reduced to permit direct broadcast to individual users is uncertain at this time.*/

C. The Direct Broadcast Satellite is Cost-Competitive Only for Reaching a Very High Percentage of Television Households from a Single Organization Point.

It will be technically feasible to provide direct broadcast to the viewer via satellite in the early 1970's. Figure 2 discloses the unit costs and capabilities of the major elements in a domestic satellite distribution system for television, using existing TV frequency bands (around 800 MHz). Two important parameters not varied in Figure 2 are frequency band and satellite antenna beam width. In the conventional satellite frequency bands -- 4 to 8 GHz -- the unit costs for the home receiver system would be about double. The use of narrower satellite antenna beams essentially provides the same capability from each narrower beam as previously

*/ Preliminary cost estimates indicate that one transmitter and antenna capable of reaching many receivers with a 15° beam, at distances up to 6 miles would cost $60-80 thousand and receivers would cost around $2 thousand. These latter costs would need to be reduced by considerably more than an order of magnitude to become attractive as a means of direct access to individual viewers.

For these purposes, the most interesting technological developments are occurring in coaxial cable, in millimeter-wave radio and in satellites.

A. Cable Television Is Attractive in Densely Populated Areas Where Cables Need Not Be Laid Underground and Where There Are Few Natural Barriers.

The elements in a cable TV distribution system are the main trunk cables, drop lines to the viewer location from the trunk and the "head end" from which TV signals are distributed. Current CATV cables have the capacity to transmit from 12 to 25 simultaneous TV signals, depending on distance and repeater spacing. The estimated cost of cabling 75% of the TV homes in the nation in 1980 (places with above 900 viewer locations per square mile -- totalling some 50 million locations) is between $100 and $200 per viewer location or $5 to $10 billion.*/

*/ The cable cost for given quality goes up as a function of distance and quantity. Sixteen miles is about the maximum distance for today's systems, providing about 200 square miles of coverage. By the late 1970's a 25-mile distance or about 500 square miles coverage may be possible at cost levels close to today's.

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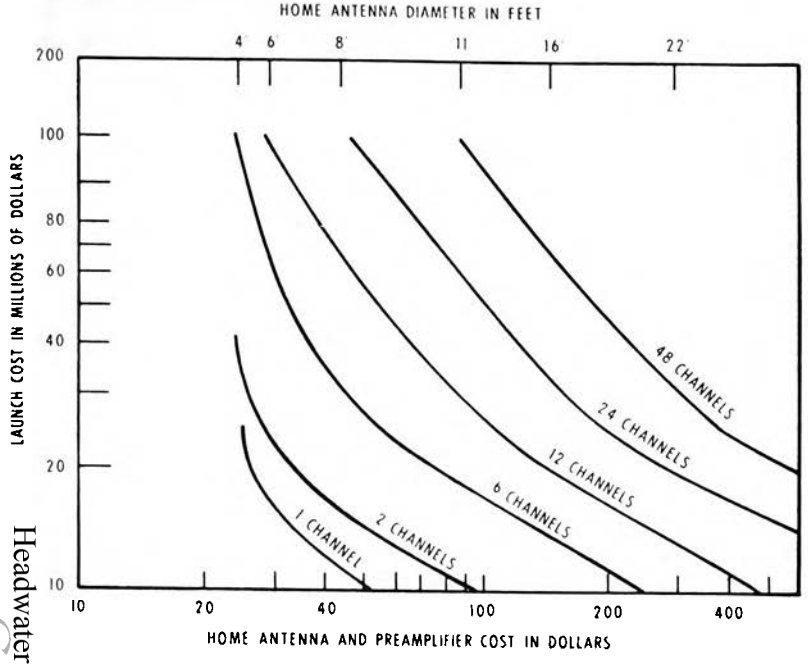


FIGURE 3

ESTIMATED COST RELATIONSHIPS IN DIRECT SATELLITE BROADCASTING

800 MHz VESTIGIAL SIDEBAND MODULATION
3° x 5° COVERAGE GRADE A

provided by the wider beam. Two other rules of thumb are useful. Figure 2 shows only launch vehicle cost; the satellite cost normally approaches the launch cost. The other is that the annual space segment cost of a 10-year system is about equal to the cost of one launch vehicle for that system.

Based on Figure 2, the least cost system for given numbers of viewers and channels is given in Table 2.

TABLE 2

5-Year Capital Costs -- Broadcast Satellite

800 MHz Frequency Region

Viewers (Millions)	1 Channel U.S. Coverage	12 Channel 50% U.S. Coverage	24 Channel 50% U.S. Coverage
1	$ 60	$ 225	$ 315
10	$ 36	$ 93	$ 113
50	$ 27	$ 43	$ 63

The per household costs of the space segment are substantial until the number of homes sharing the cost is large. Moreover, if all TV program distribution were by satellite, the viewer would be required to make an additional investment in a receiving antenna -- whose costs are estimated to range from $50 to $300 per location.

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In summary, cable clearly has a cost advantage over satellites in the lower range of total viewers, while satellites may be competitive in covering a high percentage of total viewers, especially in areas of low population density. However, cable can accommodate both local and national programming, whereas broadcast satellites accommodate only programs covering a wide area. Cable can be built on an incremental basis while the start-up cost of a satellite is quite high. And cable has an economic structure which permits the entrepeneur to charge viewers and thus amortize the whole system, while the investment in a satellite system would be more difficult to recoup directly from the viewers and would probably require advertising revenues or government subsidies.

X. NEW SERVICES

Earlier in the paper we mentioned that the telecommunications system is dominated by two services: telephone and television. The telephone handsets and television sets now in use (approaching 200 million) far exceed all other types of user terminals connected to the telecommunications grid. Taken as a group, teletypewriters, data sets, facsimile copiers and non-alphanumeric display units--all associated with teleprocessing and other record services--amount to about 200,000 terminals.

Nevertheless, it is widely anticipated that in the next decade these record terminals will account for a rapidly growing share of domestic communications traffic. Reductions in the cost of both the basic communications services and the terminals themselves are expected to make telecommunications increasingly attractive relative to other means of transferring information--in particular, transportation and the mails. At the same time, cost reductions in communications are expected to centralize nationally or regionally information-transfer services which have previously operated on a local basis. The result, it is argued, will be a trend toward supplying computer-based services over communications lines. This trend will not be limited to traditional data processing tasks. The combination of the two

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technologies, data processing and communications, will give the computer a much larger role in such services as teaching and banking.

Technical progress in communications is also expected to increase the range and quality of the two presently dominant services, telephone and television. In particular, voice telephone service with a visual capability has promise, and the number of television channels may be greatly increased through advancements in wire distribution technology. Also, mobile radio service, facsimile mail, and computer-linked services are expected to become more convenient, less costly, and more widely available.

As these services are all new and as the predictions made for them depend on the market's response to anticipated reductions in cost, past comsumption patterns are not very useful as a way to predict the future. But we can estimate the cost of providing these services over the next decade and, thereby, surmise whether they are likely to obtain substantial business or household markets within this period.

A. Computer Services Are the Fastest-Growing Market for Telecommunications

1. In-House and Single-Industry Systems Are Likely To Provide On-Line Data Processing For Customers with Complex Programs.

The desire for rapid turnaround time, (i.e., rapid access to a computer and rapid answers from it) and economies of scale resulting from use of large computers have led to the current rapid growth of time-sharing of large computers.

Computer communications or teleprocessing originated as a means of expediting batch processing. In batch processing, data are sent over communications lines to paper or card punching equipment which prepare the data for a computer. The data are then processed by the computer in batches. This is still the computer industry's principal use of communications services.

In recent years, however, batch processing over communications lines has been growing at a slower rate than computer time-sharing. The latter gives each user-terminal direct access to a central computer and permits a number of customers to use the computer's memory and processing equipment simultaneously. The annual production of on-line terminals, which stood at 25,000 in 1966, is expected to rise to 100,000 by 1970; and by the mid-1970's half the computers installed annually will probably offer on-line capabilities.

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The principal force behind this growth will be rapid reductions in cost of equipment associated with time-sharing. Since the 1950's, computer processing and memory capabilities have been growing 50% cheaper every 2 years. This trend is expected to continue.*/ The costs of user terminals and the computer's peripheral hardware, which gives customers access to its memory and processing equipment, will also decline, though at a somewhat slower rate.**/

Communications is not likely to become much less expensive for customers who reach the computer by making a local phone call or leasing a line to a time-sharing facility in the same city. But long-distance cost will go down, especially if greater line-sharing and channelizing options are made available.

Software is the only segment of time-sharing expenses for which no important cost-reducing innovations are in sight. As a result, programming, which now accounts for 50% of the cost

*/ If it does, storage capacity for 1,000 characters, which on a representative time-sharing system now rents for $.50 a month, will be available for less than $.10 by 1980; and the price of one minute of processing time (about what is consumed during half an hour of on-line use) will fall from $3.00 to $.50 in this same period.

**/ Teletypewriter consoles, now selling for $2,000-$7,000, can be expected to cost about 20% to 25% less in 1980 while the price of time on the computer terminal may be cut in half from $10/hr to $5/hr. Specialized terminal devices, e.g., cathode ray tube systems, may sell for one-fourth of the existing prices; or as little as $500.

of a typical time-sharing system, may reach as much as 80% by the mid-1970's. Then improved, standardized, general-purpose programs could stabilize the software share; but these advances cannot be predicted with any certainty.

These cost figures are applicable to the type of on-line system now most widely in use: i.e., general-purpose data processing and retrieval for customers with relatively simple programming requirements. But as processing and storage costs go down and progress is made in software design, the advantages of on-line service may become available to scientists and engineers with more sophisticated requirements; and computers may take over activities, such as administering a hospital, which demand highly complex on-line equipment.

The configuration of these systems will depend on relative cost changes among the components of a time-sharing system. Basically, potential users will have three choices:

a. An in-house system

b. Subscription to a specialized industry service, covering a regional or national market

c. Subscription to a local, general-purpose time-sharing service.

Several costs determine the economic trade-offs among these basic options:

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a) As long distance communications costs go down, regional single-industry services gain an advantage over the other configurations. Neither an in-house system (except for large, far-flung companies) nor a local, general-purpose time-sharing system benefits from cheaper long-distance communications.

b) As storage and processing costs are reduced, the comparative position of in-house systems will improve. Of course, intra-industry and general-purpose systems also benefit from cheaper hardware. But basically they offer prospective customers savings on hardware in exchange for bearing other costs such as telecommunications. And as hardware becomes less expensive, substitution of telecommunications becomes less attractive.

Computer hardware is subject to significant economies of scale up to a certain size. Single-industry systems tend to use the largest and most costly equipment, general-purpose and in-house systems follow in that order. If the relative advantage of big computers changes, in one direction or another, so do the relative costs of the three types of systems.

Cost of peripheral gear are important in accomodating a large number of users on a single system. They are most important, therefore, to single-industry systems which tend to

serve the largest number of users per computer; they are less important to general-purpose systems and least important to in-house systems.

Costs of diversity are significant when different kinds of teleprocessors (in terms of line and processing speeds, storage requirements, etc.) use a single system. Only general-purpose systems would significantly benefit if these costs went down. Right now, because the hardware and software costs of accommodating diverse users mount as a system grows larger, diversity limits the economical size of general-purpose systems. This is the reason single-industry systems tend to have more user-terminals than general-purpose systems.

The most promising approach to reducing software costs is the development of standardized programs for a profession or industry. Such standardized programs are a precondition for the development of intra-industry time-sharing, since common software is the principal advantage of a single-industry system over a general-purpose system. Thereafter, the other cost constraints dominate.

The apparent trends in these cost elements suggest that general-purpose systems are likely to lose out to the other two for users with sophisticated requirements. Of all the cost elements, the cost of accommodating users with different

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speed, storage, and software needs seems most resistant to technical progress.

2. The cost of computer-assisted instruction will decline significantly over the next decade. Computer-assisted instruction uses time-sharing technology to provide interaction between students at remote consoles and programmed teaching material. There is a great deal to be learned about making effective use of machines as teaching instruments. But initially the experience is likely to come from subsidized laboratory classrooms, because interactive hardware is presently too expensive for routine classroom use.

There is widespread opinion that program-sharing, through standardized software and regional time-sharing systems serving many school districts, will be an important expedient to the development of computer-assisted instruction. Today software rental or production would be a very small share of the total system costs; perhaps 3½% for drill material and 7½% for tutorial instruction. But over the next decade while hardware expenses are going down rapidly, software costs and instructional material development costs will remain the same, without these provisions for shared use. Thus, by 1980, we can expect machine drill and tutorial software to represent 15% and 33% of the total cost of machine instruction, respectively. Whether school districts seek to avoid these costs by sharing a multi-district system or by duplicating standardized programs

will depend on the relative costs of communications lines and computer hardware (see time-sharing discussion in previous section). But attempts to share software costs are certainly to be expected. There have been expressions of apprehension that the pressure to share will lead to homogenized school curricula with little diversity or experimentation. Certainly, the danger exists; but our projected cost estimates ($45 per student per year for drill material and $160 for tutorial), based on more limited existing opportunities for software sharing, suggest that computer-assisted instruction will certainly be feasible without resorting to a single, nationwide curriculum.

3. Data retrieval systems, with the touchtone phone serving as user terminal, are likely to be the most important household market for computer services. Data storage and retrieval are already among the most commonplace functions performed by a computer. But for access to existing systems, customers require card or tape punching devices or, if the system is on-line, teletype machines. This is limiting the market for many uses of computerized data banks. The Touchtone telephone, however, with its ability to generate data signals, will make data retrieval services available to mass markets, particularly small business and household users who are unwilling or unable to pay for a specialized data terminal. These Touchtone handsets are likely to be in wide use by the mid-1970's as computer input devices.

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a) Audio response. As the user-terminal for a telephone-accessed data retrieval service, the Touchtone phone would make an ordinary telephone connection to the computer. The customer, with the assistance of a code book, would then transmit a code for the category of information he desired. One very inexpensive way of transmitting the answer back to the customer, from the computer, is an audio-response unit. These devices, now on the market, translate pulse codes from the computer output into spoken words that can be understood over the telephone. Such systems are finding wide application in a number of customer services such as banking, credit authorization for department stores, telephone intercept services, and long-distance routing for telephone companies. * / Since most audio-response applications use only a small percentage of the available time of a central processing unit, this part of the computer is often also used simultaneously for batch processing applications.

* / A typical computer system capable of handling from 30,000 to 60,000 calls per day, each of about 1-minute duration, costs about $300 per day. This indicates, therefore, that the computer costs for 1-minute calls would be about 1 cent per call. Therefore, the application of audio-response systems to a wide range of storage-query-response types of information services is promising.

b) Visual display systems. If desired, information retrieval systems can also be designed to use a variety of other types of on-line terminals such as visual displays and hard-copy (i.e., printer and punch) terminals, but at greater expense.

A conventional television signal requires six MHz of bandwidth, more than a thousand times as much as a telephone signal; but that is because television programming requires 30 separate pictures a second to avoid "flicker" in the picture displayed. If the television receiver were permitted 30-45 seconds to assemble the picture, the signal could be accommodated on a telephone-grade circuit. And with an appropriate adapter, the television set could itself regenerate the picture repetitively for continuous display.

An alternative system to provide the same non-hard copy picture service would use a dedicated channel in a CATV system. For each customer request, the transmitter would send out a single frame accompanied by a code number that would activate only the intended receiving terminal. The same adapter as above could hold this picture indefinitely. Since a television transmitter generates 30 frames per second, a single transmitter could service as many as 100,000 customer requests in an hour by this method.

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Either type of system could provide a limited degree of interaction between user and computer. For example, the customer could indicate, initially, a general category of interest. The computer would then project onto the television screen a list or a diagram from which the customer would select the particular information he wanted. But the complexity of the information which the user could transmit would be limited by the computer input device (e.g., Touchtone keyboard which has only 12 digits). With a Touchtone keyboard it would be impossible to send anything more than numbers, alphanumeric codes and yes-no answers to the computer.

c) Improved input/output devices. Teletypewriters or other special input devices would enable users to transmit more complex information to the data processing equipment than the Touchtone station set provides and would enable them to receive printed alphanumeric (letters and numbers) output from the computer. Cathode ray display devices could perform instantaneously the same function that requires 30-45 seconds with slow scanning television technology.

The display terminals could also receive picture and other non-alphanumeric outputs from the computer. While eventually these specialized terminal devices should be substantially cheaper than they are today, the spectacular cost reductions associated with computer processing and storage capability are unlikely to be followed in the uses of terminal equipment. Perhaps teletypewriters will show a price decline of 25% by 1980, while cathode ray tube terminals may be available for as little as $500, as compared to over $1,000 today.

4. Computerized checking account systems are feasible today and might serve a useful function as a non-credit shopping cards. Computerized checking accounts would use the same equipment as telephone-accessed data retrieval systems described above. The only additional hardware element would be an attachment to the Touchtone phone, which would transmit the identifying information imprinted on a customer's banking card. The banking terminals would serve as substitutes for cash, checks, and credit cards. Even at current rates the total cost of using the computer to carry out the transaction could be as little as $.05 (assuming less than 10 seconds of central-processing-unit time at the computer terminal). The terminal attachment for transmitting the information on the card would rent for about $5 a month.

Banks have a strong economic incentive to introduce computerized checking accounts in the near future. Some people use credit cards for the short-term credit capabilities they

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offer. Many others use credit cards because they prefer not to carry cash. For the privilege of having access to customers using credit cards, restaurants, hotels, and other retail services are willing to pay a sizable fee, typically 8%. However, since banks would not have to extend credit or take risks when providing a computerized checking account service, they could charge businessman a great deal less and still earn a profit on the service. As the system becomes widespread, they would also save a large part of the expense of administering a computerized checking account service.

B. Broadband Cable Systems Could Bring Entertainment and Shopping Services into the Home at Low Cost

As discussed in Section V, broadband cables can carry large numbers of video channels at reasonable cost. For example, it is possible today to install an underground coaxial cable with a capacity of 27 television channels at an investment cost of about $96 per subscriber location.*/ A second and third cable can be laid underground at the same time

*/ Assuming $6,500 investment cost per cable mile and a market penetration of 75%.

without proportional increases in costs since the initial expense of tearing up the streets accounts for a substantial percentage of the total cable system investment costs.*/

With an installation charge of $15-25 per household and a $6 monthly fee, an 81-channel system could provide entertainment, educational programming, general information, and shopping services. The variety of potential information displays -- shopping news, local affairs, cultural and sporting events, etc. -- is extremely broad.

None of the programming materials for the broadcast system would need to be stored in a computer for instant selection and playback as in the switched systems. Rather the programs could be real-time pictures of articles or events. For instance, the channel carrying the time would simply have its program originated by a television camera

*/ For example, the capital investment costs of typical systems of even greater capacity if laid simultaneously would be $155 per location for a 54-channel system and $215 per location for an 81-channel system. In comparison, if the additional channel capacity was installed some time after the first cable was laid, so that the streets had to be torn up a second time, the investment costs would be about $192 per location for a 54-channel system and $250 per location for an 81-channel system.

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taking a picture of a clock. The stock market reports channel could be programmed using a TV picture of a stock broker's board. Airline schedules, bus schedules, train schedules, etc., would be handled the same way.

C. Only Demand for an Extremely Wide Choice of Programming Would Make a Switched Broadband Network Less Costly than a Broadband Cable

Among the ways suggested for vastly increasing the diversity of television programming is a system that would permit a subscriber to dial the program of his choice from a library of TV tapes. The facilities necessary for this service could also be used to provide television channels for remote shopping and information services of the type discussed in the previous section.

The advantage of a broadband (4-6 MHz) network over a broadband cable is the avoidance of duplicate transmission. While in the cable every signal is carried to every terminal, a network configuration brings to a terminal only the signal the subscriber chooses to receive. For entertainment or shopping programming received by large numbers of subscribers, however, a cable has an offsetting advantage. A signal need only be transmitted once to be received by every termininal on the cable. With a network configuration, on the other hand, the signal must be sent over separate

distribution lines running from a central location to the terminals.

It appears that only a demand for exterme selectivity of programming would permit a network to surpass other broadband distribution systems.

For local service alone (programming would have to be stored in every city) the capital costs for transmission and switching facilities would be about $5,000 per location, implying a monthly rental fee of about $135. */ This is about 15 times the cost of equivalent telephone or broadcast cable television systems and would permit only one program at a time to be shown at each location. Moreover, a substantial additional fee would be needed to cover the cost of storing large numbers of television tapes and of operating a computer time-sharing system to connect a customer with the program of his choice. Because average household expenditures on television facilities (including receivers) is not expected to rise above $184 a year by 1980, there seems little chance that one-way switched broadband systems will provide viable commercial services in the near future.

*/ These figures assume standards of service and a distribution of peaks and valleys of circuit demand equivalent to voice telephone. The actual requirements for television-type service would probably require an even more expensive system.

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Moreover, there are alternative and cheaper ways to provide a complete choice of programming from an inventory of television tapes in a central distribution center. Several companies are developing an attachment for the television set that would permit it to play back television tapes. These programs could be distributed on a purchase or rental basis by mail or through retail stores. The TV attachments are expected to be available for $400-600 in the 1970's. A one-hour TV tape cartridge is expected to cost $15-25 to produce.

D. Cost Reductions Would Open a Sizable Market to Facsimile and Related Services.

Since everyone receives and sends documents--bills, letters, pictures, magazines, newspapers--ways to make these transfers more convenient, less costly, and more timely are constantly being sought. The principal alternative means today are mail, messenger, and teletype/telegram. Facsimile transmission and related techniques offer promise in convenience and timeliness against all alternatives and may become competitive with teletype/telegrams.

1. Business market . We have considered both business and mass-consumer markets. The business market might take either of two paths, both currently being pursued. The businessman might make his own arrangement for equipment and

communications lines, or an entrepreneur might establish a network of facsimile stations and sell service to the user. Four non-regulated companies have now established facsimile networks, using the switched telephone network to connect stations with most leasing facsimile equipment from major manufacturers. It takes some 6 minutes to transmit a single sheet, and charges among these companies vary from $2.50 to $8.95 per page plus the cost of the telephone call. As yet, none of the companies is financially successful and at current prices, a business man with substantial facsimile needs would probably look for an alternative. He could lease facsimile equipment himself at a lower monthly cost for any two locations between which 45 pages a month are transferred. Thus, the facsimile network market, at anything like existing prices, seems restricted to the occasional user. But, the full potential business market is quite large, and cost reductions would make both in-house and for-hire systems practical.

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2. Mass-Consumer Market. This market is likely to develop more slowly than the business market. Tranferring paper into or out of the home seems less a matter of urgency than in many businesses. A receive-only market might develop where important letters are electronically transmitted into the home. Well over 100 million special delivery items are handled annually; certainly some substantial proportion is a candidate for electronic transmission at some level of cost and convenience.

E. Video Telephone Costs, over the Next Decade, Are Likely to Exclude All but a Limited Business Market

Picturephone is another important new telephone service planned for user terminals by the late 1970's. Bell's own projection is that by 1980, only 1% of its customers will be subscribing to Picturephone service. The cost data suggest that these will be largely business customers. Household users are unlikely to pay the rates that Picturephone facilities will require.

A Picturephone terminal will consist of a 5" square monochrome television screen, a small television camera, and knobs for varying the camera's range, brightness, etc. With a million customers, the installed cost of a Picturephone terminal will be about $1,000 (compared to $50 for a telephone handset) in 1980. There would be some savings if production

lots were larger; but even with 100 million terminals, the installed unit cost would be quite high.

Because video telephone pictures will have fewer scan lines than a television picture, its bandwidth requirements will be smaller; i.e., about 1 MHz instead of 6 MHz. Nevertheless, the bandwidth of a picturephone circuit will have to be about 200 times as large as a telephone voice circuit. If Bell's estimate is correct and 1% of its locations subscribe to Picturephone by 1980, this service alone will account for twice as much circuit capacity as all the voice telephone service now being provided in the Bell System. Picturephone's transmission, switching, and distribution costs, however, will not be proportionately larger, because of economies of technology. Despite the amount of bandwidth the picture will consume, the signals will be carried from the terminal to the local exchange over two additional pairs of wires whose capacity has been expanded by digital transmission technology. Over longer routes, the system will also be able to take advantage of high-density transmission methods. As a result, the transmission and distribution costs attributable to a Picturephone terminal will be about 10 times the cost of equivalent service for a voice terminal. Picturephone switching, per se, will only be twice as expensive.

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To cover these costs, Picturephone rates will have to be much higher than ordinary telephone charges. The monthly terminal rent, covering a line to the local exchange as well as the station set, is estimated at $100. Average monthly toll charges should be about $30. A New York-Washington call, for example, would cost about $7.00. At these rates a substantial household market is unlikely; and Bell will have to rely on commercial users for whom viewed contact is an important aid to business.

F. Spectrum Conservation Made Possible by Low-Power Transmission and Multi-Channel Transceivers, Could Provide the Basis for an Inexpensive Land Mobile Service Available to All Car Owners.

It has been suggested that mobile radio, including portable sets and those installed in vehicles, may eventually become an almost universal service to supplement fixed telephone services. Its prospects will depend largely on developing suitable techniques for improved spectrum sharing. If each fixed (base) station covers an entire city, as at present, land mobile radio would almost certainly consume more spectrum than is likely to be available for the service. But by using multi-channel, low-power transmitter/receivers dispersed throughout a city to conserve spectrum in crowded areas, widespread use of land mobile radio would become more feasible.

We have published, as Appendix F, one model of such a land mobile radio system. Numbers of transmitter/receiver stations, scattered throughout a metropolitan area, would interconnect low-power, a multi-channel radios with one another and if desired with the telephone network. Even allowing for peak periods in use of the system, non-terminal equipment could be provided at a rate of $.17 a call. At the same time, radios with the necessary two-way capabilities are likely to cost only about $50 more than a one-way car radio today.

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APPENDIX A

THE DEMAND FOR TELECOMMUNICATIONS SERVICES

The consumption of communications services is not independent of progress in communications technology. If innovation can lower the price of a service, that service will attract a larger market; and if demand is sufficiently sensitive to price, the dollar amount spent on the service will increase, as well.

Nevertheless, we have been impressed by certain stable relationships between expenditures on communications services and such factors as population and national income-relationships that have persisted over the years despite the varying pace of technical progress. Of course, these correlations are not available for new services which have not yet appeared in marketplace. Their prospects are discussed in a later section of the paper. For existing services and types of equipment, we have found it useful to look at consumption patterns and to use them for estimates of communications expenditures in the future. In cases where the volume of consumption is heavily dependent on the acceptance of new services (e.g. record terminals), our estimates will, of course, be tentative and will rely on cost projections.

We have addressed these consumption patterns in two separate ways. First, we have estimated aggregate expenditures for telecommunications services on the basis of relationships with other factors such as gross national product, personal consumption expenditures and population.

Second, we have analyzed particular kinds of services--both with respect to quantity and to expenditures for them. Among other things, we have considered how the demand for a particular kind of service would grow as a consequence of growth in income and population, and as a consequence of price reductions induced by technological advance.

This examination has two basic purposes: First, to give the reader a better understanding of how basic factors operating in the economy may affect the growth of telecommunications services over the next decade or so; second, in conjunction with the accompanying survey of technology, to suggest how particular technologies might be employed in fulfilling these needs. We shall show, for example, that even under very optimistic projections of communications demand across the Atlantic, during the 1970's no more than 2 INTELSAT IV satellites would be required to handle the whole traffic load.

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I. AGGREGATE DEMAND

We shall use income, relative prices, population, and technology as the primary determinants of expenditures for communications services. The first three operate directly on demand, while technology affects the supply side through cost reductions for both old and new services. The central question is the degree to which expenditures on communications services are affected by changes in these factors. In particular, we are interested in (1) the income elasticity of demand; (2) the price elasticity of demand; (3) the future growth of population; and (4) the future course of technology. Income and price elasticities can be estimated from past behavior. Technological advance complicates the analysis. As noted above, technology has a two-fold impact on the supply side by reducing both the costs of providing old services and the costs of introducing new ones. While there is a historical demand function for existing services, new services by their very nature have no past history on which to build.

Nevertheless, it would be surprising if the introduction of new services were to lead to a major revamping

TABLE 1

Communications Industry* Gross Product in Per Cent of GNP

Year	Current Dollars (billions) Communications	GNP	%	Constant Dollars (billions - 1929) Communications	GNP	%
1947	3.1	231.3	1.3	4.1	300.9	1.3
1948	3.8	257.6	1.5	4.7	323.7	1.5
1949	4.1	256.5	1.6	4.9	324.1	1.5
1950	4.5	284.8	1.6	5.2	355.3	1.5
1951	5.1	328.4	1.6	5.6	383.4	1.5
1952	5.6	345.5	1.6	6.1	399.1	1.5
1953	6.3	364.6	1.7	6.7	412.8	1.6
1954	6.5	364.8	1.8	6.6	407.0	1.7
1955	7.1	398.0	1.8	7.5	436.0	1.7
1956	7.7	419.2	1.8	8.0	446.1	1.8
1957	8.3	441.1	1.9	8.5	452.5	1.9
1958	8.9	447.3	2.0	8.9	447.3	2.0
1959	9.7	483.7	2.0	9.5	479.9	2.0
1960	10.4	503.7	2.1	10.0	487.7	2.1
1961	11.0	520.1	2.1	10.6	497.2	2.1
1962	11.9	560.3	2.1	11.5	529.8	2.2
1963	12.9	590.5	2.2	12.3	551.0	2.2
1964	13.8	632.4	2.2	13.2	581.3	2.3
1965	14.8	683.9	2.2	14.4	616.7	2.3
1966	16.0	743.3	2.2	15.7	652.6	2.4

* Comprises telephone and telegraph, radio broadcasting and television.

Source: 1947 - 1962: "Revised Estimates of GNP by Major Industries", Survey of Current Business, April 1967, pages 21 and 23
1963 - 1965: "GNP by Major Industry, 1966", Survey of Current Business, October 1967, pages 14 and 15

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of the way the consumers allocate their consumption expenditures among broadly defined categories. This trend is perhaps best illustrated by examining the amounts spent on communications as a percentage of gross national product. Table I shows that over time, the communications share has been slowly increasing--from 1.3% in 1947 to 2.4% in 1966. While the change has been small in percentage terms, large dollar amounts are involved. The differences in 1966 between 1.3% and 2.4% of GNP is $7.2 billion. Of course, new services could accelerate this growth in the communications share; but it is important to remember that communications is not the only category of consumer expenditures in which new products or services will be introduced. Competition for consumer dollars will be keen and there is no a priori reason to assume that new communications services will fare better than other new services.

Based on the projections of Dr. L. Taylor* therefore, our assumption is that communications expenditures will increase only slightly as a percentage of gross national product. Our projection of gross expenditures

* See Appendix B.

on communications dismisses the possibility that new services will change this fundamentally stable relationship by inducing consumers to substitute communications for other functions such as banking or transportation.

Two basic categories of aggregate expenditures have been separately identified and projected over time: radio and television services; and the traditional common carrier functions. The projections for each category are based on an assumed growth rate of 4% in the gross national product, which corresponds to the Council of Economic Advisers' estimate of the present potential growth rate in GNP. Other important variables are population, personal consumption expenditures and government expenditures.

A. Consumer Expenditures for Radio and Television Receivers

In contrast to communications services, radio and television sets are durable goods; this means that existing stocks are likely to have an important influence on current purchases beyond income and price. If a family has just purchased a television set, it is unlikely to purchase another soon. In short, stocks have a negative influence on the current expenditures, and this is

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reflected in a demand function more elastic in the long run than in the short run.*

TABLE 2

Consumer Expenditure for Radio and Television Receivers**

	1965	1980 (4% growth in GNP)
Total expenditures (billions)	$ 6	$13.8
Per capita Expenditures ($)	$32	$52
Percent of personal consumption	1.6%	1.9%
Percent of GNP	.9%	1.2%

In considering the projections in Table 2, it is particularly important to note that there has been only a slight growth in the percentage of per capita expenditures on radio and television receivers through time; but with the growth of total consumer expenditures through time, the increase in the dollar volume for the purchase of receivers has been large.

B. Common Carrier Telecommunications Service Revenues

We have used the FCC series, Statistics of Communications Common Carriers, as a basic source. In projecting

* Our projections for 1980 (in terms of "constant" dollars based on 1958 prices) are indicated in Table 2.

** Taylor, Table 1.

expenditures for common carrier services we have further divided these expenditures into two categories: consumer expenditures, as defined by the Office of Business Economics, Department of Commerce; and expenditures for telephone service by government/business users as provided by AT&T for all the communications common carriers. Each category has been separately analyzed and expenditure totals projected through 1980.

Both categories are shown in Table 3. Based on these projections, expenditures in 1980 for all common carrier services would be $28.2 billion (in dollars of constant purchasing power*). Although no explicit account is taken of new services that might increase communications' share of GNP, it is interesting to note that common carrier revenues (in 1958 dollars) would more than double over the next 14 years merely by maintaining its present relationship to a GNP growing at 4% per year.

The above projections have explicitly assumed a decline in the price of telecommunication services of 20%

* The division of this sum among specific services will be discussed in the following section.

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TABLE 3

Expenditures for Telecommunications
Common Carrier Services

Consumer Expenditures:

	1965	1980 (4% growth in real GNP)
Total expenditures (billions)	$6.1	$15.8
Per capita expenditures ($)	$32	$63
Percent of personal consumption	1.6%	2.2%
Percent of GNP	1.0%	1.4%

Business and Government Expenditures:

Total expenditures (billions)	$7.5	$12.4
Percent of GNP	1.2%	1.1%
Total expenditures	$13.6	$28.2

(in constant dollars) between 1965 and 1980, which is about the same percentage reduction experienced over the last 15 years. This crude assumption is merely the first step in the process of analyzing potential reductions in the cost of communications facilities which could, given a proper regulatory framework, result in very substantial decreases in price. To the extent that we can foresee additional substantial decreases in cost, we shall use them in analyzing the anticipated growth of individual services in Section II.

Table 4 includes our overall aggregate projections and the assumptions made about independent variables used--GNP, population, etc.

II. COMMON CARRIER SERVICES

The three major categories of common carrier services historically offered are telephone service, record service (telegrams, TELEX/TWX, data) and leased circuits. Almost any new individual service will probably be covered by these categories.

A. Local Telephone Service

Within the category of telephone service, local and long distance have had very different kinds of facilities. The local telephone market has grown as shown in Table 5.

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TABLE 5
Local Telephone Service

	49	50	55	60	65
Total phones (millions) 1/	27.9	43.0	56.2	74.0	93.3
% Households with phones 1/	46	62	71	78	85
% Business phones 1/	34	30	29	28	28
Phones per 100 U.S. pop. 1/	20	26	34	41	48
Per capita income 2/					
0 to $2000					35
$2000-3000					43
$3000-4000					56
Calls per phone 1/	1063	1096	1554	1542	1523
Calls per capita	291	436	454	503	602
Total revenues (billions) 1/	1.1	2.1	3.3	4.8	6.4
% of common carrier revenue	54	60	60	58	58
Revenue per phone (¢)	40	49	59	64	66

These growth rates are closely correlated with economic factors -- particularly per capita income and with population growth as the following charts provided by AT&T illustrate.

In considering the future environment of local service, we have simply extrapolated growth as a function of projected growth in the economy, per capita income, population and households (shown in Table 5. Price change does not seem to be an important factor in the basic local telephone market. 3/ More important will be the

1/ FCC
2/ Statistical Abstract
3/ Price Elasticity of Local Telephone Service Demand, Public Utility Fortnightly, Feb. 4, 1965, p. 22.

	Per Capita($)	Per Household($)	PCE(%)	GNP(%)	Total Millions	Per Capita	Per Household	PCE	GNP
					(1958 $)				
Common Carrier Services	70	107	1.6	2.2	113.6	113	210	2.2	2.5	28.2
Consumer	(32)	(107)		(2.8)	(6.1)	(63)	(210)	(2.4)	(2.5)	(28.2)
Business/ Government	(38)	--	--	(1.2)	(7.5)	(50)	--	(1.4)	(2.4)	(28.4)
Structure of Ownership and Radio Sets	32	107	1.6	1.C	6.1	55	164	1.9	1.2	13.1
Total	102	214	3.2	3.2	19.7	168	394	4.1	3.7	42.0
Gross National Product (GNP)					614					1130
Personal Consumption Expenditures (PCE)										716
Population (Millions)					195					249
Households (Millions)					57					77

1/ 4% annual growth

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introduction of subsidiary services (telephone calls following the user, remote turn on or off of appliances, direct access to computers through the phone instrument) as a means of expanding the market. These uses of the phone instrument will be a direct substitute in many cases for separate data terminal equipments. Their impact on that market will be discussed below.

TABLE 6
Local Service Projections (1958 $)

	1965	1980 High	1980 Medium
Total phones (millions) 1/	93	175	165
Calls per phone 2/	1523	1485	1495
Calls per capita 2/	662	1047	987
Phones per 100 U. S. population 1/	48	70	66
% households with phones 1/	85	98	97
% total phones used by business 1/	28	28	29
Revenues (billions) 3/	$6.4	17.5	10.9
Revenues per phone 3/	$66	100	66

The local telephone environment which we see in the future will possess the following characteristics: Nearly every household in

1/ AT&T and USITA projections of past trends
2/ Taylor
3/ The revenue projections are in 1958. One set is based on no increase in constant dollar price for service which means that the investment per local telephone in constant dollars remains the same for equivalent service. The second is based on an expanded investment per local telephone in constant dollars which includes additional services such as expanded flat rate areas, call following, two digit dialing, etc.

the country will have a telephone. There will probably be about 12 telephones for every 3 people. The telephone instrument will be useful for many things other than voice communications. Much of the electrical non-voice communications from the home or office to the outside world will be handled through the telephone instrument.

We have separately considered the future of phonovision-picture phone. While it is a subsidiary service, its potential impact on revenues and on facilities is such as to warrant individual consideration. At present, this service is commercially available in but 3 cities and only at central locations. It requires some 200 times the circuit and switching capacity needed for an ordinary call. The camera and receiver equipment now cost more than 100 times as much as a telephone. Moreover, the benefits of the service are totally intangible -- the only additional information exchanged is facial expression.

At today's prices, customers must have strong geographically dispersed communities of interest to justify the high expense and to meet the competition in local areas of travel and closed circuit TV. Its high cost (we see scant prospects that in the next decade it will be less than ten times as expensive as normal residence telephone service) and the availability of close substitutes suggests that picturephone will grow slowly. Business customers are the most likely market. AT&T has estimated

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a domestic market penetration by 1980 of up to 1% of telephones in service and up to 3% of the business telephones. A market of this size could yield annual revenues of up to $1 billion, about 10% of the telephone companies receipts from local service.

A businessman might reduce his picture phone expense by using the bandwidth to transmit data when the picture phone was not in use with the only additional expense being a data terminal.

B. Telephone Message Toll Service

The toll market has grown as shown in Table 7. We have separately identified interstate from intrastate toll calls so that the trend toward longer calls and more revenue per call is illustrated.

TABLE 7
Message Toll Telephone Market

	1945	1950	1956	1960	1965
Total calls (millions)	1600	1949	2361	3221	4474
intrastate	1300	1422	1609	2181	2905
interstate	300	527	752	1040	1569
Calls per phone	56	45	41	43	46
intrastate	46	33	28	29	30
interstate	10	12	13	14	16
Calls per capita	11	12	14	18	23
intrastate	9	8	10	13	15
interstate	2	4	4	5	8
% of calls interstate	18	26	31	32	35
Total revenues (billions)	.9	1.2	2.0	3.1	4.9
intrastate			.9	1.4	2.1
interstate			1.1	1.7	2.8
Revenues per call ($)					
intrastate			.60	.64	.72
interstate			1.48	1.70	1.78

As with local service, these growth rates are closely correlated with economic factors -- GNP, per capita income -- and with population growth. The element of price has much more impact here than in the local area. The major sources for the projections below were supplied by AT&T, by Dr. L. Taylor (whose study is contained in Appendix B) and by Dr. A. Neisser who has concentrated on price and distance factors. The same independent variables used in the "aggregate demand" analyses are used in Table 8 to project message toll's growth.

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TABLE 8

Telephone Message Toll Services

	1965	Price Elasticity	1980 High	1980 Medium
Total calls (millions) 1/	4.5		17.1	13.4
intrastate 2/	2.9		10.3	7.4
interstate	1.6		6.8	6.0
Calls per phone 3/	46		98	81
intrastate	30		59	45
interstate	16		39	36
Calls per capita 1/	23		69	54
intrastate	15		41	30
interstate	8		28	24
% of interstate calls 2/	35		40	45
Total revenues (billions) 4/	4.9		16.9	14.6
intrastate	2.1		6.0	2.6
interstate	2.8		10.9	12.0
Revenues per call ($) 4/	1.09		.99	1.09
intrastate	.72		.58	.35
interstate	1.78		1.00	2.00

1/ Taylor; AT&T has estimated a total of 14.9 billion toll calls in 1980.

2/ The trend to longer distance calls within the interstate market as demonstrated by Dr. Neisser and the growing percentage of interstate versus intrastate has been projected to 1980.

3/ AT&T and USITA phone projections.

4/ The revenue projections are in 1958 $. The medium estimate is based on a trend toward longer distance calls offset by a decrease in plant required to support toll calls -- in part as a function of increases in the areas served by flat rate local service. The high estimate is also based on a trend toward longer distance calls which is more than offset by both actual cost and price reductions. The estimated effect is to decrease in both cases the average price of an intrastate call while decreasing the price of an interstate call where volume is highest and slightly increasing it where volume is lower. The decrease is largely a function of larger toll trunk groups and fewer toll switching centers resulting in substantial economies of scale for both transmission facilities and switching centers.

We expect a continued expansion of flat rate coverage. But accounting/separations issues and its uncertain effects on the demand for telephone facilities make a nationwide free calling area a remote possibility. The picture-phone long distance market will be small -- less than 10% of revenues based on a market penetration of 1%. While the most rapid growth will be in the longest distance categories, the bulk of revenue will be derived from, and plant facilities required for short and medium distance calls -- up to 250 miles.

C. Record Services

Message telegram, TELEX and other record services are separately analyzed because historically their growth patterns have been very different from that of voice services. To carry out this analysis, it is necessary to project the growth in demand for the terminals used in both public and private record service. From this projection, we have allocated the same types of terminal into both the individual record services and private line services, since the same terminal may be used for several record services.

Our terminal projections include all types of record input-output devices which use transmission facilities. The

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principal types are teletype, facsimile, data (punched cards, paper or magnetic tapes) and alpha-numeric display devices: Alpha-numeric display and data terminals are uniquely associated with computers and data processing. Teletype machines are also regularly used with computers but provide other record services as well. The facismile terminal market is much less closely associated with computers and can be considered basically as a substitute for mail, phone and teletype messages. Our projections include high and low bounds, and are based on an analysis of demand in these three categories -- computer associated, other teletype and facsimile.

1. Computer associated terminals. In 1966, about 2500 computer systems were connected to terminals via transmission facilities -- less than 10% of the 35,000 installed computer systems. The estimate of the total terminals connected to these "on-line" computer systems ranges from 70,000 to 90,000, of which 40-60 thousand are teletype devices.

While the total number of business computer installations increases to an estimated 150 thousand, the number of on-line systems in 1980 is expected to grow much more rapidly -- from 2500 in 1966 to 50-75 thousand in 1980. These systems

will have anywhere from two or three terminals up to several hundred and, in a few cases, more than 1000. The bulk of computer systems, however, will probably be connected to 10-30 terminals. The principal reasons for such a low range are (1) the costs embodied in scheduling computer time, recalling stored programs, etc., which increases with the number of users, and (2) the availability at competitive prices of smaller, more specialized computer systems. The first point noted above is a "software" element that is rapidly becoming the major cost element in computer systems. From about 50% of total system cost today, projections are that by 1976 software will account for about 80% of system cost. */

While we see the software problem as an inhibiting factor in the growth of computer-associated terminals, the projected growth is still phenomenal. Based on an average of 20 terminals per computer system for the estimated systems, between one million and 1.5 million terminals would be in use by 1980. The proportion of teletype to other terminals should change by 1980. Today, over 60% of these terminals are teletype only -- by 1980, 50% are projected to be teletype only.

*/ W. L. Frank, Software for Terminal-Oriented Systems. Datematron, June, 1968

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Within the 50% non-teletype category, less than half are projected to be data only with the remainder being display devices.

Our projections in the computer-associated terminal category for business use in 1980 are seen in Table 9.

TABLE 9

Projected Growth of Data Terminals

	1966	1980
Computer systems (thousands)	35	150
Computer-terminal systems	(2.5)	(50-75)
Terminals (thousands)	60-90	1000-1500
Teletype	35-50	500-750
Data	10-15	200-350
Display	15-25	300-400

Computer-terminal installations for educational purposes, with all terminals assumed to be display types, are very much more difficult to estimate. There are two major uncertainties. One is the ability of our educators to incorporate this new technology into their curricula. The second is the current high cost of computer assistance, compared to teachers' salaries. While much lower hardware prices may ultimately make computer aided education competitive with the cost of teachers, there are fundamental problems with its effectiveness and the speed at which it could be integrated into our existing

systems. Accordingly, we have assumed that where cost is the only substantial obstacle, demand will grow rapidly. Where utility and integration are the obstacles, we have assumed a very slow development.

Terminal use in education is related to the number of school classrooms and pupils, projected to 1980 by the Bureau of the Census. We have used HEW current figures on classrooms in conjunction with the Census figures to estimate 1980 totals listed in Table 10.

TABLE 10

Education Statistics

	1965	1980
Student population (millions)	53.8	65.4
Elementary	(35.1)	(40.5)
High School	(13.0)	(15.2)
College	(5.7	(9.7)
Instruction Rooms (Elem-High Schools) (Millions)	1.6	2.0
Schools (Elem-High Schools) (Thousands)	123	120

In the case where demand grows rapidly, we have assumed that all instruction rooms will be equipped with terminals and that one terminal will be available for every 20 college students -- resulting in 2.5 million terminals used in education by 1980.

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In the case where "software" problems are paramount, we have assumed that the total terminals for elementary and secondary schools will reach 100 thousand or less than one per school and terminals in colleges will reach 200 thousand, or about one per 50 students for a total of 300 thousand.

The range of total (business and education) computer associated terminals in 1980 is shown in Table 11.

TABLE 11

Installed Data Terminals -- 1980

		High			Low		
	(thousands)	Business	Education	Total	Business	Education	Total
Total terminals	60-90	1500	2500	4000	1000	300	1300
Teletype only	35-50	750		750	500		500
Data	10-15	350		350	200		200
Display	15-25	400	2500	2900	300	300	600

2. Facsimile terminals. In 1968, about 20,000 terminals were in use, mostly for news photo services and weather maps. The growth rate, dominated by the business market, does not appear to be high. Almost any company must transfer documents to other locations -- within or outside the company. The major choices available to business today are mail, messenger, or teletype. Facsimile competes on three levels -- time, convenience and cost. It has a

convenience advantage over teletype and its cost compares favorably. It has a time advantage over mail or messenger but suffers a comparative cost hardship.

We have not discovered any variables such as GNP, population or business locations which correlate strongly with demand for facsimile terminals. As a result, we have little confidence in future projections. Estimates for the late 1970's range from below 100,000 to 500,000.

3. Teletypewriter terminals. The bulk of teletype terminals by 1980 will be either used with computers or TELEX-TWX type services. There does not appear to be any mass consumption (household) market. Household computerized services are likely to be telephone -- accessed over touchtone phones. TELEX-TWX type terminals are projected to grow from 70,000 in 1965 to 120-180,000 in 1980, as discussed below in more detail. Teletypewriter terminals for other uses -- company private line networks, government private line networks, local Western Union offices -- now estimated at 10,000, may reach 50,000 by 1980. This latter market is very sensitive to changes in the TELEX-TWX rate structure, the cost of private lines and growth of facsimile.

4. Overall terminal projections. The total number and types of terminals allocated to individual services are shown in Table 12.

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TABLE 12

Projection Growth of Record Terminals in Thousands
1965

	Message Telegram	TELEX-TWX	Other Switched Network	Private Lines	Total
Teletype	12	70	45-60		127-142
Facsimile	-	-	20		20
Data	-	-	10-15		10-15
Display	-	-	15-25		15-25
Total	12	70	90-120		172-202

1980 High

	Message Telegram	TELEX-TWX	Switched Network Data	Private Lines	Total
Teletype	10	180	400	1140	1730
Facsimile	-	-	400	100	500
Data	-	-	100	250	350
Display	-	-	300	3200	3500
Total	10	180	1200	4690	6080

1980 Low

	Message Telegram	TELEX-TWX	Other Switched Network	Private Lines	Total
Teletype	10	120	400	1140	1670
Facsimile	-	-	70	30	100
Data	-	-	50	150	200
Display	-	-	100	400	500
Total	10	120	620	1720	2470

5. Telegraph message service. This service has the least significance for the common carriers. There are numerous substitutes -- leased lines, TELEX, phone and mail. Yet there seems clearly to be enough demand to keep the service alive, though its market share declines drastically and even its total volume shows a slight decline. In our analyses, we have been unable to establish the cross-elasticity of this service with phone or mail service. Nor do clear relationships appear with economic factors such as income and GNP. In any event, this service will have little impact on the common carriers.

TABLE 13

Pattern of Message Telegraph Service

	1940	1950	1955	1960	1965	1980
Total messages (Millions)	192	179	154	124	94	70
Total Revenues (Millions)				180	163	105
Teletype Terminals (Thousands)					12	10

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6. TELEX-TWX service. TELEX type service is a switched record service connecting, on a nationwide basis, offices in which teletype terminals are installed. It is thus a direct competitor of public telegraph and is normally chosen when telegram volume between particular points reaches a break-even point. TELEX rates are composed of two elements -- terminal rental and minutes of circuit use. The service has been in use in the U.S. since the 1930's. It had a very rapid growth in the early years but has actually shown an absolute decline in customers in the last few years. We have been unable to isolate definite relationships with economic and demographic factors. Our projections are based on extrapolating traffic trends, modified by price changes in message telegram, in leased line services, and in the use of data phone services.

TABLE 14

Growth of TELEX Market

	1965	1980 High	1980 Medium
Total minutes (million)	200	900*	600*
Terminals (thousands)	70	180	120
Total revenue (million)	91	326	218
Terminal revenue (million)	29	86**	58**
Circuit revenue (million)	62	240***	160***

* 5000 minutes per year per terminal.
** $40 per month = $480 per year
*** $.80 per 3 minutes.

Future prospects for TELEX-TWX service depend to a large degree on the growth of its substitutes leased line, alternate voice-data and facsimile services. There is a point where traffic volume economically warrants leased line rather than TELEX switched service. Similarly, data phone service can also be used for transfer of written messages with appropriate terminal equipment as can facsimile service. TELEX will probably have a lesser share of the total common carrier market by 1980 even though it will continue to

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grow in total volume.

7. Switched network data services. Another data service -- provided by the Bell System -- permits users of the regular telephone switched network to transmit data using a regular telephone line and a data terminal. This new service is expected to have the fastest growth of any common carrier record service. However, its growth cannot easily be related to traditional economic indicators. Its market appears to be almost entirely composed of business and government users who can satisfy their teleprocessing requirements through switched data service, leased lines or the telephone instrument itself. The touch-tone telephone can be a low speed data terminal. It is now used for inventory ordering, stock control, branch bank access to central records, etc.

On the other hand, leased lines will certainly remain the vehicle through which companies transferring high volumes of data will operate. They will continue to be cheaper for high volume users than the switched system. Thus, the switched network data service is attractive to users who have too little traffic in one direction to justify leased

lines and too much traffic to use the touch-tone phone. While these break-even points will change in the future, leased lines offer the greatest promise of dramatic reductions; thus leased line services will probably cut into the data-phone market. Unlike voice communications, data is generally transmitted only to those with whom a customer has a substantial relationship, so the switched network's ability to provide universal service will not count heavily in its favor. It must compete with leased lines largely on price terms. The other important consideration is likely to be high quality service where leased lines also have an advantage.

The break-even points between the two services were calculated on the basis of leased line versus message toll costs -- using time and distance as variables. For distances of 100, 500, and 1000 miles, we have calculated the amount of time at which leased lines become economic. (See Table 15)

TABLE 15

	Leased-line Break-even Points		
Miles	100	500	1000
Calls per day/maximum minutes per day	20/60	20/120	70/210

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By 1980, the break-even point will probably be lower since leased line costs are more heavily weighted to transmission costs than a message toll. Transmission costs are declining more rapidly than other cost elements such as switching.

The projections in Table 16 assume that use of the switched network is limited to those customers who do not generate enough communications to warrant a leased line.

TABLE 16

Projected Growth of Switched Network Data Service

	1965	1980	
		High	Low
Total terminals (thousands)	30 - 40	1200	620
Total minutes per day (millions)	1.2 - 1.6	36.0	18.6
Revenue per day*	.6 - .8	14.4	7.3
Annual revenue (260 days) (mill)	156.0 - 208.0	3744.0	1898.0
Common Carrier Terminal revenue** (mill)	9:0 - 12.0	240.0	124.0
Total revenue (mill)	165.0 220.0	3984.0	2022.0

* Average price per minute in 1965 is $.50; in 1980 is $.40

** Assumes all terminals use common carrier modems with average annual price in 1965 $300 and in 1980 of $200.

The future of this service is very dependent on the growth of time-sharing and on-line computer services -- a factor partly outside the control of the common carriers. To the extent that users of data find it advantageous to have their own local computers, the market shrinks. */ A second important unknown is the value of time. The transfer of data can be most cheaply accomplished through use of the mails and, in most cases, messenger service is lower in cost than electrical transmission locally. Nothing on the horizon indicates any change in this situation. The one area, apart from local time sharing that promises real growth for switched network data services is the market now occupied by TWX and TELEX. With the modification of the foreign attachment prohibition, record users may find terminal ownership and transmission with the switched network an attractive alternative, but this is not a market that yields large revenues for circuit usage.

D. Leased Line Service.

Leased lines include a range of services from point to point circuits connecting two locations to complete networks

*/ BEMA estimated that about 90% of all computer systems would be small desk top size in 1975).

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serving many locations and using switching equipment, both local and long distance.

In 1967 the Bell System Long Lines Department had slightly more than 40% of its circuits in leased lines, although only about 30% of its channel miles were so used. */ Western Union had similar percentages in leased line services. Today, the market is exclusively business and government. The principal competitors for the leased line market are private microwave and wide-area flat rate service (WATS) operating through the switched network.

The growth in leased line service is expected to be largely in data transmission. As with switched network record service, the degree of computer centralization becomes critical. The widespread use of local computers reduces the quantities of data to be exchanged, and large quantities of data are necessary to justify lease of a full-time line.

Even with greatly reduced line costs computer service bureaus do not seem to offer much of a market for long-distance leased lines. A bureau in one city must offer customers in another city benefits which a local bureau cannot match --

*/ AT&T Long Lines estimates.

benefits which must exceed in value the cost of the long distance communication link. Further, local bureaus have a positive advantage in being closer to the customer in case of trouble.

WATS is included in our projections of long distance voice service. It is an attractive substitute for message toll on essentially the same terms as leased lines. The major difference is that it permits free access to the switched network within given geographic areas. It is also a substitute for leased lines, particularly where geographically broad communities of interest exist, and where communications between any two locations do not warrant a full-time line.

The educational use of leased lines is more difficult to predict. Most educational computer systems for primary and secondary schools will probably be local -- within school districts. Nation or state-wide computer systems do not show much promise of growth during the next decade. To the extent that many common software systems can be produced and used by several computer systems, a local smaller computer appears desirable since that would also permit locally developed programs to be used at relatively low marginal cost.

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The remaining major market is for voice and alternate voice data services. This market will be most affected by WATS which should remain cost-competitive throughout this period.

We have been unable to isolate economic or demographic variables which would aid in projecting the future. The projections below are based on AT&T long line estimates that 1400 voice circuits will be in use in 1980 of which half will be leased lines and have bounded the AT&T estimate by high and low ranges. Today, an average circuit is 815 miles long which is the revenue base used in the projections. The circuit projections have been split into "voice" and "record/mixed". Voice refers to lines used for telephoning while record/mixed refers to lines used for record only or alternate voice/record purposes. Tables 17 and 18 present an overall picture of voice and record service projections.

TABLE 17

Projected Growth of Voice and Record Leased-Line Services to 1980
(constant dollar values-based on 1958)

	1965	1980	
		High	Low
total circuits* (thousands)	100	900	500
voice only	65	300	200
record/mixed	35	600	300
circuit miles (millions)	81	735	407
total revenues** (million)	560	3600	2000
voice only	325	1200	800
record/mixed	235	2400	1200
terminals (thousands)***	35	4690	1720

* AT&T long lines facilities only
** We assume a 20% price decrease by 1980
*** Includes terminals used with local private line of which many are for educational purposes

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TABLE 18

Common Carrier Services Totals:

A. Revenues	1965	1980 High	1980 Medium
Telephone services	9200	34400	25500
Local	(6400)	(17500)	(10900)
Toll	(2800)	(16900)	(14600)
Record services	474	4175	2221
Telegraph	(163)	(105)	(105)
TELEX/TWX	(91)	(326)	(218)
Switched network data	(220)	(3744)	(1898)
Leased Services	560	3600	2000
Voice	(325)	(1200)	(800)
Record/Mixed	(235)	(2400)	(1200)
Total	10234	42175	29721
B. Volumes			
Telephone Services			
Total telephones (millions)	94	175	165
Calls per phone	1572	1583	1576
Local	1526	1485	1495
Toll	46	98	81
Calls per capita	685	1116	1041
Local	662	1047	987
Toll	23	69	54
Phones per 100 US population	48	70	66
% households with phones	85	98	97
Record Services			
Telegraph messages (millions)	94	70	70
TELEX/TWX minutes (millions)	200	900	600
Switched Network data per day min. (mill)	1.6	36	18.6
Telegraph terminals (thousands)	12	10	10
TELEX/TWX terminals (thousands)	70	180	120
Switched network data terminals	40	1200	620

Leased Services	1965	1980 High	1980 Medium
Voice Circuits (thousands)	65	300	200
Record/Mixed circuits (thousands)	35	600	300
Voice circuit miles (millions)	53	244	163
Record/Mixed circuit miles (millions)	28	489	244
Terminals	35	4690	1720
Total terminals (millions)	94	181	167

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III. BROADCASTING SERVICES

A. Television Service

This service has two elements of interest to the communications industry--program viewing and program transmission.

1. Program viewing. This area, considered a part of recreation, steadily increased its share of total recreation spending from 12% in 1960 to 16% in 1966. However, that trend has reversed itself in the last two years and there is little promise of television further increasing substantially its share of recreation spending. The market is now largely a replacement market with the exception of the educational area. Household penetration has reached about 95%; with some 75 million sets (about 1½ sets per household) in use. The sizeable expenditures of the past years reflect, in large measure, the conversion from black and white to color sets that on the average are three times as expensive.

Educational users do not offer the potential of increasing the television receiver market by more than a few percent of the total market. As noted earlier in our discussion of the educational market for computer aided instruction terminals, the number of educational aids will probably not exceed the number of classrooms--2½ million by 1980.

Our projections in Table 19 are associated with personal consumption expenditures, household, populations, and educational uses.

TABLE 19

Projected Growth of TV Set Purchases

	1950	1955	1960	1965	1980 High	1980 Low
Total sets (millions)	6.1	32.5	53.3	67.2	118.0 1/	103.5 2/
% Household penetration 3/	14	64	87	93	96	96
TV Households (millions)	6.0	30.7	45.8	52.7	73.9	73.9
Annual set purchases (millions) 3/	6.1	7.4	6.1	11.1	23.6 4/	18.6 4/
Annual consumer expenditures (billions)				4.4	8.3	6.7
hardward 5/				2.6	7/5.9	4.6
operation and maintenance 6/				1.8	2.4	2.1
Annual per capita expenditures				22	33	26

1. Total sets=1.6 sets per TV household
2. Total sets=1.4 sets per TV household
3. Television Factbook - 1967, NBC Research, p. 50-a.
4. 18% replacement rate for low estimate, 20% for high.
5. 1965 average retail price per set $237, 1980 average retail price per set $250 based on all color (constant dollars) includes factory price plus 40% markup.
6. Land Mobile Report, p. 415, by 1980, 20% reduction per set.

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2. Program transmission. The revenues for TV transmission are so small a part of overall communications revenues and so small a part of overall TV costs that we have not carefully analyzed growth in program transmission. The total growth in program transmission through 1980 seems highly unlikely to exceed 800 percent. Assuming no change in price, this would represent between $250 and $500 million out of 1980 common carrier revenues estimated to range between $30 and $37 billion.

B. Radio Service.

The market is closely tied to population households and vehicles. Saturation is estimated at 98.6%. In 1965, 228 million radios were in use of which 57 million were automobile radios.

TABLE 20

Projections of Radio Use

	1950	1955	1960	1965	1980 High	1980 Low
Total radios	85.2	121.0	156.4	228.0	415.0	334.1
home	66.2	94.0	106.0	171.0	275.0	236.0
automobile	19.0	27.0	40.4	57.0	140.0	101.1
% automobile penetration[1]	39	43	55	70	100	85
Average sets per household	1.5	1.9	2.2	3.0	3.5	3.0
Annual set purchases	13.5	14.1	17.1	24.1	69.0[2]	46.0[3]
Annual consumer expenditures	484	396	508	946	1422	943
hardware[4]	484	396	508	644	1380[5]	910
operation & maintenance	N.A.	N.A.	N.A.	302[6]	42[7]	33

1/ 65 = .66 cars per driving age person
80 = .7 (low) or .8 (high)
122.5 million cars/140 million
65 = .7 radios per car
80 = .85 (low) or 1.0 (high)
2/ 25% annual replacement
3/ 20% annual replacement
4/ Factory price + 40% markup
5/ Retail price average $20
6/ Land Mobile report, p. 418
7/ Decrease by a factor from 1965.
1965 - $1.20 1980 - $.10

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TABLE 21

Projected Growth in Total Broadcasting Services

	1965	1980 High	1980 Low
Total sets (millions)	295	533	438
TV	67	118	104
Radio	228	415	334
Total annual consumer expenditures (billions)	5.35	9.72	7.64
TV	4.40	8.30	6.70
Radio	.95	1.42	.94
Annual per capita expenditure ($)	27	38	30
TV	22	33	26
Radio	5	5	4
Average sets per household	4.1	5.1	4.3
TV	1.1	1.5	1.3
Radio (excluding cars)	3.0	3.6	3.0

III.

TABLE 22

Comparison Between Aggregate and Individual Expenditure Levels - 1980
(1958 dollars)

	High	Medium
Aggregate (billions)	47.3	42.0
Common Carrier	30.4	26.2
Purchase of TV and Radio sets	16.9	13.8
Disaggregate (billions)	51.9	37.3
Common Carrier	42.2	29.7
Local telephone	17.5	10.9
Long distance telephone	16.9	14.6
Telegraph	.1	.1
TELEX/TWX	.3	.2
Switched Network data	3.7	1.9
Leased lines	3.6	2.0
Purchase of TV and Radio Sets	9.7	7.6
TV	8.3	6.7
Radio	1.4	.9

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IV. U.S. - OVERSEAS TELECOMMUNICATION DEMAND

A. Aggregate Demand for Telecommunications

Only common carrier services are condisered: The principal variables used in the projections were total world exports and U.S. GNP. The results are indicated in Table 23.

TABLE 23

Common Carrier Revenues */
(Millions of dollars)

Projection based on:	1965	1980
1. Total World Exports		
Telephone	117	536
Record	107	286
Total	224	822
2. 4% growth in real GNP		
Telephone	117	303
Record	107	250
Total	224	553
3. 5% growth in real GNP		
Telephone	117	467
Record	107	281
Total	224	748

*/ Taylor, Appendix 1.

1. Demand for Particular Telecommunications Services. The categories analyzed are telephone, TELEX/TWX and Telegram combined, leased circuits, and TV service. We have considered these categories in two geographic regions -- the Atlantic area and the Pacific area.

Historically, the supply of telecommunications service throughout the Atlantic region has been limited. With the advent of high capacity satellite and cable facilities, this situation should soon change (by the early 1970's). The availability of more adequate facilities thus raises the question of how to project the amount of pent-up demand widely assumed to have been held back by lack of facilities. We have used a variety of variables to arrive at alternative levels of demand. The more important are U.S. overseas investment, world trade, foreign per capita income, status of foreign internal telecommunications facilities and the efficiency of handling telecommunications messages. The most useful single source of information in these areas is the Stanford Research Institute Study of International Telecommunications Policies Technology, and Economics.

Among our conclusions, level of income seems to be a much more important determinant of telecommunications consumption than price. Few foreign nations are expected to reach an income level by 1980 sufficient to generate substantial demand. The bulk of U.S. overseas communications will continue to be with Europe, U.S. overseas areas (Puerto Rico, Hawaii), Japan, Australia and New Zealand.

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B. Telephone Service

Telephone service will continue to use the bulk of facilities through 1980. We have postulated different levels of average annual growth and also assumed different degrees of price elasticity to arrive at high and medium levels of demand against which facilities are projected. No low level of demand was calculated since facilities planned and funded for the early 70's will provide for about 10 times as much traffic as in 1965.

In the Atlantic region, we have projections (see Table 24) for Europe, Africa, the Mid-East, South and Central America and the Caribbean.

TABLE 24

Projected Growth in Telephone Service

*/	1950	1955	1960	1965	1980 High	1980 Medium
Telephone calls/ circuits	526/86	832/138	1993/286	4990/705	96000/12000	44000/5500
Europe	282/45	388/64	1057/150	2465/350	51600/5700	21700/2850
Africa-Mid East	21/4	22/4	34/6	65/10	5415/670	2300/120
South America	102/17	135/22	187/30	310/45	7785/1130	7000/430
Caribbean Central America	121/20	287/48	715/100	2150/300	31200/4500	13000/2100

2. Pacific Region.

*/	1950	1955	1960	1965	1980 High	1980 Medium
Telephone calls/				1690/215	18000/1750	11000/1100
Circuits				1300/130	9000/750	6000/500
Hawaii						
West of Hawaii	93/13	178/26	183/27	390/85	9000/1000	5000/600

*/ Telephone calls in thousands.

The 1980 medium projection assumed price decreases of 25% in the early 70's with a corresponding increase in overall traffic of 32% (a price elasticity of - 1.28)*/ plus a growth rate of about 15% per year based on other factors

*/ SRI study, minus elasticity coefficient means demand will increase with a decrease in rates. Price elasticity of international communications is very difficult to ascertain. A study of Alaska to the U.S. indicates a price elasticity of - 1.8 -- for every 1% decrease in price, the quantity sold increased by 18% (Comsat). Mr. L. Kumins (Comsat), in a separate analysis of Canada/U.K. traffic concluded that for every 1% decrease in price, the quantity increased by only .7%.

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than price. The 1980 high projection assumed that prices in 1980 would be half those in 1965 with a higher increase in overall traffic (57% or a price elasticity of - 1.71*/) plus a 5% growth rate unrelated to price. The circuit estimates assume that efficiency of circuit use will not improve substantially through 1980. If international circuit efficiency in 1980 is assumed to be equal to U.S. circuit efficiency in 1967, the number of international circuits required is nearly halved.**/

C. TELEX/TWX and Telegraph Services

We have merged our analysis of these two modes since telegram service requires very limited facilities. All estimates of the future of telegraph indicate at best a leveling off and at worst a substantial decline from 1965. TELEX growth is also showing signs of leveling off in the face of competition from both telephone and leased line services.***/

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*/ See fn on preceding page.

**/ The ITU has established a factor of 150 minutes of conversation per day or 45,000 minutes per year are equivalent to one voice circuit. The AT&T Long Lines Department gets an average of 93,000 minutes of conversation per year from one voice circuit.

***/ Smith, Edward P., and Chambers, George R., "Requirements for U.S. International Telecommunications through 1975," IEEE Transactions on Communication Technology, April, 1967, p. 188.

The 1980 high estimate is reached by assuming a very substantial overall increase in U.S. business investments overseas, extension of minimum calling times (one minute) and a 50% rate reduction by 1980. In terms of facilities required, the estimates of circuits are extremely conservative, assuming that a voice equivalent circuit will provide only four TELEX Telegraph circuits and each of the four is used at 15% efficiency. Today's technology permits from 16-32 telegraph circuits to be obtained from one voice circuit. Using such assumptions TELEX traffic in 1980 would require only 2-4% as many circuits as telephone service.

D. Leased Line Service

Projections of future demands in this area have essentially no statistical basis since they have been offered for only a few years and have been bought almost exclusively by the U.S. Government. The non-government market is exclusively business. The potential demand for leased circuits seems largely to involve the transfer of data among company locations. The growth of governmental demand in the future is in question since government owned satellite systems with substantial international capacity are planned for

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TABLE 25

TELEX Traffic
Atlantic Region

	1957	1960	1965	1980 High	1980 Medium
Telex Minutes*/voice equivalent circuits	1.4/6	2.8/10	11.2/23	75.0/300	55.0/220
Europe	1.3/5	2.6/5	7.5/15	40.0/160	32.0/128
Africa-Mid East	- **	-	.4/1	4.5/20	2.0/9
South America	.1/1	1.0/4	2.5/5	23.0/90	15.0/60
Caribbean/Central America	-	.2/1	.8/2	7.5/30	5.0/22

* Millions of minutes
** Below 50 thousand minutes

Pacific Region

Telex Minutes (mill)/voice circuits	.5/3	1.8/9	3.9/21	33.0/132	18.5/87
Hawaii	-	-	.3/4	3.0/12	1.5/12
West of Hawaii	.5/3	1.8/9	3.6/17	30.0/120	18.0/75

use through the 1970's. Because of the uncertainty about governmental needs, we have estimated for 1980 use of leased lines with and without government as a user.

E. Television Transmission Service.

Projections of future demands in this area also have essentially no statistical basis. Facilities have been available only since 1964. International TV transmission growth is inhibited by language barriers and by time zone differences. It is further restricted by the limited number of hours per week when audience size justifies live international TV. If real-time transmission is not important, jet aircraft provides real competition. In our estimates of equivalent voice circuit required for TV, we have assumed that when demand for TV reaches a few hundred hours per year, a full-time TV channel equivalent to 600 voice circuits must be available.

If demand for real-time TV transmission between continents reaches 5-10 hours per week, it starts to conflict with peak traffic demands in the other services. We have further assumed that if demands exceed 1000 hours per year, a second TV channel will be required since, almost certainly, more than one program would be transmitted at the same time.

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TABLE 26

Leased Line Circuits
Atlantic Region

	1965	1980 High	1980 Medium
Total equivalent voice circuits	95	3000	2100
Without Government	7	400	140
Europe, Mid East, Africa	49	2300	1680
Without Government	5	300	100
South and Central America, Caribbean	35	700	420
Without Government	2	100	40

Pacific Region

	1965	1980 High	1980 Medium
Total equivalent voice circuits	24	1300	540
Without Government	*	110	65
Hawaii	20	300	140
Without Government	*	10	5
West of Hawaii	4	1000	400
Without Government	*	100	60

* Less that 1 equivalent voice circuit.

TABLE 27

TV Transmission
Atlantic Region

	1965	1980 High	1980 Medium
Total annual hours/voice circuits	25/-	4000/2400	2000/1200
Europe, Mid East, Africa	-	2000/1200	1000/600
South and Central America, Caribbean	-	2000/1200	1000/600

Pacific Region

	1965	1980 High	1980 Medium
Total annual hours/voice circuits	-	3000/1800	1300/1200
Hawaii	-	2000/1200	1000/600
West of Hawaii	-	1000/600	300/600

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TABLE 28

Total Atlantic Region Circuit Demand

	1950	1955	1960	1965	1980 High	1980 Medium
a. Telephone						
Calls per year (million)	.5	.8	2.0	5.0	96.0	44.0
Circuits	86	138	286	705	12000	5500
b. TELEX/Telegram						
Min. per year (million)	-	-	3.8	11.2	75.0	55.0
Voice circuits	-	-	10	23	300	220
c. Leased Lines						
Voice circuit	-	-	-	95	3000	2100
Without Government	-	-	-	7	400	140
d. Television						
Hours per year	-	-	-	25	4000	2000
Voice circuits	-	-	-	-	2400	1200
e. Total Circuits	86	138	296	823	17700	9020
(Without government)	-	-	-	(735)	(15100)	(8060)

TABLE 29

9. Total Common Carrier Revenues from Intercontinental Service

a. Telephone Service	1965	1980 High	1980 Medium
(1) Atlantic			
(2) Pacific			
(3) Total (millions)	87 */	650	468
Average cost per call ($)	11.45	5.70	8.50
b. TELEX/Telephone Service			
(1) Atlantic			
(2) Pacific			
(3) Total (millions)	72 */	259	270
Average cost per minute	4.80	2.40	3.60
c. Leased Lines Service			
(1) Atlantic			
(2) Pacific			
(3) Total (millions)	35 */	215	264
Average cost per voice circuit/year	$200,000 1/		
d. Total Revenues			
(1) Atlantic			
(2) Pacific			
(3) Total	194	1124	1002

1/ For leased lines reductions of 150 and 100% are projected

*/ Taken from Lerner, Norman C. - A Doctorial Dissertation submitted to the American University (Unpublished, 1968).

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APPENDIX B

THE DEMAND FOR COMMUNICATIONS SERVICES IN 1980

Lester D. Taylor */

I. INTRODUCTION

There is an economic analysis of the demand for communications services and two sets of projections of the demand for these services in 1980. With the data available and the constraints of time, I believe that the analysis here is as detailed and complete as possible.

In an effort to get as complete coverage as possible of the wide range of communication services offered and users involved, several sources of data have been analyzed, including: **/

1. Consumer expenditures on telephone, telegraph, and wireless from the National Income Accounts;

2. Consumer expenditures on radio and television receivers also from the National Income Accounts;

3. Broadcasting revenues of radio and television

*/ Economist, Harvard Economic Advisory Service, and Consultant to the Task Force

**/ The sources of data are found in the Appendix

4. The number of local and long distance telephone calls made each year;

5. The amount of GNP originating in the telephone and telegraph and radio and television broadcasting industries;

6. International telephone and telegraph revenues

The first category includes all expenditures (including the rent on telephones) by consumers for the services of the common carriers as reported in the National Income Accounts. In 1966, these expenditures were $6.9 billion, 1.5% of total consumer expenditure, and 0.9% of GNP. Unfortunately, accompanying data for the expenditures on these services by businesses and government are not included in the National Income Accounts. Phone calls of businesses and government are, however, included in category (4), so that only telegrams of businesses and government are not represented somewhere in the data analyzed.

Since telephones are rented, the only communication equipment purchased by consumers is radio and television receivers, and these are included in the second category. Radio and television broadcasting, however, is not paid for directly by the listening public; hence it is necessary

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separately to analyze radio and television revenues within a third category.

Although there is considerable overlap between the fourth and first categories, it is useful to analyze the number of telephone calls directly, especially long-distance calls, for, in addition to serving as a partial check on the results obtained with the data from category (1), it will also provide evidence on the price elasticity for long-distance calls. While category (3) refers to the gross revenue accruing to the broadcasting industries, category (5) refers only to the GNP originating (or value-added) in these industries. Since the latter is a direct component of total GNP, it is the best single measure of the overall importance of the communication industry in the economy. Finally, the last category covers the revenues generated by domestic telephone and telegram companies in their international operations.

II. THE DETERMINANTS OF THE DEMAND FOR COMMUNICATION SERVICES

The primary determinants of expenditures for communications services are income, relative prices, the size of the population, and technology. The first three operate directly on demand, while technology has a dual impact on the supply

side through cost reduction and the introduction of new services. Therefore, the important questions to be answered direct themselves to the quantitative impacts of changes in these factors on the expenditures for communication services. In particular, we need to know:

1. The income elasticity of demand;
2. The price elasticity of demand;
3. The future growth of population;
4. The future course of technology.

Of the four, it is clear that predicting the future course of technology is the most speculative. Income and price elasticities can be estimated with some confidence from past behavior, and the Bureau of Census has developed sophisticated techniques for extrapolating the population. Technology, however, presents an entirely new dimension. As noted above, technology has a twofold impact on the supply side through reduction of the costs of providing old, and the introduction of new, services. It is the introduction of new services that creates the difficulty. Cost reductions, which in some cases can be foreseen with clarity, eventually lead to lower prices, and therefore can be incorporated

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into the analysis. But new services, by their very nature, have no past history to build on. Even for those services already apparent on the horizon, it is very difficult to say how the consuming public will react to them.

As a result, apart from being able to translate cost reductions into lower prices (which themselves must come from technical sources), there is little that economic analysis can say about the future impact of technology. Therefore technology has been set aside in the analyses reported in this memorandum. Nevertheless, before leaving the subject completely, a couple of observations are pertinent.

First, in terms of broad magnitudes, it would be surprising if the introduction of new services were to lead to a major revamping of the way that consumers allocate their consumption expenditures among broadly defined categories. For example, it is unlikely that the introduction of "phonovision" would lead to an increase in expenditures for the broad category "communication services" at the expense of expenditures for food, transportation, or other equally broad categories (although it is conceivable that intercity travel and certain reaction expenditures would be adversely

affected). What is more likely is that "phonovision" would lead to reallocation of expenditures within the category of communication services itself. Also, it should be remembered that communications is not the only category of consumer expenditure that is likely to be introducing new products and services in the years ahead. Competition for the consumer's dollar is keen, and I see no reason a priori to assume that new communication services will fare relatively any better than the new products of any other industry. Therefore, the projections of expenditures on communication services by broad categories of service that are presented in this memorandum are, in my opinion, likely to be relatively independent of the number of new communications services introduced between now and 1980.

Second, some new communication services may simply take the form of new ways of doing old things. For example, if the "checkless" society were to become a reality, the result would not be to create a totally new category of expenditure, but rather to transfer to IBM and AT&T part of the functions now performed by the banking system. Therefore, there would be a reallocation of existing expenditures, and the best way to take this into account

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would be to project expenditure for the function of handling a checking system and then to reallocate the expenditure among industries.

III. TYPE OF ANALYSES EMPLOYED

The projections transmitted in this memorandum are based on conventional methods used in demand analysis. Those projections for expenditures by consumers for telephone, telegraph, and wireless and radio and television receivers -- categories (1) and (2) -- are based on the demand model that H.S. Houthakker and I have used extensively in preparing projections to 1970 and 1975 for the Inter-Agency Growth Study of the 80 odd items of consumer expenditure that appear in the National Income Accounts.[2/] The estimating form of this model, which is the only form that need concern us here, is

(1)

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[2/] For a description of this model, see Chapter 1 of H.S. Houthakker and L.D. Taylor, Consumer Demand In The United States, 1929-1970.

run elasticities, equation (1) also allows long-run elasticities to be calculated. (In contrast to the short run, habits have a chance to adjust in the long run.) In the present case, however, the fact that the dependent variable in equation (2) is a first difference means that it is impossible to calculate the long-run elasticity (a division by 0 is required) from this equation. However, simulation experiments with the equation give implicit long-run elasticities for both total expenditure and relative price that are well in excess of one (actually, -1 for the relative price).

The fact that the total expenditure and price elasticities are low in the short, but high in the long-run implies that expenditure by consumers for common carrier communcations services is characterized by inertia and delay, but with the very interesting property that the higher expenditures have been in the recent past, everything else being constant, the higher they will be now. Houthakker and I have found in our investigations that this characteristic is widespread among the services, and that these tend to have substantial elasticities, particularly with respect to total expenditure, in the long run.

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[illegible]

The projections for the remaining four categories have been prepared from equations that are linear in the variables concerned (or their logarithms) and which, in contrast to the model above, include only current values of variables. These equations are discussed as they appear.

Two projections have been made for each category. The first set is based on an assumed growth rate in GNP of 4.0%, which corresponds to the estimate of the Council of Economic Advisers of the present potential rate of growth in GNP, while the other set is based on a 5% rate of growth in GNP. The latter is clearly unrealistically high, but the resulting projections will indicate the extent to which the probable course of expenditures for communication services are dependent on the growth rate of GNP. The projected values of the independent values are given in the Appendix.

IV. RESULTS AND PROJECTIONS

1. Consumer Expenditures for Telephone, Telegraph, and Wireless

This item is category 5.9 of the personal consumption expenditure table in the National Income Accounts. The historical data cover the period 1929-1964, with the war years 1942-45 excluded, and are in 1958 dollars. The estimated equation is (standard errors are in parentheses):

(2) [illegible]

This is the equation that Houthakker and I will be using for this category in the second edition of our book, Consumer Demand In The United States. It differs in form from equation (1) in that the dependent variable is a first difference; this implies that A_1, in equation (1) is equal to 1.0. This special case was arrived at after estimation of equation (1) yielded an estimate of A_1 that was not statistically significantly different from 1.

The elasticities calculated at the mean values of the respective variables implied by the coefficients in equation (2) are 0.32 for total consumption expenditure and - .26 for relative price. These may seem low, but it should be noted that they are short-run elasticities.* In addition to short-

*The short-run is defined as the period during which spending habits do not have an opportunity to adjust, here taken to be one year.

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The projections (in 1958 dollars) in 1980 from this equation are as follows:

4% growth in GNP	$63.36 per capita (1958 $'s)
5% growth in GNP	$66.88
1965 level	$31.95

In computing these projections, I have assumed (arbitrarily) that the relative price in 1980 will be 20% below its level in 1965. Other assumptions might want to be made.

2. Consumer Expenditures for Radio and Television Receivers

This category is item 9.5 in the personal consumption expenditures table in the National Income Accounts, and, as for the preceding category, the historical data cover the period 1929-1964, with the war years 1942-45 omitted, and are in 1958 dollars. The estimated equation is:

(*)

The relative price does not appear here because its coefficients were statistically insignificant. As with equation (2), Houthakker and I are using this equation in the second edition of our book.

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The values of the total expenditure elasticities (computed at the means of the variables) implied by the coefficients of equation (3) are 4.20 and 3.00 for the short run and the long-run, respectively. However, because of the very sharp trend in expenditure for this item, it is perhaps more meaningful to compute the values of the elasticities at the end of the period, and for 1964 these were, respectively, 2.97 and 2.12.

In contrast to communication services, radio and television sets are durable goods, which means that, in addition to income and price, existing (depreciated) stocks are likely to have an important influence on current purchase. If a family has just purchased a television set, then, everything else being constant, it is unlikely to be in the mood to purchase another soon. In short, existing stocks have a negative influence on current expenditure, and this is reflected in a smaller total expenditure elasticity in the long run than in the short run. What is most important for present purposes, however, is the magnitude of the long-run elasticity, and this, as we have seen, is large.

Equation (3) gives the following projections (in 1958

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dollars per capita) in 1980:

4% growth in real GNP	$55.48 per capita (1958 $'s)
5% growth in real GNP	$67.88
1965 level	$31.69

3. Broadcasting Revenues of Radio and Television Stations

As noted above, a less complicated model is used in projecting this and succeeding categories. Here, broadcasting revenues are related to gross corporate product and total advertising expenditure, all quantities being measured in current dollars. The historical period is 1947-1965. Advertising, of course, is the principal source of revenue for radio and television stations, so inclusion of total advertising expenditure as an explanatory variable is obvious. Gross corporate product is included as a proxy for sources of revenue other than advertising and as a general indicator of economic activity. Projections have been made for radio and television broadcasting combined and for each separately.

RADIO AND TELEVISION REVENUES COMBINED

The equation used in preparing the projections of the combined revenues of radio and TV is the following:

$$(4) \qquad R_t = \underset{(50.88)}{-869.54} + \underset{(1.53)}{6.29}\ GCP_t + \underset{(.0363)}{.0772}\ ADV_t \qquad R^2 = .994,\ S_e = 59.78$$

where

R = revenues of radio and TV stations in millions of current dollars

GCP = gross corporate product in billions of current dollars

ADV = total advertising expenditures in millions of current dollars.

The projections are:[3/]

4% growth in real GNP	$8.30 billion
5% growth in real GNP	$9.56
1965 level	$2.76

RADIO REVENUES

The equation for radio revenues is

$$(5) \qquad R_t = \underset{(16.35)}{146.60} + \underset{(.49)}{3.67}\ GCP_t - \underset{(.0117)}{.0528}\ ADV_t \qquad R^2 = .976,\ S_e = 19.21$$

The negative coefficient for advertising expenditures may seem like an anomaly, and, in the sense of advertising being a direct source of revenue, it is. However, a sharply declining share of advertising expenditures have gone to

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3/ See the Appendix for the details on how GCP and ADV were projected in current dollars.

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radio since television made its strong appearance in the early 1950's, with the result that radio stations have had to turn increasingly to other sources of income.[4/] This can account for the negative coefficient for advertising expenditures.

The projections from this equation are:

4% growth in real GNP	$1675 million
5% growth in real GNP	$1815
1965 level	$ 793

TELEVISION REVENUES

The same equation for television revenues is

(6) $R_t = -1016.2 + 2.62\ GCP_t + .1299\ ADV_t$ $\quad R^2 = .993$
(49.2) (1.48) (.0351) $\quad S_e = 57.82$

In contrast to radio revenues, television revenues are strongly attached to advertising expenditures, which is what we should expect. Gross corporate product is also important, but its coefficient is not nearly as significant statistically as in the equation for radio revenues.

[4/] This seems plausible to me, but it comes off the top of my head.

The initial idea was to use the same model as was used for the first two categories. This is the model that is used for local calls, but a bad dose of multicollinearity precluded its use for long distance calls. [*/] As a result, recourse is made for long distance calls to a customary static model of the type used in categories (3) and (4) above.

The income variable used in the equations is GNP (in 1958 dollars), which appears in place of total personnel consumption expenditure (the income variable used in the first two categories) because business and government calls are included as well as personal calls. The historical data cover the period 1936-1965, with the war years (1942-45) excluded as before. The dependent variable is number of calls per capita; therefore GNP is also per capita. The price for long distance calls has been deflated by the implicit GNP deflator, hence it is a real price.

[*/] Multicollinearity is a statistical problem that arises when the independent variables in a multiple regression equation are very closely correlated.

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The projections in 1980 are:

4% growth in real GNP	$6.64 billion
5% growth in real GNP	$7.74
1965 level	$1.96

It will be noticed that the sum of the projections for radio and television is equal to the projection from the equation for the two combined. This is no accident, but follows from the form of the equations. Equations (5) and (6), therefore, break down the projection from equation (4).

4. Local and Long Distance Telephone Calls

I have analyzed the actual number of telephone calls in hopes of being able to isolate the price elasticity for long distance calls. Local calls have also been analyzed, but they are of less interest. For the price of long distance service, I have used the basic daytime rate for a 3 minute call between New York and Chicago. Since local rates vary considerably among locales, I did not consider it worthwhile to put together a price series for local service. Besides, the price elasticity for local service is most likely negligible.

LOCAL CALLS

The equation for local calls per capita is

(7) [illegible] $R^2 = .999$, $S_e = 3.4$

where

q = number of local calls per capita

y = GNP per capita (in 1958 dollars)

$\Delta q_t = q_t - q_{t-1}$.

The elasticities with respect to GNP (calculated at the mean values) implied by this equation are 0.14 and 2.14 in the short and long run, respectively. Thus, the inertia-type behavior that was found to characterize consumers' expenditure on the common carrier communication services (category (1) above) is confirmed here. Again, however, the major result for present purposes is the large GNP elasticity in the long run.

The projections to 1980 from equation are:

4% growth in real GNP	987 calls per capita
5% growth in real GNP	1047
1965 level	646

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LONG DISTANCE CALLS

The equation for long distance calls per capita computed in natural logarithms is

(8) $\ln q_t = \underset{(4.29)}{-5.76} + \underset{(.53)}{1.12} \ln x_t - \underset{(.23)}{.35} \ln p_t \qquad R^2 = .927,\ S_e = .13$

where

q = number of long distance calls per capita

x = GNP/Capita (in 1958 dollars)

p = the rate for a 3 minute call between New York and Chicago deflated by the implicit GNP deflator

ln = the "natural logarithm of".

Those of us with an implicit belief that the price elasticity for long distance calls will find this belief shaken by the above estimate of -.35. (Since the equation is estimated in logarithms, the coefficients are already elasticities.) In assessing this low value, however, two considerations must be weighed: (1) Business and government calls are included in the total, and we should expect the price elasticity for those two users to be considerably lower than for private consumers; (2) Both independent

variables contain rather strong trends, GNP positive and price negative, which makes them very collinear (i.e., they are highly correlated with one another). As a result, it is practically impossible to isolate the separate effect of each. What this means is that each variable taken separately will do almost as well in predicting long distance calls as both together. That this is the case is evident in equations (9) and (10), where the two variables appear separately:

(9) $\ln q_t = \underset{(.87)}{-12.10} + \underset{(.11)}{1.91} \ln x_t \qquad R^2 = .920,\ S_e = .14$

(10) $\ln q_t = \underset{(.49)}{3.30} - \underset{(.05)}{0.83} \ln p_t \qquad R^2 = .914,\ S_e = .14$

Thus, it is seen that the price elasticity is raised considerably when it appears in the equation. Although it is still above -1.0, I believe that the inclusion of business and government calls, as noted above, is undoubtedly the reason for this. The GNP elasticity is also raised substantially when it appears alone but in my opinion GNP is more a proxy for price in equation (9) than price is a proxy for GNP in equation (10).

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On the basis of these results, I am all the more of the opinion that the only way to settle the price elasticity question for long distance calls is to obtain access to AT and T data for long distance traffic bracketing a couple of significant rate changes in the past. In any event, I think that we can conclude from the above results that the income elasticity for all long distance calls is above one and that the price elasticity is higher than that indicated in equation (8), but below that indicated in equation (10).[5/]

The projections to 1980 from equation (8) are:

4% growth in real GNP	42 calls per capita
5% growth in real GNP	48
1965 level	30

In these projections I have assumed that the real price of long distance calls will continue the same average rate of

5/Although multicollinearity affects the estimates of the coefficients, it does not affect the estimates of the dependent variable, and, so long as the historical relationship between GNP and price continues in the future, it will not affect the projections either. If this latter assumption breaks down, then unfortunately the use of either equation (9) or (10) is not valid either. However, the assumption seems plausible in my opinion.

decrease as since 1950. I have also prepared projections from equations (9) and (10), and these follow.

Equation (9):

4% growth in real GNP	54 calls per capita
5% growth in real GNP	69

Equation (10) 31

Of these three sets of projections, the one from equation (10) is clearly out of the question, and, of the other two, I prefer those from equation (9).

5. Gross Product Originating In The Communications Industries

An alternative way of limning the importance of the communications industries in the economy is to look at the gross product they generate. The gross product generated differs from the information given in categories (1) and (3) in that those categories essentially measure sales, while gross product originating is in terms of value-added. Gross product originating thus measures the direct contribution to GNP of these industries.

The Office of Business Economics constructs these data

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for two communication industries, namely, telephone and telegraph and radio and television broadcasting. The historical data cover the period 1948-1966 and are in 1958 dollars.[6/] A very simple model is used here, viz., to relate gross product originating to total GNP and the relative price. The relative price is defined as the implicit deflator for the industry involved divided by the implicit deflator for total GNP.

TELEPHONE AND TELEGRAPH

The equation for gross product originating in the telephone and telegraph industry is

(11) $GPO_t = \underset{(276.56)}{570.64} + \underset{(.13)}{2.73}\ GNP_t - \underset{(2.25)}{10.09}\ p_t$ $\quad R^2 = .992$, $S_e = 29.23$

where

GPO = gross product originating in millions of 1958 dollars

GNP = total gross national product in billions of 1968 dollars

p = implicit deflator for tel. and tel./GNP deflator.

[6/] These data have been made available by OBE on a confidential basis to the Brookings Institution. I obtained them from the latter.

The elasticities computed at the means for the variables are 1.55 for GNP and -1.26 for the relative price. Although these elasticities are akin to demand elasticities, they should not be strictly interpreted as such because they are dependent on the structure of the industry (particularly on the mix between services provided by the industry and those purchased from other industries). However, the fact that the above price elasticity is greater than one (absolute value) corrobarates the conclusion reached in the preceding section that the price elasticity for long distance calls is higher than what the data there seem to indicate.

The projections in 1980 from this equation are:

4% growth in real GNP	$2.96 billion (1958 $'s)
5% growth in real GNP	$3.41
1966 level	$1.46

In preparing these projections, I have assumed that the relative price will decline 1% per year between 1966 and 1980 (this compares with an average decrease of .8% per year between 1947 and 1966).

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RADIO AND TELEVISION BROADCASTING

The equation for gross product originating in the radio and television broadcasting industry estimated in natural logarithms is

$$(12)\quad \ln GPO_t = \underset{(1.46)}{1.08} + \underset{(.11)}{2.35}\ln GNP_t - \underset{(.39)}{2.40}\ln p_t \qquad R^2 = .968,\ S_e = .07$$

where the variables are defined in the same way as in equation (11).

As for telephone and telegraph, the GNP and price elasticities are quite high, although these elasticites must be interpreted with even more circumspectly than those for telephone and television. In terms of money changing hands, the services of the radio and television industry are only demanded indirectly by consumers; the direct demand is largely by other industries for advertising time. Therefore, the above price elasticity might best be interpreted as the price elasticity with respect to radio and television advertising rates especially the latter.

The projections in 1980 from this equation are:

4% growth in real GNP	$165 million (1958 $'s)
5% growth in real GNP	$216
1966 level	$108.9

I have assumed in preparing these projections that the relative price between 1966 and 1980 will continue its 1958-1966 upward trend.

6. International Telephone and Telegraph Revenues

The final category of data investigated is the revenues of domestic telephone and telegraph companies from their international operations. A very simple approach has been followed here, namely, to tie international revenues to some measure of world income; for the latter, I have used two variables, total world exports and U.S. GNP. The historical data cover the period 1931-1965 (excluding 1942-45) for international telegram reports. The historical period for international telephone revenues is 1951-1965. All data are in current dollars.

INTERNATIONAL TELEPHONE REVENUES

The estimated equations for international telephone revenues are:

$$(13)\quad IR_t = \underset{(6.24)}{-79.53} + \underset{(.06)}{1.18}\,Wx_t \qquad R^2 = .970,\ S_e = 6.25$$

$$(14)\quad \ln IR_t = \underset{(1.00)}{-18.11} + \underset{(.16)}{3.52}\ln GNP_t \qquad R^2 = .973,\ S_3 = .14$$

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where

IR = international telephone revenues in millions of dollars

Wx = total world exports in billions of dollars

GNP = U.S. GNP in billions of current dollars

ln = the "natural logarithm of".

The projections in 1980 from these equations are:

equation (13)

world exports continue to grow at their average 1960-65 rate	$536 million
1965 level	$117.4

equation (14)

4% growth in real GNP	$303 million
5% growth in real GNP	$467

INTERNATIONAL TELEGRAM REVENUES

The two equations estimated with world exports and U.S. GNP as predictors are:

(15) $\ln IR_t = .71 + .79 \ln Wx_t$ $\quad R^2 = .980$
(.18) (.03) $\quad S_e = .04$

(16) $IR_t = 15.66 + .14\ GNP_t$ $\quad R^2 = .989$
(.95) (.03) $\quad S_e = 2.89$

The variables are defined in the same way as for international telephone revenues.

The projections in 1980 from these two equations are:

equation (15)

world exports continue to grow at their 1960-67 rate	$286 million
1965 level	$106.7

equation (16)

4% growth in real GNP	$250 million
5% growth in real GNP	$281

V. DISCUSSION OF THE PROJECTIONS

The projections are drawn together and tabulated in Table 1. In addition to levels, the projections are also expressed as a percentage of the GNP projected in 1980 (except for the first two categories, which are expressed as a percentage of total personal consumption expenditures).

Generally, the picture that emerges from these projections is the following:

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1. Consumers will spend a large proportion of their budget on telephone services and on communications "hardware" in 1980 than at present.

2. Broadcasting revenues will grow faster than GNP, but the acceleration will occur in television revenues. Radio revenues will just keep pace with GNP.

3. International telephone and telegram revenues will also grow relative to GNP.

4. Based on points (1) and (3) and corroborated by the projections of categories (4) and (5), the common carrier services will be the fastest growing communication sector during the next 15 years.

5. Although the projections do not reveal it, income is by far the most important determining factor in the demand for communication services. This is not to imply that the prices of services are not important, but rather that the influence of income swamps that of price over any period of time.

VI. CONCLUDING REMARKS

The projections in Table 1, I think, pretty well speak for themselves, and I hope that sufficient information is

Table 1

Summary of projections in 1980

Category	Equation	1958 level	1958 % GNP	1980 (2% growth in GNP) level	1980 (2% growth in GNP) % GNP	1980 (3% growth in GNP) level	1980 (3% growth in GNP) % GNP	Remarks
Consumer expenditures for telephone, telegraph, wireless	2	$31.65	1.6	$63.36	2.2	$66.03	2.1	per capita 1958 $'s
Consumer expenditures for radio and television sets	3	$31.69	1.6	$55.48	1.9	67.58	2.1	% of total personal consumption expenditure
Broadcasting revenues of radio and television stations								
combined	4	$2.76 b.	0.40	$3.30 b.	0.30	$9.56 b.	0.31	
radio stations	5	$793 m.	0.12	$1657 m.	0.10	$1815 m.	0.10	current dollars
TV stations	6	$1.96 b.	0.29	$3.64 b.	0.40	$7.74 b.	0.41	
Local and long distance telephone calls								
local calls	7	643 calls/cap.		937 calls/cap.		1047 calls/cap.		
long distance calls	8	38 calls/cap.		42 calls/cap.		48 calls/cap.		GNP and price
	9			54 calls/cap.		69 calls/cap.		GNP only
Current payment originating in the communications industries								
telephone and telegraph	11	$1.46 b.	0.22	$2.96 b.	0.26	$3.41 b.	0.26	1966 level
radio and television	12	$165.2 m.	0.017	$169 m.	0.015	$216 m.	0.016	1958 dollars
International telephone and telegram revenues								
telephone	13	$117.4 m.	0.017	$336 m.	0.032			world exports
	14			$303 m.	0.013	$437 m.	0.023	U.S. GNP
telegram	15	108.7 m.	0.016	$235 m.	0.017			world exports
	16			$230 m.	0.015	$281 m.	0.015	U.S. GNP

current dollars

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furnished in the text and in the Appendix that follows so that anyone wishing to utilize different assumptions about the growth of the economy and about price movements can do so without trouble.

In my opinion, the most important lingering questions are:

1. What is the price elasticity of demand for long distance telephone calls? As I noted above, I think that the only way now of getting at this question is with AT and T data surrounding a couple of long distance rate changes.
2. What will be the impact of technology on costs in the future? I have already implicitly made assumptions about this in projecting the prices appearing as independent variables in the equations.
3. What functions now performed by a noncommunication industry are likely to be taken over by a communication industry? The "check-less" society may be an example. My suggestion on this is to project the cost of these functions and then transfer them to the relevant communication industry.

I will finish on a technical note. The statistical properties of the equations used in this study are in general very good. The R^2's are high (to be expected with time series data) and all coefficients are at least once, and in most cases several times, their respective standard errors. The biggest problem, as might be imagined, is with positive auto-correlation in the residuals for several of the static equations. However, the only equation where this appears to lead to trouble with the projections is in equation (10), where the projection is implausibly low.

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APPENDIX

I. Source of Data

1. Consumer expenditures on telephone, telegraph, and wireless: Office of Business Economics, U.S. National Income and Product 1929-1965. Also, the relative price.

2. Consumer expenditures on radio and television receivers: Office of Business Economics, U.S. National Income and Product 1929-1965.

3. Gross National Product and Total Personal Consumption Expenditures: U.S. National Income and Product 1929-1965 and the July 1967 issue of the Survey of Current Business.

4. Broadcasting revenues of radio and television stations: Statistical Abstract of the United States, various volumes.

5. Total advertising expenditures: Statistical Abstract of the United States, various volumes.

6. Gross corporate product: U.S. National Income and Product 1929-1965 and the July 1967 issue of the Survey of Current Business.

7. Local and long distance telephone calls: Statistics of Communications Common Carriers, Federal Communications Commission, 1965.

8. The rate of a 3 minute daytime call between New York and Chicago: Historical Statistics of the United States and various volumes of the Statistical Abstract of the United States.

9. Gross product originating in the communications industries: Office of Business Economics. These data are unpublished and were made available to the Brookings Institution (Econometric Studies Division) on a confidential basis, I obtained the data from the latter. Also, implicit deflators.

10. International telephone and telegraph revenues: Statistics of Communications Common Carriers, Federal Communications Commission, 1965.

11. Total world exports: International Monetary Fund, International Financial Statistics, various issues.

12. U.S. population (includes armed forces overseas): Statistical Abstract of the United States and the July 1967 issue of the Survey of Current Business.

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II. Projections of Independent Variables

The values of the independent variables for 1965, 1966, or 1967 and the values projected in 1980 are given in Table 2. Brief descriptions of how the projections were obtained follow the table.

Methods Used in Obtaining Projections

GNP (1958 $'s): Starting from 1966, GNP in 1958 dollars was projected at 4% per annum growth and 5% per annum growth. Four percent growth corresponds to the present estimate of the potential rate of real growth of the economy by the Council of Economic Advisers.

GNP (current $'s): An inflation of 2% per year is added to the real rate of growth. The base year is 1967.

PCE (1958 $'s): Total personal consumption expenditure (in 1958 $'s) is projected to grow at the same rate as real GNP.

GCP (current $'s): Gross corporate product in current prices has been projected from the following equation:

$$GCP_t = -11.9 + .59\ GNP_t \quad (R^2 = .998)$$

ADV (current $'s): Total advertising expenditure is projected to grow 6.5% and 7.5% per year corresponding to the 6%

Table 2

Projections of Independent Variables

	growth rate	1965	1966	1967	1980
GNP (1958 $'s)	4%		$[illegible] b.		$1130 b.
GCP (1958 $'s)	5%				$1[illegible] b.
GNP (current $'s)	6%			$7[illegible] b.	$[illegible] b.
GNP (current $'s)	7%				$1[illegible] b.
PCE (1958 $'s)	4%		$2047/cap.	$430 b.	$[illegible] b.
PCE (1958 $'s)	5%				$911 b.
GCP (current $'s)	6% (GNP)				$[illegible] b.
GCP (current $'s)	7% (GNP)				$1[illegible] b.
ADV (current $'s)	6.5%	$15,295 m.			$30,[illegible] m.
ADV (current $'s)	7.5%				$45,180 m.
T. (current $'s)	8%	$164.7 b.			$[illegible] b.
Rel.price for category 1*		$94.6			75.7
Long distance rate		$1.26			$0.84
Rel. price tel. and tel.*			87.4		66.6
Rel. price radio and TV*			126.8		189.9
population		195 [illegible]			26[illegible] m.

*1956 = 100.

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and 7% rates of growth in current dollar GNP. The former figure is about the average rate of increase in advertising expenditures between 1956 and 1965, excluding the recession years 1958 and 1961. The base year is 1965.

WX (current $'s): Total world exports are projected to grow 3% per year. This is a little less than the average rate of increase of 8.5% per year between 1958 and 1965. 1965 is the base year.

Relative price of telephone, telegraph, and wireless: I have assumed (somewhat arbitrarily) that this relative price will decrease 20% between 1965 and 1980.

Long distance telephone rate: I have assumed that the real price for a daytime 3 minute call between New York and Chicago will decrease 2 3/4% per year. This essentially continues its average rate of decrease since 1950. The base year is 1965.

Relative deflator for the telephone and telegraph industry: I have assumed that this relative deflator will decrease 1% per year between 1966 and 1980. This compares to an average rate of decrease of 0.8% per year between 1947 and 1956.

Relative deflator for the radio and television industry: This relative deflator has increased 2.85% on the average between 1958 and 1966. I have therefore assumed that it will increase 2 3/4% per year between 1966 and 1980.

Population: I have assumed that the U.S. population will grow to 249 million by 1980. This agrees very closely with the Series A projection of the Bureau of the Census.

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APPENDIX C

COMMUNICATIONS SATELLITE TECHNOLOGY IN THE EARLY 1970's

1. Purpose

This appendix postulates a satellite communications system using high confidence forecasts of technologies which will become available before 1975, and estimates the first costs of this system if applied only to two-way telephony requirements. These costs are expressed as line-haul charges in dollars per voice circuit.

2. Methodology

Based on an assumed satellite configuration, the effective isotropically radiated power (EIRP) per satellite transponder was calculated, from which link transmission calculations were performed for the satellite-to-earth station path. Assuming 4-phase PSK and time division multiple access (TDMA) operation, the required earth station G/T was determined, from which the least-cost earth station was chosen. Having thus satisfied the down-link requirements, the appropriate earth station power amplifier was chosen to satisfy the uplink loss equations, and its cost added to the earth station antenna and basic electronics cost. Since only line-haul costs are normally

used in pricing transmission systems, no multiplex or multiple access equipments were included in the cost of earth stations.

Satellite costs were based on projected launch vehicle costs provided by NASA, and projected costs of the INTELSAT IV configuration, with suitable modification to account for variations in antenna and electronics assumptions. The cost of two satellites in orbit were included (each with an expected life of 5-7 years yielding a space segment useful life of 10-14 years). No satellite replacement strategy was assumed; on the other hand the cost of the second satellite was not discounted to reflect its later purchase date.

Since satellite systems are in effect complete transmission networks rather than merely two-point transmission routes, it is necessary to allocate total circuit capacity in some way among the various potential routes to arrive at an average cost per circuit. For purposes of this example, we have assumed a varying number of earth stations, resulting in a varying number of potential routes, and have then allocated the total capacity equally among these routes to arrive at both earth station costs and per circuit costs for a particular satellite configuration. This is the basis for the results presented in Figure 1.

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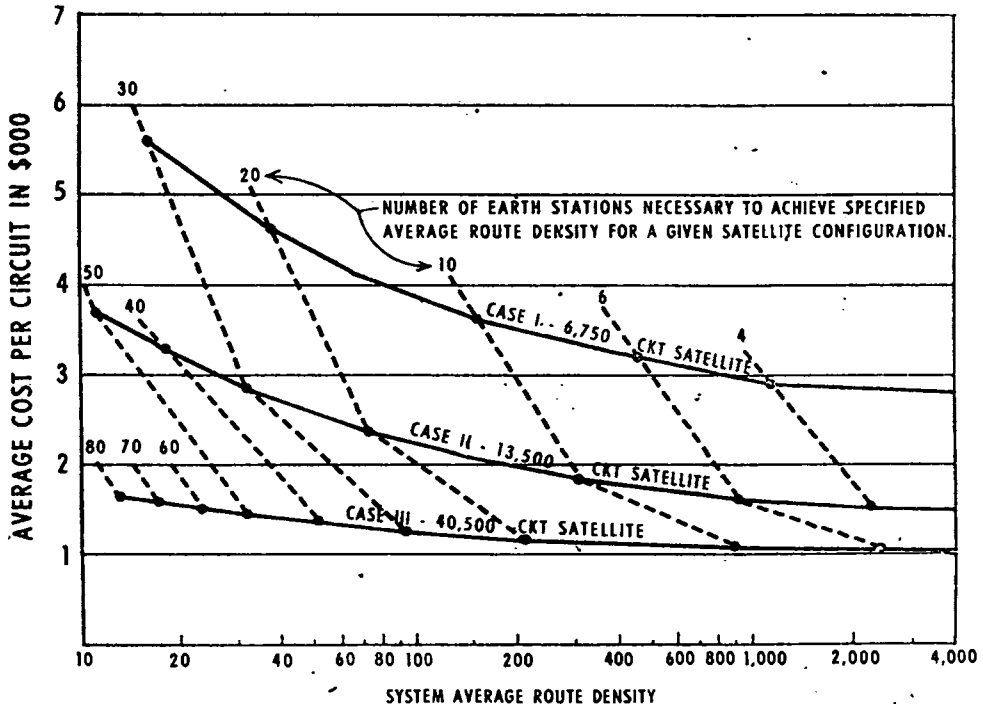


FIGURE 1. SATELLITE SYSTEMS COST TRENDS

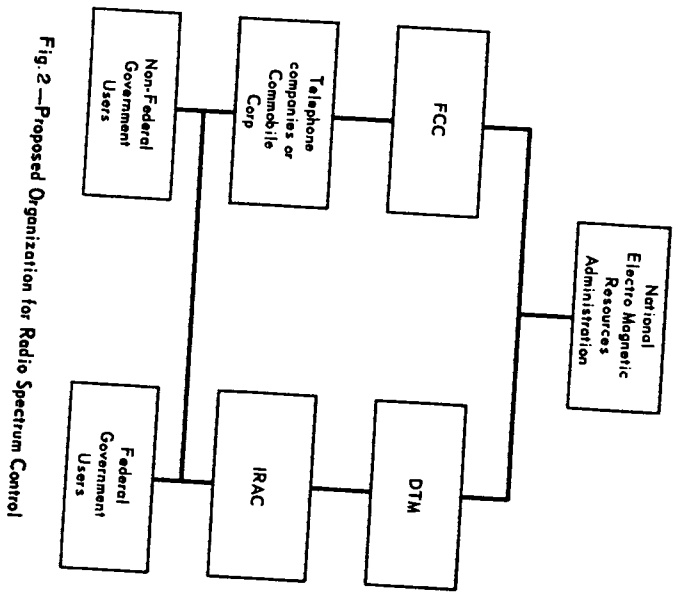


Fig. 2—Proposed Organization for Radio Spectrum Control

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3. Space Segment

The launch vehicles assumed in the study are shown in Table 1.

Assuming thin film solar cells in oriented deployable arrays, the following maximum power capability was obtained. A DC to RF conversion efficiency of 40% was assumed.

Spacecraft (lbs)	Power System Weight (lbs)	Max DC Power (watts)	Max RF Power (watts)
315	60	200	80
1,240	560	3,800	1,520

The weight allocations to subsystems is shown below. The power and electronic subsystems were combined because an additional electronics (transponders) were added, their weight was deducted from the power subsystem. The structure and antennae subsystems were combined because the antennae were assumed to be a major component of the spacecraft structure.

Satellite Weight Budget

Power/Electronics	95	720
Structure/Antennae	120 */	270 **/
Station Keeping, Orbit Trim, Attitude Control, Thermal Control	100	250
Total	315	1,240

(See footnotes on next page)

Footnotes for page 4

*/ A 3-ft. diameter parabolic dish with multiple feed yielding two beams with a 5° solid angle. Antennae gain is 30.2 db per beam. The weight of this antennae subsystem is 70 lbs.

**/ Two 6-ft. diameter parabolic dishes with multiple feeds, each yielding 3 beams, each with a 2-1/2° solid angle. Antennae gain is 36.2 db per beam. The weight of this antennae subsystem is 200 lbs.

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TABLE 1

SPACE SEGMENT COSTS

Launch Vehicle	Payload (lbs)	Vehicle Costs ($M)	Spacecraft Costs ($M)	Total Costs ($M)
Thor Delta	315	4.0	4.5	8.5
Titan 3B/Agena	1,240	6.5	12.6	19.1
Atlas/Centaur	1,700	7.2	16.0	23.2 */
Titan 3C	3,420	9.4	20.0	29.4 */

*/ These two not used because they did not offer any increased circuit capacity, given the assumed station keeping and pointing accuracy and frequency allocations.

For the power-electronics tradeoff three configurations appeared interesting: (A) In the Thor-Delta (315 lbs.) a set of 12 transponders each with equivalent bandwidth of 36 MHz. Using a 64,000 bit-per-sec, 4-phase PCM the bandwidth limited capacity is $N_n = \frac{BW}{R} \times B$ */ where:

$BW = 36 \times 10^6$ Hz

$R = 64 \times 10^3$ bits/sec

$B = 2$ for a 4-phase PSK

$$N_n = \frac{36 \times 10^6}{64 \times 10^3} \times 2 = 1{,}125 \text{ channels per transponder.}$$

Thus, the system capacity is 13,500 half circuits or 6,750 full duplex voice circuit equivalents in 500 MHz assigned frequency. For this configuration the power-electronics weight budget was:

power subsystem weight = 50 lbs
- dc power = 150 watts
- rf power = 60 watts or 5 watts/transponder
- electronic subsystem weight = 45 lbs

(b) A second Thor-Delta configuration was considered re-using the 500 MHz allocated spectrum in each of the two beams. This required 12 additional transponders and doubled the system channel capacity to 13,500 full duplex voice circuits.

*/ Schmidt, W.G. "An Efficient TDMA-System for Use by Emerging Nations with the INTELSAT IV Satellite" EASTCON 1968 Record, pp. 21-27.

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For this configuration, the power-electronics weight budget was:

power subsystem weight = 30 lbs

dc power = 90 watts

rf power = 36 watts or 1.5 watts/transponder

electronic subsystem weight = 65 lbs

(C) The Titan 3B/Agena power electronics configuration that appeared interesting was six beams with total reuse (six times) of the frequencies allocated. Thus, employing 72 transponders and with a system capacity of 40,500 full duplex voice circuits, the weight budget was:

power subsystem weight = 330 lbs

dc power = 2,250 watts

rf power = 900 watts or 12.5 watts/transponder

electronic subsystem weight = 390 lbs

Given the above assumptions, the downlink power calculations are shown in Table 2.

TABLE 2

DOWNLINK CALCULATIONS
(4 GHz)

	Case I	Case II	Case III
	Thor-Delta (no frequency reuse) (6,750 circuits)	Thor-Delta (frequency reuse) (13,500 circuits)	Titan 3B/Agena (40,500 circuits)
RF power/transponder	7 dbw	1.8 dbw	11 dbw
Satellite losses	-1 db	-1 db	-1 db
Antennae gain	30.2 db	30.2 db	36.2 db
Satellite ERP	36.2 dbw / channel	31.0 dbw/channel	46.2 dbw/ch.
Space attenuation	-195.5 db	-195.5 db	-195.5 db
Atmospheric absorption	-.1 db	-.1 db	-.1 db
Beam edge loss	-3.0 db	-3.0 db	-3.0 db
ES received power	-162.4 dbw	-167.6 dbw	-152.4 dbw
C/T required *	-134.0 dbw/°K	-134.0 dbw/°K	-134.0 dbw/°K
G/T GS antennae required	28.4 db/°K	33.6 db/°K	18.4 db/°K
Earth station Antenna and receiver required	40' diameter cooled to 150°K	60' diameter cooled to 150°K	20' diameter uncooled at 600°K or 10' diameter cooled to 150°K

* / $N_P = \frac{C}{T} - \frac{E}{N_o} - R - M + 228.6$

$\frac{C}{T} = N_P + \frac{E}{N}_o + R + M - 228.6$

$\frac{C}{T} = 30.5 + 11.9 + 48.1 + 4.1 - 228.6$

* / Ibid 3

(Continued)

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$\frac{T}{I}C$ = -134.0 dbw/°K

Where N_p = 1125 channels or 30.5 db

E/N_o = 11.9 db for 4-phase coherent PSK with 3.5 db -- degradation allowance

T = 64,000 bits/sec or 48.1 db

M + 4.1 db system margin

228.6 dbw/°K - 1+2 is Boltzman's Constant

TABLE 2 (Continued)

	Case I	Case II	Case III
Intra facility link	80	80	NA
Power divider and combiner	25 8	8	8
Transmitter */	25-150	25-150	25-150
Receiver	50-150	50-150	50-150
Antenna	140 **/	190 **/	50
Shipping & installation	120	150	40
Total	423-648	503-728	173-398
Median	535	615	285

*/ without power amplifier

**/ includes front end cooled to 150°K

The power amplifier required at each earth station will depend on the percentage of total satellite capacity available to that station. This will vary on the average inversely as the number of earth stations illuminated by a particular satellite beam. If P_{max} is the maximum ES power required per satellite beam for full utilization, then P_r (ave.), or the average power required per earth station, will be P_{max}/n where n = average number of stations/beam. For multi-beam satellites, n = N/B where N is the total number of stations and B the number of beams. Thus,

$$P_r \text{ (ave)} = \frac{P_{max}}{N/B} = \frac{P_{max} \times B}{N}$$

In determining power amplifier cost per earth station as the number of stations vary, the above considerations have been taken into account approximately by allowing HPA costs to slide downward linearly from $200-250 K per station (a typical value for present stations) to $50-75 K/station as the number of stations vary from the minimum of 1 per beam to about 1 per satellite repeater (of which there are 12 per beam). The variation in upper and lower limits of this cost range reflect the variation in total ES power required for different satellite configurations, in accord with the following uplink calculations.

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C/N req		37.0 db	
RF BW 41.6MHz		76.2 db/Hz	
Carrier/noise per density		113.2 db/Hz	
Boltzman's constant		-228.6 dbw/ok-Hz	
Satellite noise temp (NF=6db)		30.6 db/ok	
Satellite noise power density		-198.0 dbw/Hz	
Satellite receive carrier power required		(113.2 - 198.0) = -84.8 dbw	
Satellite loss		-1 db	
Satellite receive antenna gain	33.7 db		33.7 db
Atmospheric absorption	-.1		
Space attenuation	-197.0 db		
ES-ERP	79.6 dbw	79.6 dbw	73.6 dbw
req			
ES antennae gain	53.5 db	58 db	49.7 db
ES loss	-1.0 db	-1.0 db	-1.0 db
ES xmtr pwr/channel	27.1 dbw	22.6 dbw	24.9 dbw
ES power amplifier/channel	500 w	180 w	300 w
ES power amplifier total Power Pmax	6 KW	2.1 KW	3.6 KW

UPLINK CALCULATIONS

It is known that as the number of earth stations increases, the efficiency and thus the number of usable channels in multiple access decline. However this loss of efficiency can be kept within reasonable limits using TDMA */ Further, as more earth stations are produced the unit cost per station should decline according to some learning curve. It was assumed that these effects on per-channel costs were equal and thus offsetting for this general analysis.

If there are N earth stations or nodes these may be interconnected by $\frac{N\ (n-1)}{2}$ trunk routes. The average number of circuits per trunk route in Figure 1 has been arrived at by dividing the total satellite capacity by the number of routes computed from this relationship. It becomes apparent that a satellite system does not depend as heavily as terrestrial systems on the economies of scale of dense trunk routes.

*/ Ibid. 3

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APPENDIX D

THE PROSPECTS FOR HIGH FREQUENCY RADIO

High frequency radio systems, operating in the 3-30 MHz portion of the electromagnetic frequency spectrum have long been a basic economical means of providing small numbers of communication channels over distances ranging from a few hundred to several thousands of miles. These systems, relying on reflection of radio waves from ionized regions of the earth's upper atmosphere, are however subject to a number of uncontrollable--and only partially predictable--outages and variations in circuit quality. These deficiencies, as well as the limited capacity of individual HF circuits and of this communications medium as a whole, have placed HF radio at a disadvantage in the competition among long-haul transmission modes.

Recent technical developments, in conjunction with the general improvement in ionospheric conditions resulting from the 11-year cycle of solar activity, give promise of improved performance of HF radio circuits. The introduction of LINCOMPEX, a technique developed by the American Telephone and Telegraph Company, is expected to provide improve quality over an established circuit. The use of CURTS (Common User Radio Transmission Sounding), a system pioneered in the

Defense Communications Agency, has been suggested as a possibility for continuous selection of optimum operating frequencies to better establish and maintain circuits.

The LINCOMPEX system employs speech compression and expansion, along with a new fade control technique, on each individual voice channel to improve the general quality of an established HF circuit. This system cannot provide a radio circuit when propagation conditions deny such a circuit. It can however extend the time that a particular circuit can be maintained, and increase the efficiency of the circuit while it is operating.

The CURTS concept involves the continuous, worldwide "sounding" (i.e., radio probing) of the ionosphere to determine the optimum operating frequency for each path, coupled with instantaneous "on-demand" selection and use of these optimum frequencies from a common frequency pool shared by many radio links.

Neither system alters the fundamental nature of HF radio propagation; they are however intended to better accommodate circuit operations to the generally measurable and/or predictable variations in this propagation medium. To the extent that this can be accomplished, and that political

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impediments to the international pooling of HF frequencies for use on demand can be eliminated, expanded use of such circuits for light traffic demands might be anticipated. Such expansion, however, may be difficult to justify economically should the marginal cost of satellite circuits be as low as some studies indicate--particularly if earth segment costs for low-capacity earth stations are also reduced significantly.

In sum, future prospects for expansion of commercial HF radiotelephone service do not appear overly bright, although services presently provided may be improved through use of these new techniques. For certain classes of mobile radiotelephone and other specialized services, and as a backup if primary facilities such as satellites and ocean cables fail, HF radio should continue to be in considerable demand.

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APPENDIX E

AMPLITUDE MODULATED LINK – A SHORT HISTORICAL REVIEW

H. T. Ozaki and L. S. Stokes

Aerospace Group
Hughes Aircraft Company
Culver City, California

In April, 1965, a representative of the TelePrompTer Corporation contacted Hughes Aircraft Company to determine the interest Hughes would have in developing a multi-channel television link. So began the development of the Amplitude Modulated Link (AML), a new method of transmitting 12 channels of television simultaneously using a single microwave carrier to a receiver site.

It was envisioned that the AML system would use many receivers with a given transmitter. In this operation a fan beam could cover the large city area with receivers located strategically within the fan beam which could then receive the television signals and send them by cable throughout their immediate area. The Amplitude Modulated Link system would thus become an integral part of a Community Antenna Television System (CATV) replacing the expensive coaxial cable trunks through city streets. In addition to the large city application, the AML could also be used to serve satellite communities which are somewhat remote from metropolitan areas. In this case the Amplitude Modulated Link would be used to replace long runs of coaxial cable. A third attractive use of this system would be one of circumventing natural barriers such as large rivers or other waterways. In all these cases, as in the large city case, the 12 channels of television would be transmitted simultaneously to the receiving site using a single carrier. From the receiving site a coaxial cable would be used to serve the surrounding area.

There were general limitations and specifications from which an appropriate system configuration was to be selected for the AML. 1) It was to have a large bandwidth, on the order of 100 MHz; 2) it was to be used for a relatively short distance, six to ten miles with only one hop being used, or at the most two or three hops; 3) it was to conserve

radio frequency bandwidth; 4) it was to use relatively simple receivers since many receivers were to be used with a single transmitter in the normal configuration; and 5) it was not to interfere with existing services in their designated RF channelling. With these considerations in mind, the system configuration chosen was that of single side band amplitude modulation (SSB-AM). In this system, the entire television spectrum from channel two through channel thirteen, including a 20 MHz spectrum for the frequency modulated band, was translated to 18 GHz. The spectrum at 18 GHz was then an exact replica of the VHF television spectrum. A pilot signal was inserted between channels 4 and 5 which was harmonically related to the suppressed carrier.

The receiver required was a relatively simple one; having the same elements that are found in a simple UHF converter, a mixer, a local oscillator which translates the incoming frequency to one which is directly usable by the TV receiver and an "i-f amplifier." In addition, the AML receiver uses a phase locked loop to sense the pilot signal and locks the receiver local oscillator to the pilot signal.

In the AML receiver, the incoming microwave frequency is translated back to the original VHF spectrum. The various television channels from channel 2 through channel 13 appear at their exact frequencies. The output spectrum of the receiver is applied directly to a television receiver through a distribution system.

The system configuration, briefly described above, was discussed by Hughes and TelePrompTer representatives. The conclusion of that meeting was that a breadboard model would be constructed to determine basic feasibility. Since feasibility was the main object to the breadboard model, the X-band frequency spectrum was used, for the X-band components and test equipment were conveniently available. Figure 1 is a photograph of the original breadboard constructed. It was extremely simple, having an up-converter (single sideband modulator) which essentially shifted the VHF TV spectrum from its normal frequency band to the X-band microwave frequency. The up-converter spectrum was filtered, amplified in two travelling wave tube amplifiers and transmitted through a horn antenna. The receiver consisted of a

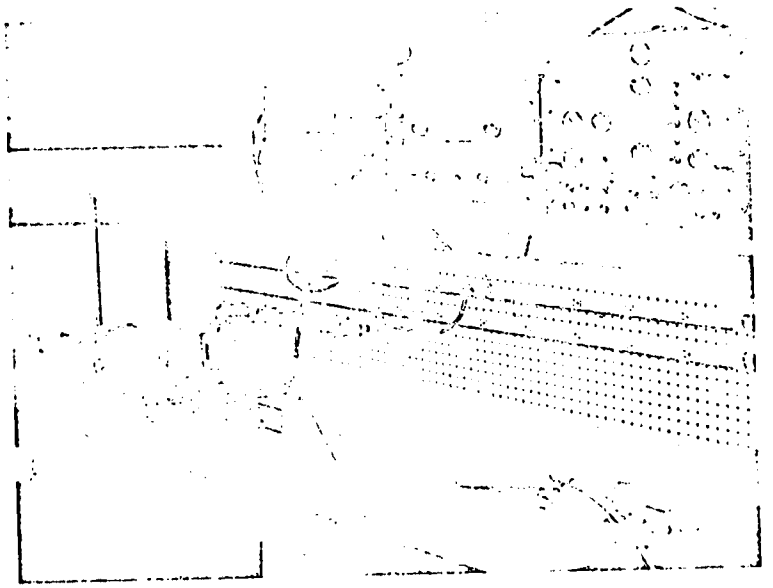


Figure 1. AML Breadboard Transmitter and Receiver

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horn antenna and a mixer with its local oscillator. The local oscillator used was either an independent microwave source or the same frequency used in the up-converter, cabled to the mixer. A block diagram of the experimental link is indicated in Figure 2. The experimental link confirmed the basic design choices; substantiating the theoretical range calculations; secondly, allowing a documentation of system problems such as intermodulation and potential solutions; and thirdly, permitting physical measurements and subjective evaluation of noise and cross-modulation under real and simulated conditions of transmission.

The Experimental Design

The breadboard model had determined the feasibility of the system design configuration. It was now decided to proceed with this system in an experimental form. The experimental model was to be a fully operable model capable of transmitting 12 channels of television from a transmitter to a receiver over a several mile link.

The center frequency for the experimental AML link was chosen to be 18.7 GHz. The reasons for this choice were: 1) This frequency band had been set aside for fixed and mobile operation. 2) The band was essentially 2 GHz wide, from 17.7 GHz to 19.7 GHz, with one small exception from 19.3 to 19.4 GHz. (The center frequency of the AML system was selected to be near the center of this band allowing it to be operated at any point in the band with only slight modifications.) 3) The 17.7 to 19.7 GHz band was not being used, thus no displacement of existing services would occur by its use for such a link. 4) This frequency band, while not being ideal from the point of view of propagation, did and does have acceptable propagation characteristics for the type of service envisioned for AML. That is, a service where short links were used.

In addition to the selection of the 18 GHz frequency, several other system goals were selected for the experimental system; these are shown in Table I.

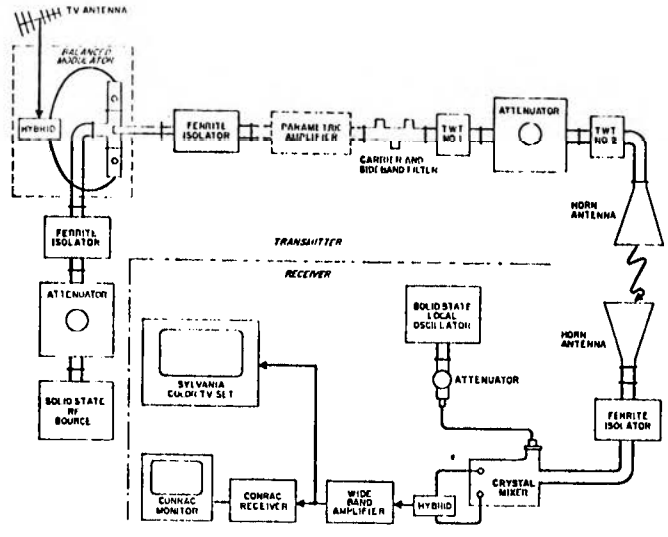


Figure 2. Experimental Link Block Diagram

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TABLE I. 18 GHZ MICROWAVE LINK SYSTEM GOALS

- Multiple channels (up to 12 channels)
- Low intermodulation products
- Low overall system noise figure
- Range of at least six miles
- Output frequencies identical to input frequencies
- Multiple receivers

Photographs of the hardware produced for the experimental system are shown in Figures 3, 4, and 5. Figure 3 is a photograph of the single-sideband modulator or up-converter. This unit is a key design component of the AML system, for it is required that the output power of the up-converter be high enough to overcome the internal noise of subsequent power amplifiers in the AML transmitter. In order to provide this output power a parametric up-converter has been designed which exhibits power gain from the VHF baseband input to the 18.7 GHz RF output. The photograph shown in Figure 4 is the ten watt experimental transmitter. The maximum transmitter power output was ten watts; however, this power was not used in normal transmission because at the ten watt level the travelling wave amplifier was operating at saturation. Since several signals were being transmitted simultaneously through this power amplifier, it was necessary that the power be reduced below the maximum level to prevent the signals from intermodulating with one another in the nonlinear power amplifier. Thus, the power output of the travelling wave tube was reduced approximately 20 db below the peak power output.

In Figure 5 the receiver and the receiving antenna for the experimental system are shown. The antenna has a gain of approximately 44 db with a beamwidth of about one degree. The receiver is shown mounted on the back of antenna in Figure 5 while the internal layout of the receiving components is exposed in Figure 6. These components



Figure 3. Experimental Transmitter Up-Converter

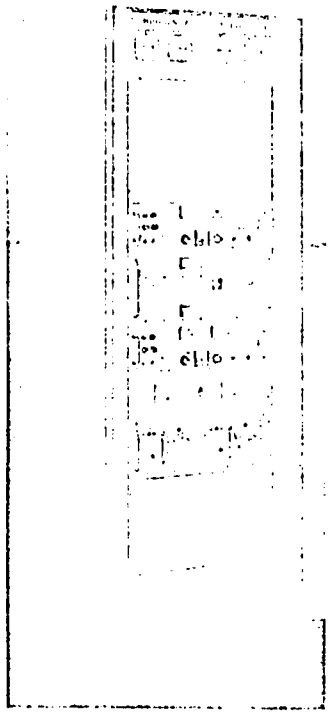


Figure 4. Experimental Transmitter

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include: The RF mixer, driven by solid state local oscillator; a wide-band video amplifier, which passes channels 2 through channel 13 and amplifies them to a level suitable to drive a normal CATV plant; a narrow band RF filter, which filters the pilot tone used to phase lock the solid state local oscillator; and a phase lock loop which locks the solid state local oscillator to this incoming pilot tone.

With the completion of the experimental transmitter and receiver certain tests were conducted. These included the transmission of 12 channels of television and the entire frequency modulation band through the transmitter and receiver. Intermodulation tests were made which varied the output power of the transmitter to determine the point at which intermodulation products became objectional, and a performance analysis was made of the phase lock loop operation. The 12 channels of television had been equalized using Channel Commanders such that the video carrier levels were all the same amplitude and the audio carrier levels were reduced to 15 db below video carrier levels. Many of the tests were run over a three thousand foot antenna range located at the Hughes Aircraft Culver City facility.

In these tests the importance of the phase locked receiver local oscillator was established. For if the phase lock loop were purposely unlocked, the television receiver, which was receiving VHF signals from the AML receiver and also directly receiving VHF signals from local television stations, had noticeable beat notes between the video carriers of these two inputs. However, when the AML receiver was phase locked to the pilot tone, producing output VHF frequencies identical to the VHF frequencies being transmitted by the local television station, the beat note interference disappeared.

A second series of important tests on the experimental AML system were conducted in New York City. The purpose of these tests was to gain field experience by operating an AML link and secondly, to determine experimentally the effect of rain upon the AML system.

The AML system was operated in New York City during the late summer and early fall of 1966. During this period of time, two months of data were analyzed in some detail. The compilation of the data



Figure 6. Experimental Receiver

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Figure 5. Experimental Receiving Antenna and Receiving Antenna

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extended from the middle of August, 1966, to the middle of October, 1966. There were ten days during the test period where significant rain attenuation data was obtained; seven different storms passed through the New York City area. Signal fades as large as 40 db were noted on several occasions. However, these rain-caused fades were rather brief, in the order of two to five minutes. The cumulative time that attenuation was greater than 20 db totaled 45 minutes during the August, September and October time period. This extrapolated to 2.56 hours annually and was in close agreement with Weather Bureau data and with other data for the New York City area. Similarly, 22 minutes of data were noted during the two month sample period where the attenuation was 30 db or greater. This extrapolated to an annual basis of about 1 hour a year. This data was also in close agreement with statistical rainfall data for NYC. The statistical weather data used to determine the subjective performance of the AML system over a period of one year is shown in Figure 7. This plots the hours per year of reduced signal strength, due to rain attenuation, against signal level given both in decibels and in the subjective TASO scale. The data in Figure 7 is for the Washington, D. C./New York City area for a frequency of 18.7 GHz. The figure shows parametrically the effect of link range on the hours per year when signal strength is somewhat reduced. For instance at a six mile range the picture quality is less than "Good" for approximately six hours per year. However, only two of those six hours would the signal level be called "Not quite passable". Thus, the use of an SSB-AM system for transmission of the data not only maintains the minimal RF bandwidth and a simple receiver design, but provides a picture to the viewer which has excellent quality for 99.94 percent of the year. It should also be noted that for a range of 4 miles the average signal degradation per year is only 3 hours for a signal strength less than "Good" and is less than "Not quite passable" for 1 hour per year. (One hour per year outage corresponds to approximately 99.99 percent reliability.)

The Culver City tests and the New York City tests with the experimental AML system showed the feasibility of simultaneously

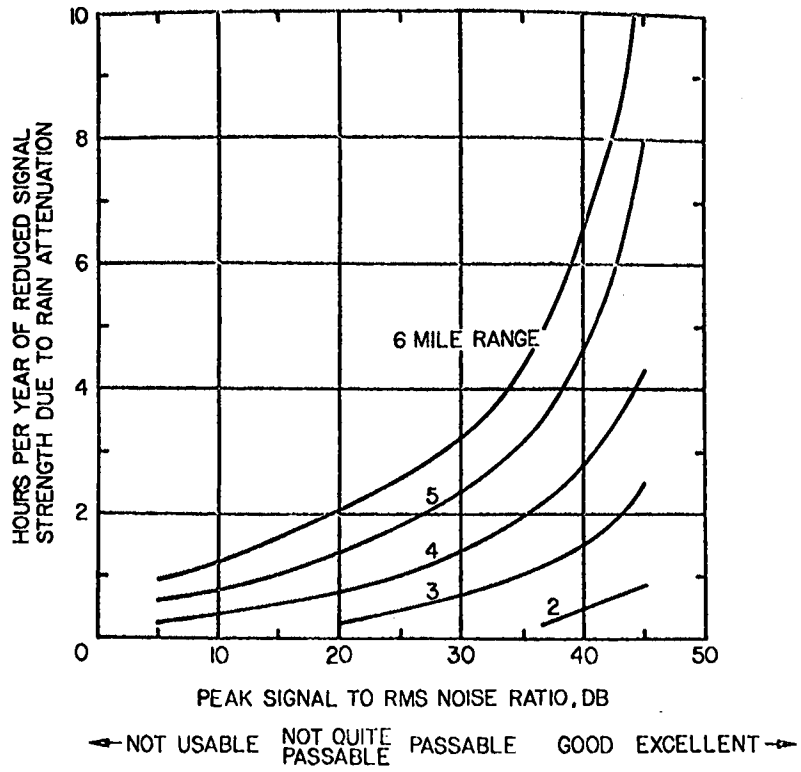


Figure 7. Subjective Effect of Rain on AML Performance in One Year in the Washington, D.C. Area (18.5 GHz)

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transmitting 12 channels of television and 20 MHz of frequency modulated signals. The next step in the development was that of designing and building a prototype AML system.

The Prototype AML System

The AML system consists of a transmitter and its antenna and the receiver and its antenna. The receiver forms a new "head end" and as such may be used to drive entire CATV plant in its immediate vicinity. The prototype AML receiver is shown in Figure 8. The dimensions of this unit are approximately 14" x 9" x 2 1/2". The receiver is completely weather proof and will withstand a temperature range of -10°F to +110°F. The receiver is divided internally into several shielded sections; these are part of the cast frame. The receiver may be mounted directly on the back of the receiving antenna, thus reducing RF losses to a minimum.

The AML transmitter is divided into two major components. The first major component is shown in Figure 9. This is the driver unit which has as an input the 12 VHF television channels and the FM spectrum. These are then shifted to the 18.7 GHz frequency with an average total power output of approximately 10 milliwatts. The two RF outputs of the AML transmitter driver are the "Low band" television channels (channels 2 through 6) and the "High band" channels (channels 7 through 13). The two outputs of the AML transmitter driver may be summed to drive a single power amplifier or each output may drive a power amplifier depending upon the output power required for the particular installation requirements. The use of two power amplifiers provides three advantages. First, the total power output is increased by 3 db, secondly the number of intermodulation products will be lower since fewer TV channels are being passed through each power amplifier, and thirdly, the power amplifiers may be used as redundants in case of failure. If one power amplifier should fail, it is possible to transmit the entire spectrum through the remaining power amplifier until the failure is corrected. During this time the signal-to-noise ratio will be somewhat reduced; however, this will only be slightly noticeable in most instances.

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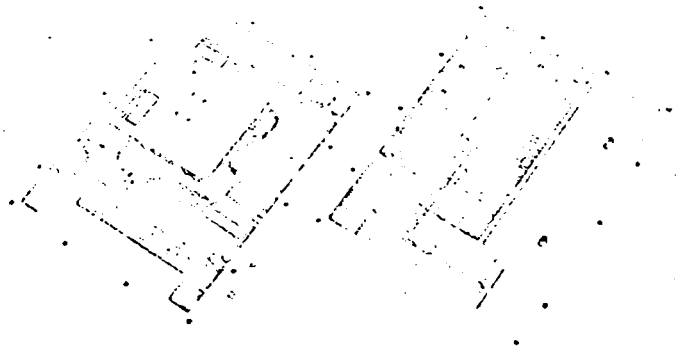


Figure 8. Prototype AML Receiver

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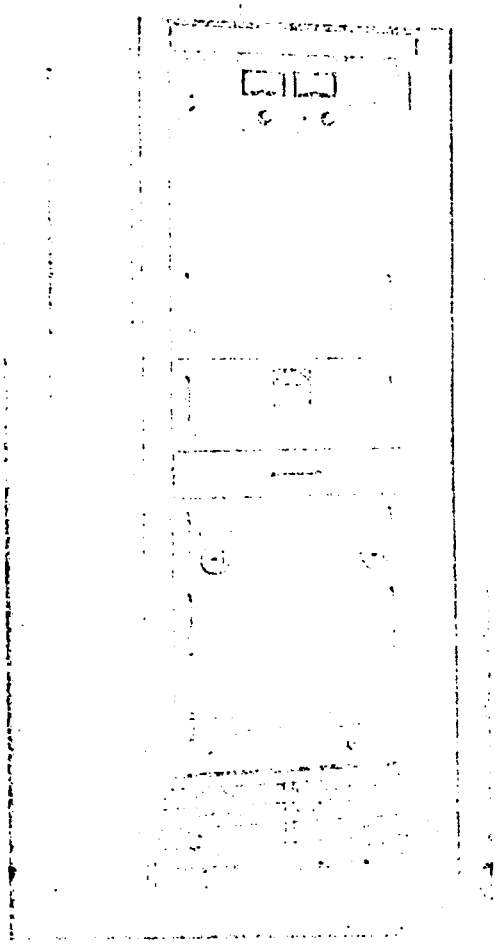


Figure 9. Prototype AML Transmitter Driver

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The power amplifier consists essentially of a travelling wave tube amplifier and its power supply. This travelling wave tube has been designed especially for the AML system by the Hughes Aircraft Company. Certain special requirements were incorporated into this design. These include design considerations to maintain low intermodulation products, low internally generated noise, a power output of approximately 1 to 2 watts, and a saturated power output of approximately 250 watts. The maximum saturated power level is never used for it was realized that the travelling wave tube must operate 20 to 25 db below the saturated power output in order to maintain suitably low intermodulation products. The photographs in Figure 10 a, b, c, and d show the travelling wave tube in various stages of incorporation into the final power amplifier rack. Figure 10a reveals the internal structure of the travelling wave tube. The electron gun is at one end of the tube, the slow wave structure, the input and output waveguide flanges, and the heat sink at the anode and of the tube. In addition, a small ion pump is used to maintain the ion level within the travelling wave tube at a suitably low level. Figure 10b shows the travelling wave tube with its electro-magnet. Figure 10c shows the complete travelling tube with the fan jacket for cooling, and Figure 10d exhibits the rack mounted travelling wave tube power amplifier and its power supply. The travelling wave tube is designed to have an operating life of five thousand hours.

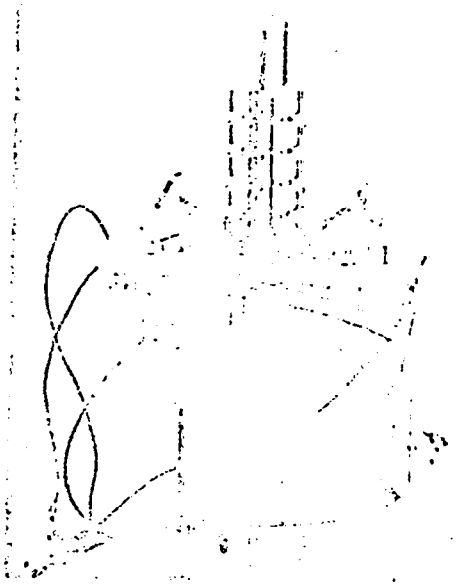
Figure 11 is a photograph of the antenna used at the receiving site. It has a gain of approximately 44 db with an antenna beam of 1-degree. A small feed dome is used over the feed structure and may be operated without any further shelter. The receiver, shown in Figure 11, is mounted immediately behind the receiving antenna. The receiver is also a weatherproof design.

The photographs of transmitting antenna are shown in Figures 12a and b. This antenna is actually two antennas in one. These "two" antennas are mounted side by side with a waveguide input for each. The antenna concept used is one of exciting an electro-magnetic field within the antenna cavity such that it reflects against a parabolic surface at the back of the antenna. The reflected wave then forms a plane wave front

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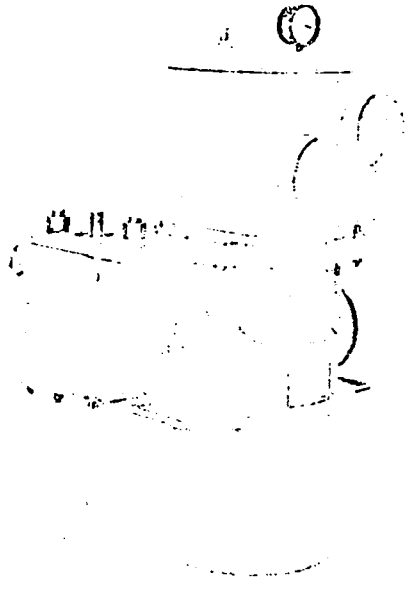


a. TWT Internal Structure

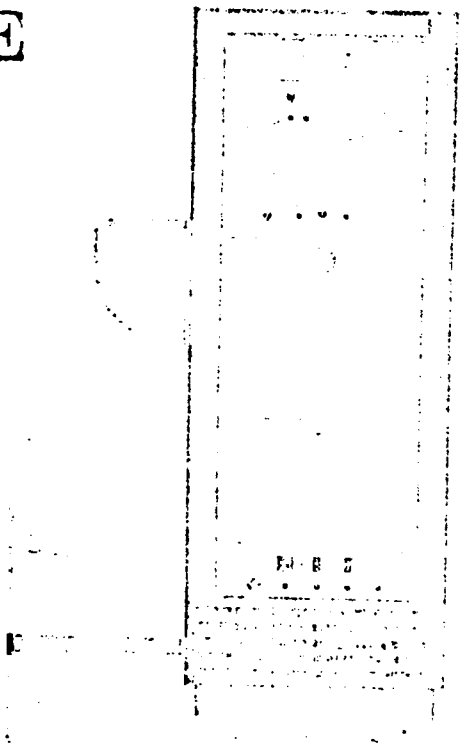


b. TWT Enclosed in Magnetic Structure

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c. Packaged Travelling Wave Tube



d. Power Amplifier and Power Supply

Figure 10. Prototype AML Power Amplifier

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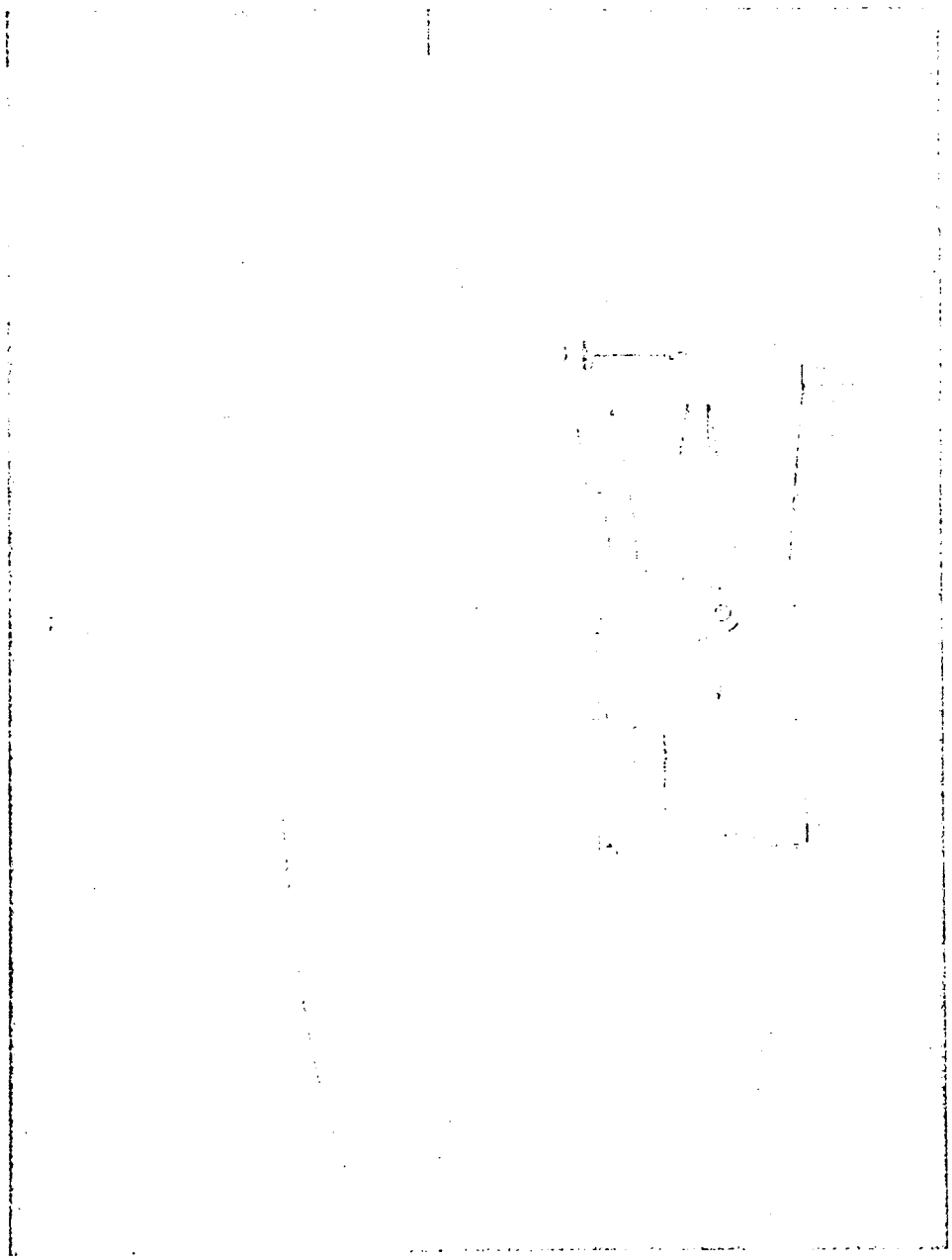


Figure 11. Prototype AML Receiving Antenna

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a. Side View

b. Front View

Figure 12. AML Transmitting Antennas

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midway in the antenna structure. From this point, the plane wave front is conducted through a microwave horn to the open aperture. This antenna, with its large vertical dimension and narrow horizontal dimension produces a 15-degree fan beam in azimuth and a 2-degree beamwidth in elevation. Figure 12b is the front view of the transmitting antenna and shows the two parts of the antenna. In a normal configuration, the transmitter driver unit would drive two power amplifiers; they, in turn, would drive the two parts of the dual transmitting antenna. The RF energy is added in space rather than in any waveguide structure. (It should be noted that the RF energy coming from the left side of the transmitting antenna is at a different frequency from the energy coming from the right side of the transmitting antenna since the left side corresponds to the low band TV channels and the right side corresponds to the high band TV channels.) Clearly other types of transmitting antennas are possible and will undoubtedly be used; however, this transmitting antenna was designed for the large metropolitan city configuration and is shown here for illustrative purposes. Antennas with a high gain, such as are used for the receiving antenna, could be used in the transmitting position.

Conclusion

The Amplitude Modulated Link provides a means for transmitting the entire VHF television spectrum. This is done with a minimum use of radio frequency bandwidth and with a relatively simple receiver, which has, as an output, the VHF television spectrum at a power level suitable to transmit directly to a home television receiver. This system is designed to meet the distribution needs found in Community Antenna Television. Initially, the system was designed to be used in an urban environment where a single transmitter would be transmitting to many receivers. The illustration in Figure 13 depicts this type of distribution system. A variant system is depicted in Figure 14. Here, outlying communities are able to receive TV signals sent from a central transmitter, thus bypassing the use of long runs of non-profitable coaxial cable. The illustration in Figure 15 shows the use of AML to cross

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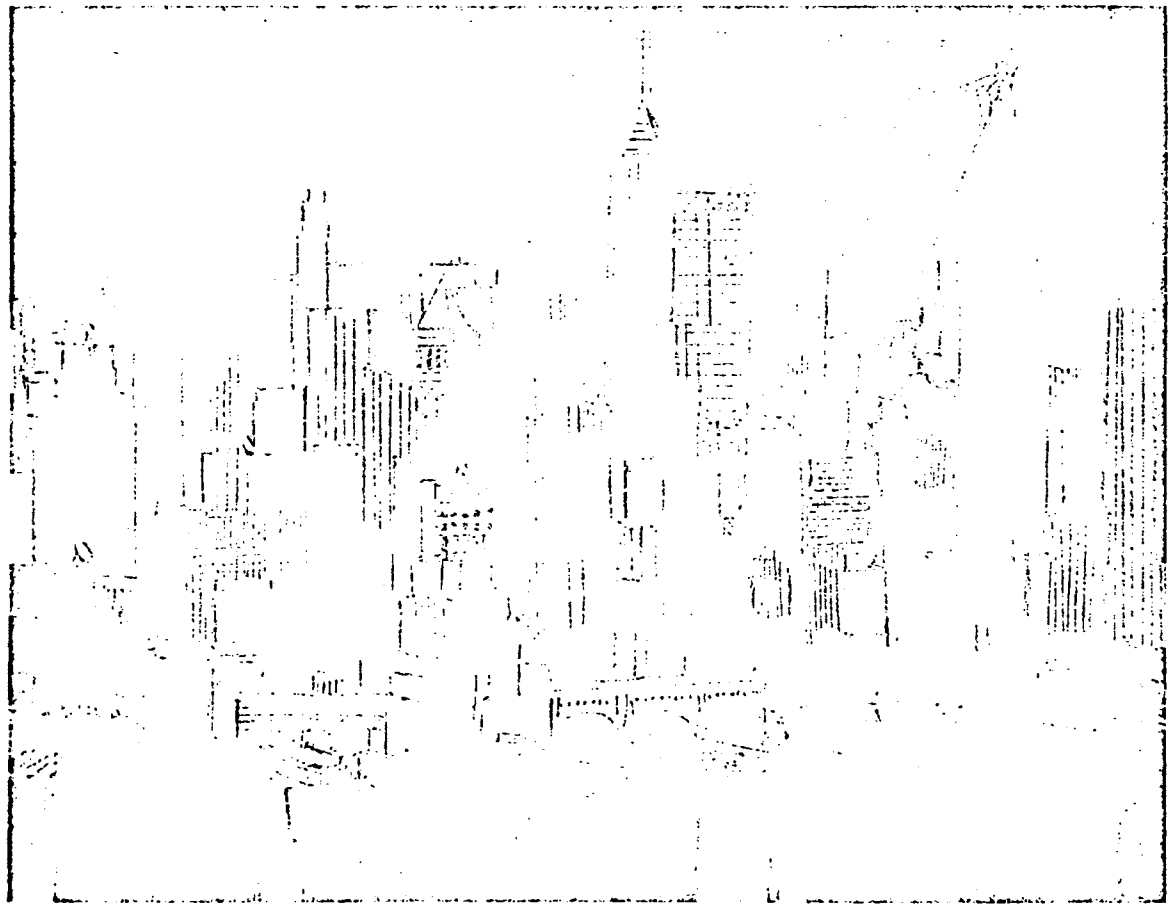


Figure 13. Artist Concept of Urban Use of AML System

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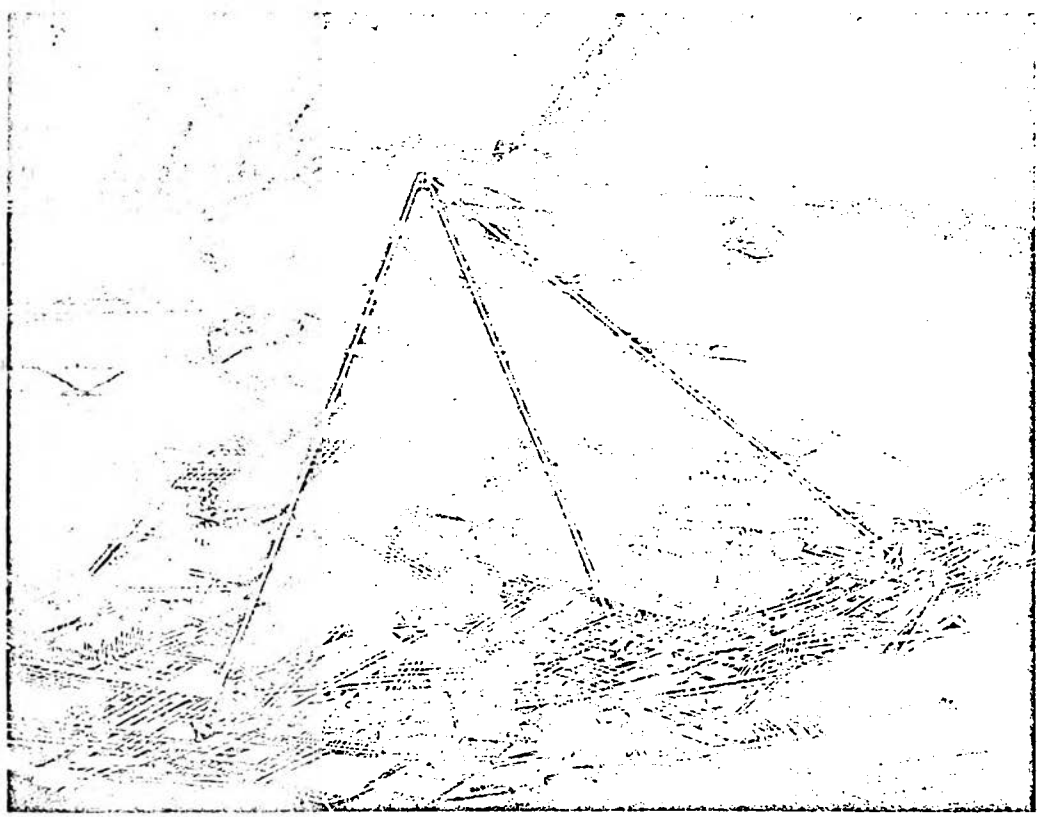


Figure 14. Artist Concept of Suburban Use of AML System

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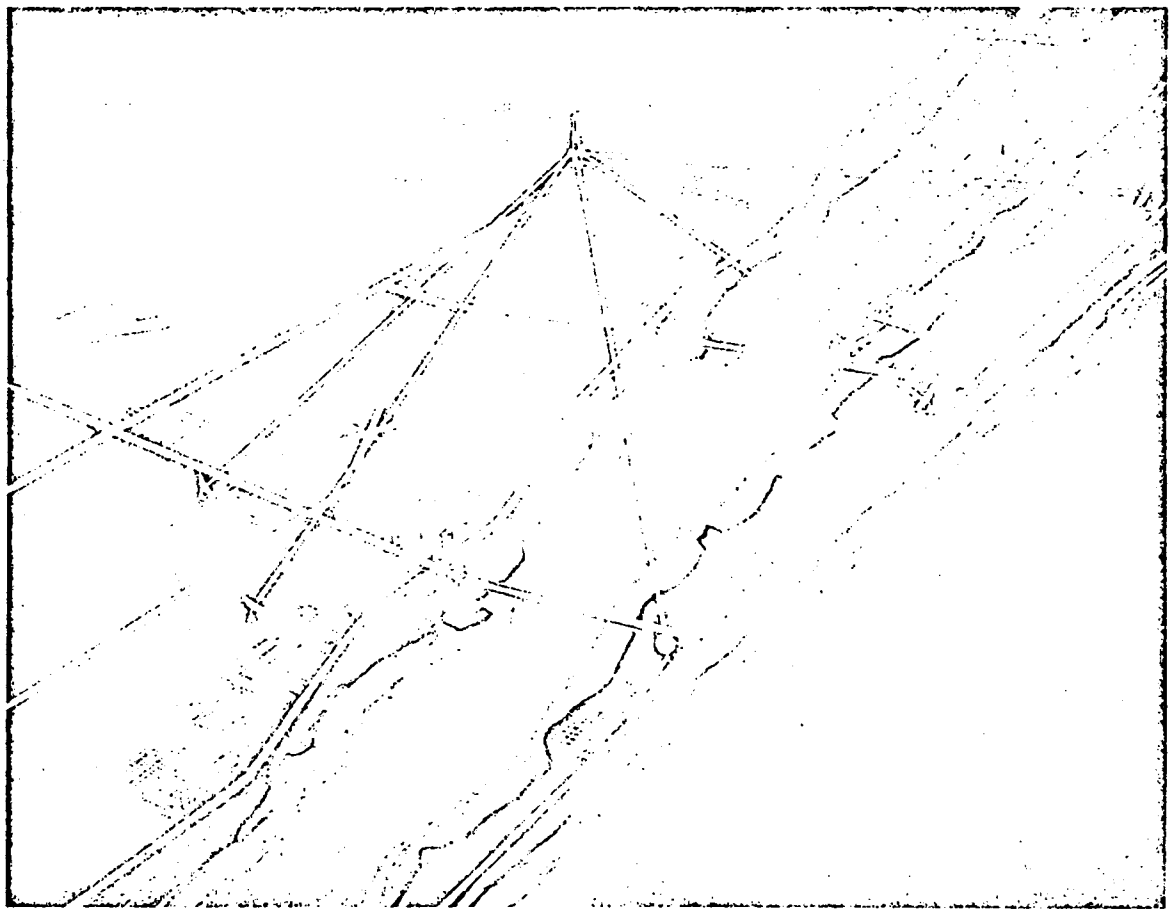


Figure 15. Artist Concept of AML Usage in Crossing Natural Barriers

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natural barriers. Again a central transmitting site beams the TV signals to specific locations. Here the central site comprises five transmitting antennas, each with a high gain and each pointing at their individual receivers.

The Amplitude Modulated Link represents an addition to the CATV industry which will allow this industry to expand into areas which were previously not economically feasible to serve. With the expansion will also come the economic impact of additional CATV plant networks and the availability of greater numbers of television channels to the individual TV viewer.

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APPENDIX F

CONCEPTS FOR IMPROVING LAND MOBILE RADIO COMMUNICATIONS

F. R. Eldridge */

Two hundred million Americans use 100 million telephones, drive 100 million vehicles, and own 262 million radio and 88 million TV receivers served by 6 million radio and TV transmitters. Of the radio transmitters and receivers, about 2.5 million are mobile two-way radios used by Government and non-Government organizations to provide public safety and other special radio services.

A number of reports (e.g., Report of the FCC Advisory Committee for Land Mobile Radio Service, 1968) have indicated the impending critical shortage, within large metropolitan areas, of frequencies allocated to certain special two-way radio services such as police, taxicabs, business, special industrial, and domestic public land mobile services.

This study examines some possible goals of the land mobile radio system and possible ways of achieving them. Specifically it:

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*/ Member, Research Council, Research Analysis Corporation, and consultant to the Task Force.

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Compares present radio frequency allocations and assignments as well as spectrum use of present Federal Government and non-Federal Government two-way radio systems, particularly those within 100 miles of the center of 10 selected major metropolitan areas of the United States.

Compares present and projected spectrum needs for Government and non-Government two-way radio systems in these urban areas.

Compares alternative two-way radio system designs, and methods of operating these systems, that can be used to alleviate spectrum crowding for these services in the selected urban areas.

Explores alternative methods of allocating, assigning, and managing the frequencies used for these services in the selected urban areas.

The goals of land mobile radio systems are, in general, to provide adequate radio services to and between all vehicles and persons desiring these services at a minimum possible cost to the consumers. A limited objective might be to provide the capability of supplying these services to and between the approximately 100 million vehicles used in the United States. An ultimate objective might be to supply this type of service to every person in the United States, each of whom would carry a small personal radio transceiver. To accomplish these objectives the number of transceivers now using the air waves would have to be increased by factors of about 50 and 100 respectively. The following discussion shows that these types of goals do not appear unreasonable if the radio spectrum now allocated to land mobile services is used efficiently. Figure 1 indicates that if the demand for land mobile services continues at the present rate, these levels (one radio transmitter per car or one transmitter per person) would normally be reached before the year 2000, provided that wasteful use of the radio spectrum does not constrain the demand for land mobile radio systems.

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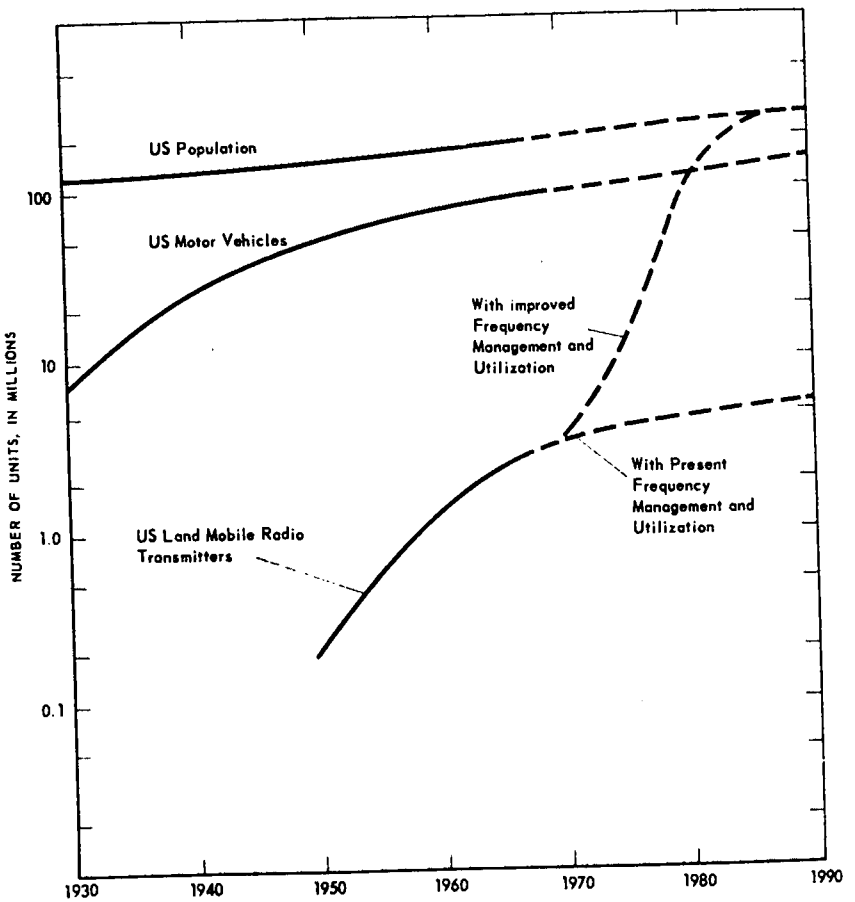


Fig. 1—Trend Estimates for US Land Mobile Radio Transmitters

If this level of service becomes universally available, a number of other supplementary functions can be performed that are not now available. These will become apparent as we describe various system alternatives. Such supplementary functions may in turn be expected to increase the demand for the universal type of system and generate greater rates of system implementation than now exist.

Let us assume that a universal land mobile system can be built that will not be constrained by available radio spectrum space. What type of system might this be and what social benefits might accrue from its use?

To utilize available spectrum space most efficiently the universal system would probably use a mixture of radio circuits and landlines to interconnect the small personal transceivers carried by each person. To reduce the required size of personal transmitters as well as to enable available radio frequencies to be reused many times and simultaneously within a given geographical area, a fixed relay or trunking network would be employed, composed of many low-power fixed transceivers distributed over a specified geographical area and interconnected by landline circuits and circuit switching points.

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To complete a call in such a universal system, one of its required functions would be to identify the location of the low-power fixed transceiver that can be used at any given time to relay the signal between a mobile transceiver and the fixed landline network. One approach to solving this problem would be to provide an identifying name or number for each personal transceiver. Perhaps the name of the person carrying the transceiver could be used for this purpose. If the name is a common one, a number could be added for more specific identification -- such as "John Smith 42." Each personal transceiver would have a code generator that would transmit its identification at specified intervals. This would be picked up by the nearest fixed transceiver. The fixed transceiver would add its own identification code and the composite message, consisting of the personal transceiver and the fixed transceiver identification codes, would be transmitted to a central computer that would store the information. If somebody called "John Smith 42" during the period between identification transmissions, the call would be switched to the last fixed transceiver in the network that received an identification call from his transceiver.

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Such a "person locator" system could be extended from, say, a single urban area system to a multiurban area system or a nationwide or worldwide system by providing suitable regional and nationwide switching systems that would relay identifier information on people traveling large distances from their home territory. The personal transceiver identifier might be suffixed with an area or regional code to handle these cases. For example, if a fixed transmitter in a Los Angeles network received an identifier signal "John Smith 42, New York" it could transmit this information to the Los Angeles computer center which, in turn, would send it to the New York computer center. A call for "John Smith 42, New York" received by the New York computer center would then be relayed to Los Angeles during this time period. A system such as this, then, could locate "John Smith 42, New York" and relay a call to him wherever he might be.

One objection to a "person locator" system is that it might be considered an invasion of privacy. "John Smith 42, New York" may not wish to disclose his location at a particular time or, for that matter, at any time -- even to a

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computer/communications system with built-in privacy features. To overcome this objection, provisions could be made for him to turn off his identifier transmission. The computer would hold information on persons trying to reach him and he could call in to the central computer, intermittently, to determine how to reach these callers.

Many advantages to a universal land mobile system of the type described are anticipated. It could serve a variety of functions including:

- Voice telephone communications
- Radio broadcast reception
- Computer query
- Person or car locator and navigation
- Credit card type functions

For instance, if each person carried a transceiver he could have ready access to the police, fire department, ambulances, emergency maintenance and other emergency services. The system could use "hot lines" for immediate access of police to their dispatch centers as well as touchtone dialing for cases where calls are switched through the fixed network.

The system could be used to receive radio broadcasts when not in use for voice telephone communications. It could also be employed for computer query using touchtone dialing inputs from the mobile transmitter and voice response answers from the computer. This type of service could be used to obtain the correct time, possibly eliminating the need for a conventional wrist watch; to receive weather reports and stock market reports; to provide a personal calendar or shopping list memory and recall service, etc.

The identifier provided with the system might possibly be used for law enforcement purposes by identifying persons at the scene of a crime, or, alternatively, suspicious people caught at the scene of the crime who have turned off their personal transceiver identifier code.

Route guidance services could be supplied to travelers. For instance, those lost in an unfamiliar area could be told where they are and how to find their destination.

Route identification and conveyance identification could be used to provide a billing mechanism for travelers. Each person using a public conveyance could be identified by his personal transceiver signals and billed at periodic intervals for his travel charges.

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Many other services could be provided by the system, using it in the same fashion as credit cards are used at present. For instance, it could be used for billing items purchased in a department store or a supermarket. It could be used for billing leased or rented cars, gasoline, etc.

Other functions might be served by the system such as recording opinion polls, voting on issues, or even for election purposes.

For many of the functions described the identifier code would, of course, have to be foolproof and tamperproof; each person would have to guard his personal identifier transceiver just as he guards his billfold or his credit cards. If a transceiver were lost it would have to be reported to the proper authorities and a new transceiver issued. In other cases privacy provisions will be necessary, such as when a secret vote is being recorded. Furthermore, proper policing will be needed to prevent fraudulent misuse of these devices in performing some of the services. However, the fact that a number of credit card systems operate successfully leads us to conclude that such functions can also be successfully performed using the personal identifier transceivers described here.

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A number of limitations and constraints exist in present methods of utilizing the radio frequency spectrum that if not corrected would prevent development of such a universal personal transceiver system. As mentioned previously, it will be necessary to increase the number of land mobile transmitters on the air by factors of about 50 to 100 to implement the types of systems discussed above. As the population increases with time, this factor will also increase. Present methods of allocating, assigning, and utilizing radio frequencies will have to be reviewed and carefully modified to make these systems feasible.

Development and utilization of a common user system, as described above, where each person carries a personal transceiver and provisions are made to supply hot lines where needed for dispatch purposes, should solve many current and critical land mobile problems, including those already discussed.

Let us review at this point the possible approaches that could be used to attain our proposed goal of one mobile transceiver per person. Other studies (e.g., F. R. Eldridge, "A Comparison of the Utilization of Government and Non-Government Communications in Urban Areas") have

shown that increased use and sharing of frequencies among Government and non-Government radio services in urban areas can be expected to increase utilization by at most a factor of 4.5 or 6.5, if present land mobile system designs employing umbrella coverage are retained.

FCC and others have given some thought to using the UHF TV allocations in the 470-890 MHz band for land mobile purposes. Assume for the moment that this entire band were allocated to land mobile radio services. This would increase allocations to land mobile radio services, in the region of the spectrum above 150.8 MHz, by a factor of about 13.5. If used in conjunction with the other improvements mentioned, a utilization improvement factor of between 60 and 90 could probably be attained. This is close to our goal of 100 for this factor.

There appear, however, to be many drawbacks to this approach. For instance, other methods of distributing radio broadcast services now provided by UHF TV transmissions must be devised. One possibility is using coaxial cable distribution systems in urban areas. The ramifications of this approach are presented in other studies of the President's Task Force on Communications Policy.

Still another serious drawback confronts a system that utilizes umbrella coverage for two-way land mobile transmissions. Such a system requires mobile equipment with large output power to reach other fixed or mobile transceivers with which it communicates throughout the area. This increases size and weight requirements as well as costs of the personal radio transceivers that would be used in a universal system. In any universal system, the mobile transceivers can be expected to be by far the most numerous of the syatem elements and should contribute more to the total cost of the system than any other element in the system. It is important, therefore, to explore methods of making more effective use of the present land mobile portion of the spectrum through improved land mobile system designs and improved operating methods.

There appear many feasible approaches to land mobile systems design that could improve utilization by factors of 100, or even 1000 or more, through use of distributed low-power radio transmitters. The aim here is to tailor the radiation patterns and use low enough power so that

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the radiation from each transmitter is confined to a small, well-defined geographical area. Transmissions to and from mobile units would be relayed over relatively long distances throughout the city through use of distributed fixed transmitters and the interconnecting landline network. If this is done effectively, then the radio frequencies may be used over and over again in different areas of the city to serve other mobile or portable transceivers.

It is not within the scope of this study to design a universal land mobile system of optimum design, from the standpoint of cost and effectiveness. Rather, it is our purpose to show that it is well within the present state-of-the-art, and economically feasible, to build systems that would increase spectrum utilization by factors of 100 or more. This, in turn, would be expected to make possible enough portable transceivers, operating within the present land mobile portion of the spectrum to allow every person in the United States to carry a personal transceiver enabling him to talk to any other person carrying such a transceiver. Such a system could also provide many other benefits of the types discussed previously.

A number of designs for distributed low-power systems are now being explored. Bell Telephone Laboratories is investigating the transmission properties of frequencies from 890 MHz to 11 GHz to determine their effectiveness for such systems in large metropolitan areas. One possibility is to use highly directional antennas for the fixed transmitters which would beam the radiation down a city street and would take advantage of the shielding properties of the buildings to allow reuse of the same frequencies on adjacent parallel streets.

Another possibility is a system using long, twin-lead antennas that extend along highways or city streets or even into buildings. Such systems are now being used for paging within buildings as well as by the NYC Transit Authority and others for communications in subways and tunnels. These antennas can be designed to confine their radiation to within a few hundred feet, in horizontal distance, along their entire length. It should, therefore, be extremely effective in distributive systems where the need is to tailor and confine radiation to individual sectors and yet be able to reuse the same frequencies in adjacent sectors without interference.

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Each twin-lead antenna may cover a sector several miles long and could be used to carry up to several thousand discrete frequencies, either on a frequency multiplex basis or, alternatively, in a high-speed, time division multiplex system.

Several laboratories are investigating the possibility of providing simple, microminiaturized frequency stability circuits for the mobile and portable transceivers used in such systems. One promising method is to broadcast standard frequencies from fixed transceivers that can lock all the mobile transceivers on their appropriate frequencies, thereby reducing co-channel and adjacent channel interference. Each portable or mobile transmitter using such a system might also contain a microminiaturized digital synthesizer enabling it to select any of several operating channels to reduce waiting or queuing time when channels are busy. As indicated previously, each mobile transceiver would also transmit a coded identification signal which could be used to indicate when it is entering a new antenna sector. These coded identification signals would be combined with the coded

addresses and messages and transmitted to central switching points over landlines. The coded address associated with each message would then be used to distribute the message through the landline network to the appropriate antenna sector where it would be transmitted by radio from the fixed transmitter and antenna serving the addressee.

This distributed system can be expected to be basically much more efficient in frequency usage than present systems using a single high-power transmitter to provide umbrella coverage over large areas. For instance, in a city containing several thousand miles of roadway, each frequency in a distributed system, with carefully controlled coverage, could be expected to be used simultaneously by hundreds or thousands of vehicles in the city network without mutual interference or cross-modulation between individual sectors of the system. On the other hand, umbrella-type transmissions, indiscriminately covering wide areas with large amounts of radiated power, allow only one vehicle at a time to use a single frequency within, say, a 100-mile radius of the transmitter.

The cost of a low-power distributed system will, of course, depend on the specific design and method of operation

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that is eventually selected. If everyone carries a mobile transceiver in the ultimate system, there may be no need for the fixed telephone terminal sets now used. Under these circumstances the fixed switching plant and landline transmission facilities could be used entirely for the mobile service. The incremental cost of the distributed, low-power system would then be the incremental cost of providing mobile transceiver terminal sets rather than the fixed terminal sets and the cost of the fixed transceivers and their antennas.

Estimates presented here are for the cost of an interim system where additional switches and landlines are used to supplement the telephone plant used for fixed telephone terminal. These costs may, therefore, be conservative. They are based on a report by the New York City Transit Authority (NYCTA) "Two-Way Radio Communication Mass Transportation Demonstration Project" NY-NTD-8. The NYCTA system provides about 300 route miles of communications using two assigned frequencies in the 150 MHz band. The investment cost for the system was about $12,000,000. We will assume that additional investments of $1,000,000 will be needed for landlines and $5,000,000 for computer and

and switching functions to provide a 300-mile highway telecommunications system of the type described above. This makes a total investment of $18M for 300 miles of system. */ It is also assumed that the system will be amortized over a 15-year period and that the interest rate on the investment will be 5% a year. In these estimates, therefore, we are using a Capital Recovery Factor of .096. In addition, we are assuming that operating and maintenance cost for the system will be 25% of the investment cost for each year of operation. On this basis, the annualized cost per mile would be as follows:

ANNUALIZED COST PER MILE

Investment	$1.8M/year/300 miles =	$6,000/year/mile
O&M	$4.5M/year/300 miles =	$15,000/year/mile
	TOTAL =	$21,000/year/mile

*/ Note that this cost includes the cost of the fixed transmitters, antennas, and control consoles, as well as landlines and switches, but does not include the cost of the mobile transceivers. It is estimated that the latter would use about 0.1 watt of power or less and would probably cost about $150 to $250 apiece in mass production lots.

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For a typical urban area with, say, 2,000 miles of highways, streets, and roads equipped with communications, the annualized cost of the system would then be about $42M a year on the basis of the above assumptions.

A typical system that could provide public mobile communications, as well as communications for public safety vehicles, might be based on the allocation of one UHF TV channel for this purpose. Assuming that duplex channels will be used, each occupying 60 KHz of bandwidths, about 100 channels could be derived from the UHF TV channel. If the antenna sectors are each 2 miles long, our hypothetical system of 2,000 route miles would contain 1,000 antenna sectors. The entire system would, therefore, have a capacity of 100,000 independent channels.

Let us define percentage occupancy and traffic loading (Erlangs) as follows:

$$\text{Percentage of Occupancy} = \frac{\text{Erlangs} \times 100}{\text{No. of Channels Available}}$$

$$\text{where Erlangs} = \frac{\text{No. of Calls Per Hour Per Channel} \times \text{Average Holding Time Per Call (Sec)}}{3600 \text{ sec/hour}}$$

Let us make the following assumptions:

Number of Channels Per Vehicle = 3

Average Holding Time Per Call = 200 seconds

Average No. of Calls Per Hour Per Channel = 5

For channels available to each vehicle the following conditions would hold:

$$\text{Traffic loading} = \frac{5 \times 200}{3600} = .30 \text{ Erlangs per channel}$$

We will assume that the mobile transceiver carried will have a channel occupancy indicator for each channel in use, to reduce lost calls and interference. Assume that normal density for the road system is 100 vehicles/mile/lane and that the average city street has 4 lanes of traffic. On this basis, there would normally be 800 vehicles in a 2-mile sector. Assume that each antenna sector has 100 channels (two-way) available. Assume that each vehicle has three channels available to it from the 100 channels available to the antenna sector.

For each antenna sector the following characteristics would be expected under these conditions:

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Traffic loading = $\frac{500 \times 200}{3600}$ = 30 Erlangs per antenna sector

Percentage of occupancy = $\frac{30 \times 100}{100}$ = 30% per antenna sector

Probability of lost calls << 1% for antenna sectors */

Based on the above assumptions the traffic capacity of the total system could be estimated roughly as follows:

5 calls per hour per channel x 100,000 channels x 30% occupancy = 150K calls/hour

150K calls/hour x 10 hours/day = 1.5M calls per day

1.5M calls/day x 250 days/year = 375M calls per year

This compares with about 1.2B calls a year handled by the non-mobile local telephone distribution plant of a typical city such as Washingto, D.C. The mobile telephone system, described above, using one UHF TV channel, would provide, therefore, about 25% of the capacity of the local plant in a city of this size. Note that a certain percentage of the channels of the system could be reserved for priority public safety services such as police, fire, and ambulance. Reserving, say 5% of the channels in the above distributed system would

*/ See CCITT Red Book, Vol. II bis, Geneva, 1961.

provide 5,000 independent channels for these purposes, or about one channel for each critical public safety transceiver, assuming that each patrolman, fireman, and ambulance attendant used personal transceivers.

Estimates of the cost of each call for the above system is as follows:

Fixed Plan--$42M per year/375M calls per year	11 cents/call
Mobile Transceiver--$50 */ per year/500 calls per year	10 cents/call
Total	21 cents/call

In contrast, a typical umbrella-coverage transceiver will cost about $10,000 for original equipment and installation. A typical urban area of the size considered here might currently have about 6,000 fixed-base transmitters of this type for land mobile functions. Using the same methods of estimating annualized cost as for the distributed antenna system, we estimate the following:

*/ The difference between the cost of transceivers that are likely to be available in the 1970's and the cost of receive-only radios.

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ANNUALIZED COST, PRESENT SYSTEM

Investment Cost	$6M/year
O&M Cost	$15M/year
	$21M/year

While these estimates are lower than the $42M/year for the distributed antenna system, the higher cost of the higher-power mobile transceivers that must be used with the umbrella-coverage system (i.e., $500 to $1,000 apiece as opposed to $250 apiece or less for the transceivers used with the low-power distributed system), the limited number of channels available (i.e., 6,000 as opposed to 100,000 for the distributed antenna system described), and the interference stemming from time-sharing and intermodulation in the umbrella-coverage system all point toward less effectiveness for the umbrella-coverage as opposed to the low-power distributed system.

Through use of an efficient low-power distributed system as described above, it is estimated that the entire land mobile requirements of the nation can be met for many years, using only a small fraction of the spectrum space now used for this purpose, and can be accomplished at a reasonable cost to all users.

This study indicates that a number of organizational changes might be considered aimed at improving frequency management of the radio spectrum used for Federal Government and non-Federal Government land mobile radio services. One possibility for such a reorganization is shown in Figure 2.

A National Electromagnetic Resources Administration might be created along lines recently suggested by Commissioner Bartley. Its function would be to continually review the allocation of frequencies to Federal Government and non-Federal Government radio services. To accomplish this, long-term trends in the needs for various types of radio services would be reviewed. For instance, increased demands for land mobile radio services in urban areas; increases in civil disorder; decreased activity in some military functions such as bomber defense, and increased activity in other functions such as missile defense; increases in highway traffic; decreases in demands for low-speed railroad passenger service, and increased demands for high-speed railroad passenger service; shifting trends in population; and many other factors would all be considered in establishing current needs for land mobile radio services throughout the

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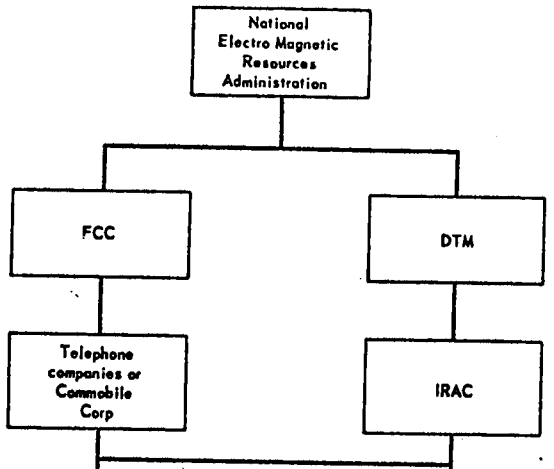


Fig. 2—Proposed Organization for Radio Spectrum Control

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country. These studies, together with systems analyses and studies of social, political, legal, and other factors would be used for a judicious reallocation of the frequency spectrum at periodic intervals.

Since mobile telephone terminal sets may eventually replace present fixed telephone terminals, it may be judicious to give the telephone companies responsibility for providing the mobile terminals. This would also assure that the entire system would be self-compatible.

Alternatively, a carrier's carrier somewhat similar to the Comsat Corporation, or the Aeronautical Radio, Inc., might be established to provide common-user mobile telecommunications services nationwide. A suggested name for this organization would be the COMMOBILE Corporation. This corporation would be a public utility regulated by the Federal Communications Commission and designed to provide effective public land mobile services in the national interest at minimum cost to the consumer. In its charter it would also be assigned responsibility for research and development of improved land mobile radio system design and operation. It is contemplated that it would provide land

mobile radio services on a common-user basis to the public, to industry, to Federal, State, and local governments, and any other organization that elects to use its services.

Federal, State and local governments may wish to reserve some radio frequencies for critical governmental functions. These assignments would be coordinated through IRAC, which would be augmented by representatives from State and local organizations requiring such assignments.

This study has explored some possible near-term and long-range goals of land mobile radio communications services. It has compared alternative ways of designing and operating two-way radio systems to show how they might be used to alleviate spectrum crowding in major metropolitan areas. Finally, it has explored alternative methods of allocating, assigning, and managing frequencies, utilized for land mobile services in urban areas to show what improvements might be achieved through these alternatives.

The general conclusions and recommendations of this study and the studies presented in Reference 1 and 2 */ can be

*/ F. R. Eldridge, "A Comparison of the Utilization of Government and Non-Government Communications in Mobile Areas," August 1968. (Reference 1)

F. R. Eldridge, "A Comparison of Common-User Land Mobile Communications Systems," August 1968. (Reference 2)

summarized as follows:

1. Use landlines to distribute communications in urban areas, wherever both possible and economical, to conserve radio spectrum space.
2. A corollary -- For land mobile radio services use landline distribution system with distributed antennas, to minimize radio transmission power and increase possibilities for multiple reutilization of radio frequencies in geographical areas where spectrum congestion exists. Another important objective is to reduce the size of the mobile transmitters required in land mobile systems.
3. For near-term improvements -- Abolish block allocation of frequencies within the non-Government land mobile bands and increase sharing of frequencies among all radio services using these bands.
4. For near-term improvements -- Consider the possibility of reallocating some Government frequencies to non-Government land mobile uses in urban areas. Promising candidates are those

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land mobile frequencies now allocated for Government use in Chicago, Pittsburgh, St. Louis, and Detroit.

5. For near-term improvements -- Reallocate some UHF TV frequencies for shared use with low-power, distributed land mobile radio systems in some urban areas. Promising candidates are Los Angeles, Washington, D.C., San Francisco. Philadelphia, New York, and Boston.
6. For near-term improvements -- Consider the possible establishment of a National Electromagnetic Resources Administration to improve future coordination of assignment and sharing of frequencies used by Government and non-Government land mobile radio services.
7. For long-term improvements -- Allocate the 26MHz portion of the spectrum adjacent to the upper end of the UHF-TV band to common carriers for use in a nationwide, low-power distributed land mobile radio service. The common carriers assigned these frequencies should be asked to

provide high-capacity, common-user systems, for both dialed and "hot-line" land mobile radio services in this band. One interesting alternative to assigning these frequencies to the common carriers is to create a carrier's carrier, such as the COMMOBILE Corporation described above, to provide this type of service on a nationwide basis.

8. For long-term improvements -- The common carriers should also be encouraged to initiate systems analysis studies and R&D on high-speed switching networks and mobile transceiver locator systems for low-power distributed networks of the type described in 7 above.
9. For long-term improvements -- Initiate further systems analysis studies to investigate the possibility of using the type of system described in 7 above, for personal radios, carried by each citizen at all times. This type of system may be instrumental, for instance, in deterring and reducing all types of crimes involving personal

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assault. It could also be used to provide other valuable services as described in this report.

An orderly resolution of present crowding problems of the land mobile radio spectrum in urban areas might include:

- Delegation of authority to develop a low-power, distributed common-user system to either the common carriers or a carrier's carrier and allocation of sufficient frequencies to implement the system.
- Reallocation of adequate spectrum space in urban areas to alleviate the immediate spectrum shortage for non-Government radio services.
- Development and installation of the low-power distributed land mobile system by the common carriers or a carrier's carrier.
- Reallocation of surplus land mobile frequencies to other uses such as low-power distributed common-user systems for personal radios.

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A SURVEY OF TELECOMMUNICATIONS TECHNOLOGY PART 2

Eugene V. Rostow

President's Task Force on Communications Policy
Washington, D.C.

June 1969

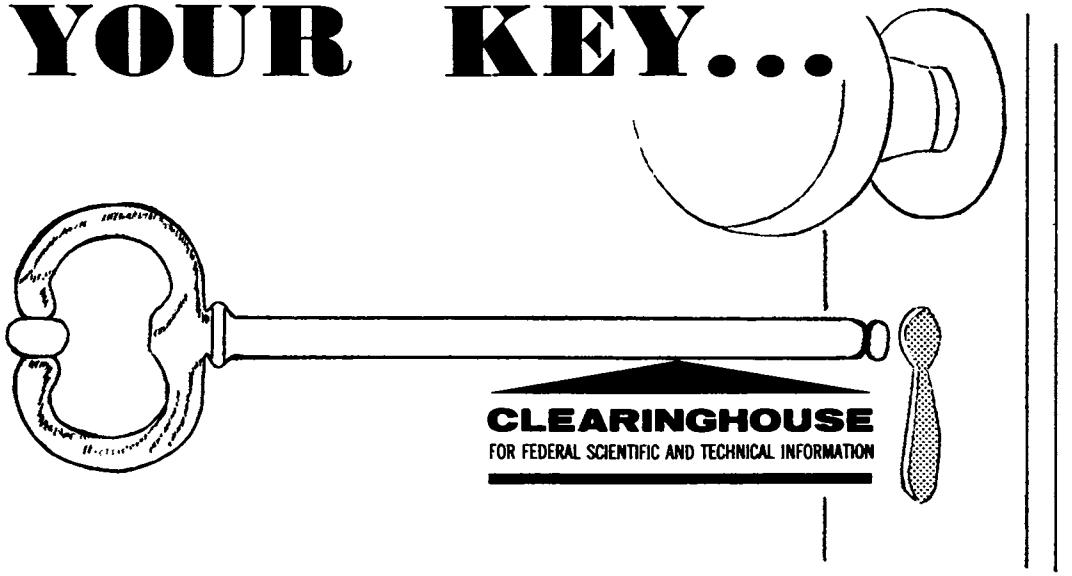
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PRESIDENT'S TASK FORCE ON COMMUNICATIONS POLICY

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THE ROLES OF THE FEDERAL GOVERNMENT IN TELECOMMUNICATIONS

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THE DIGITAL LOOP: ONE APPROACH TO THE WIRED CITY

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SUMMARY

Contents

This report is intended to help provide a basis for planning the Nation's system for telecommunication in the forthcoming few decades. It is concentrated toward the problems of non-radiating telecommunications systems in urban area: urban areas because it is expected that most of the population will live in urban areas in the near future (although highly developed telecommunication facilities might themselves allow significant diffusion away from urban areas in the future) and non-radiating systems because it is in the urban areas that the problems of efficient use of the electromagnetic spectrum are the greatest. The time frame for the technological forecasts is the decade 1970-1980. The report includes a list of some of the services which might be offered on a general purpose telecommunications system, a detailed description of the techniques which seem to us most promising for such a system, discussion of the problems of transition from our present paired-wire system or our present CATV systems to the general purpose system, and comments on the potential costs of the general purpose system.

We do not suggest that it will be possible to reach most homes and offices in the nation with a digital multipurpose system by 1980. But the nation could be well into the transition by that time.

Assumptions

We have based the discussion on a number of explicit assumptions:

(1) A list of assumed needs for telecommunications service, which we have categorized according to the information rate required and whether the service must be one-way or two-way.

(2) There is no major technology which will be used on a large scale in public telecommunications systems by 1980 which is not already under development or at least being explored at this date.

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(3) Solid state technology will be able to provide large scale integrated circuits (LSI's) of high quality at at low cost and in large numbers. This is probably the key assumption in this list, and also the one least subject to control or precise forecasting.

(4) Government regulation and legislation will encourage, or at least permit, the incorporation of new technology into the public telecommunications system.

(5) Both the U.S. population and the per capita demand for telecommunications services will expand significantly in the next few decades. (It is predicted that the building plant in the U.S. will double by year 2000. The doubling time for the telephone network has been about 10 years for several decades.)

Approach

We consider three basic systems for non-radiating transmission of information:

(1) Paired wires carrying single analog signals, as in the present telephone system.

(2) Coaxial cables carrying multiple analog signals, a frequency division multiplex (FDM) system, and

(3) Coaxial cables carrying multiple digital signals, a time division multiplex (TDM) system.

These three types of systems are compared to each other with respect to flexibility, adaptability, security, maintenance, cost, and other factors. Most of the detailed description is centered on the possibilities for digital TDM systems, since they are less familiar than the other two and because they seem to offer the most interesting possibilities in versatility, multiple use, efficiency, and probable cost improvements due to new (particularly solid state) technology.

Characteristics of Digital Systems

An important characteristic of pulse code modulated digital systems is that they apparently take more bandwidth for a given signal than their analog counterparts do. However, this problem is not quite so straight forward as it seems, since the digital systems can perform a given function with a much

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lower signal-to-noise ratio than is acceptable in an analog system. In addition, the digital signals are much more susceptible to redundancy reduction operations than are the analog signals, which can help to offset this extra use of bandwidth. The fundamental advantages of the digital systems are:

(1) The lower signal-to-noise ratios permitted.

(2) Versatility due to the fact that all signals are in the same digital form, and therefore the system can carry many types of information interchangeable.

(3) Small size, weight, and in the future, cost, of the multiplexing equipment, since it can make extensive use of large scale integrated circuitry.

(4) That digital switching, handled largely at the terminal equipment itself, may in the future be both simpler and cheaper than the switching required for either paired wire or carrier systems.

(5) That the information rate is easily varied by using multiple time slots on the transmission medium.

(6) They they are readily used for data transmission of all sorts, since the system is already designed for the digital signals characteristic of data transmissions.

(7) That digital signals can easily be encrypted for secrecy.

(8) That digital systems may be more susceptible to redundancy reduction techniques than are analog systems.

Costs

We have not yet been able to make detailed cost estimates for the digital systems in comparison to the other systems. We can, however, point to areas wherein the costs may be higher (terminal equipment) and where there are probable savings (cable costs, laying of cables, maintenance, switching, re-wiring for additional services, adaptability of the system, and others.)

The most direct comparison we can make with respect to system costs is in the passenger entertainment system for the forthcoming Boeing 747 jumbo jet. This entertainment system

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will be a digital multiplexed system, and will cost four to five times what the comparable paired-wire analog system would cost to install. (It is being used in the airplane because of the large weight savings.) Most of the extra cost of the digital system is in the solid state circuitry. Thus, the expected reduction in the cost of solid state equipment due to production of large scale integrated circuits at a low price may make such digital systems competitive in cost with their analog paired-wire counterparts within only a few years.

Conclusions

Time division multiplexed, pulse code modulated digital systems do indeed offer significant advantages in versatility and other characteristics which are important in low information rate and medium information rate services, such as voice, data transmission, videophone, facsimile, and many others. In addition, the cost of digital systems is expected to be competitive with paired-wire systems within the decade, although the evidence we can present for this statement is indirect at this time.

On the other hand, if it is desired to allow for a great deal of diversity in television programming by making available a large number of television channels, the local distribution will be most efficiently accomplished by a frequency division multiplex (carrier) system similar in concept to that used by CATV operators today.

The ownership of terminal equipment, performance standards, and maintenance of the equipment will be more complex problems than now exist in either the telephone or the television networks. The public demands very high reliability and rapid repair in the telephone system, which is consistent with ownership and maintenance of terminal equipment by the system operator. The television system seems to be better served by the variety of choice which comes with private

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ownership of the terminal equipment. If it is true that private ownership of terminal equipment is desirable in order to encourage variety, advanced equipment and responsiveness to public desires, the operator of the system must be prepared to carry information impressed on the line by equipment which he does not own. The system operator must, of course, have control over performance specifications of that equipment, for the protection of the system and its other users.

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I. INTRODUCTION

The nation's telecommunication system has a vital role to play in the solution of many of our present major problems, including education, transportation, air pollution, race relations, probing of public opinion, and others. In some cases the connection is quite obvious, as in education and public opinion gathering. It is also perfectly clear that we could not control our present (let alone the future) transportation system without good telecommunications. In other cases the connection is less direct, but nonetheless very real. For example, it has been suggested that television has played a very important role in bringing racial unrest to a head by simply showing underprivileged people something of how the rest of the nation lives. Telecommunication facilities which allow a better approximation to face-to-face contact between individuals and groups of individuals would greatly reduce the need for physically transporting these individuals. This could have not only a direct effect on the transportation system, but could also significantly affect the need for some natural resources (fuel and metals for vehicles) and thereby reduce air pollution. Reduction of traffic fatalities and even noise in densely populated areas could be a dramatic secondary effect.

It is quite clear that if the telecommunication system is to have an optimum impact on these problems, it will have to be very much more versatile than our present telephone-telegraph-radio-TV system. It will be required to carry many kinds of information, having widely varying information rates and often having rather different interconnection requirements. For example, both the information rate and the interconnection requirements are quite different for television distribution from those for private telephone (or even videophone) conversations. Automatic reading of utility meters and the extremely fast transfer of data from one computer to another are further examples of widely disparate requirements. Thus, one of the most important things to keep in mind in designing the future telecommunications system is that there is already need for great versatility, and that the need will doubtless increase in ways we cannot now foresee.

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Paralleling the need for versatility is a wide spectrum of possible media for transmitting information: the atmosphere, paired wires, cables of paired wires, coaxial cables, waveguides, light pipes, and even the earth and the ocean waters. The criteria for deciding which medium to use for which communication tasks are three:

(1) ability of the medium to perform the task (cables won't do for communicating with aircraft),

(2) availability of the medium (the spectrum in the atmosphere is becoming crowded), and

(3) relative cost (keeping in mind that a more expensive system which can perform multiple tasks with a minimum of modification may be cheaper in the long run).

It is in urban areas that the problem of spectrum crowding in the atmosphere is most severe, and doubtless will remain so as long as we know cities in more or less their present form. Thus, in such areas criterion (2) above becomes important, and suggests the use of non-radiating media whenever it is feasible under the other two criteria. This report is addressed to the problem of forecasting what technology will be available by about 1980 for non-radiating telecommunications systems in urban areas.

Cost is a primary parameter in any such considerations. Chronologically, however, it cannot be the first consideration -- one cannot discuss in detail the cost of a system which is not reasonably well described. In this report we have concentrated most of our effort on the description of technically feasible systems and how the present system might evolve into the systems described. We have, however, tried to point out where the new systems are expected to be more expensive than present ones and where they should be less expensive. At the same time, we have tried to identify the differences in available service, flexibility, maintenance, adaptability, security, and other characteristics between present and possible future systems.

The forecast is supposed to be for approximately the year 1980, which really is not very far away, when one considers that it takes some time to develop laboratory prototypes, and to produce and introduce new equipment on a large scale. This is particularly true, of course, in an industry which is regulated by the government, which has a plant investment now of around

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30 billion dollars, and which amortizes this investment over a long time period. Since any future non-radiation communication system for cities must obviously go through a period of interfacing with the present telephone system, which does have these characteristics, they certainly must be considered. Thus, we make the explicit assumption that no major technique which is not at least being investigated now will be in extensive use in urban non-radiating telecommunications systems by 1980.

Our approach to describing possible systems is to assume a list of possible services to be offered; categorize them into narrow, medium, and high information rate services; detail pertinent characteristics of paired-wired, frequency division multiplex, and time division multiplex systems; and then describe several feasible systems for supplying those three types of services. In the original description of the possible systems we do not explicitly consider problems of interfacing with the present systems or of transition from the present systems to the possible new systems. These problems are considered separately, on the grounds that it is better to describe an ideal and then see how much of that ideal we can attain than it is to think in terms of incremental steps from our present system and accept whatever system those steps may lead to.

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II. ASSUMED NEEDS AND SERVICES

Characteristics of Services

In this Section we consider a list of needs which might be met by some future telecommunications system or systems. We have first categorized these items according to certain required characteristics of the telecommunications systems which will meet the need. The two systems characteristics of highest interest are:

Information rate (band width or bit rate):
- (l) low (voice)
- (m) medium (videophone)
- (h) high (television)

and

whether the communication is inherently:
- (o) one-way (entertainment broadcasting), or
- (t) two-way (telephone conversation)

The (binary) bit rates corresponding to the above categories, assuming no compression (or redundancy removal), are approximately as follows:

- (l) 50 kb/sec (kilo-bits per second)
- (m) 7 Mb/sec (Mega-bits per second)
- (h) 50 Mb/sec

Possibilities for and the significance of redundancy removal will be discussed in later Sections of this report. At this point, it suffices to say that in most cases except transmission of data, reductions by factors of about 5 to 10 are sometimes feasible, but are quite expensive at the present time.

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Services	Service	System Characteristics (letter abbreviations explained above)
	Telephone	l; t
	TV (Commercial or private)	h; o
	Stored TV (see 1/ below)	l or m; o
	Radio Broadcast	l; o
	Videophone	m; t
	Record Communications 2/	l; t
	Facsimile 3/	m; o or t
	Shopping	l or m; o or t
	Advertising	l, m, or h; o
	Teaching devices	l; t
	Voting by the public	l; t
	Meter reading (utilities)	l; o
	Alarms (fire, burglar, system failure, etc.)	l; o
	Emergency Communications 4/	l; o or t
	Banking	l; t
	Access to time-share computers	l; t
	Communications between computers	l, m, or h; t
	Mobile communications	l; t
	Vehicle traffic control	l; t m or h; o

1/ This refers to use of terminal equipment which receives large amounts of information, perhaps at a low rate during a period of otherwise low use of transmission facilities, and stores it for later use by the receiving party, perhaps at higher rates.

2/ Record communications are those transmitted symbol-by-symbol, like teletype. Transmission of pictures and non-standards symbols is excluded.

3/ By "facsimile" is implied high resolution but a low frame repetition rate. For example, 1000 by 1000 lines per frame with a six digit binary code for intensity and color at each point and the ability to display a frame in one second would require 6×10^6 bits per second. This information rate is comparable to that required by low resolution, high repetition rate, picture signal like videophone.

4/ Emergency communications are technically different from ordinary low-rate one-way or two-way communications in that the telecommunications system permits properly designated authorities to pre-empt any part or all of the system for emergency purposes.

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Medium and High Rates

Note that there are some of these possible services which require medium or high information rates and which could or do require that the individual user have control over what information is being sent to him at a particular time. Videophone is a service which inherently does require this control capability. It has also been proposed that users might create a demand for movies (TV), books (facsimile), or advertising to be delivered to their homes at their individual demand.

As will be shown in more detail later, such individual use of medium and high information rate services could make tremendous demands on the wire or cable systems serving homes and offices. Thus it is reasonable to examine alternatives which accomplish much the same things without using up such large amounts of system capability.

Private Movies

For example, it would probably be quite impractical (in the foreseeable future) to build a distribution system which could supply any movie to any home on demand at any time. It would not be nearly so difficult, however, to build the capability of sending the desired program material to the user's home during low-use periods (night) for automatic recording and later playback at the user's convenience. Thus, the suggested "Stored TV" service in the list above. A large demand for news programs to be available "on call" could well be met by devoting one entire TV channel to re-running the latest newscast until that newscast was replaced by a later one. We cannot afford to use a TV channel with our present broadcast systems, but if 20 to 50 channels were cheaply available on a cable system (as is shown to be reasonable later in this report), such a solution would be quite feasible.

Facsimile and Shopping

Many facsimile and advertising services might be treated in similar ways. Fashion shows or auto shows, for example, could be given according to announced schedules on a channel dedicated

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to shopping, reducing the need for private "on demand" use of medium or high rate facilities. In addition, advertising or shopping services might demand only a "low" information rate if a several-second time for displaying a picture of only moderate resolution would be acceptable. It is interesting that videophones have been unsuccessful to date in experiments using them for shopping, because their resolution is too low. Resolution seems necessary, but perhaps the "movie" aspects are less important.

Television

It is important to notice in the list of services and characteristics above (page 4) that the only consumer and business need for "high" information rate services is in the field of television, public or private. (The high rate needs of advertising would be met by television). This suggests that it may not be necessary at all to incorporate this high rate capability into the same wire system which serves the low and medium rate needs. It may be most practical economically, to build a separate special-purpose system for television distribution in cities, as the present-day CATV systems are now separate from the paired-wire telephone system. Later in this report, after discussion of the relative merits of analog and digital systems, we suggest that this is, indeed the case. It seems that the great bandwidth requirements for TV signals which are converted to digital (over 50 Mb/sec per TV channel) and the difficulty of maintaining high quality under compression of more than a factor of about 5 to perhaps 10, and the fact that one can put up to 60 channels on an unswitched coaxial cable system using analog (frequency division multiplex) signals, points to continued use of the analog system for TV.

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Computer-to-Computer

It has been suggested that computer-to-computer communication may require information rates considerably in excess of those needed for television. However, there seems to be good reason to question that suggestion.* Consider two types of intercomputer communication which might demand high information rates:

(1) Computer A wants to consult data stored in computer B At present a typical high speed core memory holds about 130,000 words of 60 bits each, a total of about 8 megabits. At a bit rate corresponding to that required for a TV channel (about 50-60 Mb/sec), this entire memory can be transferred in around 150 milliseconds. If memories grow in size by a factor of about ten, the transfer can still be made in a second or so. Actually, it should be fairly rare that computer A really wants the entire storage of B--in general, B would search or process its own stored data and transfer only a small part of it to A, and a slower transfer rate would probably be quite adequate.

(2) For problems too large for the core storage of a single computer to handle, it might be desirable to have two computers jointly work on the problem rather than use a single computer and slower peripheral storage. In that case a frequent high speed "dialogue" between the computers might be desired. However, since the cost of large amounts of core storage has been decreasing rather rapidly for some time and is expected to do so for some time to come, an alternate possibility is simply to build larger core storage for the single computer.** It is certainly not obvious that the high speed communication link over a significant distance is the optimum solution. Note also that today's very fast computers operate at an internal processing rate of around 600 Mb/sec, and that rate is getting fairly close to the limit imposed by the transit time of signals on wires inside the computer.

* These comments on computer-to-computer communications are based on conversation with a recognized expert in computer timesharing.

** We are talking here about situations in which such large problems occur frequently. If they are infrequent, it would probably not be worthwhile either to build larger storage or to build a very high speed communication link over a large distance.

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Since the transit time between computers separated by miles is so very much longer than the transit time between two points within the same computer, it is not likely to be economically feasible to build communication links which operate at information rates of the same order as the internal processing rates of the computers themselves. Thus, a 50 Mb/sec rate (about the same as a TV channel) may be about all that is ever practical for transfer between two computers separated by a significant distance from each other.

Very High Rates

Of course, if it were necessary to interconnect many such computers in a common system such that trunk lines would be handling several 50 Mb/sec messages at the same time, the information rates required for the trunk line would rapidly become extremely high, by today's standards * [1] **. In any case, a telecommunications system for computers would have only a small number of nodes (computers) to interconnect, compared to the large number of potential consumer terminals in a telephone system. It is probably not reasonable to require that the general purpose consumer and business telecommunication system be prepared to handle information rates greatly higher than those required for the general purpose uses.

Although many businesses and perhaps even some private citizens may make direct or indirect use of such interconnected computer systems, the input-output capability needed would generally involve low data rates and therefore be compatible with the general purpose system. Thus, special purpose needs for (possibly) extremely high information rates will not be considered further in this report.

*The highest bit rate actually imposed on a laser beam, for example, seems to be 448 Mb/sec, accomplished at Bell Labs and reported in Ref [1]. This was an experimental system, and doubtless not economically practical at this time.
**Numbers in brackets [ ] refer to references in the bibliography.

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III. DIGITAL TELECOMMUNICATIONS SYSTEMS

This Section is devoted to describing characteristics -- both advantages and disadvantages -- of digital telecommunications systems. Figure 1 is given to help clarify relationships between some of these characteristics.

In Figure 1, an arrow from one characteristic to another means that the second characteristic exists because of the first, or that it is possible to design a system with the second characteristic because of the existence of the first. (Sometimes two or more features together imply a third, as shown by multiple arrows.) The numbers in the boxes refer to numbered paragraphs in the text which discuss the named characteristic.

1. Digital Signals

Transmission of information over wires of any kind requires, of course, an electrical signal of some kind. The most common electrical signal in telephone systems of today is an analog signal, in which the voltage of the electrical signal is proportional to the pressure in the original sound signal at any instant in time. Another possibility for the electrical signal is a digital form, in which the sound pressure at any instant is represented by an electrical pulse (or pulses) having some characteristic(s) which can be recognized at the receiving end and reconverted to a sound wave. (Of the several possible ways to impress information on a sequence of pulses, we shall confine our consideration to the so-called Pulse Code Modulation (PCM) system.)

2. TDM

There are basically two methods for imposing multiple signals on the same cable or pair of wires. In the Frequency Division Multiplex (FDM) system, each signal is present on the channel all of the time. But each of them occupies a finite and distinct frequency interval not occupied by any other signal.

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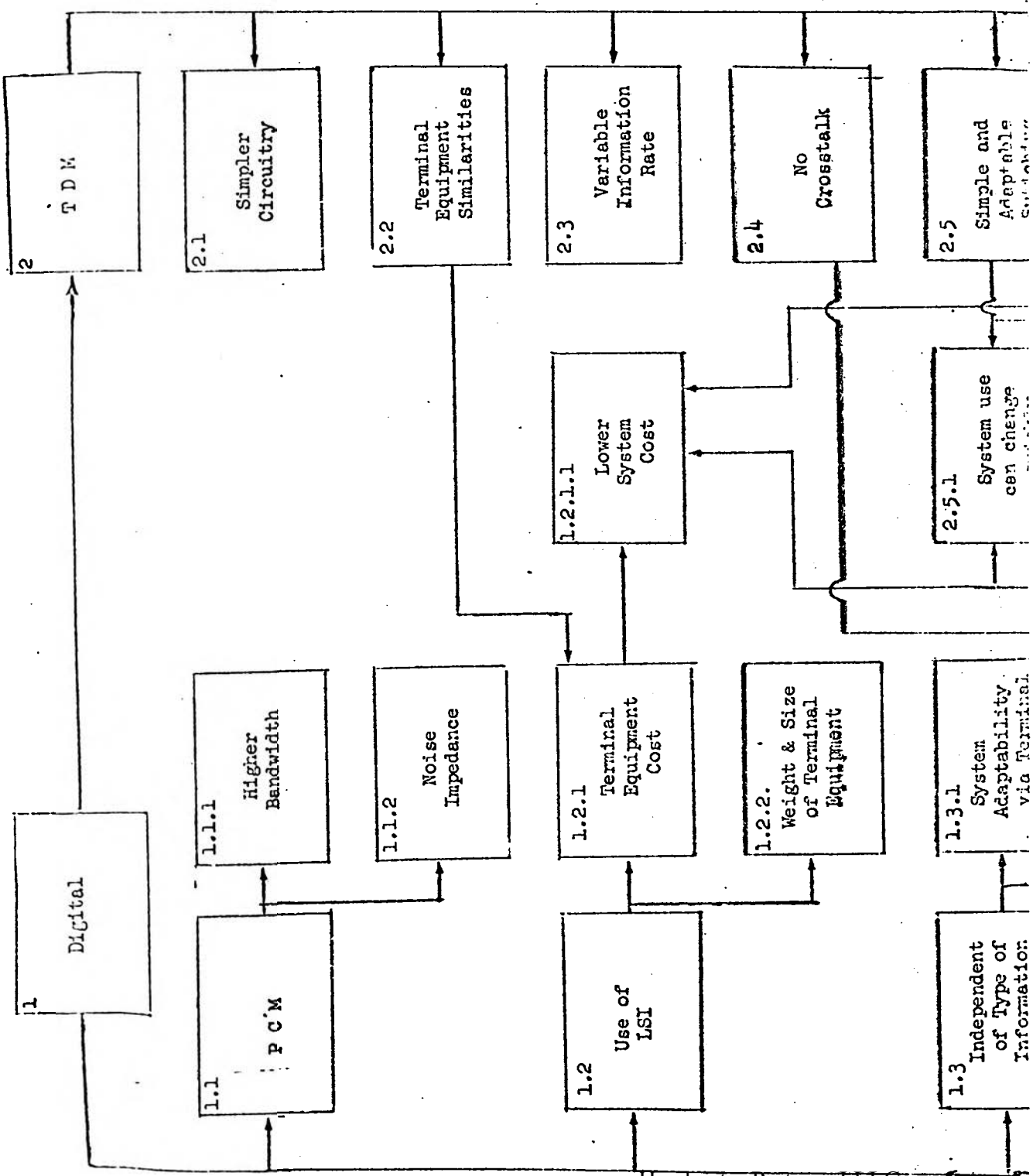
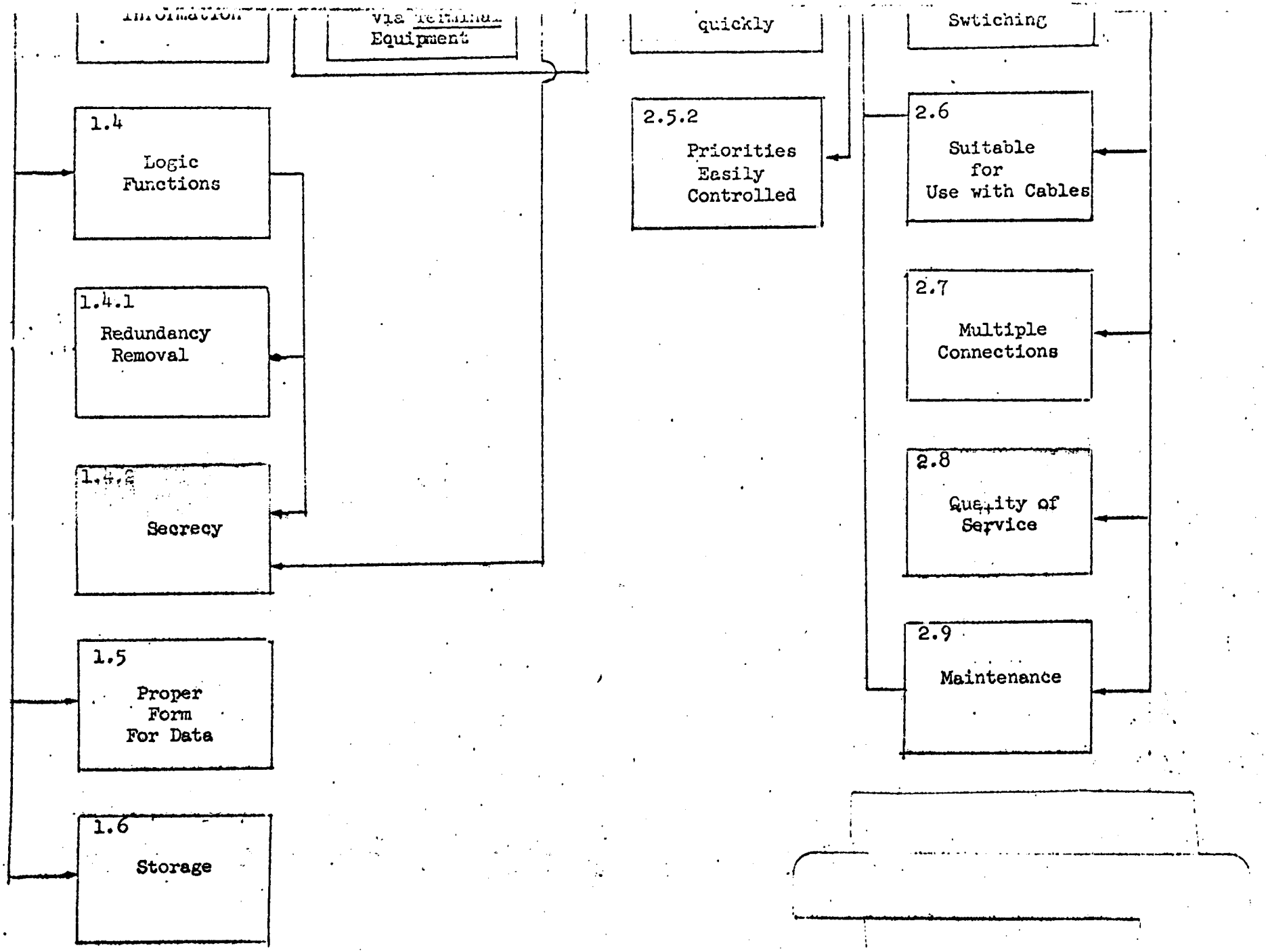


Figure 1

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Figure 2a, taken from reference [2], shows this on a set of coordinates labeled frequency (ω) and time (t). In a Time Division Multiplex (TDM) system each signal occupies a distinct time interval and is occupied by any other. But the spectra of all the signals have components in the same frequency interval. This is shown in Figure 2b.

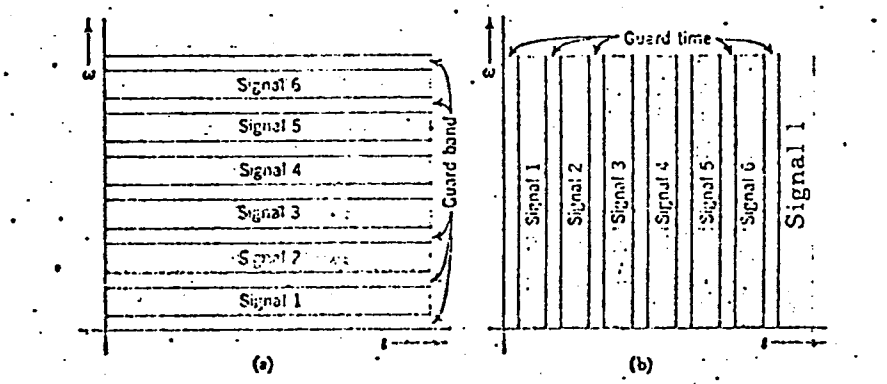


Figure 2. Representation of frequency and time multiplexing

Clearly, bandwidth-limited analog signals are appropriate for the FDM system and digital signals, being time-limited, are appropriate for TDM systems.*

Figure 1 separates characteristics which are direct consequences of the digital character of the signals from those more closely associated with the time division multiplexing. We first discuss the consequences of using digital signals, as compared to analog.

PCM

To generate a Pulse Code Modulation (PCM) signal, one first samples the amplitude of the original signal at a rate high enough to adequately determine the character of that signal. This required sample rate is twice the highest frequency which one wants to preserve in the original signal. Having assigned

*In fact it is possible to use both time and frequency division multiplexing at the same time on the same cable by using bandwidth-limited pulses. This technique could prove quite useful in the cable systems described in this report because it could permit full utilization of cables by low bit-rate equipment. Double multiplexing has been used in the telemetry system of missiles and rockets and is also used by Headwater Parents LLC, Bell Telephone See Ref. [4], page 15.

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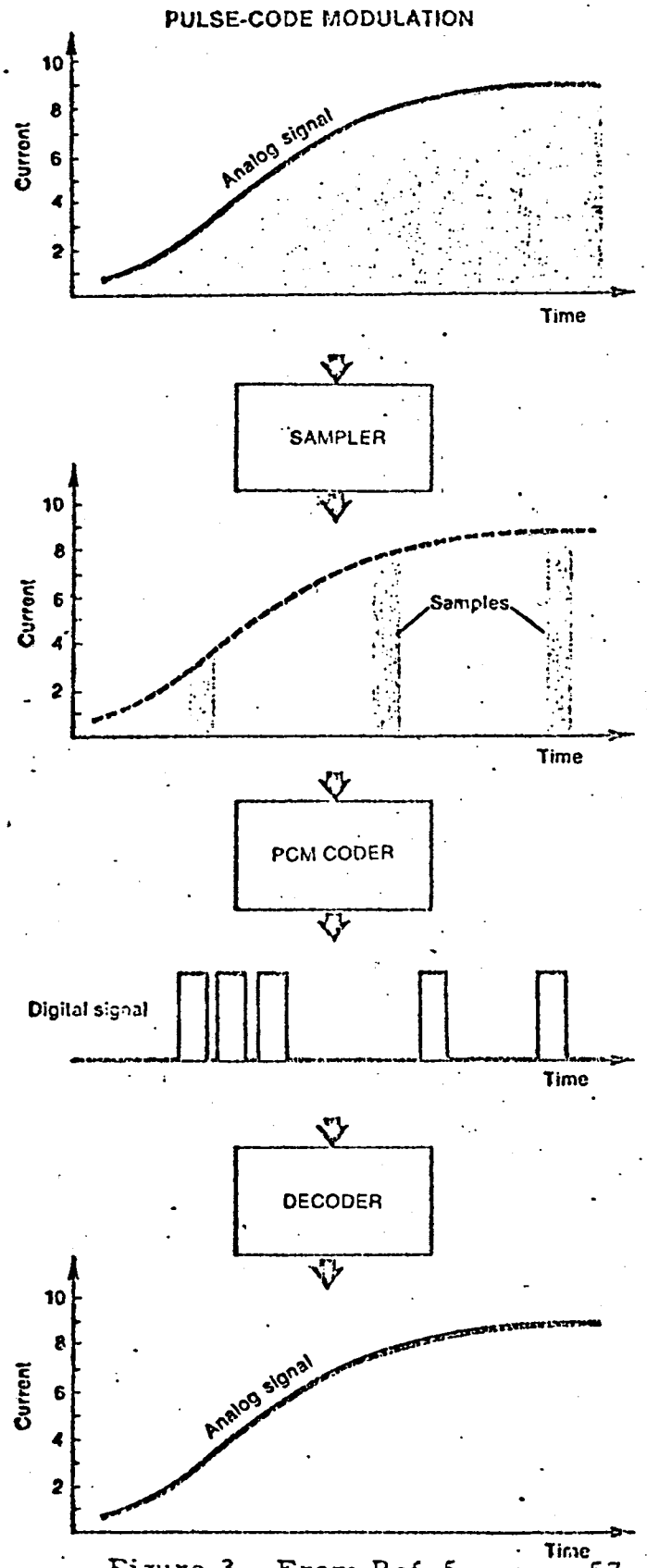


Figure 3. From Ref 5 , page 57.

The graphical representation of pulse-code modulation depicts processing of analog signals into digital form for transmission. Analog samples are expressed as a binary number in the form of a series of pulses. The demands for future point-to-point transmission capacity will be met by use of this coding technique.

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the sample amplitude a numerical value, that value is then converted into a binary number, which is then represented by a sequence of pulses, each representing either 1 or 0. (See Figure 3, taken from Ref. [5], p. 57.)

The number of pulses required to adequately represent each sample is, of course, dependent on the accuracy with which one desires to preserve the amplitude of the original signal. For example, it is found that speech can be reproduced with high quality if six or seven binary digits (bits) are used to represent each sample, in fact, about the same number of bits per sample are required for television signals.

1.1.1 Higher Bandwidth

This immediately brings up the question of the bandwidth necessary to transmit such a signal. The original signal of bandwidth W hertz is converted into a stream of 2mW pulses per second, where m is the number of pulses per sample. The bandwidth required to transmit 2mW pulses per second can theoretically be as low as mW hertz, but under practical conditions it is about 2mW hertz. Thus PCM requires about 2m times as much bandwidth as the original analog signal [3]. In considering possible uses of digital systems in the "wired city," we must always answer whether, for the particular application at hand, the advantages of digital signals are sufficient to offset this requirement for extra bandwidth. We shall see that there are a number of advantages which more than offset this disadvantage in many cases.

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One point which helps offset this bandwidth requirement is that PCM signals lend themselves readily to redundancy removal ("bandwidth reduction") schemes. This is discussed more fully in paragraph 1.4.3.

There is also an important trade-off between power and bandwidth, which is complicated by transmitter power limitations, repeater spacing, cross-talk problems, temperature problems, and other factors. This is discussed briefly in paragraph 1.1.2.

1.1.2 Noise Independence

Perhaps the most fundamental advantage of PCM over analog transmission arises from the nature of the repeaters which one must periodically insert in the line to amplify (or regenerate) the signal.

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To quote from a recent article in "Scientific American," [3],

> "In conventional AM systems the repeater is really nothing more than a high-quality amplifier. It therefore amplifies noise of all kinds along with the signal proper. Sources of noise include extraneous noise picked up by the cable, noise coupled in from other conductors ("cross talk") and thermal noise due to the random motion of electrons in the cable and amplifier circuit. The analogue amplifier has no mechanism for separating signal from noise.
>
> Contrast this with the repeater that can be designed for a digital system. The PCM repeater is not a conventional amplifier but rather a circuit designed to detect whether an electrical pulse is present or absent. A moderate amount of noise added to a pulse does not alter the basic fact that a pulse is present. Conversely, if a pulse is absent from a particular time slot, a considerable amount of noise must be present before there will be a false indication of a pulse. In short, a repeater for digital signals (commonly called a regenerative repeater) can receive a digital pulse train that has been highly contaminated by noise, extract a clean signal and pass it along to the next repeater."

The complex relationship between this advantage and the apparent disadvantage of higher bandwidth requirements is discussed in Ref. [4]:

> But the bandwidth problem is not that clear cut. "For a clean transmission with frequency-division multiplexing," points out Dave Sadlers of Raytheon, "with reasonable gain margin, etc., you've got a choice. You can either keep the bandwidth real narrow and boost the power, or you can cut back the power and increase the bandwidth -- that is, you use a larger modulation index.
>
> "There's no clear cut answer as to which system requires the most bandwidth because in both cases you can trade off bandwidth for power and antenna size and other factors.
>
> "In PCM you don't have to transmit much information through the band and it doesn't matter if it's distorted quite a lot. It doesn't matter if the gain margin isn't particularly good. We can work with a poorer signal-to-noise ratio than in FDM"

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Errors

Occasionally a regenerative repeater will insert an extra pulse or drop out an existing one. If the error rate is less than one in a million (10^{-6}), the impairment is usually undetectable. Error rates of less than 10^{-6} are, in fact, routinely achieved in transmission circuits having thousands of repeaters in tandem [3]. To achieve comparable performance conventional AM and FM systems generally require much higher signal-to-noise ratios than do PCM systems.

From a recent article in "Electronic Products" [4]:

> "A second error source in digital voice comes from the dynamic range of spoken sound, ranging from the whisperer to the genuine loudmouth. When quantizing to 7 bits, for example, the quantized signal can have any one of 128 levels (actually, 127 since 0 is not used). If the 127 levels are used to form an envelope for a low voice, then a loud voice will be outside the envelope most of the time and the reconstructed signal will have a lot of flat tops -- it will be severely clipped. If the envelope is widened to cover loud sounds, then low sounds won't be quantized adequately.
>
> Two techniques are available to solve this problem. Either the analog voice signal goes through a logarithmic compressor, which significantly reduces the dynamic range of the signal, or the signal is quantized in unequal steps -- that is, the quantizing is finer (more levels) around zero signal than it is for high-level signals. At the receiver the signal goes through a reverse process.
>
> Digital jitter is another source of error. Jitter is a term used to describe the slight and erratic displacements of pulses or bits from where they are supposed to be. Noise at the leading edge of a pulse, for example, can advance or retard a pulse, thus putting jitter into a system, although other causes are probably more significant.
>
> [A kind of] crosstalk is generated by digital jitter. If the digital jitter is occurring as a sinusoid at integral multiples of 4 kc (say 12 kc), intelligible crosstalk can occur. As the frequency digital jitter moves away from n x 4 kc, the intelligibility of the crosstalk decreases.

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Despite all the opportunity for errors, Bell designs for an error rate of less than 1 in 10^6."

Where extremely high accuracy is necessary, error correction techniques can be used with little loss of information rate. In fact, on paired-wire lines with present-day switching, the information rate can actually be increased by using such techniques. (Ref. [5], p. 50.)

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1.2 Use of LSI

In comparison to the present telephone equipment, which largely consists of rather simple analog devices, the circuitry in digital equipment is rather complex. However, since the complexity arises mostly from requirements for logical handling of digital information and since modern integrated circuits (IC's) and large scale integrated circuits (LSI's) are so well adapted to such chores, the complexity need not necessarily lead to prohibitive costs. As we have already seen so dramatically with transistors and to some extent with IC's, the nature of the manufacture of solid state devices is such that large-scale use of the devices has a huge negative effect on the price of the devices. Thus, the act of building a digital telecommunication system in this country would itself lower dramatically the price of the components of the system.

Integrated circuits are now being used in analog equipment, and doubtless will be used more extensively in the future. Thus, cheaper LSI will lower the cost of both digital and analog systems. But the overall cost of digital systems probably depends more heavily on availability of low cost integrated circuitry than does the cost of analog systems.

It is certainly not absolutely clear that LSI will in fact fulfill its promise to make digital systems competitive in cost to analog systems. There are serious problems to be solved, such as reliability, performance checking and debugging, and precision of the components, as well as manufacturing costs. For example, the best resistor which has been built into IC's to date has had about a 20% tolerance, which is not good enough for many purposes. At a recent computer conference it was not possible to reach a consensus that LSI would be used in computers on a large scale within the next five years or so.

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Note that in box 2.1 in Figure 1 is entitled "Simpler Circuitry". This refers to comparison between TDM-PCM systems and frequency division multiplex systems. In that comparison digital systems do have significant advantages in simplicity, but in the end the most important parameters are system capabilities and system costs rather than the niceties of circuit design.

The importance of the trade-off between terminal costs and transmission line costs in multiplex systems is discussed in Ref. [5], p. 58 (underlining is ours):

"Yet multiplex-transmission systems are not always economically attractive. Such systems require a pair of multiplexing terminals regardless of the distance spanned. If the system is to prove-in economically, the cost of these terminals must be more than offset by the savings due to sharing the transmission medium. When a pair of wires is used for an individual channel, the cost is vanishingly small for zero lengths but increases rapidly and linearly with distance. With a sharing of that pair, there is the fixed cost of the multiplexing terminals for zero length and then a more gradual increase with distance. The result is a minimum distance, called the prove-in distance of the transmission system, below which the use of multiplexing does not pay. The local network of subscriber lines and exchange trunks is a particularly difficult environment from the standpoint of the application of multiplex-transmission systems. Large

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capital investments are required to provide for growth of these facilities, and most things are too short for existing multiplexing methods to prove-in. There are prospects that this will change when the full impact of such a new technology is low-cost solid-state circuits, digital techniques, and integrated transmission and switching are felt."

1.2.1 Terminal Equipment Costs

The present cost of digital terminal equipment is somewhat higher than the present cost of analog non-multiplexed terminal equipment, perhaps by a factor as high as ten. However, when one compares the cost of the present-day ordinary telephone (about $10) with the average plant investment per phone (almost $500 for the Mountain States Telephone Co.), it is obvious first of all that the total system cost does not depend only on the cost of the telephones themselves. Savings in other parts of the system, such as substitution of few cables for many paired wires, simpler digital switching systems for complex mechanical or electronically controlled mechanical (ESS) switching systems, and other substitutions mentioned in this Section help offset that cost. And, as mentioned in paragraph 1.2, reduction in costs due to economies of scale in the manufacture of LSI's is expected to be great. According to the IEEE journal "Spectrum", "recent rapid developments in integrated circuits have started to reduce the cost of PCM equipment drastically." [6]

Even now, digital terminals can be cheaper than carrier system (frequency division multiplex) terminals, according to Ref. [5], page 57.

1.2.1.1 Lower System Cost

Since the cost of laying cables in an urban area would be more or less comparable for TDM and FDM systems, depending on the channel capacity which could be built into each, the lower expense of digital equipment indicates that the digital system is economically more preferable. Ref [4] states:

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"The characteristics of digital communications gives it certain advantages and disadvantages. The most decisive advantage is pure economics. A digital communication system costs less than analog, especially for short links. Dan Hoth of Bell emphasizes this point strongly. Backing him up is Dave Sadlers of Raytheon, who estimates that the Army can buy digital terminal equipment for considerably less per channel than equivalent frequency division equipment."

Cost comparisons with paired-wire systems are not so simple. However, considerations of maintenance (paragraph 2.9), costs of laying hundreds of paired wires as compared with one (or a pair of) coaxial cables (paragraph 2.6), indicate that probably TDM systems would be significantly cheaper than paired-wire systems if both were to do the same operations. Detailed economic consideration of all the many factors involved would be a major effort in systems engineering, and is considerably beyond the scope of this report. We can, however, point to technical and utilitarian advantages of digital systems and cite evidence of rapidly increasing use of digital equipment (see particularly Section VII).

1.2.2 Weight and Size of Terminal Equipment

Again because of the potential use of LSI's the weight and size of digital terminal equipment like telephones is comparable to present equipment and significantly less than FDM equipment. This consideration is of obvious importance in mobile applications, particularly airborne; but it also becomes of significant interest in some stationary cases.

1.3 Independent of Type of Information

Ref. [4] states:

"Another advantage is that a digital communication link has a fine disregard for the character of the inputs it has to handle. Once the information gets into digital form, it's all the same to the digital link--voice, data, video, facsimile, real time, nonreal time, whatever. The ability to interleave all types of signals, Hoth points out leads to great standardizations in equipment, maintenance and signal quality." *

---

*Mr. Dan Hoth is with the Bell system.

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From Ref. [3]:

"If PCM develops as vigorously as expected, one can visualize a vast nationwide communication network in which all kinds of signals--voice, television, videotelephone and data--are transmitted in the form of binary digits. Once digitized, all signals are in the same electrical format and can be intermixed indiscriminately by time-division multiplexing without incurring penalties in cost or performance."

And from Ref. [5], page 57:

"An important advantage is that once all the signals are in digital form, voice, telegraph, television, facsimile, data, and others can be time-division multiplexed and carried over the same transmission medium without interfering with each other. In analog carrier systems, by contrast, a good deal of care must be taken to avoid interferences due to intermodulation when different types of signals are multiplexed."

1.3.1 System Adaptability via Terminal Equipment

Since the transmission system itself does carry only standardized pulses regardless of the type of information carried, the system as a whole is readily adapted to new uses by means of changes in the terminal equipment alone. The cables, repeaters, and digital switching equipment can remain unchanged. By contrast, a change in bandwidth for a signal on a FDM system would in general require expensive modification of switching arrangements in a central switching office, not to mention possible expensive changes in other terminal equipment to vacate an adjacent channel for the additional bandwidth and possible changes in the repeater amplifiers. Cables made up of paired wires are so strongly bandwidth limited and so prone to crosstalk problems that it might be simply impossible to make such a change without completely replacing the cable. To accomplish an analogous increase in information rate in a digital cable system, one simply uses additional channels, not necessarily adjacent to the original channels. No system changes, outside of possible modification of the terminal equipment affected, are needed.

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1.4 Logic Functions

Since the language of computers is made up of binary digits, it is clear that digital signals are quite compatible with computer control of the signals.* Such controls would include route-finding and switching, billing, automatic transfer of calls, automatic notification to a party using a phone that another call is waiting, tracing of crank calls, redundancy reduction functions, and many other possibilities.

Examples of problems that are susceptible to computer solution are given in Ref. [5] :

Page 47:

"A third requirement is effective network control. In a versatile network, the various switching offices must talk to each other to control the establishment and disconnection of transmission paths in response to user demands. Supervisory signals between switching offices are therefore necessary to provide this real-time control within the network. Another form of control is required to meet the changes in traffic that occur within the system. For example, we know from experience what traffic load to expect on Christmas Day, how it will be distributed geographically, and what hours of the day the traffic will be heaviest. We have similar figures for Mother's Day and other special days, and can thus restructure the network in preparation for these predictable loads. In addition, this kind of network control must also be available to restructure the network for the unpredictable changes--the loss of a radio repeater station, or the accidental digging up of a coaxial cable."

Page 62:

"Still another dimension of transmission performance is continuity of service. A communications network must be able to minimize interruptions due to equipment failure and to disasters. Large-capacity systems are provided with alternate transmission paths, coaxials or radio channels, on the same route to protect service quickly and automatically in the event of microwave fading, or failure of system components. The inadvertent cutting of a cable or the destruction of a radio tower requires the use of spare

* In fact, AT&T expects to go to digital control signals eventually, whether the message signal is digital or analog.

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channels on other routes to restore transmission service. Because of the large weblike network of compatible transmission facilities, it is practical to accomplish rerouting in tens of minutes The main challenge for the future lies in reducing the time for rerouting, and in maintaining ability to restore service during the transition periods when new types of systems are first introduced into the network. Solving this problem will require constant vigilance to avoid putting all our eggs in one basket. It has always been an accepted practice to maintain a diversity of routings in the transmission network, and even to construct special bypass routes around areas likely to be targets in a nuclear war. Analyses which examine the costs of alternative growth plans must continue to incl this important constraint even if it delays the introduction of profitable new large-capacity systems."

1.4.1 Redundancy Removal

In general, there is a great deal of redundancy in an analog signal. That is, if the past history of the waveform is known the amplitude in the not-too-distant future can usually be predicted with reasonable accuracy. This redundancy is retained, of course, by the PCM signals generated by the straightforward sampling techniques described in Paragraph 1.1. It is very difficult to remo this redundancy from an analog signal and thereby decrease the bandwidth needed to transmit the information. However, since the binary digits of a PCM signal are so readily subjected to automatic logical analysis it is relatively easy to remove redundancy by a standard set of rules and replace it at the receiving end of the transmission line to regenerate almost exactly the original signal. Thus the effective information carrying capacity of the transmission line is increased significantly.

It is possible today to reduce the bit rate required for voice transmission by a factor of about five, and still maintain good qualit but apparently the "naturalness" of the reconstructed voice signal is affected. This equipment is far too expensive for use in every telephone terminal today, and may not be cheap enough for such use in the forseeable future; but it will very likely be practical to use redundancy reduction much more extensively than it is now used in the analog system.

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The maximum bit-rate reduction for video which seems to be likely using methods known today and maintaining approximately the quality of picture seen today on TV is a factor between 5 and 8. Thus, a 50 megabit per second (Mb/sec) TV signal might be reduced to say a 7 to 10 Mb/sec signal, which would require the equivalent of at least 7 to 10 MHz in bandwidth on a cable distribution system. This is to be compared to the 6 MHz spacing now practical using FDM cable distribution, as the CATV companies use. Also note that the most important operational gains from use of TDM distribution lie in versatility, adaptability, ease of switching, and noise-free transmission over long distances. None of these are serious problems in the one-way distribution in urban areas of unswitched TV signals which must feed the simplest possible consumer receivers. The increase in complexity in the home TV receiver which would be required for redundancy reduction in such a complicated signal would be rather expensive, in the foreseeable future. It would not be at all impossible to distribute up to 60 high quality TV signals in a band from 50 to 400 MHz via an FDM cable system similar to the present CATV systems. Thus there seems to be no significant advantage in going to TDM systems for distributing TV in cities, although TDM will doubtless be used more and more in inter-city transmission.

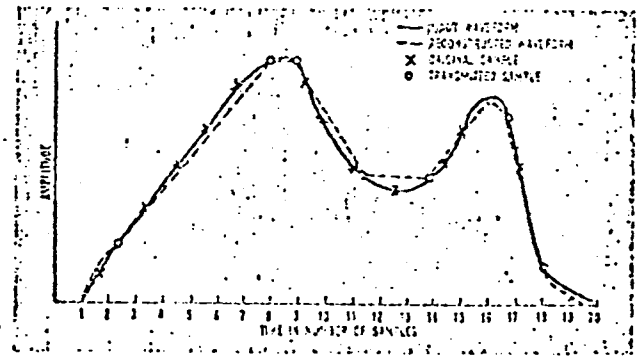
We include here a brief description of redundancy reduction techniques, taken from Ref. [7].

"Redundancy-reduction techniques are based on the principle of representing the voice waveform as a series of interconnected straight-line segments. Thus, the output signal will be a straight-line approximation of the original waveform. Processing operations are controlled to guarantee that all points on the output waveform will fall within certain specified percentages of the original input point. The operation of the reduction techniques is illustrated in Fig. 4. The input waveform, shown as a solid line,

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is sampled at regular intervals and converted to synchronous PCM data. The redundancy-reduction circuitry selects for transmission only those data points that cannot be predicted within the specified accuracy at the receiver."

Fig. 4. The first-order redundancy-reduction technique reconstructs the analog signal from straight-line segments. Only the differences between the samplings are transmitted, together with the time intervals between them.



"To reconstruct the straight-line segments at the receiver, it is necessary to transmit only the amplitude of the beginning and end points plus the time interval occurring between these two points. At the receiver, this information is then converted to analog and filtered prior to outputting as a reproduction of the original input waveform. To take advantage of the compression thus obtained, storage buffers are necessary in both the transmit and receive portions of the system. Since the nonredundant samples are being generated at an asynchronous rate, they must be stored in the buffer to allow transmission at a lower synchronous rate. At the receiver, the buffer provides the necessary storage to allow the reconstruction of the waveform."

"Listening comparison tests indicated that quality equivalent to that produced by a 48-kilobit PCM system was feasible using the described redundancy-reduction techniques."

"Bandwidth reduction can be obtained by methods other than waveform approximation. The schemes all use signal processing and the major trade-offs are the amount of bandwidth reduction obtained vs loss of voice quality and equipment cost and complexity.

Delta modulation: After a voice sample has been converted to binary, it is compared with the previous sample and only the two least significant bits are transmitted. Thus a two-bit pulse stream can do the work of a six-bit stream.

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Legend for Figure 5

Curve	Bit Rate (low)	Number of Low Bit Rate Circuits in "Channel Set"	Bit Rate (Medium)	Number of Medium Bit Rate Circuits in "Channel Set"
1	10^4/sec	100	---	0
2	10^4/sec	100	1.2×10^6/sec	1
3	10^4/sec	100	1.2×10^6/sec	10
4	10^4/sec	100	6×10^6/sec	1
5	10^4/sec	100	6×10^6/sec	10
6	5×10^4/sec	100	---	0
7	5×10^4/sec	100	6×10^6/sec	1
8	5×10^4/sec	100	6×10^6/sec	10

Figure 5 shows the number of "channel sets" consisting of 100 low bit rate and 0, 1, or 10 medium bit rate channels as given in the table above, which can be served simultaneously by a unit system having the total bit rate capacity shown on the abscissa. If the channel set were really considered as a discrete unit which could not be subdivided the curves should be stairstepped, as shown by the dotted lines with Curve 1. The curves are shown as straight lines, however, for simplicity and because the straight lines come closer to representing the way the systems would actually be used.

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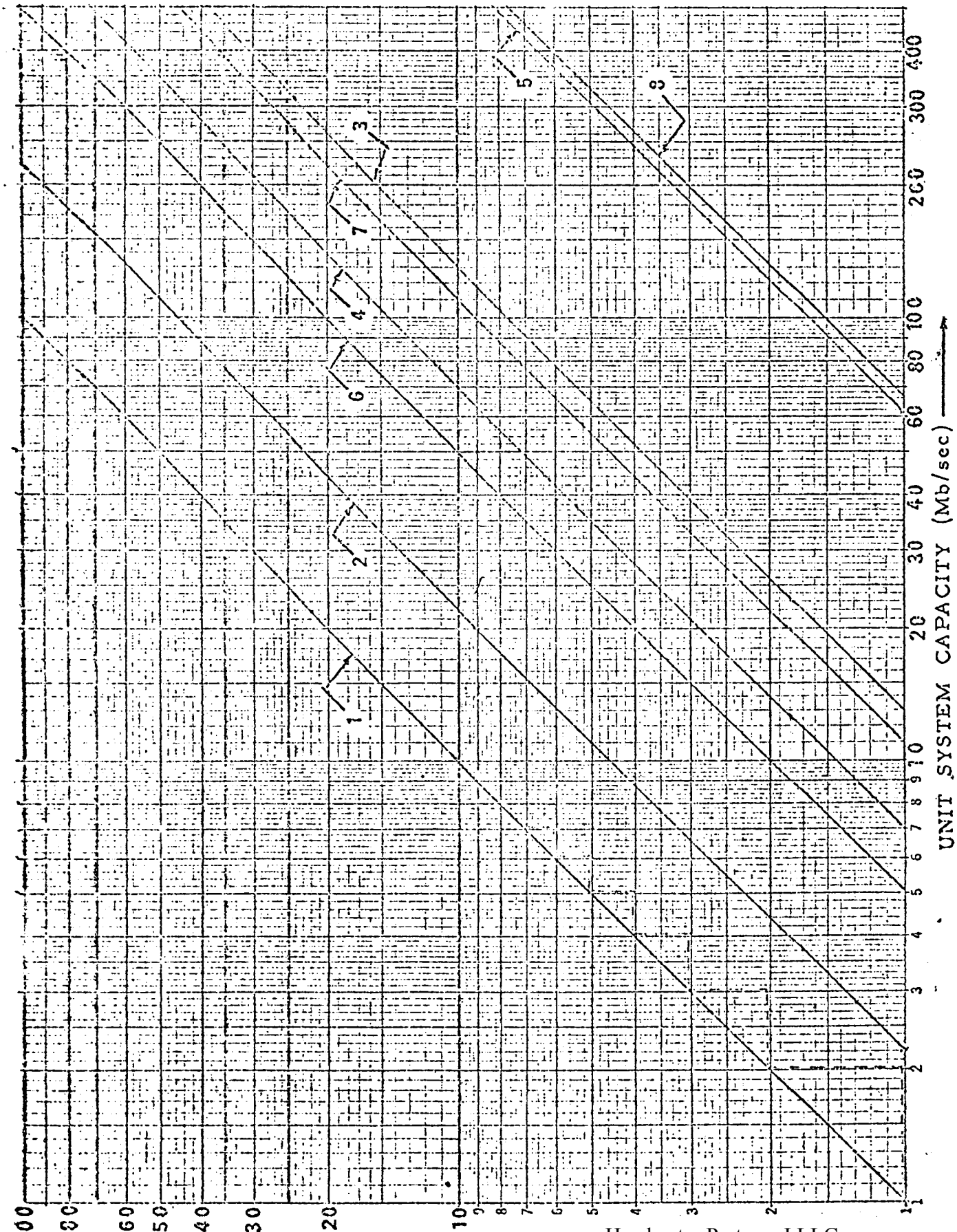


FIGURE 5

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Unit System Bit Rate in Megabits/sec	Possible Number of Simultaneous Two-way Services 10 kb/sec (each direction)	50 kb/sec (each direction)	6 Mb/sec (each direction)
1	50	10	0
3	150	30	0
5	250	50	0
10	500	100	0
30	1500	300	2
50	2500	500	4
100	5000	1000	8
300	15000	3000	25
500	25000	5000	41

Table 1. Number of simultaneous two-way services available, assuming various bit-rates in the Unit System. The 50 kb/sec rate corresponds to a high-quality voice channel; the 6 Mb/sec rate would serve videophone and other "medium" information rate needs. The 10 kb/sec rate corresponds to a voice signal with redundancy reduction.

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the already rather wide separation in bit rate requirements for low (audio) and medium (videophone, etc.) rate services.*

Since the medium rate services require 100 to 600 times the bit rate of a voice circuit, depending on the amount of redundancy removal, the demand for such services will have a powerful effect on the possible size of the unit system, for a given system bit rate.** Table 1 shows the number of channel pairs available on unit systems with various basic bit rates, for the various types of services. Figure 5 gives further information, in graphical form. The curves show the number of "channel sets" which can simultaneously be served on a unit system having the bit rate given on the abscissa. For purposes of this Figure, a "channel set" consists of 100 channels having "low" bit rates, as given by the legend, plus either zero, one, or ten "medium" rate channels. The figure demonstrates how rapidly the addition of a few per cent of medium rate services reduces the possible size of the unit system, for a given system bit rate.

The 1% use of the medium-rate service is based upon AT&T forecasts of the penetration of videophone into the telephone market. However, if the many possible medium-rate services were available to all subscribers on a TDM system, as described in the following paragraph, the 10% figure might be realistic.

---

*Redundancy removal is not pertinent for data signals, which are generated in digital form and presumably already contain only the information which it is desired to send.

**The high-rate services would have an even stronger effect. We do not consider them in this Section, assuming that they are all met by the 50 TV channels which might be carried on a separate one-way cable system. Of course, one of the many variations which might be useful in some special cases would be to put a few TV channels on a cable by FDM techniques and use the rest of the cable capacity for a small TDM unit system.

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Bit Rates Available

At the present time, bit rates up to about 10 Mb/sec are readily and economically available. (A rate of between 1 and 10 Mb/sec is planned in the military MALLARD system. See Section VII.) Bit rates up to about 50 Mb/sec are technically practical, but at a higher monetary cost. Rates approaching 500 Mb/sec have been attained in laboratory investigations, have been imposed on laser beams, and can be counted. Judging from this rather meager information, it may not be reasonable to expect large scale communications systems using more than about 50 Mb/sec in consumer equipment before 1980. One of the first steps in the design of such a system would be a concentrated forecasting effort on what bit rates should be economically available in the future.

Bit Rates Required

In Section II we categorized telecommunications services by the information rate required. Assuming no redundance removal, a reasonable bit rate assignment for these categories is 50 kb/sec, 6 Mb/sec, and 50 Mb/sec, for low-, medium-, and high-rate services. Assuming a degree of redundancy removal which would not significantly affect the desired qualities of the information transmitted reduces these numbers to approximately 10 kb/sec, 1.2 Mb/sec, and 10 Mb/sec, respectively.

This brings up another question which must be more carefully investigated early in the design of wired-city systems: What is the projected cost of this redundancy removal? Those in the forefront of redundancy removal research for video signals suggest that the circuitry required will be too complicated and expensive for use in every home receiver, but useful in the long-distance distribution system. The information we have at this time indicates that redundancy removal in voice signals is much simpler, and may be economically feasible, but this needs further investigation. If indeed this is the case, it increases still further

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IV. POSSIBLE "WIRED-CITY" SYSTEMS

Unit Systems

Since a single coaxial cable in a multiplex system does carry many channels of information, the wiring map of a city using a digital multiplex system would look quite different from that of a city using a paired-wire system, in which each pair of wires is dedicated to the service of a single telephone station (neglecting the operation of party lines and the occasional use of a second "carrier" signal on a pair). The multiplex system would consist of a collection of unit systems (or unit subsystems) connected together by trunk cables or by interfacing directly with each other. The number of stations served by each unit system would depend on a number of factors, discussed below. If the unit systems were large enough, there would be no need for a central switching station, as is required for a paired wire system, except to serve as a connection point for trunking services leading outside the community. Transfer of signals from one unit system to another would be accomplished by small digital switching stations, one for each interface between unit systems.

The number of stations connected in a single unit system depends upon the bit rate to be used in the system, the bit rate required at each station, and the fraction of the stations expected to be accommodated simultaneously. Clearly, the higher the system bit rate is and the lower the bit rate per station and the fraction to be served at any one time is, the larger the unit system can be. The advantage of larger unit systems is, of course, the reduction of interfaces (digital switching stations) and trunk lines between the unit systems. Note that the lower limit of one station per unit system corresponds approximately to a paired-wire system In the upper limit, a single unit system serves the entire community without any intra-community trunking. Thus, the difficulties of trunking strategy will depend heavily on the possible site of the unit systems. As mentioned in Section III, computers are quite well adapted to these problems in a digital system.

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> scale application of PCM was used to transmit 24 simultaneous telephone conversations over a pair of telephone wires. This system is now widely installed in the U.S. with the result that millions of people have heard speech transmitted by PCM without being aware of it."

Thus it has only recently been possible to use PCM circuits on a large scale. Even in applications where the advantages of PCM are of very great importance, the technique is just beginning to be used. Witness not only the rather recent introduction of PCM into long telephone lines but its very recent introduction into aircraft: the passenger entertainment system in the Boeing 747 will be the first fully digital communication system in an aircraft. The large scale introduction of PCM into the type of general purpose consumer telecommunications system described here clearly depends in a vital way on the development of inexpensive integrated circuits and LSI's to perform the myriads of logical operations required.

Even now these vital elements are not yet sufficiently inexpensive and reliable for immediate application in such general purpose systems. However, even a conservative extrapolation of the past history of the solid state electronic device industry, where lower costs and higher reliability seem to follow so dependably on the heels of large scale demand, indicates that the necessary components will be available within a very short span of years. General purpose TDM systems could be installed on a large scale experimental basis within a matter of two years or so. Operational systems, interfacing with paired-wire systems where necessary could be built long before 1980--probably by 1975. (See Section VII for comparison with military plans for much more complex digital systems in the mid seventies.)

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System Failure

If a TDM system should sustain an accident like a cable break, it would fail rather grandly, since a large number of subscribers would be connected to the same cable. However, redundancy in the form of alternate cable pathways might be considerably less expensive than in the paired-wire type of service. Certainly most trunk cable systems would include redundancy.

History and Future

One might well ask, as does J. S. Mayo in Ref. [3], "If PCM is so straightforward and simple in concept, why is it considered new? Why was it not widely applied long ago?" Mayo goes on to answer the question:

> "The idea of transmitting analogue signals in pulse form is indeed not new; several early patents involved one or more of the basic concepts. These concepts were not easy to reduce to practice, however, until rather advanced vacuum tubes were available. The recognized "father" of PCM is A. H. Reeves, whose basic pulse-coding patent was issued in 1938. It was Reeves who pulled the concepts together and first produced drawings that showed the fundamental features of a complete PCM system.
>
> Although a successful PCM system was built for military in World War II, it had severe limitations that made it unattractive for commercial purposes. These limitations were almost wholly associated with the use of vacuum tubes, which are too big, consume too much power and are too prone to fail to be used in large numbers. Moreover, vacuum tubes tend to be good amplifying devices but not good switching devices. A PCM system requires switching devices that can be turned on and off very rapidly. This is precisely the same requirement presented by the electronic computer. Designers of both PCM systems and computers found the device they needed in 1948, with the invention of the transistor. That same year Shannon's work on information theory made it possible to assign quantitative values to the merits of PCM systems, thereby confirming intuitive and qualitative evaluations.
>
> By 1955 serious development of PCM for widespread commercial use was under way. Preliminary models of PCM systems for telephone communication were tested in 1958 and commercial operation of production systems began in 1962. The first large-

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The signaling procedures for setting up conference calls would have to be thought out and standardized before terminal equipment was built, so terminal equipment in all parts of the system would understand the same codes and signals. Code converters could be used to some extent, but good original planning would certainly be important.

2.8 Quality of Service

"Quality of service" refers to the probability of not getting a dial tone within a certain short time of lifting a telephone receiver or of not getting a trunk line when one is needed. This finite probability results, of course, from the fact that there are always more subscriber phones connected to the central switching station than there are switches to handle them, should they all want to make calls at once. A TDM system would be designed with a similar philosophy in mind--there would be no point to having the number of channels available in a unit subsystem much greater than the probable demand at any one time. The point to be made here is just that the same kinds of decisions would have to be made about this problem, whether the system is paired-wire or TDM. In either case the Quality of Service can be adjusted to any desired level.

2.9 Maintenance

The reliability of any system is controlled by several factors, including the intrinsic reliability of the components as well as design characteristics such as the amount of redundancy built in. Thus, once again the key parameter is cost: higher initial costs will buy lower maintenance costs. Thus it is not possible to say very much about maintenance itself until the detailed design is done. However, we can point out that typically solid state circuitry is intrinsically highly reliable, so it should not be any disadvantage to use the solid state circuitry which is so closely associated with the digital system.

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to each of 490 seats on the airplane, in addition to the usual announcement system and stewardess call system. A TDM system using very small coaxial cable will be employed, largely because of the weight savings. The TDM system will save about 1000 pounds on each airplane, as compared with the paired-wire system which would have been required. Since the airlines reckon the cost of weight on an airplane at about $150 per pound, this represents a saving of $150,000 per plane, which is more than enough to pay the additional cost of building the system even with today's technology.

Size is sometimes a significant consideration even in stationary systems. In the 747, the cable of paired wires necessary for the entertainment system would have been about four inches in diameter. The coaxial cable used in its place is about 1.5 mm in diameter. This difference has some clear implications with respect to installation costs of wiring in buildings and under city streets.

Since all signals present at any time on a "unit subsystem" in a digital system are present at every point within that subsystem, the need for re-wiring to effect modifications of the subsystem is minimized. A new service, for example, can be added by simply tapping into the existing cable rather than by having to install a new pair of wires. This process cannot be continued indefinitely, of course. The capability of any cable can eventually be used up. Planning for the future is as necessary in a cable system as in a paired wire system.

2.7 Multiple Connections

Conference calls are easy, and do not require an operator. (Automatic 3-party conference calls are possible on the new electronic switchboards of the Bell System.) This facility would be inherent in the terminal equipment, not in the cables. This is an example of where careful original planning is needed.

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2.6 Suitable for Use With Cables

It is certainly obvious already that PCM systems are married to wideband transmission media, but let us here mention explicity some of the consequences of this fact. A quotation from Ref. [3] :

> "Because PCM signals normally require generous bandwidths they are well matched to "guided wave"transmission mediums: cable pairs, coaxial cables, intercity wave guides and light beams. The last two are extremely promising for the more distant future. Moreover, the pecularities of wave guides and light beams are such that it is difficult to employ them except with digital-modulation schemes. Because these two mediums have enormous capacity, they can carry many digital signals simultaneously over different portions of their total frequency band. Their transmission characteristics are such, however, that there can be appreciable interference among the many signals being simultaneously transmitted. Removing such crosstalk is a specialty of regenerative repeaters. For this reason almost all development work on intercity wave guides and light beams has taken for granted the use of PCM."

If, indeed, intercity transmission will become predominantly digital signals transmitted on wideband media, it will certainly be simple for the intercity system to interface with it if the intercity system is also digital. This in itself is certainly not reason enough to go to digital systems within cities--AT&T can and now does cope with the interface problem--but it is a contributing factor.

The use of cable in itself has implications with respect to weight and size of the systems, installation, and modification of the system.

Weight is not often very important on stationary systems, but it is interesting to note a striking example provided by the passenger entertainment system in the Boeing 747 airplane. The entertainment system will provide 15 entertainment channels

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so-called Electronic Switching Systems being installed now by AT&T. (These systems are controlled electronically, but still must use mechanical contacts to connect and disconnect paired wires from each other.) It is suggested in Ref. [6]and Ref. [5], page 57, that digital switching will not only simplify switching problems, but may lead to lower costs and improved performance.

See Paragraph 1.4 for a discussion of the compatibility of logic functions with digital switching.

It is probably true that with the exception of arbitrarily changing the information rate available one can do almost any logical function with electronic control of mechanical contacts that one can do with purely electronic switching using solid state "gates". Because of the speed required, however, purely electronic switching is a necessary element in a TDM system.

2.5.1 System Use Can Change Quickly

Because of the TDM system's compatibility with logical control functions, simple and adaptable switching, and the system's independence of the type of information carried, it is possible to change very quickly the use to which the system is put. Channel widths could be changed, for example (as suggested in Paragraph 2.3), as needs changed according to a daily cycle. Or the system use could be changed almost instantly in case of a military or natural emergency.

2.5.2. Priorities Easily Controlled

Any station in a TDM system can very easily be given an over-ride capability to be used in case of emergency. It is possible to do this in analog paired-wire systems, and in fact has been done in military systems, but apparently is not easy enough to be common in the civilian phone system.

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Ref. [2]makes a comparison between TDM and FDM systems with respect to crosstalk:

> "The second advantage of the time division multiplexed system is the relative immunity from interference within channels (interchannel crosstalk), which arises in frequency division multiplexed systems because of nonlinearities in the amplifiers in the path of transmission. The nonlinearities in various amplifiers produce harmonic distortion (due to frequency multiplication) and hence will introduce interference within channels (interchannel crosstalk). Hence the nonlinearity requirements in a frequency division multiplexed system are much more stringent than those for a single channel. On the other hand, for time division multiplexed systems, the signals from different channels are not applied to the system simultaneously but are allotted different time intervals. Hence the nonlinearity requirements in a time division multiplexed system are the same as that for a single channel. For these reasons the time division multiplexed systems are being used more commonly in such applications as long-distance telephone communication. "

2.5 Simple and Adaptable Switching

The hardware required to perform switching is a major part of a paired-wire system. Within a "unit subsystem" of a TDM system (all subscribers on the "unit subsystem" are connected to the same pair of cables -- one cable going in each direction away from the subscriber's terminal), however, there is no switching at all, except for the selection of time slots by the individual terminals. The more channels those unit subsystems can be made to accommodate, the less trunking will be required between the subsystems. This is an important part of the pressure toward higher bit-rates and use of redundancy removal techniques. If the unit subsystems can be made large enough, say several thousand subscribers, the need for switching stations within cities would decrease dramatically.

The switching that would be needed would, by the nature of the cable TDM system, be entirely electronic, unlike the

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2.3 Variable Information Rate

It is easy to build into the digital TDM terminals, whether telephone or other types of terminals, the ability to "capture" and use more than one channel of the transmission line. Thus the information rate can be readily responsive to the needs of the moment. This is not readily possible in a FDM system, since it would require redesign of the frequency domain filters for each different bandwidth needed. Also, in general the FDM equipment would require adjacent channels, whereas the TDM equipment need not use adjacent channels.

The bandwidth available in a paired-wire system is fixed by the nature of the cables of paired wires and the repeater amplifiers and the switching system. Expanding the bandwidth capability of the system is possible only to a limited extent, and then only by special arrangement with the common carrier.

The channels (time slots) in a TDM system need not all have the same time duration. In fact, since the terminal equipment differentiates one time slot form another by counting code pulses (say at the beginning of each time slot), the duration of individual time slots can be changed without affecting the performance of terminal equipment not using the changed time slots, as long as the total time required by all the time slots (this is the sampling period) remains unchanged.

2.4 Crosstalk

Comparing crosstalk problems in paired-wire and TDM systems, Ref. [4] says the following:

> "Crosstalk between signals in a time-divided channel ideally cannot occur as long as the channel remains synchronized and properly framed. If the wires of two independent channels are physically close together, however, pulses on one channel can get into the other channel."

For comments on other kinds of crosstalk in TDM systems, see Paragraph 1.1.2.

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2.1 Simpler Circuitry

Ref. [2] has this to say about the ciruitry required for TDM systems, as compared to FDM systems:

"From the practical point of view, the time division multiplexed system proves superior to the frequency division multiplexed system. The first advantage is the simplified circuitry used in time division multiplexed systems compared to that used in frequency division multiplexed systems. In the latter, one needs to generate different carriers for each channel. Moreover, each channel occupies a different frequency band, and hence needs a different bandpass filter design. On the other hand, time division multiplexed systems require identical circuits for each channel, consisting of relatively simple synchronous switches or gating circuits. The only filters in the detection process are the low-pass filters which are identical for each channel. This circuitry is much simpler compared to the modulators, demodulators, carrier generators, and bandpass filters required in the frequency division multiplexed systems."

This relative simplicity already shows up in the relative cost of the two types of equipment, although integrated circuitry and LSI's are not yet developed to their ultimate capability. From Ref. [5], page 57:

> "When transmitting over wire-pair cable, and perhaps in the case of other media also, digital terminals are less expensive than carrier system terminals."

Digital terminals also have considerable advantages in weight and size (see Paragraph 1.2.2).

Digital terminals are compared with paired-wire analog terminals in Paragraph 1.2.1.

2.2 Terminal Equipment Similarities

As pointed out in Paragraph 2.1, identical circuits are required for each channel in a TDM system. This has not only the obvious implications with respect to the manufacture of terminal equipment, but has great importance with respect to economies of scale in the manufacture of integrated circuits and LSI's.

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of data signals between machines and from man to machine has already shown dramatic growth and will have an increasing impac in the future. To transmit nonvoice signals over the telephone lines, a data set is attached to the subscriber's line in lieu of the conventional telephone instrument. The function of this adapter i to process the data signals so that they are compatible with the conventional analog phone signals. Within the United States there are now about 39,000 of these data sets in service--exclusive of teletype and telegraph terminals--and the number is doubling eve twenty months. Although less than 5% of common carrier revenu now comes from data services, this will probably change signific during the 1970's."

In a digital system, however (Ref. [5], page 57):

". . . in handling inherently digital signals, such as data, the digital system is more efficient than carrier systems. With currently available terminal equipment a 50 kilobit/sec data signa occupies the space of 12 voice signals on a carrier system, but o that of three voice signals on a digital system."

1.6 Storage

Digital storage facilities are becoming cheaper at a rapid rate. The cost of a unit of storage of digital data has been droppi for two decades at the rate of 50% or more every two years (Ref. page 30). If this trend continues, the cost of temporary storage significant amounts of information may become feasible in the con sumer field. These data, whatever they might be, could be fed in the home during times of low use rate of the transmission facilitie for later use by the consumer. At this time, however, we have n been able to do a thorough study of the possible future relative costs of digital storage with analog storage such as magnetic tap for audio or video information.

The advantage of digital storage for short-term low volume purposes is, however, rather clear. Again, use of inexpensive LSI's makes "store-and-forward" functions and the buffer stages needed for redundancy reduction quite feasible.

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new source of unintentional loss of privacy on TDM system is reception of an incorrect channel by a receiving unit. With reliable solid state circuits, the possibility of intelligible accidental reception could easily be made extremely remote.

Wire-tapping is clearly very easy on a paired-wire analog system. The only problem is accessibility of the pair which it is desired to monitor. For a person familiar with operation of a TDM system, it would be equally easy to "tap" a coaxial cable and monitor any or all calls on the cable. In fact, it would be easier to get access to the cable, since all the signals on a given subsystem are present at all times at each terminal on the subsystem.

Thus, wire-tapping is rather easy on either type of system. The significant difference, however, is that the digital system, being readily compatible with logic circuitry, is very easy adapted to encrypted messages. It would be rather inexpensive for any phone sets to have built-in scramblers and unscramblers with any desired degree of complexity. Encrypting could be controlled by simple matrix cards inserted into the sets by pre-arrangement.

Crank Calls

It would also be inexpensive to build into the terminal equipment the facility for recording the address of incoming calls, so that crank calls or threatening calls could be traced. (It would probably be desirable to have that address recorded in such a way that it could only be retrieved by the proper designated authorities.) Or, if such calls are expected, the address of the caller could easily be relayed directly to a police station on command by the receiving party.*

1.5 Proper form for Data

Discussing transmission of data signals over paired-wire analog lines, Ref. [5] page 60 has this to say:

"In addition to the introduction of new media to meet increased transmission requirements, the future will see a stepped-up demand for the transmission of signals other than voice. The transmission

*It is possible to perform these functions in an analog system, as well. Some are now available in parts of the Bell System.

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Extrema sampling: Only the peaks of the voice waveform are encoded and the whole sample is transmitted. The reconstructed signal is a string of variable height, variable duration, rectangular pulses, which are then filtered.. Honeywell has developed asynchronous equipment using this technique and claims good voice quality.

Vocoders: These devices analyze the voice and develop signals that allow the voice to be synthesized--rather than reconstructed--at the receiver. Philco-Ford says it has built 95% of all such devices; Sylvania has recently announced "fast Fourier Transf equipment to accomplish the same result.

Electronic speech recognition: These devices recognize phonemes (each word has several) and in sophisticated systems, whole words. Great bandwidth reduction is possible."

Extreme bit-rate reductions are possible using the electronic speech recognition techniques mentioned in the quotation above. But all recognition of characteristics of an individual's voice is lost. Ordinary conversation can be transmitted in this way with a bit-rate of about 25 bits per second. This is quite useful, for example, in military systems, but not generally acceptable to public consumer Incidentally, when this highly compressed speech is encrypted, it is extremely difficult to decipher.

1.4.2 Secrecy

Let us compare two types of systems (paired wire analog and TDM) with respect to two kinds of loss of privacy (unintentional and intentional). An FDM system would be similar to the TDM system in this respect, except that it would not be easy to encrypt the signal

The major sources of unintentional loss of privacy on the paired-wire system are party lines and intelligible cross-talk. In a TDM system there would be no party lines, by the very nature of the system, and the possibility of intelligible cross-talk, even on long distance calls, is very remote (see Paragraph 2.4). A possible

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A Fundamental Comparison

This points up a fundamental difference between paired-wire and TDM systems. If, in a paired-wire system, one really can solve, for an economically feasible cost, the great problems of bandwidth, crosstalk in cables, high frequency line loss, and switching of high frequency circuits on a pair of wires, then it makes no difference whether the pair carries a medium-rate service or a low-rate service. On a TDM cable, on the other hand, the capacity of the entire cable is used up just in proportion to the information rate being carried at the time. In a paired-wire system the lines to supply the medium information rate service must be specially constructed at considerable cost to the potential user, independent of the use he later makes of the capability. On a TDM cable, however, the medium-rate capability is immediately available to each and every subscriber and can be paid for according to his actual use of the service.

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Effect of Velocity of Light

Since the speed of light is, indeed, finite, a pulse impressed on a cable is not present at all points on the cable at that instant. Thus there can be confusion at a given point of the cable between pulses traveling in one direction and those traveling in the other. Pulses must, then, be impressed on the cable with a preferred direction, with the "backwards" direction sufficiently attenuated that the next subscriber's receiver will not detect the backwards pulse. This in turn implies that the cable serving the unit system must either be

(1) a pair of cables, one carrying pulses in each direction,
(2) a single cable, using a combined frequency division and time division multiplex system to separate the two sets of pulses, or,
(3) a single cable which forms a complete loop, such that the signal from a given station eventually reappears at that station from the other direction.

Any of these (and perhaps other) solutions is apparently acceptable. No interfacing problem should occur if different unit systems used different solutions. The decision which to use would be determined by such considerations as the average distance between stations, the total number of stations to be served, and the basic bit rate used.

The main cable for the unit system would not have to actually enter every building containing subscribers. Drop lines could be used in spite of the fact that the drop line might "contain" several pulses. At a 50 Mb/sec rate, for example, with the pulses traveling at the velocity of light there are only about 20 feet on the cable allowed for each complete pulse. A pulse generated on the drop line would have to be carefully timed so that it arrived at the main line at the proper time to meet its assigned time slot. Alternatively, the launching of the pulse on the main cable could be controlled at the intersection of the drop line with the main cable.

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Standardization Problems

As in any such complex system, standardization is necessary for the proper operation of the system as well as for simplifying manufacture, installation, and maintenance. In this case, for example, the unit system simply could not operate unless all terminal equipment on the unit system operated at the proper bit rate, generated pulses of the proper shape and amplitude, and impressed them on the main line at the proper time with the proper directional characteristics. In addition, identification codes, address codes, and the impedance of taps must be standardized. Initial measurement and periodic or continuous monitoring of all these parameters and others will be necessary for a properly functioning system.

Variation on a Theme

In very densely populated metropolitan areas the placing of cable under streets can be a very expensive project. In order to avoid this expense it has been proposed that TV might be distributed through the atmosphere, using an 18 GHz carrier, with an 18 GHz receiver and equipment to reconvert the signal to the VHF frequencies in each block of the densely populated area. The TelePrompTer Corporation, a CATV company operating in New York City, has been developing such a scheme, and claims that it can serve about a seven mile radius even in heavy rain, when the attenuation at that frequency is high due to absorption by water. The system not only solves the problem of placing cable under streets, but also conquers natural obstacles such as rivers.

In such a densely populated area, where it would be desirable to have the unit system as large as possible, it might be feasible to supply the medium-rate services via such a system. If the spectrum space at 18 GHz were available, such a system could make use of the same receivers used for the TV distribution. Of course, the two-way nature of some of the medium-rate services would require a transmitter to serve each block as well as a receiver.

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V. TRANSITION TO WIDEBAND DIGITAL SYSTEMS

The ease of transition from one system for providing a given service to another system providing similar service plus new services depends on many factors — technical, economic, sometimes sociological and political, and others. Among the most important are the following:

(1) Size of existing capital investment which would not be carried over into the new system
(2) Rate of growth of demand for both the old and new services
(3) Difficulty of interfacing the new system with the old, if such interfacing is necessary
(4) Regulatory policy, if any

In this Section we discuss some technical aspects of possible transitions to systems carrying many kinds of information on wideband media (cables, waveguide, mm waves, etc.) in a digital form, with TV distributed on cables in analog form. In addition to considering purely technical aspects of the problem, we point to several aspects of the technology which do have implications with respect to problems of capital investment and regulatory matters.

System Growth

By the end of this century there may be twice as many dwellings in this country as there are now (References [8] and [9]). Thus, the demand for telephone service alone will at least double by that time. In fact, this undoubtedly is an extremely conservative indicator of future demand for communications services. Reference [5], page 45, states that "In the next ten years, the telephone network will be required to handle more than twice as much traffic as it now carries." The same reference, on page 55, states that "The growth of transmission facilities is exponential — about 15% per year —

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and is likely to continue in the foreseeable future." If this latter prediction is correct, we will double our transmission facilities in only five years.

Thus, the installation of a new type of communications system could proceed at quite a rapid pace without junking outright the present $30 billion investment in analog paired-wire systems, provided the interfacing problem is soluble. The present capital investment is, however, largely not transferrable into a digital system, except for such items as buildings.* Present equipment would be replaced either when it was worn out or when it became cheaper to replace it than to modify it to provide new services demanded by the public.

If, indeed, a general purpose digital system were to evolve from the present telephone system, distribution of television and other similar high information rate one-way services could continue more or less independent development, as CATV companies are now doing.

However, it is technically quite possible for the general purpose digital system to evolve from the CATV operations rather than from the telephone system. Since double multiplexing** is feasible, a cable system installed primarily for the TV-type distribution could very well

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* In fact, the need for building space might be considerably less in the digital systems, due to elimination of large amounts of central switching. As pointed out in Sections III and IV, no central switching is required for calls within a "unit subsystem." If these subsystems can be made large enough, the demand for central switching could decrease significantly.

** Putting both TDM and FDM signals on the same cable at the same time.

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begin offering general purpose digital service. This service could be connected to the Bell system in the same way that any other independent telephone company is connected to the Bell system.

Interfacing

It is already clear that there is no insurmountable technical problem in interfacing digital systems with analog systems – the Bell system now has in service thousands of digital circuits in its long lines, and is installing more every year. Each circuit must interface twice, once on each end, with an analog paired-wire system. Also it is clear that in any digital system there must be two interfaces between analog and digital for each phone call -- human voices and ears are analog devices, after all, as are microphones and speakers that are used in the terminal equipment. Interfacing a digital system with an analog system does pose technical and economic problems, but they are being solved for some cases today, and hopefully will be more generally soluble in the future.

A second sort of interfacing problem arises when one imagines the possibility of two (or more) separate digital subsystems, operating, for example, with different bit rates, different synchronizations, or different control codes. Such situations would almost inevitably arise as technology progressed, and higher bit rates, better redundancy removal techniques, or different control codes were developed. Once again, the fact that digital signals are well adapted to logical operations comes to the rescue: it can always be arranged that a signal in one format can be converted to another format. The trade-off, of course, is good planning for money.

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The more standardization there is between subsystems, the less conversion circuitry will be needed. The important point is that the form of the entire system is not frozen forever by initial decisions. Interfacing is possible, when it is judged to be both desirable to gain some new advantage and economically feasible. The nation's telecommunication system would doubtless never be uniform in all places, but each subsystem could be made compatible with its neighbors and remain adaptable to new technology.

Regulation

Even in a free enterprise system it seems necessary to exert some public control over industry in some instances. The primary example of this is when economies of scale are so great that an organization with some slight advantage can eventually drive its competitors out of the free marketplace. Another example of where regulation is sometimes necessary in the public interest arises when the product or service provided is considered extremely vital to the public interest. Operation of the nation's telecommunications system falls under both categories, whether that system is digital or analog. We need here only to point to differences between implications of analog-paired-wire and digital-coaxial-cable technologies. The question of which of the services to be provided are considered vital to the public must be decided by the public.

There are clear economies of scale in the construction of transmission systems, whether the transmission line used is a cable of paired wires, a coaxial cable, or some other multichannel system. Thus, a change from a paired-wire system to a coaxial-cable system will make no change in the

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fundamental need for some kind of regulated monopolistic organization (or organizations) to provide the basic system (or systems). However, the technologies which may be employed to provide the great variety of services which is now or very shortly will be feasible, lead to a much more complex situation than that produced by telephone service alone. We have suggested, for example, that particularly in large cities it might be most practical to build separate systems for the high information rate one-way (TV) service and the low and medium information rate two-way (phone, facsimile, etc.) services. In that case there is no technical reason why both systems must be operated by the same organization.

Terminal Equipment

The technical aspects of the terminal equipment are somewhat more complicated. The present telephone system and the present CATV (and TV broadcast) systems represent two different existing approaches to ownership and regulation of terminal equipment. In one case all terminal equipment is manufactured by the same maker and owned by the operator of the transmission facilities. In the other, terminal equipment is purchased by the user, on the open market. There are clear reasons for both cases.

The telephone terminals not only receive signals from the transmission system, but they generate signals of their own and impress them on the transmission lines. These signals must be carefully controlled so that they do not damage the system. In addition, they must be compatible with respect to frequency bandwidth, voltage level, control signals, and other factors. From a purely technical point of view, these reasons are still not sufficient to require that

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all terminal equipment be owned by the system operator. Technically speaking, these problems could be solved by rigid enforcement of performance standards. More compelling reasons for ownership by the system operator include the following considerations:

A highly reliable telephone service at the lowest possible cost has come to be regarded almost as a right rather than a privilege by the public. High reliability implies a very rapid repair service, without consideration of costs, whenever trouble does occur, whether that trouble be in the transmission system or in the terminal equipment. This implies that the system operator have at least control over the terminal equipment, if not outright ownership.

Another consideration is that of how system modifications are made. If the system operator owns the terminal equipment, he can replace it at will, if he finds it advantageous from the system point of view to do so. For instance, if the system operator wants to raise the output signal level and lower the transmission wire size, he is free to do so without having to sell the consumer on the idea of buying a new phone. It is our understanding, for example, that in France progress in the telephone system is held back immeasurably by the fact that terminals are owned by individuals, and they cannot be persuaded to buy new equipment to match a new transmission system.

In a television or radio broadcast system, on the other hand, the receiver cannot react to the detriment of the system. Even on a cable (CATV) system, the terminal equipment is effectively prevented from causing system damage. Also,

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the demands for reliability are not so high -- it is rarely a true emergency if a TV set quits working. Thus, private ownership of terminal equipment is not incompatible, although it still does, perhaps, increase the problems of system modification. Also, various features such as color TV would probably not have been developed without the competition of the open market.

Digital System Terminals

The situation in the possible "wired-city" systems discussed in this report is similar with respect to the telephone service, and also similar with respect to radio and TV services. However, the ownership and regulatory problems associated with the many other kinds of services which might make use of the digital transmission system are new and demand some study.

In Section II there is a list of services which might be provided on a "wired-city" telecommunications system. The variety of terminal equipment which will be needed to provide these services in various forms to suit various tastes and pocketbooks is already quite large. If one considers the many other possibilities for very special-purpose equipment designed to meet special needs for small numbers of business and private users, particularly data-producing equipment, the list becomes quite staggering in length. This is clearly a situation which demands the great proliferation of variety typical of a competitive market more than it demands the uniformity, dependability, and simplicity of repair required of a telephone system.

The implication is, then, that the system operator must learn to provide the dependability necessary for a

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phone system, and should own the terminal equipment if that is deemed necessary; but at the same time he should be prepared to allow use of the transmission facilities by many other types of terminal equipment without himself being held responsible for its maintenance and replacement. Of course, performance specifications must be met by this other terminal equipment for the protection of the system and its other users.

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VI. EFFECT ON TELEVISION

Cable Capacity

Cable systems, using only present-day technology, can easily be made to handle nearly 30 TV channels, with frequency-division multiplex techniques (as is now used by CATV companies). Those familiar with cable TV technology say that it is practical to extend the range to over 50 TV channels on a single cable.

Programming

What does it mean to have 30 - 50 TV channels? Where would one get so many programs? Almost 40% of the cost of the average TV station operation is in program generation, under the present system.

There are many kinds of programs. There is certainly not enough financial support available to make many more channels full of the very expensive programs (Olympic games, top-quality plays, concerts, and other entertainment) associated with the major networks. But the CATV companies are finding that some of their most-watched channels are those which show very simple and inexpensive programming. For example:

A camera watching a "lazy susan" with weather instrument readouts mounted on it, and watching a time-of-day display at the same time, is a very popular service offered by some CATV companies.

One CATV company set up a very simple studio with little equipment besides a camera and lights, to be used at little or no cost by almost any person or group which wanted it. One such program was a discussion by the local school board of an upcoming bond issue referendum. A telephone survey during that very simple, inexpensive, and rather amateurishly produced program indicated that 40% of the company's users were watching that program rather than the major network shows!

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Many other events (particularly of local interest) require essentially nothing more than a camera and a minimally trained operator; city council and board meetings, school sporting events, school and amateur entertainment productions.

Other program sources include student TV studios, which need not broadcast on the air, but which could be put on cable systems. The classrooms themselves are another source of inexpensive programming.

The availability of many channels would encourage repeat programming.

If advertisers find that people tend to watch such programs to a significant degree, in comparison to the network programs, it may dramatically change the patterns of advertising support, which in turn could redefine the role of the major networks.

Economic Development Impact

Such inexpensive distribution methods could help dramatically in training or retraining people in economically depressed areas or ghettos.

South Carolina now has a statewide educational TV system which broadcasts about 84 separate programs per day, on wire and broadcast systems. The state legislature has backed this system very strongly, largely on the grounds that such a system will hopefully attract to South Carolina the kind of people who will help it develop, as well as offer economically valuable training to those who already live there.

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VII. EXISTING AND PLANNED DIGITAL SYSTEMS

In this Section we describe briefly a few selected existing and planned digital telecommunications systems. Our object is to reinforce previous assertions that digital technology has now progressed to the point that such systems are feasible.

AT&T

It has already been mentioned that the Bell system is using more and more digital circuits in its long lines. According to Ref. [4], "More than 100,000 digital circuits a year are going in. By the end of 1968, there will be over 400,000 digital voice circuits in use."

Aircraft

It has also been previously mentioned that Boeing is to use a digital system for the passenger entertainment system in its new 747 passenger plane, seating 490 passengers. The system will provide 15 channels to each seat and control the passenger's seat lights, in addition to the usual announcement and stewardess call systems. The major reason for using a multiplex system in the 747 was the weight savings made possible (about 1000 pounds) by replacing the many paired wires with a single coaxial cable about 1.5 mm in diameter. These savings more than paid for the additional cost of building the digital system using present technology. An engineer who was intimately involved in the design of the system expressed confidence that in about five years the cost of the digital system would be competitive with the paired wire system even on a first cost basis; that is, without considering the savings due to the lighter weight. This implies a factor of about four reduction in cost.

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As airplanes get larger and more complex, the amount of wiring required for the pilot's information and control system mushrooms. Already in the 747 the engine controls, meters, etc. require so much wiring that it would be advantageous to use a TDM system for that purpose as well as the passenger entertainment. Apparently the only reason for not doing so was lack of experience with TDM systems in aircraft. A second generation version of the aircraft might use a TDM system, if the reliability of the passenger entertainment system now being built proves high enough.

Another aircraft example is the proposed SST. The pilots' "office" and the highly complex engine and control system are so far separated that it is apparently essential to use some kind of multiplex system for communication.

Navy

The Navy is considering a digital TDM system for all telecommunications in a proposed new 3000 employee research laboratory building. The system would provide not only the telephone, public address, paging systems, and probably some video service, but standard frequency signals and other services peculiar to a research laboratory.

MALLARD

The U.S. Army Signal Corps is planning a worldwide telecommunications network by which personnel in any of the military services of the U.S., Canada, Australia, and Great Britain can contact appropriate members of any of the other services. The difficulties inherent in such a project, called MALLARD by the Signal Corps, are huge compared to the difficulties of a civilian network.

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Dr. Pritchard, who is the Division Chief for Project MALLARD, states that MALLARD is indeed feasible now, with today's technology. It will be a discrete address, multiple access, digital PCM system, using solid state circuit elements and digital switching. It will handle voice, data, tactical net radio, teletype, and other communications, and will interface with any other system in DOD and the military services of the other three countries.

The field unit, corresponding to our "unit system," will consist of between 30 and 70 individual terminals. It is hoped to have operating systems in the field by 1975.

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APPENDIX H

REPORT OF THE PANEL ON URBAN COMMUNICATIONS

Committee on Telecommunications

NATIONAL ACADEMY OF ENGINEERING

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> ... while the problems in foreign affairs are difficult and dangerous, they are not insoluble. On the other hand the problems at home are of a kind that are not even theoretically soluble in the short period of four years. Solutions for our deep and general malaise are not to be thought of in the time scale of an administration but in that of at least a generation.
>
> --Walter Lippman
> Newsweek, October 7, 1968

Technology and the City

Only a hundred years ago, the United States population was about 80 percent rural and 20 percent urban (metropolitan). Today these proportions are essentially reversed. It is not simply that we are creating cities instead of farming communities, but rather that we are creating huge urban complexes. The standard metropolitan areas of over 500,000 population, 60 in all, account for nearly 48 percent of the total population. In 1959, the Civil Rights Commission said:

> If the population density in some of Harlem's worst blocks obtained in the rest of New York City, the entire population of the United States could fit into three of New York's boroughs. (17)

Because urban life offers significant economic and social advantages, great masses of people are electing to crowd together; but the necessary provisions to serve their needs for housing, education, jobs, safety, and transportation have not kept pace. These needs exist wherever there is interaction among people. Bringing large groups together introduces very

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few problems that are new, but it greatly accentuates those that already exist. As the United States tends more and more to become a country of very large metropolitan areas, the critical urban problems - adequate housing, cheap and efficient transportation, safety at home and in the streets, proper employment at acceptable wages, education at all levels - become the critical national problems. Those are the problems that arise when we seek:

- o More stable economic growth and development
- o Greater and more nearly equal opportunities for the individual
- o More progress toward the "good life" for all citizens

No engineer can claim that technology will solve the present problems of the city. In fact there are even those who will maintain that technology contributes more to the problems than to their solution. Nevertheless, we are willing to assert that the present problems will not be solved without the intelligent application of modern technology. We will discuss here a number of areas in which communications technology (or more properly the entire range of electronic technology) can contribute to the solution of urban problems. By urban problems we mean those of the entire metropolitan area, because of the strong interaction between the acute problems of the inner city and the similar although less acute problems of the surrounding area. The depth and extent of our discussion is, of course, limited by the time and resources available to us. It is clear to us, however, that a need exists for the following two-pronged approach to the problems of the city:

- o Long-term studies to identify and analyze the benefits that telecommunications technology may bring to urban functions over an appreciable time, leading possibly to a fundamental restructuring of present urban patterns.
- o Short-term studies and action programs whose purposes are primarily ameliorative. As will be seen from the studies cited below, enough is known already to permit significant improvements in urban life. The pressure for long-overdue reforms coupled with the moral requirement for equity and justice will force these ameliorative steps.

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Long-Term Studies

This panel became convinced that the greatest probable benefit from its efforts would stem from attention to relieving problems caused by urban congestion. It also realized that feasible solutions are necessarily long range, both in implementation and effect, and require long-range study. So far, the panel has tentatively formulated one view of what it needs to explore and has advanced some hypotheses that need to be tested.

Above all there is need for a data base of urban characteristics, available from existing sociological studies that includes data on the historical development of cities; an account of the forces of mutual security, social intercourse, commerce, industry, culture, and technology that act on cities; demographic distributions and trends; economic distributions and trends, and the dynamics of such factors as employment, education, family, crime, and recreation. The data base can be assembled, summarized, compared with the bases of other workers, and then refined.

From this data base it should be possible to see, for example, the correlation of various social ills with population density and to identify probably causal relationships here as well as among other data. Then methods of counteracting the ills at given densities can be sought, as well as methods of reducing the density (or other causal factors) without prejudicing the social benefits associated with city life.

One hypothesis suggested by the panel is that employment opportunity is one of the major determining factors in city development and that lack of employment opportunity is a major factor in city decay. Inasmuch as these are under the control of management, they can be used to direct urban development to some degree. Why, for example, do large corporations so frequently build production centers in the center of large cities rather than in some alternative pattern?

Another hypothesis suggested by the panel is that telecommunications technology can facilitate the decentralization of employment. It is safe to say that to accomplish this, practically all necessary inventions have already been made, but the method of applying them and the systems engineering needed to satisfy the ultimate purpose represent a massive process of innovation. A testing of this hypothesis would

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involve studying the required mode of communication between dispersed departments of given companies now operating in a single location, the economic factors applying to proposed decentralization, and the optimal communications system including specific technological developments required to meet its needs.

Finally, any study that may recommend significant changes in urban patterns will have to analyze the degree to which the benefits that people demand from urban life can be retained or compensated. It is another hypothesis, needing development and testing, that telecommunications technology can be applied here also.

As a result of these considerations, the panel recommends initiation of such long-range studies.

Short-Term Studies and Action Programs

In studying the potential of electronics for the city, we became aware of a continually recurring pattern:

- A problem situation demanding urgent attention is identified (we shall cite below a number of these situations).
- The social, economic, and technical elements of a system for solving or at least ameliorating the situation are defined.
- The technology for this system is found either to exist already or to be close at hand.
- Despite the availability of this technology, the rate of progress toward solving the problem proves to be disappointingly slow.

In our view, technical and social innovation is not limited by technology, although it is retarded by the conflicting and exaggerated claims by both zealots and critics as to what technology can do. Far more importantly, however, the rate of innovation in the city (or more properly the public sector) is retarded by the lack of incentives and institutions for fostering change.

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From the studies cited below, it will be clear that the application of electronic technology in areas not now using it intensively has a high likelihood of yielding benefits that are large compared to their costs. Therefore, we recommend that selected pilot projects be undertaken promptly to provide us with some operating experience and with more precise information on the benefits and costs that we may actually obtain.

The Needs of the City

The modern city is a complex socioeconomic system, certainly the most complex system ever devised by man. For our purposes it will be useful to consider the needs of the city from three points of view:

- The private sector - a bundle of industry and commerce, localized in space and drawing on a regional pool for labor and a variety of professional services. The firms making up the urban economy depend increasingly on electronic technology - computers, communications, displays, and a wide variety of terminals and input-output devices.

- The citizen - who as an individual has need for a wide range of choice in jobs, in mode of living, in leisure activities, in social interaction, and in educational and cultural activities. Closely related is his need as a member of a group for resolution of conflict with other social, ethnic, and racial groups making up the city. Radio and television satisfy these needs in part, although there has long been continuing criticism of the quality and diversity of radio and TV program content.

- The public sector - upon which both firms and individuals depend for certain basic services: education, public safety, transportation, and mail delivery. The public organizations providing these services need electronics for much the same reason as do the private firms - to achieve higher levels of productivity and effectiveness.

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In the private sector, the market mechanism provides firms with the incentives, institutions, and financial resources necessary for rapid innovation. The goad of competition helps to offset any tendencies toward complacency and inertia. On the other hand, individual citizens (particularly those who are disadvantaged) and the public sector may not have the means, the incentives, or the institutions for assuring progress. Accordingly, we shall focus our attention on the individual citizen and on the public sector, asking what electronic technology can do for education, public safety, transport, postal service, and social purposes.

Technology for Education

For the school year 1966-1967, estimated expenditures for formal education, public and private, amounted to nearly $49 billion.(18) By way of comparison, the 1966 value of shipments for the electrical machinery industry was about $41 billion.(19) Of the total education expenditure, some $32 billion was spent in elementary and secondary education, and $17 billion in higher education. Estimated enrollment in public and private educational institutions in 1966-1967 was about 56 million, with 50 million in elementary and secondary schools and 6 million in higher education. By any standard, education is very big business.

On the basis of gross cost per pupil, in elementary and secondary education the United States spent about $642 (distributed as $550 in current outlays and $92 in capital outlays). Of the current outlays, salaries for instruction accounted for more than 60 percent whereas instructional materials, equipment, and supplies accounted for a little more than 3 percent - clearly a labor-intensive activity. During the decade 1955-1965, enrollment increased 37 percent while costs increased 48 percent.(20)

With these figures in mind, let us look more closely at this field. The educative process seeks to:

- Instill in the individual a wide range of knowledge and cultivate continued self-education
- Inculcate a sense of commitment to the values of his community
- Develop his ability to perceive, organize, and perform value judgments

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These functions must be accomplished better and better as the amount and complexity of knowledge grows. In this process, learning may take many forms: a teacher explaining a knotty problem to a student, a student exercising himself through programmed instruction (with or without computer assistance), or a group of students watching an instructional TV program. Much of the instruction at elementary and secondary school levels is directed toward teaching basic skills and knowledge. Instruction of this sort is relatively amenable to preplanning and formalization; the teacher generally has clear objectives as to the desired products of his instruction. These are the conditions under which technology is likely to be particularly effective as an aid to the educative process. Beyond this, there may be need for cultural enrichment or for teaching skills in critically short supply (for example, mathematics, science, and foreign languages). Locally available teaching skills may then be supplemented by instructional materials on slides, films, TV, or magnetic tape.

Here then are four circumstances in education that motivate thinking toward educational technology as a means of increasing productivity: (1) a labor-intensive enterprise, (2) inflating costs, (3) the demand for better quality, and (4) the availability of technological aids.

Instructional Television

Instructional television (ITV) has been surrounded by much argument. The televised lecture or demonstration can reach large numbers of students economically. With large audiences, such programs can afford excellent teachers and professional production talent and facilities. The televised performance can then be a dramatic demonstration using techniques too expensive for the individual classroom and, hence, one that can better excite the students. Moreover, ITV in the classroom can invigorate the classroom teacher through exposure to the knowledge, methods, and personality of the televised instructor.

The critics of ITV claim that it furthers the drift toward mass processing in education. It removes the instruction from the classroom and interposes impersonal equipment between student and teacher. To offset these criticisms, many schools attempt to combine ITV with classroom instruction and drill in ways that will maintain a close two-way interaction between students and teachers.

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The basic effectiveness of ITV has been proved by hundreds of experiments for a wide range of subject matter in schools throughout the world, yet it has achieved little real acceptance by the American educational community.(21) This slow rate of innovation may be explained by the following:

- Poor quality of much ITV programming - the result of inadequate financing and the difficulties attendant to the development of any new art. Too much emphasis has been given to hardware, and too little to program content. By way of contrast, costs of commercial TV programs range from about $25,000 to $250,000 per hour, with an average of about $120,000 per hour(22); noncommercial TV programs at key stations are produced for about one tenth of these costs; ITV for about one hundredth of these costs. With more adequate financing for research and program production, the quality of ITV programming could be markedly improved.

- Inability of the method to provide feedback from the individual student to the instructor, and hence, difficulty of adapting the instruction to the needs of the student.

- Inability of the method to force the student into an active role in the learning process.

- Excessive fragmentation of the institutions promoting the use of ITV. Some more effective institutional arrangement for promoting ITV is necessary both to overcome the resistance to change within the educational community and to provide the large student base over which programming costs may be spread.

Existing regional and national arrangements for the production and exchange of high-quality programs should be strengthened and expanded. Only in this way can the capabilities of the finest teachers in every subject field be fully utilized.

In a recent report the Committee for Economic Development (CED) estimated that the cost of supplying a school system of 100,000 students with one hour of ITV a day for each student would range from $0.8 million to $4.6 million a year depending on the quality and proportion of programming rented rather than locally produced.(23) Since this cost includes current outlays

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plus amortization of capital outlays, it should be compared with the figure of $642 per pupil per year derived earlier. ITV would therefore add from 1 to 7 percent to the annual cost, part of which would be offset by teachers released for services requiring more personal attention. Moreover, to the extent that ITV programming costs could be spread over several school systems, the incremental cost would tend toward the lower end of the range.

Computer-Assisted Instruction

The strength of ITV is essentially distributive. It fits well into those learning situations that involve lectures or demonstrations. Although it facilitates the sharing of excellent teaching, lecture-demonstration teaching is still controlled by the lecturer or broadcaster. It is therefore not very responsive to the special needs or individual learning rates of different viewers. On the other hand, the strength of computer-assisted instruction (CAI) lies in the fact that the learning experience is under the control of the student. Through the flexibility of the computer program, the machine can be made to fit the needs of the individual child, thus adapting the curriculum to his ability and rate of learning. CAI can be used to reinforce learning through exercise, to teach new concepts through a tutorial approach, to follow the student's progress in learning, and to use his past performance as a basis for selecting the new problems and concepts to which he should be exposed next. In these respects, then, ITV and CAI offer complementary techniques.

CAI is still in its early stages, with the main need being the development of an economically viable system. The key problem at present is the unavailability of flexible but inexpensive terminal equipment. Continued hardware development can be expected to solve this problem, driving unit costs down and yielding increased reliability. In addition, of course, there are the usual problems of a behavioral nature associated with any educational process - how to sequence the various concepts to be presented to the students, how to tailor the content and format of problems to the objectives of the exercises, and how to intersperse the exercises within the sequence of concepts to be learned. To this extent, development of CAI requires close cooperation with educational and research institutions.

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In university and industry laboratories a number of experiments are aimed at developing systems that will permit various types and levels of interaction between student and computer. Many manufacturers are promoting programming languages for educational applications of their equipment. These languages are essential in permitting the teacher-author to describe with a minimum of restrictions the instructional materials and strategies that are natural to him. He can then use the program logic to treat students or subject differentially.

As with any innovation, there is vigorous debate about the value of computers for instructional tasks. Most of the debate centers around the cost and effectiveness of CAI in relation to other means for accomplishing the same end. These questions will be resolved only after we have gained more experience with this new educational tool. The CED report cited earlier provided an estimate of $27 million per year for a school system of 100,000 pupils, each of whom would receive one hour of CAI per day.(24) The $27 million annual cost breaks down into $20 million for hardware rental, $1 million for software, and $6 million for other services. The cost increment of CAI, $270 per pupil per year (or equivalently, with one hour of CAI per day, $1.50 per student per hour), should decrease dramatically over the next decade as computer and terminal costs are reduced. There is promise that a cost increment as low as $0.25 to $0.30 per student per hour will be achieved within five years. Again as in the case of ITV, some of this increment will be offset by teachers released for services requiring more personal attention.

Pilot CAI projects already under way should be strongly supported, and additional projects should be established at selected institutions to refine the development of such instruction for both academic and vocational programs. The institutions selected should also have conventional classroom and booklet-type programmed instruction courses in operation concurrently with the CAI project in order to permit controlled comparison. Careful records should be kept on the costs of each project, on the rate of achievement of students, and on the significant features and peculiarities of each. Student reactions should be solicited and noted. Cost data should be collected in such a way as to identify those elements that vary with the scale of operations and thus to facilitate estimation of costs for larger-scale use of CAI. Post-institutional follow-up of students in each group should measure their subsequent progress.

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Technology for Transportation

Transportation plays a many-faceted role in the development of the city by:

- Enabling goods and passengers to be transported between and within centers of production and consumption, thus tying the city to its hinterland and to other cities
- Facilitating individual choice in jobs, education, leisure, and mode of living
- Promoting social cohesion among the groups making up the city

To an ever-increasing extent, this role is being vitiated by congestion of the airways and roadways.

Air Traffic

The present high volume of air traffic and the accompanying praiseworthy safety record would have been impossible without electronic aids to navigation and control. However, despite the present electronics-intensive system, traffic on the existing facilities is causing serious delays at the more heavily used air terminals; and indications are that traffic may double by 1972.

Far from being insensitive to the problem, both industry and the Federal Aviation Administration are investigating ways of alleviating this congestion. These include changes in schedules and rates as well as the addition of terminal facilities. The continuing promise offered by more effective electronic aids has drawn support, but many authorities familiar with traffic control problems believe that a more vigorous effort to apply existing technology can pay large dividends.

Larger and faster airplanes will focus public attention more sharply than ever upon air safety. With space for 400 or more passengers, each plane becomes equivalent to a small town. Any possibility for accident, especially due to human error, must be minimized. Again, more help from electronics is seen as the best feasible solution.

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As airspace becomes more and more congested, its recognition as a national resource will require some method of rationing to ensure its most beneficial use. Efforts are already being initiated to limit the number of landings per hour at the largest airports. This rationing, in turn, will require a highly sophisticated electronic support capability. A large and continually increasing commitment to electronic technology may be expected in air transport.

Surface Traffic

The automobile has led to urban sprawl and to increasing urban congestion. As in the case of air traffic, it may soon be necessary to apply electronics extensively to the control of vehicular traffic and, eventually, to charge for or to ration travel on the city's streets. Incremental improvements from now on will naturally be greater per unit of investment for surface traffic than for air.

The logic of vehicular traffic control becomes clear when we compare highway costs as measured in millions of dollars per mile with communications costs as measured in thousands of dollars per mile. Although a vehicular control system will include sensors, computers, and actuators - in addition to communications - the cost per road-mile for electronics will still be orders of magnitude less than that for another mile of highway. Yet improvements of 10 percent in traffic throughput surely ought to be attainable. The logic here suggests that we can achieve given improvements in traffic flow more cheaply by substituting electronics for concrete and steel. One pilot project involving computer-controlled traffic reported that the average delay per vehicle was reduced by 14 percent and that the probability of a stop was reduced by 18 percent.(25) The cost of a stop was calculated at about 2 cents, and the aggregate savings per year proved to be substantial even for the pilot project.

In addition to the direct savings to the motorist in time and fuel, there are other indirect benefits. Each additional mile of highway that transfers private property from taxable uses to tax-exempt transportation corridors depletes the city's tax rolls. Moreover, adjacent commercial property declines in value as potential customers speed past, unable or unwilling to stop except perhaps at certain entrances and exits. Finally, residential property values adjacent to the highway may decline because of exhaust fumes, noise, and impediment of local traffic.

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User charges and rationing could help unsnarl urban traffic jams and also ease local public finance problems. Tolls and license taxes on private vehicles that use key streets at rush hours would tend to shift motorists from cars to buses or subways, thus lessening congestion directly. Insofar as some people would choose to stay in their cars and pay, user charges would automatically generate the revenue to build and maintain the expensive facilities they want. Since it would be impractical to collect user charges at the time they are incurred, it would be necessary to use electronic sensing, processing, and billing.

Much the same argument for use of electronic controls for air traffic will apply to mass transit. Road-mile costs for subways are measured in the tens of millions of dollars. Control of train schedules and speed, as well as automatic fare collection, provides the basis for more effective use of these expensive facilities.

Technology for Public Safety

To understand better the role of the electronic technologies in public safety, we sketch first the nature of the criminal justice process:

- Statutes define what conduct is criminal and provide the mandate for enforcing agencies to act against violators.
- Police seek to detect and apprehend all violators of these statutes.
- Courts screen the evidence to separate the guilty from the innocent and to mete out appropriate punishment.
- Correctional institutions carry out the sentences and seek to rehabilitate the inmates.

Since violators have a tendency to repeat their crimes or to escalate to more serious offenses, the criminal justice system too often works in a closed-loop fashion - cycling violators from police to courts to correction and back to police again.

In varying kind and extent, technology may be applied to each of the several stages of the criminal justice process. In its reports, the President's Commission on Law Enforcement

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and Administration of Justice gave major attention to computer technology, information systems, communications engineering, and systems analysis, since these appeared to offer the greatest unrealized potentials for improvement - particularly in police operations.(26, 27) Among the recommendations made by the Commission were the following:

- Develop a computer-assisted system for command and control of police resources.
- Develop improved police radio networks.
- Require metropolitan areas to coordinate requests to the Federal Communications Commission for additional frequencies. Make greater use of multichannel radio trunks.
- Initiate research on an automatic fingerprint recognition system.
- Develop devices for automatic and continual reporting of all police car locations.

The basic objective of several of these recommendations is to reduce the overall response time from call for service to arrival of police at the scene. Arrest probability increases as police response time decreases. The Commission reported that when response time was 1 minute, 62 percent of the cases led to arrest. (28) When all cases with response time under 14 minutes were grouped together, only 44 percent led to arrest. To the extent that its incidence is affected by increased probability of arrest, crime can be said to have been deterred.

The court system could be improved by the application of information storage and retrieval and analysis techniques to court records. There is need for integrating the records of any particular court system with the records of the other institutions in the criminal justice system of that state and with those of other states by telecommunications links. This would have to be done in such a way as to protect defendants from the unfair use of criminal court records. By integrating and rationalizing the court records, we would be able to improve the management of our court calendars. More importantly, we would then improve our capacity to predict the effects on convicted persons of various options for sentencing treatment.

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Integration of records at correctional institutions with those of the courts would permit better tracking of convicted persons through the criminal justice system. At present there is a lack of information feedback on individual cases for use either by authorities or by social researchers. ITV and CAI might also be used to teach vocational and academic skills to inmates in order to reduce the probability that they will recycle through the system.

As in the case of education, technology can provide considerable help to law enforcement. But society must decide what devices and systems it wants for the price it is willing to pay in economic and social costs.

Technology for Postal Services

While looking at the city infrastructure - the public services upon which industry and commerce as well as the individual depend - it is natural to include the postal system. Although this service is only a part of the broader category of communications, it is the only significant part that is in the domain of public management. For this reason, we mention it specifically.

An analysis of postal costs made by the Post Office Department [29] gives the following breakdown:

Delivery	42 percent
Retailing	9 percent
Transportation	11 percent
Administration	6 percent
Processing of mail	32 percent

Because of the necessarily labor-intensive aspect of delivery and retailing and the nature of transportation and administration, savings from increased use of electronics in these areas are not likely to constitute a significant percentage of the total postal budget. However, the processing of mail, which consumes almost a third of the annual Post Office budget, is susceptible to very large economies both by the wider use of current machines and by the rapid acquisition and use of more advanced machines. The Kappel report, a recent comprehensive study of the United States postal service, stated that the multiposition letter-sorting machine, which requires ten fewer employees to sort the same amount of mail and pays for itself in two years or less in the normal installation,

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is used in only 39 post offices out of a total of perhaps several hundred post offices where the mail volume would justify it.(30) The optical scanner is an example of a more advanced machine. It is presently held that when this machine is operative, it will save almost three times as much processing manpower as the multiposition letter sorter does.

In short, a very large savings may be realized in postal operations by providing funds for the installation of electronic aids in the processing of mail. This provision will require a massive effort, as it is seriously overdue, but its benefits will more than compensate. To quote from the same report,

> The mechanization gap comes from a chronic shortage of funds for capital investment. Despite recognition by most Congressmen of the urgency of postal problems, the accumulated need for facilities and equipment exceeds $5 billion according to Post Office estimates. The Commission's observations tend to confirm the need for a sum of this general magnitude. (31)

We endorse the increased use of mechanization and recommend that the necessary funds be made available.

Technology for Social Purposes

In every land the metropolitan areas attract people from the rural areas because they offer opportunities for higher incomes, a greater variety and wider choice in modes of living, and a way of life that is more stimulating, more enlightened, and more conducive to innovation. Applied to communications and transportation systems, electronic technologies provide an efficient means of influencing urban density, form, and growth; applied to educational systems, they foster development of the individual; applied to public safety systems, they permit enjoyment of urban opportunities without fear of lawlessness and violence. Now we consider what the electronic technologies can do to promote wider choice for the individual and to help resolve conflict among the groups that make up the city. Here the policy issues revolve around provision to the public of additional wide-band communications channels with diversification of program source and content. To a limited extent, the unused broadcast television allocations can provide more channels. Beyond this, we must look to the wired city to furnish many inexpensive channels. If local program sources do not fill up these channels, a domestic satellite can provide the ability to draw upon program sources in other cities.

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One of the studies sponsored by the President's Task Force was "Telecommunications in Urban Development," by the RAND Corporation.(32) The RAND report dealt competently and perceptively with the multiple uses of TV in the ghetto and suggested some modest experiments that would provide TV programs for and by ghetto dwellers on jobs, education, city business, public service, minority culture, and community interaction. Low-powered TV broadcast stations would provide a voice for the ghetto, permitting its inhabitants to communicate among themselves and with other groups in the city. Using locally available management and production talent, costs could be kept low and programming emphasis could be focused on the needs of the ghetto. Diversity in programming would flow directly from the varied interests, cultural backgrounds, and value systems of the ghetto dwellers.

Urban communications provides an opportunity for city-wide and regional educational programs for special groups. Special courses in English for the non-English-speaking are already available in several metropolitan areas. An urban cable TV system would permit further decentralization of the city through the dissemination of programs developed for special groups within the city. As school decentralization is followed by decentralization of other governmental functions, the realization of community responsibility will require continuing education of the public.

To complement community programming, city-wide efforts are required in the training of adults for particular job opportunities appropriate to the changing nature of the city's employment picture. The recruiting of personnel for vacant jobs, the attraction of workers to the location of semiskilled labor needs, and the general upgrading of work skills require a continuing educational program. For example, the current acute shortage of paramedical personnel is related to the ignorance of the public about the nature of such jobs and the paucity of training programs attractive to the adult.

Need for continuing education exists in medicine, dentistry, law, and science, as well as in such occupations as business, nursing, and teaching. The reluctance of many nurses (and doctors) to utilize computers in the automation of hospital information services is a commentary on the absence of this concept in their formal education compounded by the lack of appropriate continuing education programs offered in a manner useful, convenient, and attractive to professional groups. Meeting the needs of these groups requires an urban communication system in which learning activities can be individually structured and paced.

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Still another area of interest is health care. With the physician becoming a suburban phenomenon and with the very small number of nonwhite physicians, the residents of the urban ghetto are unable to receive even minimal medical care. In New York City, for example, about 40 percent of the women who deliver children each year have not seen a doctor during pregnancy.(33) The high infant mortality rate and the relatively poor life expectancy within the United States seem to be directly related to this unavailability of medical help for large segments of the population. Attempts to ameliorate this situation by the development of regional health-care plans (including automated screening facilities as a major element) can succeed only if they are accompanied by educational programs to explain to prospective users the availability, characteristics, and capabilities of such technology.

Two other reports sponsored by the President's Task Force ["The Wired City: 1980," Robert S. Powers, ed.(34); and "Identification and Analysis of the Alternatives for Achieving Greater Television Program Diversity in the United States," by Spindletop Research (35)] dealt with closely related aspects of the same problem: how best to use communications technology for social purposes. The key to the problem seems to lie in lowering the cost of and permitting broader access to a wide-band communication system connecting diverse groups to a greater number of program resources. If the RAND experiments are successful in demonstrating that the benefits of ghetto TV outweigh the associated costs, we might then expect other urban groups to seek their own channels in a common cable facility, ultimately leading to the wiring of the cities. The domestic communications satellite would provide still further diversity by permitting TV interconnections of the various wired cities at lower cost than by terrestrial communications facilities.

Innovation and the City

A common thread runs through our entire discussion: how to speed the rate of application of technical innovations to social problems. Some of the elements of the city - the teachers, the police, and the courts - are expected by our society to preserve and transmit traditional community values, an essentially conservative function. Yet these are the very groups that find themselves today in the front lines of urban strife and violence. They must now both preserve traditional values and support experiment and innovation.

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The Panel on Urban Communications believes that changes may be required in the incentives and institutions needed by the public sector to permit it to correct the root deficiencies in our society while preserving basic values. We need to create the mood and means that will enable us to explore new instruments and new procedures. A series of small experiments chosen from those discussed above could provide a set of alternative solutions and the data necessary for intelligent selection among them. As the better alternatives emerge, we should move with all due speed to implement them on a larger scale.

We know much about what needs to be done. The question is whether we as a society will assign the priorities to talents and resources that are required if we are to deal effectively with those needs.

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Findings and Recommendations of the Panel

The major findings and recommendations of the Panel on Urban Communications, which emerge from the foregoing discussion, may be stated as follows:

1. Changes in the nature of the cities in the United States are bound to come, whether by violent efforts to attain more tolerable conditions of life or by plan. Fundamental gains from the application of technical innovation to problems afflicting urban (that is, metropolitan) areas may be expected, but they will require long terms for their realization.

   Recommendation: Those Federal agencies with mission responsibility in the urban area should ensure that a range of studies by organizations with a substantial technological base are undertaken to identify and analyze the benefits that technology may bring to urban functions for the long term, leading possibly to a fundamental restructuring of present urban patterns according to planned change. The steps in the studies should include:

   A period of orientation to the problems and their documentation, as already formulated by social experts, and possible reformulation from the point of view of opportunities offered by technology.

   Planning and conduct of interdisciplinary symposia designed to match available technology with the problems.

   Proposals for a coordinated set of action experiments and programs designed to realize the opportunities, and continuing concern for their implementation.

2. Enough is known already to permit significant improvements in urban life by the increased use of electronic technology in areas not now using it intensively.

   Recommendation: Short-term studies and action programs whose purposes are primarily ameliorative should be undertaken by the responsible agencies at all levels of government. Some suggested areas are identified below, with a brief statement of justification and possible action.

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Instructional television has been proved basically effective by hundreds of experiments for a wide range of subject matter in schools throughout the world. Its slow rate of innovation may be explained by poor quality of much of its programming and by excessive fragmentation of the institutions promoting its use. Existing regional and national arrangements for the production and exchange of high-quality programs should be strengthened and expanded.

Computer-assisted instruction offers effective and individualized instruction at costs that compare favorably with classroom teaching. The key hardware problem remaining is the development of inexpensive, flexible terminal equipment. Such equipment development should be promoted; pilot instructional projects already underway should be continued; and additional projects should be established to assess the relative merits of such instruction at all levels of academic education and vocational training.

In traffic flow it is likely that we can achieve given gains more cheaply by substituting electronics for concrete and steel. Research and development should be promoted embracing theory, hardware, systems, and field trials for the application of electronics to traffic management.

Technology may be usefully applied to each of the several stages of the criminal justice process. Hardware and systems, such as mobile teleprinters and computer-assisted command and control of police resources, should be developed; computer-assisted information retrieval and instructional systems in support of courts and correctional institutions should be adopted.

Large savings may be realized on postal operations by providing funds for the installation of electronic aids in the processing of mail. We endorse the increased use of mechanization and recommend that the necessary funds be made available.

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Various social needs of the citizen may be served by an urban communications system of great channel capacity. Pilot experiments on multiple uses of TV and its effects on all critical areas of the modern city should be carried out.

3. Although the prospect of profit motivates the private firm to innovate and to use the most modern technology in its operations, in governments at state and local levels the incentives and institutions for promoting innovations are often weak or completely lacking.

Recommendation: The Federal Government as well as private foundations should support studies of the incentives and institutions needed by governments at state and local levels to permit them to promote innovation for correcting deficiencies in our society.

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APPENDIX I

FINAL REPORT

TASK II

CONTRACT: OEP-SE-68-101

A STUDY OF DISTRIBUTION METHODS FOR TELECOMMUNICATIONS

By

COMPLAN ASSOCIATES, INC.

For

THE PRESIDENT'S TASK FORCE ON COMMUNICATIONS POLICY

Complan Associates, Inc.
19 Mile Road
Suffern, New York 10901

24 May 1968

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PREFACE

GENERAL

This study has been prepared at the request of the President's Task Force on Communications Policy. It is intended to assist them in formulating policy particularly in the area of distribution methods for the transmission of video and equivalent signals to and from the home or office. It is identified as Task II of a contract which has been negotiated with the United States Government - Contract No. OEP-SE-68-101.

REASONS FOR STUDY

There are two major areas of opinion regarding TV distribution methods in responsible private organizations and in government which have a sufficient number of supporters to justify detailed consideration of their implications. There is a "need to know" what would happen if these opinions were translated into action. Specifically how might these changes be accomplished, what would be the results, and what are the costs to the economy. These opinions are:

1. Shouldn't all TV broadcasting ultimately be provided by wire rather than over the air.
2. Shouldn't the American public have available to them a substantially larger selection of programs and similar services than are now provided by industry and government.

There is a body of opinion which holds that all broadcasting should reach the home, office or school by wire distribution

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somewhat similar to the current methods employed by the CATV organizations. The reasons given are better reception quality, a major increase in spectrum space for other purposes such as mobile service and possibly lower costs if major increases in programs are to be made available to the American public. It would be of assistance to the Policy Task Force if the advantages and disadvantages of government action to encourage such change could be identified along with the development of supporting data.

There is a second opinion that the American public needs and would use a substantially larger number of TV or equivalent channels if they were available. The number of 20 is mentioned quite frequently and while no complete analysis has been made to identify the specific types of programs which would comprise this large increase, it would include more educational coverage, a greater range of cultural material, knowledge banks, shopping guides, computer query and response services, newspaper and mail transmission. It will be noted that some of these services include both one-way and two-way transmission. The technical problems involved in accomplishing these two methods are very different. It would be helpful to the Task Force if the problems of achieving such an increase or some part of it could be identified and some measure of the costs established.

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CORALLARY QUESTION

The Telecommunications Common Carriers have instituted Picture-phone service for the transmission of both voice and visual services between their customers. Service is on a very limited scale so far but predictions of substantial increases are being made by industry representatives. Since this is a two-way visual service with a picture definition somewhat less than full TV grade, it must be considered along with the other one and two-way services. This report makes a detailed survey of the possibilities and presently estimated costs of providing this service.

METHOD OF PROCEDURE

Complan contacted the major industries, associations and common carriers involved to obtain as much background as is available in this whole field. Opinions, facts, costs, quantities and related information were obtained. Using this background, plans were set up which reflect, as far as possible, the results which might be anticipated if the major changes outlined above are accomplished.

Complan does not have fixed opinions in any of the above areas and has not tried to justify any programs, for or against, the adoption of policies by government which would bear on the questions. We have developed facts and provided observations and conclusions from which policy might be adopted.

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SUMMARY OF CONCLUSIONS

The details and discussion in this report lead to the following general conclusions:

1. It is not economically sound to contemplate furnishing all TV broadcasting by wire rather than over the air.
2. Wired service will grow rapidly. However, the use of the frequency spectrum for TV broadcasting will not diminish but will in fact increase as new stations are added for both commercial and educational purposes.
3. In many situations wired service offers sufficient improvement in signal availability or quality to attract large numbers of subscribers at rates possible today. Projected growth in the next 15 years could increase the service from a present figure of a little over 4% to 30%.
4. There are a number of situations in the wired service picture which justify further study.
   a. TV Set costs for wired service.
   b. Area covered by one "head end".
   c. Costs of cable and repeaters.
   d. Accommodations with utility companies.
   e. Accommodations with broadcasters.
5. Picturephone service will be in a cost range to justify substantial development, primarily in the business market. The common carriers should be given encouragement to promote this service.

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6. Video grade two-way switched service is presently so costly that any growth in this area will be very limited. To the extent that business requires switched data services of 4-6 MHz there might be some use for it. However, there will most likely be a number of steps from today's limited offering of 50,000 cycles to the full 4-6 MHz range before the higher limit is required.

7. The American Public has an average of 6 TV channels available to select from today. This average exposure will increase without any stimulation from government. The industry estimates are for an increase to 850 commercial stations from the 650 available today. Educational TV is hoping for an increase to around 400 stations from the 150 available today. Should this occur, the exposure at a TV location might on the average be 8 to 10 channels. To increase this to 12 would seem to be supportable by the projected advertising budgets of the 1980's, and the government interest in expanding its educational facilities. To go to an average of 20 channels at each TV location stretches the available funds too far and there is no finite indication that the public would make good use of such numbers.

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OBJECTIVES AND BASIC ASSUMPTIONS

OBJECTIVES

The objectives of the study were as follows:

1. To set up possible systems for a major expansion of both one-way and two-way video or equivalent services.
2. To establish costs for various ranges of development and comparative costs for major alternative arrangements.
3. To look at possible major improvements in program reception such as might be achieved with complete wire distribution of broadcast signals.
4. To identify problem areas where government needs to obtain more information or where it could justify more study to establish policy that would encourage desirable advancements.

BASIC ASSUMPTIONS

1. It was assumed that the demands of the American public for the future will justify the availability of up to 20 program channels having the technical characteristics of present TV programs. In order to provide a range for the exercise of judgment as to public needs, statistics are provided for average availability to all consumer locations of 6, 12 and 20 channels.

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2. Two major categories of service are covered, namely one-way and two-way. One-way service is the type available today where an individual owning a TV set may select any one of the programs being broadcast (by air or by wire) by turning a knob at the set. Two-way service makes available to the individual both the regular broadcast types of programs and also a personal choice of material which he wishes to see with the possibility of a complete interchange of both audio and visual communication between the two ends of a channel. Picturephone being offered by the telephone companies is an example. The interrogation of knowledge banks for an answer to a specific question where a visual response is required is another. Computer query and response (static visual, motion visual or data transfer) are others.

3. In order to project the present situation into some future time, it was assumed that the period of the study would cover the time when the economy reaches 100 million TV locations (TV sets will be much larger in number) and 100 million telephones (main stations). It was assumed that these two conditions will be arrived at in the same year which should be in the early 1980's.

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4. Costs have been developed to portray what the effect on the total economy will be under various plans. Estimates of what the individual consumer will have to bear directly as compared to the portion taken by advertisers and government are provided. Studies do not identify the serving body. In the case of one-way communication, it might be one or more organizations. In the case of two-way service, it will almost by the sheer volume of the underground plant have to be done by one common supplier at least for the distribution facilities. Two-way video service is impractical using broadcast techniques.

5. The place of wiredTV (Currently called CATV) in the national picture is a matter of wide difference of opinion. For this reason, costs have been developed for four different conditions, ranging from what is the present situation to a much more speculative situation. These are: 1) the present, 2) 10% of the locations served by wire, 3) 50% by wire, and 4) 100% by wire. This is for one-way service. For two-way service, it will all have to be done by wire but here again costs have been developed for 1%, 10%, 50% and 100% of the using public taking the complete service. Two-way video service existing today is negligible.

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In the case of two-way service, there are two grades of service for which full costs have been developed. These are the present TV grade which requires 4 to 6 MHz of bandwidth and the Picturephone grade which is about one MHz. Estimated costs will cover both first costs and annual charges including operating expenses and the cost of money. Cost of equity capital or income taxes are not included except where indicated.

6. The proposed distribution layout for one-way service is shown by Exhibit I, for the case where the reception at the "head end" is "off the air". Exhibit IA shows the case where the reception at the "head end" is by land lines. For two-way by Exhibit 2. Major switching arrangements are required for two-way service as shown.

The effect of domestic satellite transmission on inter-city network costs is discussed. It has been assumed that direct satellite to home broadcasting will not be economically or operationally possible in the next twenty years.

7. Assumptions as to the technology available cover all existing methods and in some cases it has been necessary to include solutions for which the exact device or system is not fully worked out. Completely theoretical possibilities have been avoided. This approach has resulted in some costs which are higher than will actually be obtainable in the future when the impact of new

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technology is obtained. Where specific cost reduction possibilities are recognized, they have been pointed out. Possible alternative costs have also been developed in some cases where there were substantial variations in the estimated costs from our various sources.

8. For two-way operation, it is necessary to dedicate a channel to one individual if service is expected to be available to him around the clock. Party lines are not desirable and so it has been assumed that every location has an individual channel to some central switching point. This then becomes analagous to a telephone line and the central switching point is similar to the local telephone office which serves all the lines in a particular neighborhood. For large concentrations such as occur in multi-story buildings, there will be switching centers on the premises similar to today's telephone PBXs.

9. The question of two or more simultaneous usages of broadcast channel facilities in one location, i.e., the home, must be cared for. In a one-way system, this is taken care of quite simply by bringing all channels to the TV set

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cver an antennae system, coaxial cable or other conducter, and making the selection by turning a knob. In this manner, all the members of a household can look at different programs at the same time, if sufficient TV sets are available.

This is not so with two-way service, and here there may need to be combinations of the major services. In one case it has been assumed that if simultaneous uses are desired the householder will lease additional lines to the switching office just as he would if he wanted to make two telephone calls at the same time. Another alternative which is offered is to have the TV programs on a one-way facility with two-way service limited to those calls which require this type of transmission.

It is recognized that the future may provide economical ways of multiplexing more than one TV channel on a single pair of wires. This will mean installing comparatively expensive equipment in the home. Should this become practical, it will have to compete with the simple solution assumed in this study of three pairs of wires. Since two or more pairs of wires for two or more simultaneous uses is a completely practical solution, the impact of any radically new multi-

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plexing arrangement will be on the cost aspects of the study and not on feasibility.

10. Arbitrary numbers of network, local and educational program sources have been assigned for each of the three situations of coverage, i.e, 6, 12 and 20 channels. The assumptions for each situation are as follows:

Six Channels
- 3 Network
- 2 Local
- 1 Educational

Twelve Channels
- 6 Network
- 4 Local
- 2 Educational

Twenty Channels
- 8 Network
- 8 Local
- 4 Educational

11. Since two-way operation will provide for calling local and remote sources as well as transmissions of the Picturephone type, assumptions as to traffic characteristics have been made. It is assumed that the occasional use for special calls to computers, knowledge banks, etc. will have the same calling rates per line as are anticipated for business telephones in the time period being studied. The TV use during this period will be the same as for the other sections of the study.

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12. The F.C.C. February 13, 1968 report shows 796 TV Broadcast Stations in operation. A Nielsen study shows that the average number of commercial TV stations receivable by the average household was 5.6 in September 1967. (See Exhibit 3) Including educational TV stations, it has been assumed that the following number of stations will be in operation for the various situations covered by the study:

	1968	In the 1980's		
	6 Channels	6 Channels	12 Channels	20 Channels
Networks	3	3	6	8
Network Stations-Owned	15	15	30	40
VHF Commercial	489	485	570	660
UHF "	145	150	700	1,500
VHF Educational	72	75	100	100
UHF "	75	75	200	400
	796	800	1,600	2.700

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BROADCAST

vs.

WIRED DISTRIBUTION PROJECTIONS

GENERAL

It is of interest to know the economics for the country as a whole of increasing the wired type of TV broadcasting to the extent that it is no longer necessary to use the frequency spectrum for this purpose. The effect on the quality of service and costs for the individual homeowner are also needed. Such a study must take into consideration a mix of both broadcast and wired type services.

BROADCAST TV - 1968

As of the first part of 1968 there were about 800 TV broadcast stations in operation, including both commercial and educational stations and 76 million television sets in 56 million households. The number of sets in business locations, educational institutions, restaurants, etc. is not known, but probably amounts to another half million. There were about 15 million color sets and an estimated 25% of the homes had color. The capital costs and annual charges for operating this medium for 1968 are estimated as follows:

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BROADCASTING COSTS

	Units	Unit Costs (Millions) Capital	Unit Costs (Millions) Annual*	Total Costs (Millions) Capital	Total Costs (Millions) Annual*
Commercial Networks	3	$ 61	$ 310	$ 183	$ 930
VHF Com'l Stations	504	1.5	1.5	756	756
UHF Com'l Stations	145	.7	.7	102	102
VHF Educational Stas.	72	4.3	2.46	320	177
UHF Educational Stas.	75	1.	.33	75	25
Ø Interstate Circuits	3			97	20
Ø Intrastate Circuits	796			24	5
TOTAL BROADCAST				$1,557	$2,062

RECEIVING COSTS

				(Millions)	
TV Sets					
Monochrome	61M	150	45	9,150	$2,745
Color	15M	500	150	7,500	2,250
TV Antennae	56M	60	10	3,360	560
TOTAL RECEIVER				20,010	5,555
GRAND TOTAL				21,567	7,617

* Costs do not include equity capital or income taxes.

Ø Circuits obtained from the common carriers. The interstate portion is for the three major networks plus the Sports Network plus a small Educational Network. The intrastate circuits consist of links from the TV station or studio to the transmitter to remote program sources and to the TOC of the common carrier. It is estimated that there are 1-1/2 such links for each TV station.

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WIRED BROADCASTING (CATV)

As of the first part of 1968, there were about 2,000 CATV systems in operation serving about 2.4 million subscribers. The capital costs and annual charges for operating this medium for 1968 are estimated as follows:

RECEIVING COSTS - WIRED SYSTEMS

Today's Development

		Unit Costs		Total Costs	
	Units	Capital	Annual	Capital	*Annual
Head End Equipment	2,000	$75,000		$ 150M	
Cable & Repeater	2.4M	75Ø		180M	
Drop Connection	2.4M	25#		60M	
Annual Costs	2.4M		$ 40		96M
GRAND TOTAL WIRED SERVICE				$ 390M	$ 96M

TOTAL COST TO THE ECONOMY

	Capital Millions	Annual
TV Broadcasting-Transmission	1,557	2,062
TV - Receiving	20,010	5,555
Wired Broadcasting Reception	390	96
GRAND TOTAL	21,957	7,713

Ø Largely aerial plant and smaller towns.

Largely aerial plant.

* Costs do not include equity capital or income taxes.

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PROJECTIONS TO THE 1980's

As stated earlier in this report, it is proposed to get the estimated costs for serving 100 million TV locations with an average of one and one-half sets per location. Sets will be 90% color and consequently no distribution between monochrome and color will be made in the calculations. The study covers 6, 12 and 20 channels and three mixes of serving methods, namely 1) 90% broadcast, 10% wired; 2) 50% broadcast, 50% wired; and 3) 100% wired. For purposes of illustration, the calculations for the 6 channel case with 90% of broadcast and 10% of wired are as follows:

BROADCAST TRANSMISSION COSTS

6 Channels - 10 Million TV Locations Served by Wire

		Unit Costs		(Millions) Total Costs	
	Units	Capital	Annual	Capital	Annual
Com'l Networks	3	$ 61.	310	183	930
VHF Com'l Stas.	500	1.5	1.5	750	750
UHF Com'l Stas.	150	.7	.7	105	105
VHF Educational Stas.	75	4.3	2.46	323	185
UHF Educational Stas.	75	1.	.33	75	25
Ø Interstate Circuits				97	20
Ø Intrastate Circuits				24	5
TOTAL BROADCAST TRANSMISSION				1,557	2,020

Ø Obtained from common carriers.

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BROADCAST RECEIVING COSTS

6 Channels - 10 Million TV Locations
Served by Wire

TV Sets	150M	250	100	37,500	15,000
TV Antennae	90M	60	10	5,400	900
TOTAL BROADCAST RECEIVING				42,900	15,900
Possible Reduction due to Elimination of Front End Tuner on Sets Receiving Wired Broadcast	15M	50	20	750	300

WIRED SERVICE

In 1968 almost all wired service starts with a "head end" receiving "off-the-air" signals and little intra-city or inter-city circuit connections are used. As the service gets to the 100% situation and broadcast transmitters are taken off the air, it will be necessary to connect the wired service complexes directly to the regular TV studios or to the Television Operating Centers (TOC's) of the common carriers. For the purposes of this study, it will be assumed that the regular broadcast networks, studios, intra and inter-city links are the same whether the service is provided over the air or by wire. Over the air broadcasting cannot be discontinued until the whole country is substantially 100% wired because the advantages of wired service in certain areas such as the suburban complexes of the larger cities are not enough to make the service attractive to the home owner at the

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present rates of $4.50 to $7.00 per month. There are, therefore, no costs to the wired service for land line transmission from broadcast studios to the "head ends". However, at the 100% wired situation, the costs of picking up the programs at the regular studios or the TOC's and carrying them by wire (provided by the common carriers) to the head ends have been included.

The growth of the wired service will be dictated by two principles:

1. Areas where there are no broadcasting stations within acceptable distances.
2. Areas where signals are poor due to reflections from structures within the serving area.

The present design of wired distribution systems can cover an area of 200 square miles with good reception of up to 20 channels. The total area of the United States would be served by 15,000 such systems. The whole population density and its distribution into areas which have varying degrees of TV reception today has been studied. This has been done to determine a logical program for growth of the wired service. As a result the geographical area of the United States has been divided into five types of serving areas as follows:

1. Densely settled areas such as are found in large cities where signal quality particularly for color is apt to be poor. This category has a density of 3,000 TV locations per square mile and represents 37% of the population. Cities over 50,000 population are in this category.

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2. Suburban areas of the large metropolitan complexes where signal quality is usually excellent. This category has a density of 1,230 TV locations per square mile and represents 16% of the population.
3. Smaller cities and towns where there may not be adequate coverage by the network programs. These are the areas largely covered by CATV today. They range in population from 2,500 to 50,000. This category has a density of 910 TV locations per square mile and represents 20% of the population.
4. Places of 2,500 population or less, where there are usually no broadcast stations but some signals, are received from nearby locations. This category has a density of 210 TV locations per square mile and represents 5% of the population.
5. The open country and unoccupied areas where there is not sufficient concentration to justify either a broadcast transmitter or wired service. Signals are, however, received from nearby towns or cities. This category has a density of 7.6 TV locations per square mile and represents 22% of the population. There is about one million square miles of unoccupied territory in this category. The settled portion has a density of 11.6 TV locations per square mile.

The total TV set homes represent over 93% of all homes. As the wired service grows, it will fill up the unserved areas in category 3 above, and the poor reception situations in category 1 as the first priorities. At 10% wired service, those areas will be

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involved along with a small part of category 4. It has been estimated that 3,000 systems as compared to the 2,000 now existing (handling 4.4 per cent of the TV sets) will care for 10% of the TV locations in the 1980's. At 50% wired service, some of category 2 will also be involved. At this point, it is estimated that 7,500 systems will be in existence. Category 2 will still have a large number of locations served by "over the air" broadcasting. The statistics for the 10%, six channel case are as follows:

WIRED RECEIVING COSTS

6 Channels - 10 Million TV Locations Served by Wire

	Units	Unit Cost Capital	Unit Cost Annual	Total Cost Capital	Total Cost Annual
Head End	3,000	$12,000	2,500	$ 36M	7.5M
Receiving Antennae	3,000	20,000	4,200	60	12.6
Cable & Repeater	10M	92	19	920	190.
Drop Connection	10M	65	14	650	140
Intra-City Circuits	0			0	0
Inter-City Circuits	0			0	0
TOTAL WIRED SERVICE RECEIVING				1,666	340.1

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TOTAL COST TO THE ECONOMY

6 Channels - 10 Million TV Locations Served by Wire

	Capital	Annual
TV Broadcasting-Transmission	1,557	2,020
TV Broadcasting-Receiving	42,900	15,900
Wired Broadcasting Reception	1,666	340
	46,123	18,260
Possible Savings in Set Costs at Wired Locations 20%	750	300
NET TO ECONOMY	45,373	17,960

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SUMMARY AND CONCLUSIONS

Broadcasting and Wired Service

GENERAL

The entire range of assumptions for 6, 12 and 20 channels and for wired development of 10, 50 and 100% was treated in the same manner as just discussed. Immediately following this section is a condensed summary of the statistics for these various conditions identified as Exhibit 4. From this summary, it is possible to draw the inferences outlined in the discussion which follows.

Annual costs to the broadcasting industry in going from the present average of 6 channels available to every TV location to 12 and then 20 could increase the present annual costs of $2. Billion to $3.6 Billion and $5. Billion respectively. These costs do not include equity capital, income taxes or profit. As a rule of thumb, the addition of these costs would increase the amount the public has to pay for this service by about 50%. The present total income of the TV broadcasting industry is about $3. Billion.

Included in these added costs are about $100 Million for increases in educational TV from one to two channels and $170 Million for increases in educational TV from one to four channels. Assuming the government pays for these costs, there remains about $1.43 Billion for the industry to absorb in going to ten commercial channels and $2.83 Billion to go to sixteen commercial channels. These figures include allowances for profit and income taxes.

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This means that the total industry bill which must be paid for by advertisers would be $5 Billion for an exposure of ten commercial channels and $7.5 Billion for an exposure of sixteen commercial channels.

Industry sources have come up with estimates that by 1977 television advertising expenditures will have increased from about $3 Billion today to around $6 Billion. It could well be that in the early 1980's this could go to $7 Billion. The sources also predict 200 new commercial stations by 1977.

Summarizing all of these facts, it is Complan's opinion that industry and advertisers might absorb the costs and stay profitable with an increase to an exposure of ten commercial channels per location. This would mean increases of 650 stations as compared to the 200 which the industry now estimates will occur in this period. Even this number would be stretching the advertising budget of the country when the constantly increasing costs of existing networks and stations are considered.

As far as increasing to an exposure of sixteen commercial channels per location, this would mean an increase of 1550 stations as compared to 200. It would appear from current estimates that this would be beyond the normal expectation of what advertisers will pay and there is always the question of whether the general public could use this much television exposure.

As far as the educational stations are concerned, the estimates include increases up to 500 stations which is only

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slightly higher than the Carnegie report indicates is essential to get adequate coverage for this purpose. The costs obviously will have to be born by government or private contributions and run from a total yearly cost today of around $200 Million for 150 stations to $300 Million for 300 stations and $400 Million for 500 stations. Whether or not such expenditures are reasonable in light of benefits received is a matter for government determination.

WIRED SERVICE

The costs of wired service for going from the present situation of approximately 2.4 million locations served in this fashion to 100 million or 100% of the television receivers are as follows:

	Capital (Millions)	Annual (Millions)	*Annual Cost Per Location
Present 2.4 Million wired (4%)	390	100	42
10 Million wired (10%)	1,700	340	34
50 Million wired (50%)	8,300	1,750	38
100 Million wired (100%)	84,400	19,800	198

* Rates to Subscribers about 50% higher.

The costs for a development increasing from the present 4% to 10% of the locations seems well within a reasonable figure in view of the substantial service improvement which can be reached in those locations where there are no adequate sig-

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nals. Increasing this to 50% of all locations wired also seems within reason. Such an increase can be accomplished with annual costs of about $1.75 Billion more to the economy as a whole and if savings are possible in the set design by eliminating the tuner, the total net cost to the economy would not increase very much. However, when the wired service extends beyond the 50% point, the density of homes goes down quite rapidly and the total costs increase well beyond reasonable expectations and what the public would pay. To go the entire way and wire everything which gives the possibility of taking TV broadcasting stations off the air would increase annual broadcasting costs by around $17 Billion and even if the savings in set design were realized, it would be $14 Billion. With figures such as these, there appears to be no possibility of reclaiming the frequencies used by the broadcasters to transmit television programs.

The question of savings in set design for a set arranged for wired reception only were discussed with a number of manufacturers and others who are knowledgeable in this field. The study already assumes that set price in color will come down to about $250 in the 1980's. Further reductions due to eliminating the tuner were stated by some to be unlikely. Some said that it could be as much as 20 to 25%. For purposes of this study, we have used both assumptions and shown a zero reduction and a 20% reduction.

The question will be raised as to why broadcasting stations couldn't be taken off the air in the larger metro-

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politan cities as wired service grows to a substantial percentage of the whole. A look at the probable markets for wired service is of interest. The assumptions made in this study as to the density of potential customers and costs were as follows:

	LOCATION OF MARKET				
	TV Locs. Per Sq.Mile	% of Pop.	Percent Taking 10%	50%	100%
1. Densely Settle Areas in Large Cities	3,000	37	60	47	37
2. Suburban Areas to Large Cities	1,230	16	0	20	16
3. Smaller Cities and Towns	910	20	32	26	20
4. Rural Areas Where Signals Poor	210	5	8	7	5
5. Open Country and Unoccupied Areas	7.6	22	0	0	22

COSTS

red	No. of Systems	Miles of Cable Per System	Total Miles	Capital Cost Per Mile	Total Costs (Millions)	Cost Per Location
0%	3,000	47	141,000	$ 6,500	$ 917	$ 92
0%	7,500	100	742,000	6,500	4,823	96
0%	15,000	600+	11,635,000	6,500	75,628	756

The results of the above assumptions favor the wired service concept to some degree because the maximum density is assumed for all categories even where less than 100% of the category is wired.

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As will be seen from the above tables, the major markets for the wired service occur in categories 1 and 3 and it might be expected that most of the growth will be here up to around 40% of the total TV locations. The attractiveness of wired service in category 2 is not great and the cost in categories 4 and 5 will limit expansion to these locations. It is much more probable that the growth in the number of broadcasting stations located more strategically to cover to some degree categories 4 and 5 will provide the service here rather than it being done by wire.

As far as growth of wired service is concerned, the estimates range from a conservative 20% of all locations served by 1980 to very much higher figures. Complan feels that a figure of 30% is quite probably if the current difficulties can be cleared up promptly and if the industry is properly managed.

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AREAS JUSTIFYING FURTHER STUDY

WIRED SERVICE AND BROADCASTING

WIRED SERVICE

The present technical arrangements and current costs of equipment are favorable to the growth of wired service at prices the public will pay. Costs in this study for cable, repeaters, drops and the head ends are all on the basis of providing 20 channels to each TV location. There are some areas, however, which need further study if the service is to be made available to as many locations as the public might want as soon as it is needed.

Sets: A determination should be made by discussions with manufacturers and others as to the possible savings if the set details not needed for wired reception are eliminated.

Transmission Quality: This study assumes that a wired system will cover an area of about 200 square miles making 15,000 systems needed for the United States. Covering 200 square miles means a distance from the "head end" to the "top of the tree" of about 16 miles. The technical people are not of the same mind as to whether or not in the 1980's it will be possible to greatly enlarge this area at current costs. Some say it could easily be 500 to 600 square miles meaning 25 to 30 miles from head end to top of the tree and even more.

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A further look at this point is needed. It does not matter very much from a cost standpoint what possible enlargement of the area might be obtained in the early stages of development but if connections are to be made from broadcast studios to the head ends by land lines, the area served could be quite important.

Cable, Repeaters and Drops: The loop costs for cable and repeaters in the early stages are in the order of $100 per location served and represent over 50% of the plant costs of wired service. Some technical improvements in these items would help to prove in borderline systems. The drop connection represents about 40% of the plant costs but it does not appear that major reductions are possible in this area since so much of the cost is labor.

Accommodations with Utilities: The anticipated growth of the wired service makes it essential that some arrangements be made to work together with the utilities involved in providing telephone, power, gas and water to the communities. In the 1980's, it will be mandatory that most plant be underground. The study assumes a figure of 95%. If the best economic solution is to be obtained, some common approach to getting the various services underground is needed.

Accommodations with Broadcasters: The problems of the present CATV operators and the broadcasters are already in the courts and before the F.C.C. Some resolution of these difficulties is needed.

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ADDITIONAL CHANNELS

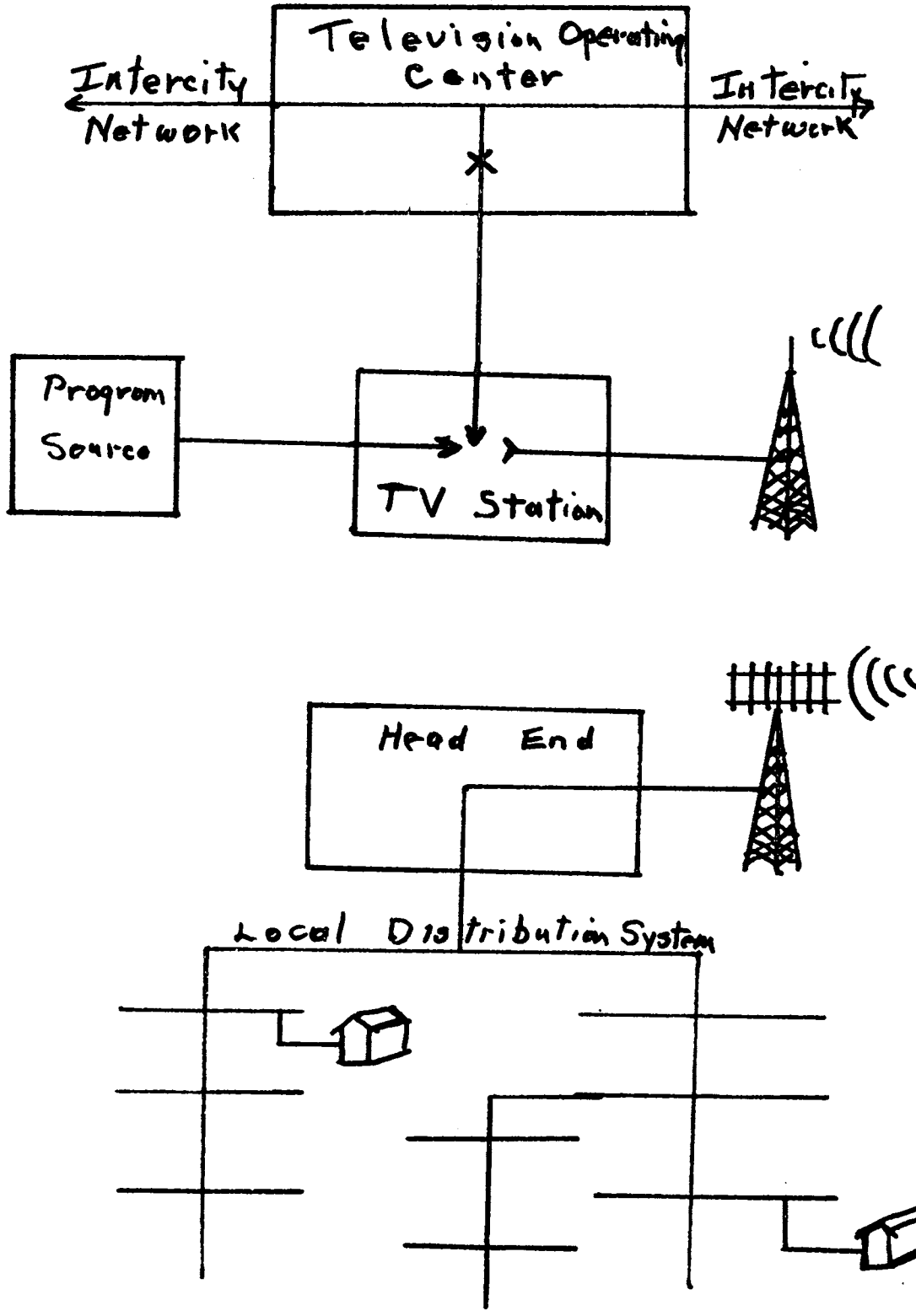
Comments on the problem of providing additional channels in the commercial field have already been given. Some will be added but to make 16 commercial channels available at all TV sets looks like more than the public can use. Some further study is needed to get an appraisal of this possibility.

In the educational field, the Carnegie Report has covered the need for more service in great detail. The whole question is "who pays" and for "how much". Obviously, further work is already going on in this area.

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EXHIBIT I

1-WAY WIRED VIDEO SYSTEM
"Off The Air" Pickup

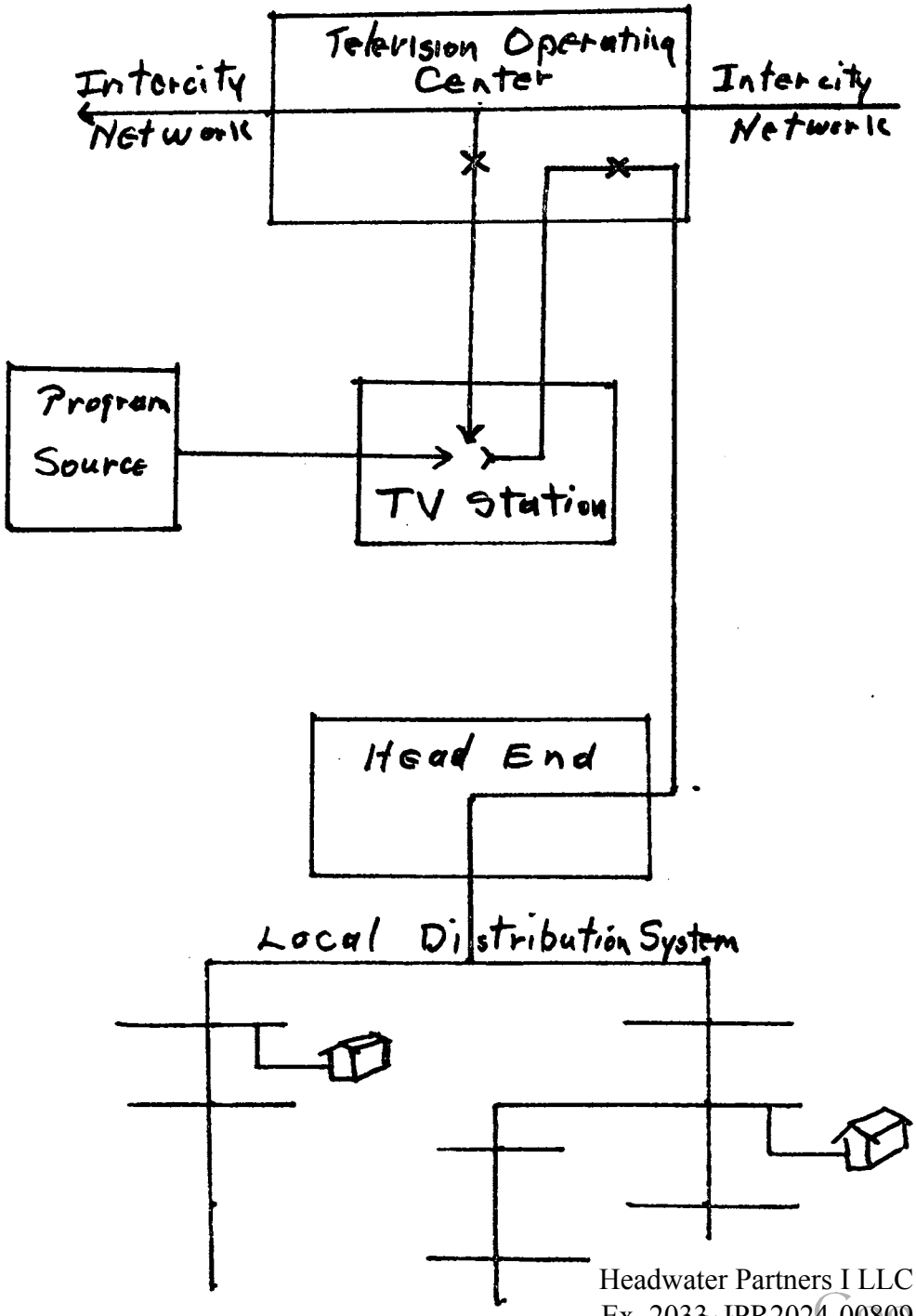


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EXHIBIT 7

1-WAY WIRED VIDEO SYSTEM

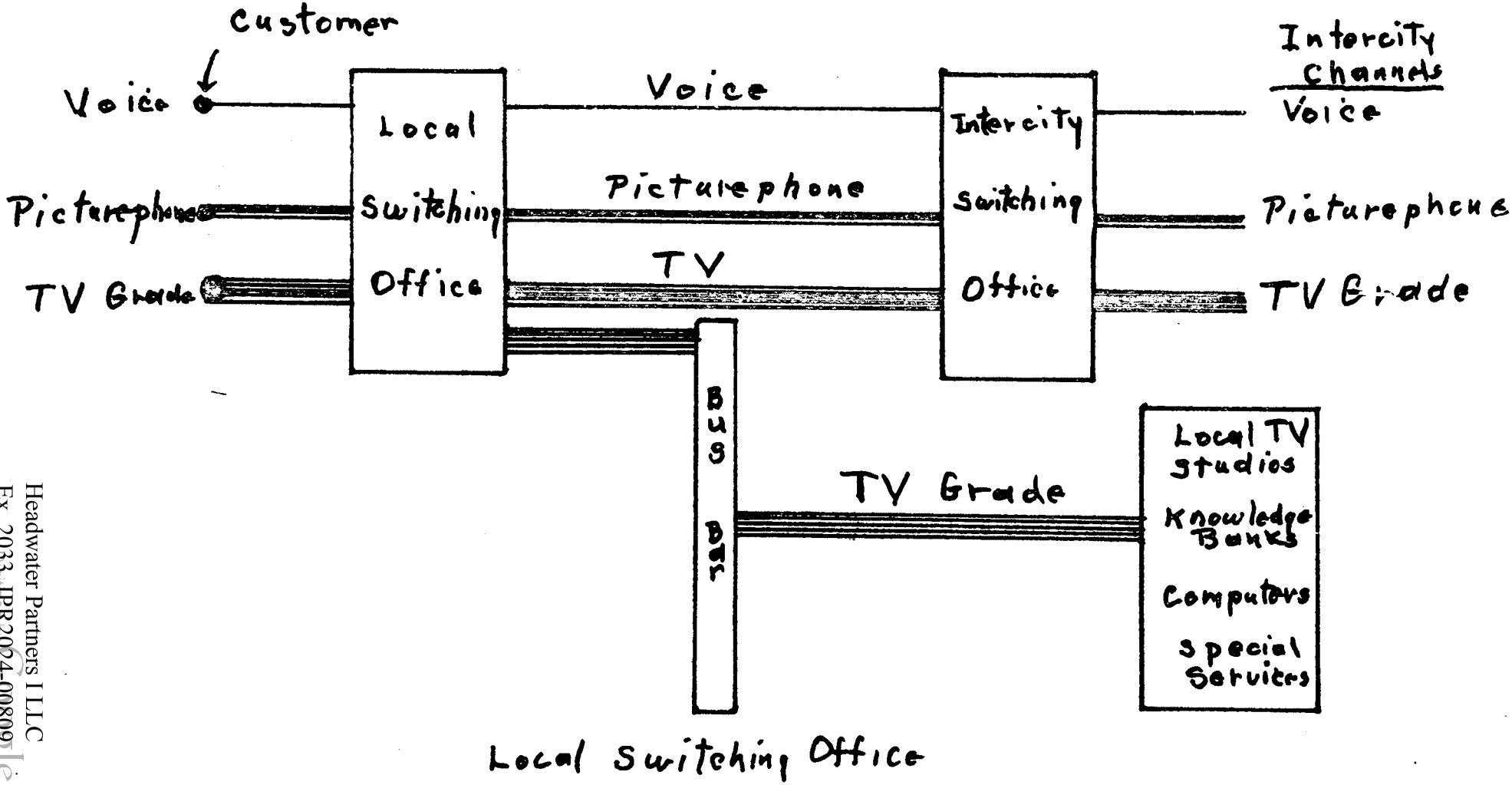
"Land line" Pickup



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Exhibit ~

LOCAL DISTRIBUTION LAYOUT FOR TWO-WAY SERVICE
(Switching Type)



Local Switching Office

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Exhibit 2

I. Average number of commercial TV stations receivable by average household is 5.6.

II. % of Households Capable of Receiving Various Number of Commercial TV Stations*

Number of Stations	% of Households Able to Receive
1	.8
2	2.6
3	16.3
4	16.0
5	13.0
6	18.7
7	16.0
8	7.0
9	4.0
10	3.4
11	1.6
12	.5
13	.1

* No educational TV included in this distribution.

Source: Nielsen National Sample Sept. 1967

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Exhibit 4

SUMMARY OF BROADCASTING STUDY

INCLUDING WIRED SERVICE

Development in the 1980's - 100 Million TV Locations

Average Six Channels	Today's Development 56.5 Million TV Locations 2.4 Million Wired Capital (Millions)	Annual	10 Million Wired Capital (Millions)	Annual*	50 Million Wired Capital (Millions)	Annual*	100 Million Wired Capital (Millions)	Annual *
The Broadcasters	1,600	2,100	1,600	2,000	1,600	2,000	1,200	1,900
The Public for Over the Air	20,000	5,600	42,900	15,900	40,500	15,500	37,500	15,000
Added Costs to Public for Wired	390	100	1,700	340	8,300	1,750	84,400	19,800
Total	21,990	7,800	46,200	18,240	50,400	19,250	123,100	36,700
Possible Savings if Sets Down 20%			750	300	3,750	1,500	7,500	3,000
Net to Economy			45,450	17,940	46,650	17,750	115,600	33,700
Average Twelve Channels								
The Broadcasters			2,600	3,600	2,600	3,600	1,800	3,400
The Public for Over the Air			42,900	15,900	40,500	15,500	37,500	15,000
Added Costs to Public for Wired			1,700	360	8,400	1,800	108,600	23,000
Total			47,200	19,860	51,500	20,900	147,900	41,400
Possible Savings if Sets Down 20%			750	300	3,750	1,500	7,500	3,000
Net to Economy			46,450	19,560	57,750	19,400	140,400	38,400
Average Twenty Channels								
The Broadcasters			3,700	5,000	3,700	5,000	2,400	4,700
The Public for Over the Air			42,900	15,900	40,500	15,500	37,500	15,000
Added Costs to Public for Wired			1,760	370	8,500	1,800	123,000	25,800
Total			48,360	21,270	52,700	22,300	162,900	45,500
Possible Savings if Sets Down 20%			750	300	3,750	1,500	7,500	3,000
Net to Economy			47,610	20,970	48,950	20,800	154,400	42,500

* Annual Costs of Broadcasters and wired service must be increased by about 50% to cover equity capital, income taxes, and profits.

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Exhibit 4

PICTUREPHONE PROJECTIONS

GENERAL

The common carriers have announced Picturephone services and some estimates have been made indicating that 1% of the telephones might be so equipped in the next decade. The present thinking is that the picture will be monochrome, that the size will be 5-1/2 inches wide, 5 inches high and that the transmission channel will require about 1MHz of bandwidth. Exhibit 5 gives more details of the set characteristics. Based on these assumptions, the added costs and possible tariffs have been estimated to provide 1%, 10%, 50% and 100% of the telephones with this feature. The results are shown on Exhibit 6. Costs are forward looking but do not reflect any real "blue sky" guesses. Good judgment indicates that they could be attained with today's technology if the volumes studied are realized. It should be stated early in this discussion that the estimated costs will, in our judgment, severely limit the rapid development of the service.

Costs for the service at the 1% level might be $100 per month added to the charges for local telephone service and $30 to the toll service for those calls using Picturephone transmission. These costs would come down as the service grew but even at 100% they are estimated to be $55 Local and $25 toll. This represents one Picturephone set at each location and it is difficult to anticipate that very many residence customers would be willing to pay this kind of

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charges. On the other hand, there are very definite advantages of such service in the business community. Not only are there advantages of the face to face type of discussions, but the bandwidth available opens up a whole new field of data transmission. Capacities for data transmission at the 1 MHz level on a public switched basis are almost as great as any visualized need in the next twenty years.

The present switched offering which is furnished on a very limited basis is for 50,000 cycles.

Details of the costs assumed are shown on Exhibit 6 and about all that can be said about a more rapid growth of the service is that costs will have to come down. In this case, some major technical breakthroughs in local distribution and inter-city circuits are needed. The common carriers will no doubt be doing their best to improve the current estimates.

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PICTUREPHONE SET

The Bell System's Picturephone see-while-you-talk set has been completely redesigned to incorporate additional features that trials have shown the public wants in a video-telephone. With the "model II" Picturephone set, the user can change the size of the field of view to close-up or wide-angle by "zooming" electronically, display drawings and printed matter (in a "graphics mode" of operation), move more freely from side to side while remaining "on camera", and change the camera focus to transmit larger scenes up to 20 feet away.

The display unit of the new Picturephone set -- a tapered, cube-shaped unit with rounded corners -- swivels through nearly a full circle on a pedestal slanting up from a frosted chrome, ring-shaped base.

A new silicon-target television camera tube makes the "electronic zoom" practical and provides a better picture under both poor and normal lighting conditions. An important feature of the new camera tube is that it is not damaged by direct exposure to bright lights. In addition, an iris in the camera automatically compensates for a wide range of ambient light intensities.

The screen of the Model II set, measuring 5-1/2 inches wide by 5 inches high, is larger than the screen of the first Picturephone sets. This larger screen, along with a new camera lens with a wider field of view, gives the viewer more freedom to move from side to side.

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The user can set the focus of the camera to one foot for the graphics mode, three feet for normal viewing, or 20 feet for a distant field. A built-in mirror automatically swings to a 45 degree angle in front of the lens when the graphics mode is chosen. When the material to be transmitted is placed in front of the base of the Picturephone, its image is reflected into the camera tube.

The three-foot focus, used for normal face-to-face communications, has a deep field in which the user is in sharpest focus between 24 inches and 40 inches from the set. For distant, wide-angle viewing -- of a blackboard drawing, or of two or more persons, for example -- the camera focus is set at 20 feet. During either normal or distant viewing, the user can change the field of view of the scene over more than a two to one ratio simply by turning the knob.

The Picturephone station set is comprised of a display unit, a control unit, and a service unit. A standard Touch-Tone telephone set equipped with a 12-button dial is used for dialing and for providing regular telephone service. The compact control unit contains four knobs and four push-buttons, and can be placed in a convenient position in front of the Picturephone display unit. One knob electronically adjusts the height of the center of the camera's field of view. Another knob regulates the camera electronic zoom, a third controls the brightness of the displayed image, and a fourth knob is the volume control for the speakerphone. The microphone for the speakerphone is also contained in the control unit.

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The four pushbutton controls enable the user (1) to initiate or answer a Picturephone or voice-only speakerphone call; (2) to see the picture he is sending out; (3) to prevent his picture from being transmitted (a pattern of three horizontal bars is sent instead; and (4) to end the call. The speakerphone microphone can be turned off, for momentary privacy if desired, the pressing the first pushbutton.

The compact service unit contains the power supply and control circuitry. It can be remotely located up to 85 feet away from the Picturephone display unit.

Modern electronic components like silicon integrated circuits and thin film circuits are used throughout the Picturephone station set. Vacuum tube technology is used only in the picture tube and in the camera tube, both part of the display unit. However, integrated circuit technology is used to fabricate the silicon target in the camera tube. The display unit also contains the speakerphone speaker and some of the video controls.

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CHARACTERISTICS OF THE MODEL II PICTUREPHONE SET

Viewing Distance	One foot for graphics mode, two to twenty feet for general purpose viewing
Picture Size	5-1/2 inches wide 5 inches high
Zoom Ratio	Viewing area increases about 250%
Display Unit Size	13.9 inches high x 7.7 inches wide x 11.6 inches deep
Control Unit Size	2.6 inches high x 6 inches wide x 3.2 inches deep
Service Unit Size	14.1 inches wide x 8.4 inches high x 6.2 inches deep

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Exhibit 6

ADDITIONAL COSTS FOR PICTUREPHONE SERVICE

Over and Above Regular Telephone Service

CAPITAL	One Million Locs. Unit Cost	One Million Locs. Total Cost	Ten Million Locs. Unit Cost	Ten Million Locs. Total Cost	Fifty Million Locs. Unit Cost	Fifty Million Locs. Total Cost	One Hundred Million Locs. Unit Cost	One Hundred Million Locs. Total Cost
		(Millions)		(Millions)		(Millions)		(Millions)
Station Set (Installed)	490	490	410	4.100	380	19,000	365	36,500
Local Distribution (Incl. Interoffice)	2,235	2,235	2,235	22,350	1,535	76,650	1,085	108,500
Local Switching (Incl. Land & Bldgs.)	184	184	184	1,840	184	920	184	18,400
Toll Switching		35		328		1,520		3,040
Interexchange Circuits		1,210		11,214		51,912		103,824
Total Capital		4,154		39,832		150,002		270,264
POSSIBLE RATES								
Local Plant		2,909		28,290		96,570		163,400
*Annual Charges 40%		1,164		11,316		38,628		65,360
Local Tariffs per Mo.		100		94		64		55
Toll Plant		1,245		11,542		53,432		106,864
Annual Charges 30%		373		3,462		16,029		32,059
Toll Charges per Mo.		30		30		25		25

One set per location at prices installed ranging from $540 down to $415. The added costs for Picturephone are estimated at $50 less or $490 to $365.

Local distribution ranges from $2500 down to $1350 with the added costs for Picturephone $265 per line less or $2235 to $1085.

Local Switching costs were $368 with the added costs for Picturephone $184.

Toll switching costs were $3200 per trunk switched with added costs for Picturephone of $1600.

Interexchange circuits cost $276 per mile with added costs for Picturephone at $24 less or $252 per mile.

*Includes overhead, profit and income taxes

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Exhibit 6

TWO-WAY VIDEO GRADE PROJECTIONS

GENERAL

The Picturephone study showed costs which would require tariffs of around $130 per month more than regular telephone service. It is of interest to learn what the costs would be for providing a picture quality equivalent to a standard TV set, i.e. 525 lines and 30 frames per second in both black and white and color.

Such an offering could open up whole new avenues of possible consumer services including knowledge banks, shopping by TV, home newspapers and a host of business services including data switching channels which would care for any foreseeable needs.

Costs were developed for this service in the same manner as was done for Picturephone only using the appropriate unit values for the more comprehensive offering. The results are shown on Exhibit 7. They indicate additional capital required and possible monthly rates as follows:

Number of Locations Served	Added Capital Required (Millions)	Possible Monthly Rates
1,000,000	$ 15,600	$ 440
10,000,000	149,400	422
50,000,000	630,800	350
100,000,000	1,147,500	312

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Annual charges on this added capital to pay costs, income taxes and provide equity would be about 40% per year for the local plant and 30% per year for the toll portion. Possible rates which customers would have to pay would range from $440 down to $312 per month. It seems quite clear that at these levels the fact that a better Picturephone service would be offered would not attract any measurable volume of business. Some use by business would be found but it is so uncertain under the present outlook that the better Picturephone concept should be deferred for the time being.

The possibility also exists that if such a service were provided it could do double duty and care for the ordinary entertainment and educational needs of one-way television.

> The concept would be that for regular TV service you would dial the channel number on the regular telephone and pick up the program on a bus bar at the local central office. Programs would be fed to the 15,000 telephone central offices in the country rather than going to the 15,000 "head ends" of the wired service. Exhibit 2 shows this possibility.

The hope might be that major savings in broadcasting costs would be realized by eliminating transmitters and making TV sets less costly. There are, however, many problems with such a concept which seem to rule it out for any foreseeable future. Some of them are as follows:

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1. Costs of the service in black and white would be around $400 per month more than regular telephone service or four times the Picture-phone costs.
2. Only one program could be seen on a single loop to the central office at one time. Different programs for additional sets in the home would require more loops to the central office as do additional telephone today.
3. At least two loops to the central office would be required so that programs would not have to be turned off to answer the telephone. Loop costs around $6,000 each.
4. Color would be even more costly and it would be essential at least to the entertainment portion of the programs. Discussions with some manufacturers developed very high costs for color cameras. A figure of $10,000 as a forward looking cost for a color camera at home has been projected. If this were to hold for the period ahead, it could add another $250 per month to the already high costs.

To sum up, it does not appear that two-way TV service in the home will be possible at costs which are saleable in any foreseeable period. This does not mean that every opportunity shouldn't be taken to work toward the

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possibility when it can be done for a little extra cost along with other major programs. Also, any possibility of using this method for getting wired service to the home seems out of the question.

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ADDITIONAL COSTS FOR 4-6MHz SERVICE

Over and Above Regular Telephone Service

CAPITAL	One Million Locs. Unit Cost	One Million Locs. Total Cost (Millions)	Ten Million Locs. Unit Cost	Ten Million Locs. Total Cost (Millions)	Fifty Million Locs. Unit Cost	Fifty Million Locs. Total Cost (Millions)	One Hundred Million Locs. Unit Cost	One Hundred Million Locs. Total Cost (Millions)
Station Set (Installed)	640	640	560	5,600	530	26,500	515	51,500
Local Distribution (Incl. Interoffice)	5,560	5,560	5,560	55,600	3,860	193,000	2,735	273,500
Local Switching (Incl. Land & Bldgs.)	552	552	552	5,520	552	27,600	552	55,200
Toll Switching (Incl. Land & Bldgs.)		106		984		4,560		9,120
Interexchange Circuits		8,525		79,030		365,860		731,710
Total Capital		15,648		149,384		630,770		1,147,530
POSSIBLE RATES								
Local Plant		6,752		66,720		247,100		380,200
Annual Charges 40%		2,701		26,688		98,840		152,080
Local Tariff per Mo.		225		222		165		127
Toll Plant		8,631		80,014		370,420		740,830
Annual Charges 30%		2,589		24,004		111,126		222,249
Toll Charges per Mo.		215		200		185		185

One set per location at prices installed ranging from $690 down to $565. The added costs for 4-6MHz are estimated at $50 less or $640 to $515.

Local distribution ranges from $5825 down to $3000 with the added costs of 4-6MHz $265 per line less or $5560 to $2735.

Local Switching costs were $736 with the added costs for 4-6MHz $552.

Toll Switching costs were $6400 per trunk switched with added costs for 4-6MHz $4800.

Interexchange circuits cost $1800 per mile with added costs for 4-6MHz at $24 less or $1776 per mile.

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Exhibit 7

Appendix J

FUTURE COMMUNICATIONS SYSTEMS

VIA SATELLITES UTILIZING LOW COST EARTH STATIONS

JULY, 1968

Prepared By

An Ad Hoc Group

of

The Engineering Committee

Satellite Telecommunications Subdivision

Industrial Electronics Division

Electronic Industries Association

Washington, D. C. 20006

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PREFACE

The Industrial Electronics Division of the Electronic Industries Association, based on the interest shown at its 1967 seminar on Communications Satellite Development, established a Satellite Telecommunications Subdivision to consider matters associated with Satellite Telecommunications Systems. Since satellite systems are becoming prominent in telecommunications and policies concerning these systems are being formulated, it was appropriate that industry consider its position and relationship to this field. The subdivision has three committees which deal with the various areas of Satellite Telecommunications Systems; namely, (1) Engineering (2) Policy, and (3) International. Ad hoc groups are established to undertake specific tasks.

The Engineering Committee considers engineering aspects of space telecommunications systems. This includes transmitters, receivers, antennas, spacecraft, and associated equipment, both as to the space and earth segments. It also includes multiple access and the interface with other systems, as well as radiation phenomena, the characteristics of propagation, and all data transmission which is an integral part of the space systems.

The Policy Committee is concerned with policy, economic, social, legal, and organizational matters affecting the development, growth, and diversification of space telecommunications systems. This committee draws together the views of industry and provides advice to telecommunications entities, executive and regulatory agencies of the Government, and the Congress of the United States for the purpose of encouraging the exploitation of space telecommunications.

The International Committee handles questions pertaining to international matters that arise out of the activities of the other committees in EIA. This committee concerns itself with international developments, financing, trade, and trade restrictions, as well as the international use of telecommunications satellites.

Among the matters under consideration by the Satellite Telecommunications Subdivision is the need to promote the development and use of telecommunications satellites and to substantiate their advantages. In this connection, the subdivision, on 25 April 1968, took the policy position that a domestic telecommunications satellite system should be aggressively pursued and implementation should be effected at the earliest possible date. The resolution reads:

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" RESOLVED:

The Satellite Telecommunications Subdivision of Electronic Industries Association (EIA) hereby calls for the aggressive pursuit of a domestic telecommunications satellite system with implementation to be effected at the earliest possible date. We urge that all appropriate responsible governmental, legislative, and industrial activities vigorously work toward this end without further delay. Problems of ownership, financing, frequency allocation, etc., must be resolved in a positive manner, but without unduly comprising the United States' worldwide leadership position. It is in the national interest to resolve the terrestrial satellite interface and interference problems as rapidly as possible by an early implementation of a U.S. domestic communications satellite project. The recently approved Canadian and Soviet National Satellite Telecommunications Systems are positive proof that other communities are proceeding to assume a lead role in the implementation of national satellite telecommunications. The Satellite Telecommunications Subdivision of EIA feels that the United States can ill afford to be pre-empted."

At the same time, the subdivision established an ad hoc group to prepare a report in accordance with this policy position. This report represents the subdivision's major contribution to the President's Telecommunications Task Force.

It is to be noted that the positions taken in this report have been arrived at by members of industry, in an attempt to represent the best interest of the public. The positions must be considered as consensus positions in which not every member and associate member of this subdivision concurs on all points. Furthermore, the information in this report is purposely presented with a wide range of cost figures which can be used, hopefully, to gauge the magnitude of the project and cost trends, but cannot be used or construed as a basis for accurately gauging the costs of any specific project in the future.

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SECTION 1

SUMMARY

1.1 GENERAL

Considerable attention and controversy has been evidenced in the past year as to the direction and extent of using satellites for telecommunications. Systems are being proposed having national and international characteristics. A basic economic competition between this new technology (e.g., satellite telecommunications) and conventional systems has arisen. Claims as to the cost effectiveness of each system are being made, and each proponent is claiming his system as the most cost effective. As is usually true in controversies of this nature, each case has merit when viewed within a limited scope.

The importance of this matter has been evidenced, for example, by the fact that the President established a Task Force on Communications Policy. Furthermore, the Satellite Telecommunications Subdivision sponsored the preparation of this report, the object of which was to develop informed engineering/economic judgments on future satellite telecommunications systems.

In order to develop these judgments, significant system parameters were evaluated for their economic impact, and models were developed to illustrate, in some detail, these engineering and economic effects. The key to increased usage of satellites is to reduce the per-unit cost to the user. The per-unit cost at the present time is primarily established by the expense associated with the terrestrial communications equipment, a major portion of which is the satellite earth station. This report, therefore, concentrates on this aspect of the communications satellite system. A second reason is that studies have shown a much greater demand for domestic communications traffic as contrasted to the longer distance point-to-point traffic. Therefore, in order for communications satellite systems to become an economic alternative to conventional terrestrial means, especially for developing nations, costs must be lowered.

The most costly area in today's commercial earth station is the antenna subsystem and associated low-noise receiver. Specifically, the need for large, steerable antennas with automatic tracking plus cryogenically cooled parametric amplifiers must be eliminated. This can be accomplished by reducing the required sensitivity of the earth station and by correspondingly increasing the satellite effective radiated power. The reduction of earth station sensitivity can be accomplished by using uncooled low-noise preamplifiers and smaller-diameter antennas. It is recognized that the use of smaller-diameter antennas leads to a reduction in

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theoretical orbital channel capacity; however, it has been demonstrated that there is also a significant reduction in earth station cost when using smaller-diameter antennas.

In preparing this report, higher satellite effective radiated power capability was evaluated and found feasible during the early 1970's. Furthermore, it was determined that the cost of an earth station can be significantly reduced by removing the need for large steerable antennas and cryogenically cooled amplifiers. These actions will result in sufficient cost reductions to warrant implementing low-cost earth stations as a possible economic alternative to conventional terrestrial communications systems.

Existing earth stations utilizing large antenna subsystems are fundamentally compatible with the proposed systems utilizing low cost earth stations. Modulation techniques considered are consistent with existing practice, only the modulation index has been reduced. This planned compatibility will permit existing earth stations to be phased into an over-all satellite network utilizing low cost earth stations and higher power satellites.

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1.2 CONCLUSIONS

- Satellites radiating relatively high output power, coupled with low-cost earth stations, will lead to a significant reduction in overall user costs. There are no technological limitations that prevent the immediate fabrication of low-cost earth stations. Satellites radiating relatively high power are feasible and will be available for system implementation in the early 1970's.

- The dominant cost components in current standard earth stations have been the large steerable antennas with automatic tracking facilities and cryogenically cooled parametric amplifiers. The use of smaller nontracking antennas and uncooled low noise receivers results in the multiplex equipment becoming the dominant cost factor, especially for high-voice channel capacity stations.

- Earth stations utilizing smaller antennas lead to significant savings in installation and operational costs, e.g. real estate purchase, site preparation, maintenance, etc.

- There is an essentially linear reduction in maximum orbital channel capacity as the diameter of earth station antennas is reduced.

- There is a significant cost reduction in the earth station as the diameter of the earth station antenna is reduced.

- The extensive use of frequencies in excess of 10 GHz appears promising under certain circumstances or conditions, e.g. point coverage, high arrival angles, geographic diversity, etc. as with a future "domestic" system. Millimeter waves cannot, however, be considered as a substitute for the more desirable frequency bands below 10 GHz for area coverage.

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1.3 TECHNICAL SUMMARY

1.3.1 Scope

Satellite Communications Systems must be developed to provide multi-point TV and two-way communications service to continue to compete economically with the more conventional terrestrial means (e.g., microwave, cables, etc.). Typical low-cost earth station models have been developed and are described in this report.

Current satellites have low effective isotropic radiated power (EIRP)*. For example, the INTELSAT III satellites, which are scheduled for launch beginning in August 1968, have multiple access capability through a linear transponder which furnishes only +22 dBW EIRP over 225 MHz of usable bandwidth. Two independent transponders cover the 500 MHz allocated frequency band.

The earth stations that complement the INTELSAT III satellites, 70 of which are currently envisioned, require G/T** ratios of 40.7dB/^{o}K and a top voice channel signal-to-noise ratio of 52 dB; these are typical specifications for existing earth stations. To accomplish this, 85- to 105-foot diameter antennas, cryogenically cooled parametric amplifiers, and threshold extension demodulators (for message traffic) are used. Automatic tracking for the antennas is usually employed and highly recommended; however, it is not a requirement.

The relationship between Satellite EIRP and G/T ratio, expressed in dB, is a simple one (refer to Paragraph 2.1.2.1d for the derivation):

$$EIRP = (K-G/T)\ dBW \qquad (1-1)$$

where

EIRP = Satellite Effective Isotropic Radiated Power in dBW.

---

* This is also called equivalent isotropic(ally) radiated power.

** The figure of merit of the earth terminal is stated as the ratio of antenna gain (G in dB) to the receiver system noise temperature (T in dB = 10 log t, t in degrees Kelvin).

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G/T = The figure of merit of the earth station, where G is the antenna gain in dB, and T is the equivalent system noise temperature.

K = A parameter dependent upon the frequency of operation, the path length, and the performance grade or service, expressed in dB. When these parameters are established, K becomes fixed.

Once K is determined, the economic and performance trade-off between EIRP and the G/T ratio can be determined. Thus, applying Equation (1-1) to current satellite communications systems, which are EIRP limited, establishes the need for high G/T ratio.

As the satellite EIRP is raised, the earth station antenna size and installation costs can be reduced, and cooled front ends can be eliminated, thus effecting cost economies in both the installation and operation of the earth stations. These two subsystems plus installation comprise a major portion of the current earth station costs, as shown in Section 2.3. The increase in EIRP will be achieved using greater satellite antenna gain coupled with increased transponder output power. By 1980, satellite EIRP's of up to +70 dBW will be feasible. As satellites with these higher EIRP's become operational, the utilization of low-cost earth stations can be realized.

The primary assumptions used in the model developments and system calculations are:

a. Only geo-stationary satellites have been considered.

b. The required EIRP has been achieved by increased satellite antenna gain coupled with increased transponder power.

c. Current CCIR Flux Density limitations are not exceeded.*

d. Earth station antennas of 30-foot diameter or less with mechanical positioning are considered.

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* This limitation applies to the 1-10 GHz frequency band (CCIR Recommendation 358, OSLO, 1966).

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e. Present commercial satellite frequencies are assumed (receive** 3.7 to 4.2 GHz and transmit** 5.925 to 6.425 GHz), except for systems using vestigial sideband amplitude modulation.

f. Modulation techniques considered are:

(1) Frequency Modulation (FM)

(2) Vestigial Sideband Amplitude Modulation (VSAM)

The modulation techniques used in the models are consistent with existing practice and the modulation index has been reduced to correspond to existing CCIR terrestrial link standards. It is recognized, however, that there will be a continual increase in digital traffic, leading to an increased use of digital modulation techniques during the 1970-1980 time frame. Investigations to date indicate that costs associated with the use of digital techniques will not markedly differ from the data in this report; in fact, the integrated use of digital techniques is expected to lead to further economies.

g. Only uncooled low-noise preamplifiers are used.

h. Threshold extension demodulators are not necessary.

i. Total usable satellite bandwidths of 500 MHz are assumed, except for systems using vestigial sideband modulation.

The system calculations in Section 2 have been developed to show system feasibility. The calculations are not intended to be used in establishing actual specifications or standards for a specific system.

1.3.2 System Models

The system models considered are:

** These terms refer to the earth station. "Receive" corresponds to down-links, and "transmit" corresponds to up-link.

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a. Color TV Service

(1) Vestigial sideband amplitude modulation (VSAM)

(2) Frequency Modulation (FM)

b. Communication Service

(1) Preassigned

(a) Multi-Destination Carrier System (FDM/FM)*

(b) Single Destination Carrier System (FDM/FM)*

(2) Demand-Assigned (SCC/FM)**

For conceptual clarity and model simplicity, the preassigned and demand-assigned systems have been considered separately, as if they were to use separate satellites and earth stations. One recognizes that a single satellite could accommodate both services simultaneously by using separate parts of the frequency band. Preassigned service is primarily intended for heavily used routes, i.e., continuously or nearly continuously used message channels, whereas demand-assigned service can be used advantageously for light routes (low message channel usage).

Models for earth stations which handle TV or two-way communications are detailed in Section 2.2.

1.3.2.1 Color TV Service

Figure 1-1 shows a possible one-way multichannel TV distribution system providing continental coverage and serving upwards of 250 (perhaps as high as 1000) commercial receiver earth stations. Separate earth stations are used for transmission and reception. Both regional and national reception and transmission stations are depicted. The difference between the two is the number of RF carriers that the station can handle simultaneously. Regional stations can be tuned to any of the twelve TV channels, but can receive or transmit only one RF carrier, while national stations can handle up to five.

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* Frequency Division Multiplex/Frequency Modulation

** Single Channel Carrier/Frequency Modulation

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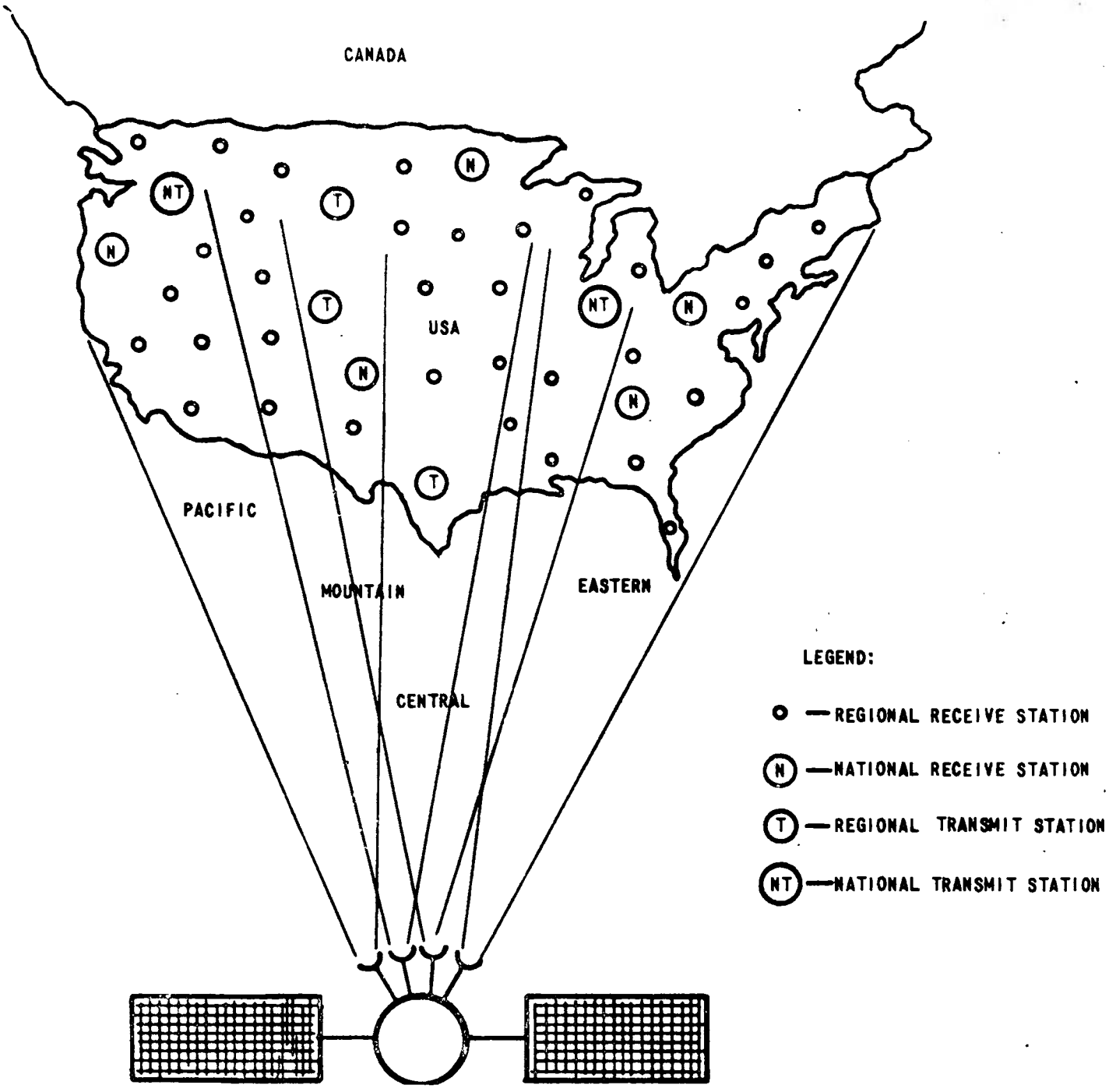


Figure 1-1. Domestic One-Way Multichannel TV Distribution System Showing National and Regional Stations

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Table 1-1 shows TASO* TV performance characteristics for Service Grades 1 through 6. The table is based upon subjective evaluation by viewers of a TV monitor.

Table 1-1. TASO TV Performance Characteristics**

Grade	Median Observer Signal-to-Interference Ratio (dB)	Impairment	Quality
1	44.5	NONE	Excellent
2	34	Perceptible	Fine
3	27	Not Objectionable	Passable
4	23	Somewhat Objectionable	Marginal
5	17	Definitely Objectionable	Inferior
6	—	—	Unusable

For reception to cable heads (CATV) or interfacing with terrestrial microwave links for TV distribution, a peak-to-peak signal-to-rms noise ratio $(S/N)_o$ of 53 dB has been selected as a representative value. This value allows for noise degradation by the terrestrial equipment, thus making it possible for the ultimate viewer to receive a Grade 1 TV picture.

For reception directly to the home, a peak-to-peak signal-to-rms noise ratio $(S/N)_o$ of 33 dB has been selected as a representative value, thereby making possible Grade 3 or better TV service to the home.

---

* Television Allocations Study Organization

** G. L. Fredendall and W. L. Behrend, "Picture Quality-Procedures for Evaluating Subjective Effects of Interference," Proc. IRE, Vol. 48, pp. 1030-1034; June, 1960. Also, C.E. Dean, "Measurements of the Subjective Effects of Interference in Television Reception," Proc. IRE, Vol. 48, pp. 1035-1049; June, 1960.

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The modulation techniques used are frequency modulation operating in the Commercial Satellite frequency bands (receive 3.7 to 4.2 GHz and transmit 5.925 to 6.425 GHz), and vestigial sideband amplitude modulation operating in the UHF band (receive 818 to 890 MHz and transmit 1.5 to 1.572 GHz*).

To achieve the necessary Satellite EIRP for TV receive time zone coverage, 3 degree beamwidth is assumed. Four beams will provide separate time-zone coverage of the continental United States. Since a 7.5 degree beamwidth can cover the continental United States, three 3° beamwidths can be used to provide coverage when two time zones are combined as in standard broadcast practice.

1.3.2.1.1 Vestigial Sideband Amplitude Modulation (VSAM) - A single RF carrier has been assumed for the transmission of both the TV video and TV audio information, the latter being sent on an FM subcarrier. The RF bandwidth required for reception is approximately 6 MHz.

a. Down-Link Considerations (818-890 MHz)

The equations relating Satellite EIRP to the G/T ratio for $(S/N)_o$ = 53 dB and 33 dB are as follows:

$$EIRP = (72.6 - G/T)\ dBW\ ((S/N)_o = 53\ dB) \quad (1-2)$$

$$EIRP = (52.6 - G/T)\ dBW\ ((S/N)_o = 33\ dB) \quad (1-3)$$

For national or regional receive station models, a G/T ratio of 13.5 $dB/^{o}K$ at 850 MHz has been assumed; this corresponds to a 30-foot diameter antenna using an uncooled paramp. The EIRP requirement thus becomes 59.1 dBW per TV channel. A satellite antenna with a 3° beamwidth will yield a gain of 34.6 dB (55 percent efficiency is assumed); thus the required actual satellite power is 24.5 dBW, or approximately 300 watts per channel.

A similar analysis can be performed in the case of direct service to the home (see Figure 1-2). In the model considered the equipment used is a 5-foot diameter antenna, an RF amplifier, and a current consumer television receiver.

---

* This frequency band has been selected only as a frame of reference. It is recognized that other services plan to use part or all of this band, e.g., the F.A.A. aircraft-to-ground communications via satellite relay, which plan to use the band 1.54 - 1.66 GHz. Therefore, in actual practice another available frequency band may be selected.

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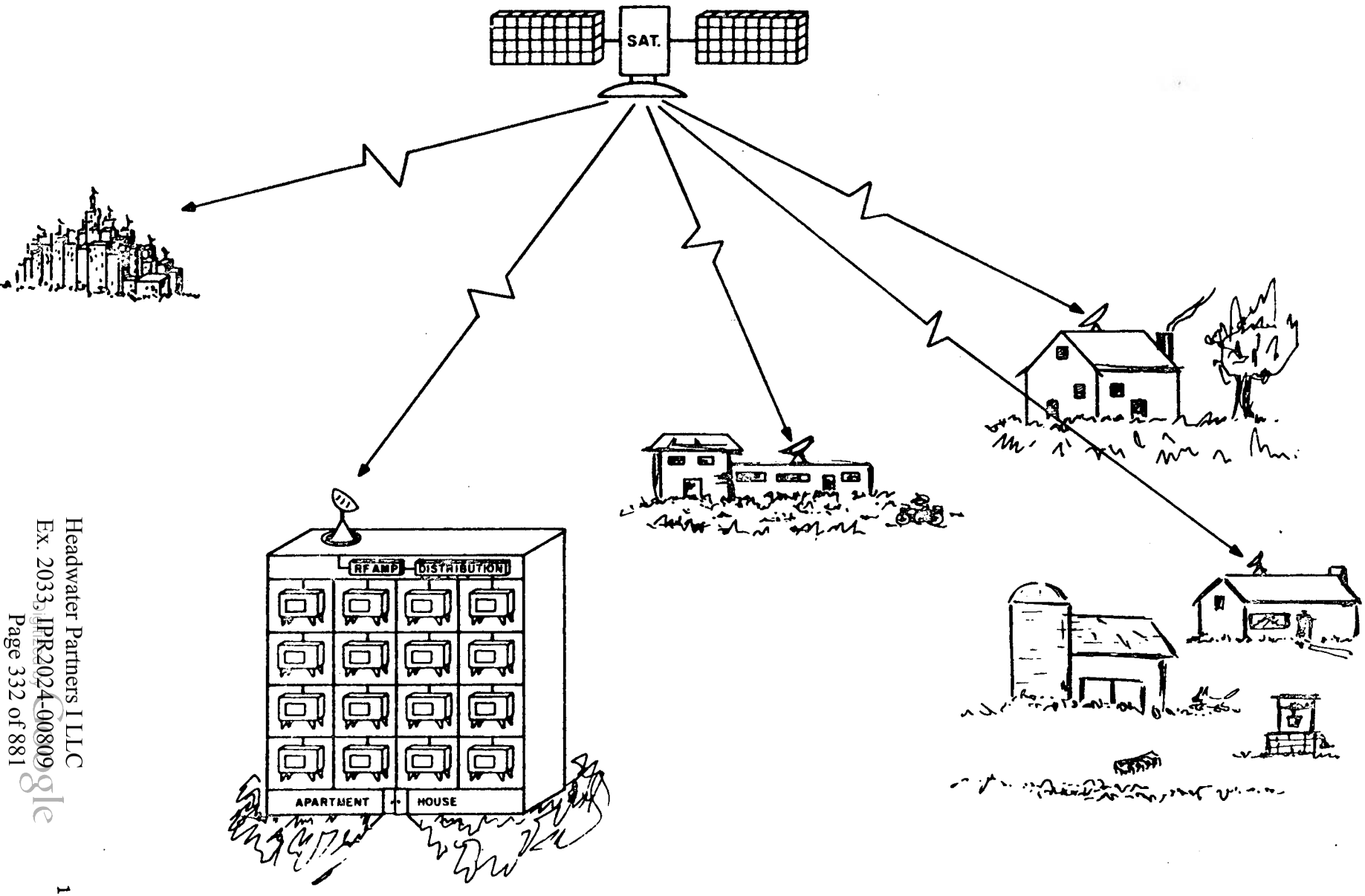


Figure 1-2. TV Service Directly to the Home

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A G/T ratio of -7.0 dB/^{o}K has been assumed, yielding an EIRP requirement of 59.6 dBW. This value of EIRP is very close to that required by CATV, broadcasters, and other commercial users. Therefore, the same satellite can serve both users. Obviously, improved home performance can be obtained by using larger antennas at the home or increasing Satellite EIRP.

The required EIRP for both cases is realizable in the time frame allotted (1970's).

b. Up-Link Considerations (1.5 to 1.572 GHz)

The equation relating the power required at the earth station as a function of the system antenna gains is expressed as follows:

$$P_{tg} = \left[117.4 - (G + G_t)\right] \quad \text{dBW}, \tag{1-4}$$

where

P_{tg} = earth station high power amplifier (HPA) output

G = earth station antenna gain in dB

G_t = satellite antenna gain in dB

In the model (Subsection 2.2), we have assumed an earth station antenna with a diameter of 30 feet and an efficiency of 68 percent. For this discussion we have assumed a more average-quality antenna (55 percent efficiency), G becomes approximately 41 dB at 1.5 GHz. Assuming a 1.7^{o} satellite antenna coverage, $G_t \approx 39$ dB. This complements the 3° beam coverage used in the receive-only earth stations, which operates at a lower frequency.

Therefore,

$(G + G_t) = 80$ dB, and

$P_{tg} = 37.4$ dBW ≈ 5.5 kW.

High Power Amplifiers (HPA's) of this capability are available, and have been used in the model earth station transmitter.

It should be noted at this point that, since VSAM is susceptible to amplitude distortion, a separate HPA is used for each carrier.

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1.3.2.1.2 Frequency Modulation (FM) - Separate RF carriers are used for TV video and TV audio information. This technique is consistent with current earth station practices.

The RF bandwidths required for TV video and TV audio information are, respectively, 40 MHz and 3 MHz. The video requirements predominate the audio requirements; hence, the latter will not be considered. The peak deviation used for TV video information is 15.2 MHz.

a. Down-Link Considerations (3.7 to 4.2 GHz)

The equation relating satellite EIRP to the G/T ratio for $(S/N)_o$ = 53 dB is:

$$EIRP = (60.6 - G/T)\ dBW \qquad (1\text{-}5)$$

For national or regional receive station models, a G/T ratio of 21.0 dB/^{o}K at 4 GHz has been assumed; this corresponds to a 15-foot diameter antenna, using an uncooled paramp. The EIRP requirement thus becomes 39.6 dBW/TV video carrier.

A satellite antenna with a beamwidth of 3 degrees will yield a gain of 34.6 dB (55 percent efficiency is assumed). Thus, the required actual satellite power is 5.0 dBW, or approximately 3 watts per channel. Since this power is readily available, the possibility of using a satellite antenna with a wider beamwidth arises. If we assume a beamwidth of 7.5^{o}, which would provide U.S. continental coverage, we have an antenna gain of approximately 26.5 dB. The actual satellite power requirement per channel is 13.1 dBW, or approximately 20 watts, which again will be readily achievable. The required EIRP for FM is easily realizable in the time frame allotted in the 1970's.

b. Up-Link Considerations (5.925 to 6.425 GHz)

The equation relating the power required at the earth station as a function of the system antenna gain is expressed as follows:

$$P_{tg} = \left[103.6 - (G + G_t)\right]\ dBW \qquad (1\text{-}6)$$

where

P_{tg} = earth station high-power amplifier (HPA) output,

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G = earth station antenna gain in dB,

G_t = satellite antenna gain in dB.

In the transmit earth station models, we have used a 30-foot and a 15-foot diameter antenna for the national and regional earth station respectively. The 30-foot diameter antenna allows up to 6 dB backoff for the common HPA used in the national stations. In the discussion that follows the regional station with the 15-foot diameter antenna will be used.

Assuming a 15-foot diameter antenna and an efficiency of 55 percent, we have an antenna gain G of 46.5 dB at 6 GHz. If the satellite antenna beamwidth is 2 degrees, the antenna gain is $G_t \approx 38$ dB. This complements the 3-degree time zone coverage used in the receive-only stations which operate at lower frequencies.

Therefore,

$$(G + G_t) = 84.5 \text{ dB, and}$$

$$P_{tg} = 19.1 \text{ dBW} \approx 80 \text{ watts.}$$

If we assume a satellite antenna beamwidth of 5.2°, this beamwidth complements the national coverage given to the receive-only earth stations.

$$G_t \approx 30 \text{ dB (satellite antenna efficiency of 55 percent)}$$

Therefore

$$(G + G_t) = 76.5 \text{ dB and}$$

$$P_{tg} = 27.1 \text{ dBW} \approx 520 \text{ watts.}$$

In both cases HPA's of this capability are available. An HPA with a 1 kW capacity has been postulated in the earth station model.

1.3.2.2 Communications Services

The communications services have duplex capability (two-way service) as opposed to TV service, which is one-way. Multi-access satellite operation is assumed. The system models considered are preassigned (multi- and single-

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destination carrier) and demand-assigned. Any of these services can be accommodated by a multiplicity of satellites or a common satellite.

The preassigned models use FDM/FM with a message (voice) channel capacity of 24, 60, 132, 300, and 600 voice channels per RF carrier. In addition, for the multi-destination carrier (MDC), TV operation has been considered. The per-channel test tone deviations complement current CCIR terrestrial line-of-sight (LOS) microwave standards. With the exception of 24 voice channels, which use a deviation of 140 kHz rms, all voice channel loadings use a deviation of 200 kHz rms. The output signal-to-noise ratio assumed is toll quality (52 to 53 dB psophometrically weighted).

The demand-assigned model is a modified version of the "STAR" system*. The demand-assigned technique used is SCC/FM. An RF spectrum of 100 kHz has been allotted to each demand-assigned (message) channel. The output signal-to-noise ratio will be of toll quality.

1.3.2.2.1 Preassigned Models -

a. Multi-Destination Carrier System (MDC)

The Multi-Destination Carrier System makes use of the broadband satellite transponder by using multi-destination carriers, which results in each earth station transmitting fewer RF carriers than it receives. The transmitted carrier from a particular earth station in a network is sent to the other earth stations in that network. Each earth station in the network receives as many carriers as there are other stations within the network; each carrier is demodulated and the preassigned channels for that particular station are extracted. Figure 1-3 shows such a communications system being used for both inter- and intra-continental communications.

The Multi-Destination Carrier (MDC) system provides a moderately high capacity for communications among earth stations and can be used for intra- and intercontinental links, thereby allowing various key cities to be incorporated within a given network.

* M. Morita, T. Fukami, and S. Yamato, "Project STAR," Telecommunications, Volume 1, No. 2, pp. T22-T25; October, 1967. Also, M. Morita, et. al., "STAR System," NEC Research and Development, No. 8, pp. 1-66, October, 1966.

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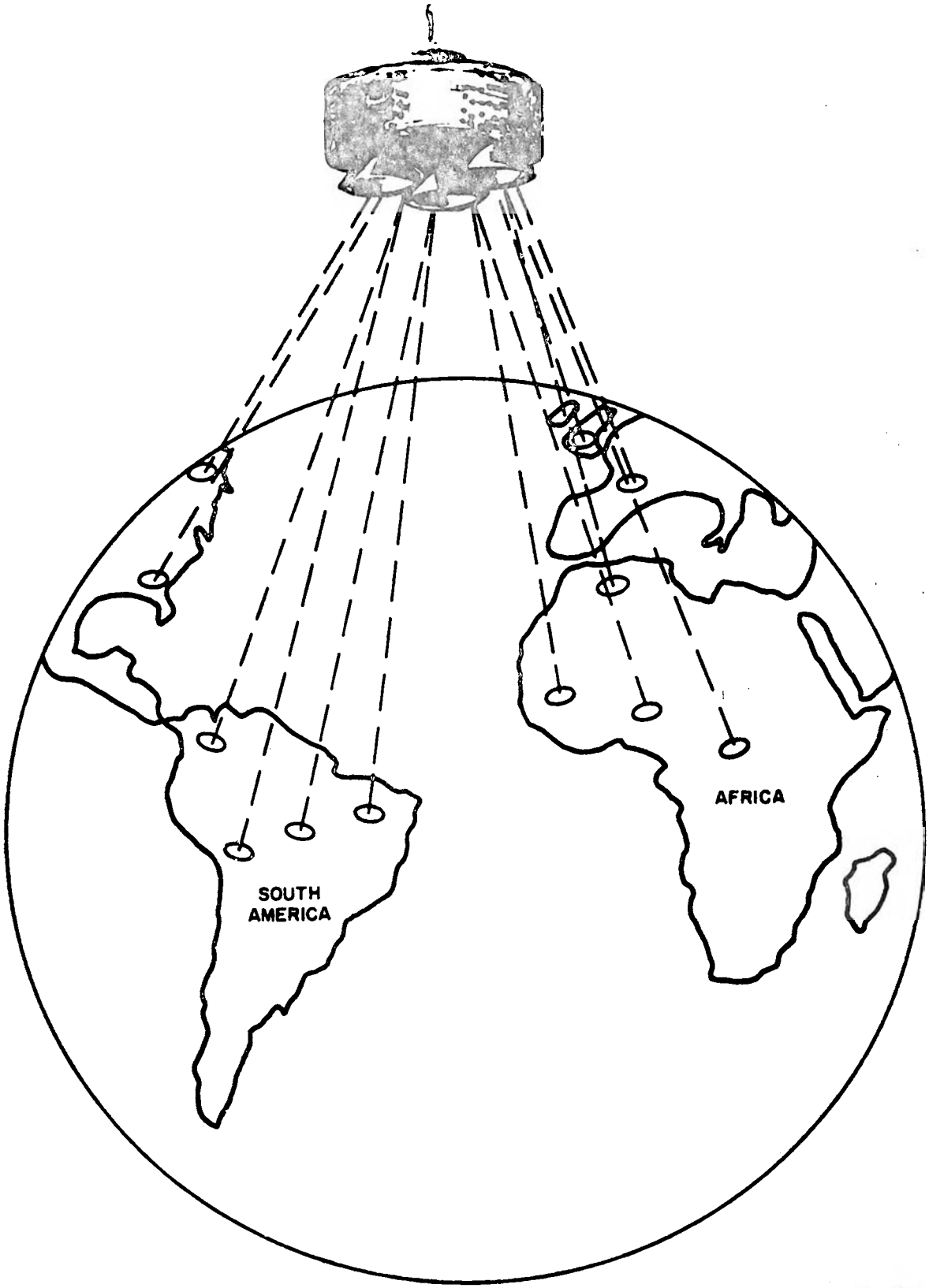


Figure 1-3. Preassigned Multi-Destination Satellite Communications Systems Used for Both Inter-and Intracontinental Communications

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The satellite can be considered as a pool of 500 MHz which can be shared by a number of networks; the exact number of networks accommodated by the satellite is a function of the number of multi-destination carriers within each network and the bandwidth required per network. The bandwidth, in turn, is a function of the number of voice channels required (see Table 1-2).

This system as described does not preclude the possibility of inter-network communications by the use of additional carriers. In fact, there is no reason (other than cost and inefficient use of circuits) why each of the stations which use a particular satellite could not communicate with one another.

Table 1-2. IF Bandwidth as a Function of Voice Channel Loading, Using CCIR Loading Standards*

Carrier Capacity Voice Channels	24	60	132	300	600
B_{if} in MHz Nominal	3.0	5.0	7.0	10.0	15.0

The earth station model developed in Section 2 has the capability of transmitting one and receiving five RF carriers**; in addition, provision is made for transmitting and receiving TV video and audio (program) information. The requirements of TV transmission and reception have been discussed previously and will not be included in this discussion. The TV receive-only stations discussed in the previous section are compatible with this system.

In the system described above, a network consists of six earth stations, each transmitting 300 voice channels. Thus, the transmit capacity of the network is 1800 voice channels.

The bandwidth B_{if} required for 300 voice channels is 10 MHz, and the satellite bandwidth is 500 MHz. Thus the maximum theoretical satellite capacity is 15,000 voice channels.

The earth station model developed has a figure of merit (G/T ratio) of 27.0 dB/^{o}K at 4 GHz. This is achieved by using a 30-foot diameter antenna and an uncooled parametric amplifier. The satellite EIRP requirements for 300

* CCIR Recommendation 353-1, Volume IV, Oslo, 1966.

** Each transmit RF carrier accommodates 300 voice channels; the bandwidth required is 10 MHz.

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voice channels[1] and the TV program traffic[2] are, respectively 38.6 dBW/carrier and 21.6 dBW/carrier. The requirement for TV video is 33.6 dBW per carrier. This value is 6 dB less than that of the TV receive-only case discussed previously, and results from the increase in the antenna diameter from 15 feet to 30 feet.

The power amplifier used in the earth station model has a capacity of 2 kW (33 dBW) and a bandwidth of 500 MHz. If we assume U.S. continental coverage, the satellite antenna gain is 26.5[3] dB at 6 GHz added to the earth station antenna gain of 53.5 dB, the approximate powers required per carrier on the ground are as follows:

TV Video	23.6 dBW, or 235 Watts[4]
TV Program	11.4 dBW, or 13.8 Watts[5]
Telephony	28.6 dBW, or 720 Watts[6]

The HPA used in the earth station model has sufficient reserve power capability, allowing for back-off to minimize the intermodulation problems.

b. Single-Destination Carrier System (SDC)

This type of communications system is a special case of the MDC system, primarily intended for use in heavy-loaded point-to-point systems covering large distances, e.g., an east coast location (Washington, D.C.) to Western Europe (Paris) or the west coast (San Francisco). Figure 1-4 depicts such a system.

An 1800 voice channel FDM/FM capacity is assumed per earth station. This capacity is accomplished via three RF carriers. Each carrier handles 600 voice channels. The IF bandwidth required to accommodate 600 voice channels is approximately 15 MHz (see Table 1-2); therefore, the spectrum utilized by each terminal is 45 MHz. Consequently, the satellite can handle 10 stations, or a total theoretical maximum capacity of 18,000 voice channels.

---

(1) EIRP = (65.6 - G/T) dBW for 300 voice channels.
(2) EIRP = (48.6 - G/T) dBW for TV program (audio).
(3) 7.5 degree antenna beamwidth, (antenna efficiency of 55 percent is assumed).
(4) Ptg = $[103.6 - (G + G_t)]$ dBW for TV Video.
(5) Ptg = $[91.4 - (G + G_t)]$ dBW for TV Program (Audio).
(6) Ptg = $[108.6 - (G + G_t)]$ dBW for 300 Voice Channels.

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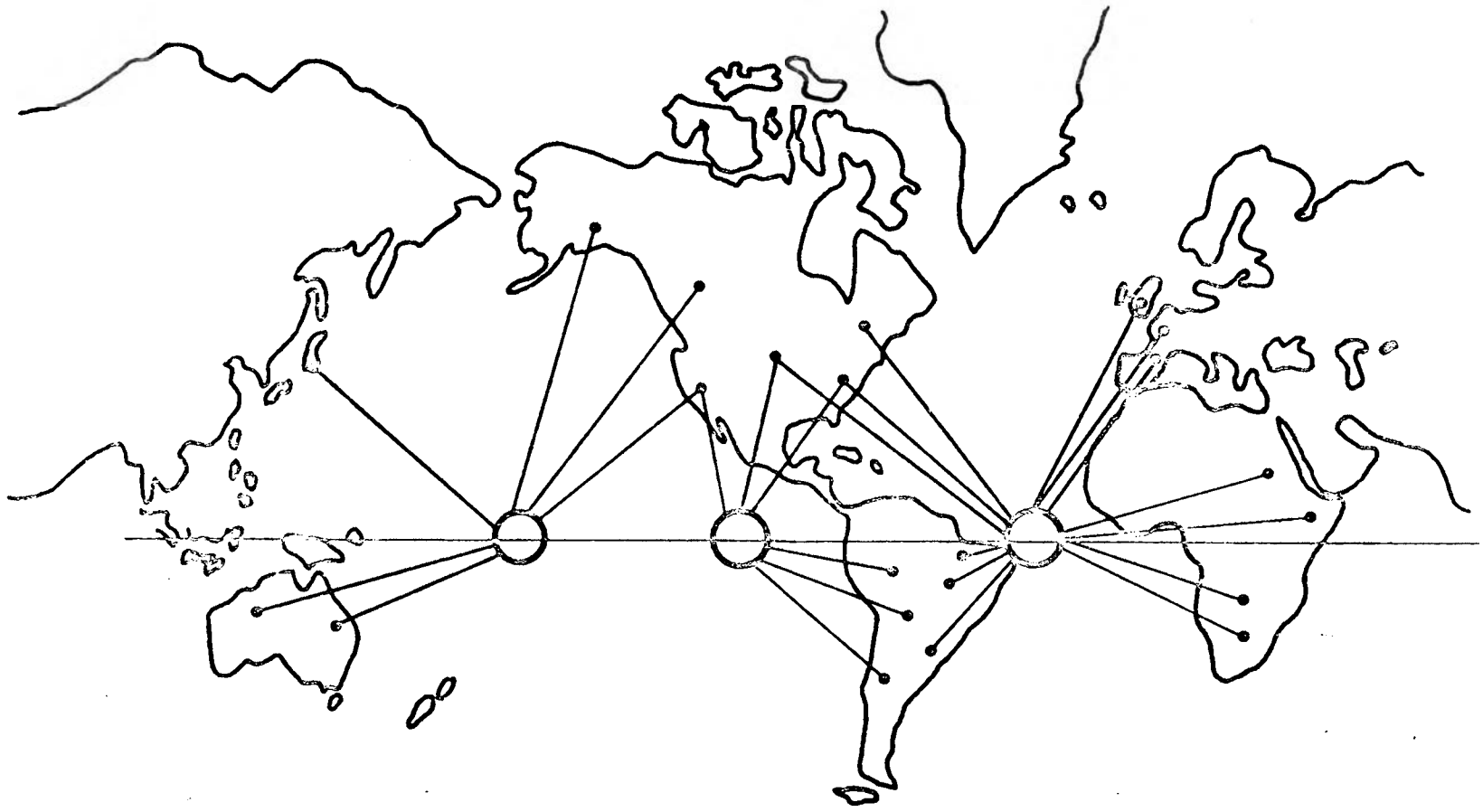


Figure 1-4. Preassigned Single Destination Satellite Communications System Used for Both Inter- and Intracontinental Communications

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Under most circumstances, the earth stations will handle different numbers of voice channels, resulting in different voice channel loading in the satellite, depending upon its usage. From Table 1-2 it can be seen that the IF bandwidth does not vary linearly with the voice channel loading; consequently, the greater the voice channel loading per RF carrier, the greater the capacity of the satellite.

The figure of merit (G/T ratio) of the earth stations considered is 27.0 $dB/^{O}K$ at 4 GHz which results from using a 30-foot diameter antenna and an uncooled paramp. The EIRP required per 600 voice channel RF carrier is 45.1 dBW*.

The high-power amplifier (HPA) used in the model station has a capacity of 2 kW (33 dBW) over a bandwidth of 500 MHz. If we assume a satellite antenna gain ≈ 34.6 dB at 6 GHz, which corresponds to time zone coverage (3-degree beamwidth), and add the earth station antenna gain of 53.5 dB to this value, the approximate power required on the ground is 410 watts (26.2 dBW) per carrier (each carrier transmits 600 FDM/FM voice channels).**

1.3.2.2.2 Demand-Assigned Model - The model uses a form of SCC/FM. Each voice channel frequency modulates one carrier, and the carriers are arranged within the transmission bandwidth of the satellite.

The channel capacity of the system is limited not only by the bandwidth of the satellite but also by its output power and the performance of each earth station which is linked to the others by means of the common satellite.

Voice channels through the satellite are not assigned to each earth station, but are assigned on a demand basis. This on-demand assignment is the so-called automatic routing operation.

In an operating voice channel, the carrier is not continuously transmitted; that is, a technique in which the wave is emitted only for the time in which a voice is present, and in which the wave (signal) is cut off for the period during which no voice is presented, is the so-called "Start-Stop" function. Using this approach, the number of usable channels is increased by utilizing the limited output power of a satellite most effectively, and the interference to other channels is minimized by cutting off the unmodulated waves.

---

* EIRP = (72.1 - G/T) dBW for 600 Voice Channels.

** $P_{tg} = \left[114.3 - (G + G_t)\right]$ dBW for 600 Voice Channels.

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The earth stations are always connected through the routing center by means of data transmission links for channel assignment. Time-division multiplex is used for the data link. However, the voice channels are transmitted using frequency modulation. Thus, each earth station has an analog system for voice channel transmission, and digital system for voice channel demand assignments.

This system for developed and developing nations is described. The essential difference between the two is the earth station channel capacity and the application of the "Stop-Start" function. Thus, conversion from developing to developed nation earth terminals is readily accomplished.

Each demand channel has been allocated a 100 kHz spectrum. Thus, a channel can accommodate a single voice channel.

The satellite has a bandwidth of 500 MHz; therefore, a theoretical maximum capacity of 5000 voice channels can be accommodated. The number of earth stations that can be accommodated by the satellite is a function of the expected traffic (data, voice, etc.), the allowable delays, etc. and is a traffic engineering problem.

Many earth stations can use the satellite. The applications of the "Start-Stop" further decrease the activity factor, thereby reducing the average power required in the satellite transponder.

The demand-assigned system offers flexibility in the use of satellite transponder bandwidth, and allows many earth stations of low traffic capacity to tie into the satellite. A useful application of the demand-assigned system would be in the case of many topographically separated communities which lack adequate terrestrial links but desire to communicate among themselves and with the centers of commerce. Figure 1-5 is a pictorial application of the demand-assigned principle.

The capacities of the earth stations for developing and developed nations have been assumed as 12 and 85 channels respectively.

The demand-assigned earth station includes a 15-foot diameter antenna and an uncooled parametric amplifier, yielding a G/T ratio of approximately 21.0 $dB/^{o}K$ at 4 GHz. Therefore, a satellite EIRP of 13.6 dBW per carrier is required.*

---

* EIRP = (34.6 - G/T) dBW per voice channel.

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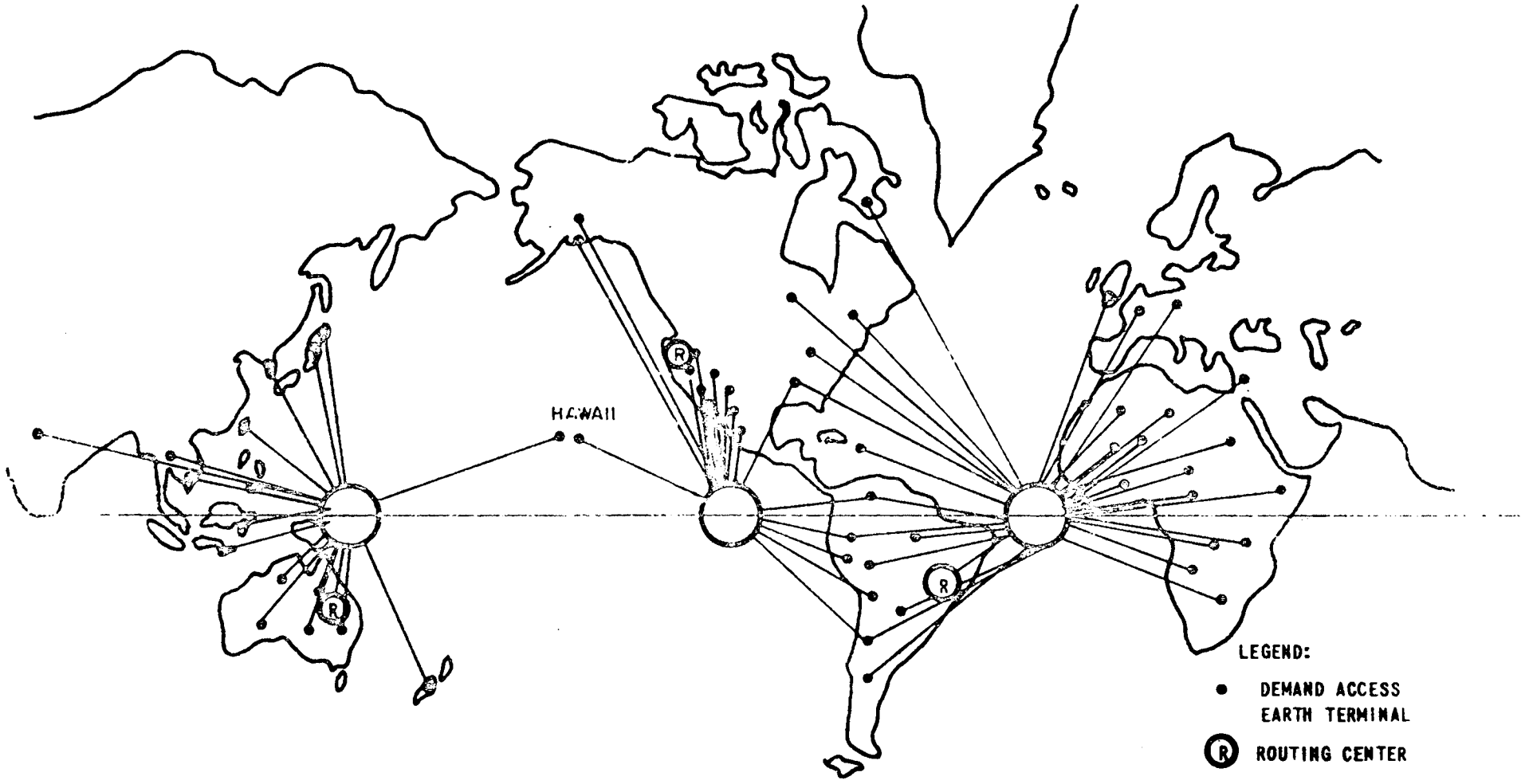


Figure 1-5. Demand-Assigned Satellite Communications System for use in Developing and Developed Nations

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The high-power amplifier (HPA) associated with the earth station model is 1 kW and has a bandwidth of approximately 500 MHz. If we assume global (hemispheric) coverage, 18-degree beamwidth, the satellite antenna gain is 19 dB at 6 GHz (antenna efficiency of 55 percent); adding the earth station gain of 47.5 dB, the approximate power required per carrier at the earth station is 13 watts.* The HPA postulated for employment has more than sufficient reserve power capabilities to be used by developing and developed nations.

An analysis similar to that presented above can be performed for the Routing Center. The G/T ratio of the station is 21.0 dB/^{o}K. Correspondingly, the EIRP required for the data channel is 24 dBW. The HPA associated with the Routing Center is 20-watt power amplifier with a bandwidth requirement of only 5 MHz.

---

* $P_{tg} = \left[77.6 - (G + G_t) \right]$ per voice channel

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1.3.3 Cost Comparisons

The model used for cost comparison is a standard station* that complements the INTELSAT-III-type satellite. This station has typical characteristics as follows:

Transmit:	3 RF Carriers:	one TV Video
		one TV Audio (Program)
		one redundant telephony** (132-voice-channel capability)
Receive:	7 RF Carriers:	five telephony (132 voice channels per RF carrier)
		one TV Video
		one TV Audio (Program)
		one spare; provides 1:7 backup

The total cost of this standard station ranges from $2.65 to $5.173 million, with a mean cost of approximately $4 million. Details are given in Subsection 2.3.

Tables 1-6 and 1-7 shown at end of this section give a comparison of the mean costs of the standard or existing earth station and the models projected for the 1972-1980 time frame. The models are discussed in more detail in Subsection 2.2. In addition, the cost of the antennas and multiplex equipment, where applicable, is expressed as a percentage of the particular earth station cost.

a. Per-Channel Cost Comparison (Initial Investment)

In order to determine the economic impact of low-cost earth stations and higher-power satellites on initial investment, the cost per channel for an existing INTELSAT-type system is compared to projected systems utilizing low-cost (MDC) earth stations. The quality of message service is equivalent for all models.

---

* $G/T = 40.7 dB/^{o}K$

** One of the redundant telephony carriers can be used as a spare for TV video or audio backup.

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The total cost per channel is the sum of the earth station transmit per-channel cost and the satellite per-channel cost. This relationship is expressed as follows:

$$\frac{\text{Total earth station cost}}{\text{Number of transmit channels}} + \frac{\text{Total Satellite cost}}{\text{Total Satellite channel capacity}} = \text{Total per-channel cost}$$

(1) Earth Station Per-Channel Cost

The standard earth station has a message transmit capability of 132 channels.* The cost of the earth station is approximately $4 million; therefore, the per-channel cost is given by the following relationship:

$$\frac{\text{Total earth station cost}}{\text{Number of transmit channels}} = \text{Cost per channel}$$

Therefore, by applying this relationship to the standard earth station we obtain:

$$\frac{\$4M}{132} = \$30,000 \text{ per channel}$$

The low-cost earth station with comparable message channel transmission capacity costs approximately $400k; therefore, the per-channel cost is:

$$\frac{\$100k}{132} = \$3000 \text{ per channel,}$$

or 1/10 the cost of the standard earth station.

---

*All earth station models compared include single TV video and audio (program) channels. It has been determined that the costs associated with this TV capability do not exceed 10 percent of the total station cost, and therefore, to simplify comparison, these TV channel costs have been distributed across the message (voice) channels.

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The MDC low-cost earth station model postulated (see Table 1-6, Item 1) has a 300-channel transmit capability and costs $480k; therefore, the per-channel cost is:

$$\frac{\$480k}{300} = \$1600 \text{ per channel}$$

(2) Satellite Per-Channel Cost

The INTELSAT III (low satellite EIRP type), which complements the standard earth station, costs approximately $10 million including launch. Its capacity is 2400 channels. The per-channel cost in the satellite is given by the following relationship:

$$\frac{\text{Total satellite cost}}{\text{Total satellite channel capacity}} = \text{Cost per channel}$$

Therefore, by applying this relationship to the INTELSAT III satellite, the cost per channel is:

$$\frac{\$10M}{2400} \approx \$4200 \text{ per channel}$$

The high EIRP satellite that complements the low-cost earth stations has a cost of approximately $30 million. Its total channel capacity is a function of the number of channels transmitted per RF carrier (see Table 1-2). Conservatively speaking, the total channel capacity is 6000 and 10,000 for an RF transmit carrier capacity of 132 and 300 channels respectively. Therefore, by applying the satellite per-channel relationship previously developed, the cost per channel is $5000 and $3000 respectively.

Table 1-3 summarizes these comparative costs on a per-channel basis. The results are quite dramatic and show the cost advantage of the high-EIRP satellite system coupled with the low-cost earth stations.

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Table 1-3. Comparative Per-Channel Cost*

(Initial Investment)

	Existing	1970's Projected	
Earth Station transmit capacity*	132	132	300
Earth Station cost	$4M	$400k	$480k
Earth Station per-channel cost	$\frac{\$4M}{132} = \$30,000$	$\frac{\$400k}{132} = \$3000$	$\frac{\$480k}{300} = \$1600$
Satellite channel capacity	2400	6000	10,000
Total Satellite cost	$10M	$30M	$30M
Satellite per-channel cost	$\frac{\$10M}{2400} \approx \$4200$	$\frac{\$30M}{6000} = \$5000$	$\frac{\$30M}{10,000} = \$3000$
Total per-channel cost	$34,200	$8000	$4600

where k = thousand

M = million.

*See previous footnote.

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b. Total System Cost Comparison (Initial Investment)

In order to determine the economic impact of low-cost earth stations and higher-power satellites on total system cost, the subsystem costs for an existing INTELSAT-type system were compared to those of a projected system utilizing low-cost (MDC) earth stations. Also included in the comparison is a projected system utilizing lower-power satellites, such as INTELSAT-III, which require present-day G/T ratios (40.7 dB/^{o}K) at the earth station. In this last case, however, we have economic improvements due to technological advances in both the earth station and the satellite which will have occurred by this time.

To simplify the comparison, a system having 4 satellites and 70 earth stations was used for both time frames. The estimated average subsystem costs are shown in Table 1-4. It can be seen from this table that the cost for the existing INTELSAT-type system is about $320 million, while the cost for the projected high-EIRP system is about $155 million. The difference is $165 million, which is substantial, especially when coupled with the increased message channel capacity. A future high-EIRP system can accommodate up to 300 or 600 duplex voice channels with a relatively small increase in cost for the additional multiplex equipment. Furthermore, if projected future requirements for telecommunications using 6 or more satellites with up to 700 earth stations are considered, total system cost saving by using high-EIRP satellites becomes even more substantial. See Table 1-5.

Table 1-4. Comparative System Costs - 4 Satellites, 70 Earth Stations

(Initial Investment)

Subsystem	Existing	1970's Projected	
		High-EIRP Satellite	Low-EIRP Satellite
Satellite (incl. launch cost)	$10M	$ 30M	$ 7M
Earth Station	$ 4M	$ 0.5M	$ 3M
Total System Cost	$320M	$155M	$238M

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Table 1-5. Comparative System Cost - 6 Satellites, 700 Earth Stations

(Initial Investment)

Subsystem	Existing	High-EIRP Satellite System
Satellite (including launch cost)	$ 10M	$30M
Earth Station	$ 4M	$0.5M
Total System Cost	$2860M	$530M

The significance of these projected systems utilizing higher EIRP satellites and low-cost earth stations is that, for a given investment, a network with greater capacity and more flexibility can be established. In other words, the per-unit cost to the user will be greatly reduced and will provide more than adequate channel capacity for developing nations and the smaller user. This will, in effect, accelerate the development of a large market, in that communications services can be provided at much lower installation and operational costs.

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Table 1-6. Cost Analysis of Communications Service Earth Stations

Description	Block Diagram Figures	Grade of Service	Equip. List Table No.	Capacity	User	Cost* Comparison	Antenna Cost Normalized	Multiplex Cost Normalized
A. Preassigned								
1. Multi-Destination Carrier (FDM/FM Station)	2-13	TV-No. 1 Message-Toll quality (S/N=52dB)	2-41	Ties in with a network of five ground stations-300 voice capacity plus one TV channel	Developed or Developing *** Nations	12%	7%	30%
2. Single Destination Carrier (FDM/FM Station)	2-14	Message-Toll quality (S/N=52dB)	2-42	1800 voice channels point-to-point	Developed Nations (e.g. USA to Europe)	30%	3%	72%
B. Demand Access								
1. SCC/FM System **	2-16	Toll quality	2-43	85 demand access voice channels		15%	3%	60%
2. SCC/FM System **	2-16	Toll quality	2-44	12 demand access voice channels		6%	8%	30%

* Ratio of the particular earth station to the Cost Model in percent.

** The cost of the routing earth station is counted with the cost of the satellite.

*** Could reduce cost by having a multiplex of lower capacity, e.g., 132 voice channels.

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Table 1-7. Cost Analysis of Color TV Service Earth Stations

Description	Block Diagram Figures	Grade of Service	Equip. List Table No.	Capacity	User	Cost**	Antenna Cost Normalized
A. Reception							
Regional (VSAM) $850 MHz	2-6	No. 1	2-33	One channel	Commercial*	2.0%	40%
National (VSAM) @850 MHz	2-7	No. 1	2-34	Five channels simultaneously	Commercial*	5.0%	20%
Home (VSAM) @ 850 MHz	2-8	No. 3.5	2-35	1 channel	Home	.01%	10%
Regional (FM) @ 4 GHz	2-10	No. 1	2-37	One channel	Commercial*	2.0%	14%
National (FM) @ 4 GHz	2-11	No. 1	2-38	Five channels simultaneously	Commercial*	5.0%	6%
B. Transmission							
Regional (VSAM) @ 1.5 GHz	2-9	No. 1	2-36	One channel	Commercial*	5.0%	20%
National (VSAM) @ 1.5 GHz	---	No. 1	2-36	Transmits three channels simultaneously	Commercial*	13%	7%
Regional FM @ 6 GHz	2-12	No. 1	2-39	One channel	Commercial*	3.0%	10%
National FM @ 6 GHz	---	No. 1	2-40	Transmits three channels simultaneously	Commercial*	5.0%	20%

* Cable head or interfaces with terrestrial microwave for distribution by TV stations.

** The ratio of the particular earth station to the COST MODEL expressed in percent.

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1.3.4 Millimeter Waves

Table 1-8, below, summarizes the link loss factors which are sensitive to frequency. The first of these factors is free space loss. The additional loss factors are system noise, temperature, and propagation loss due to absorption through the atmosphere (rain, clouds, oxygen, and water vapor).

Table 1-8. Link Loss Factors ***

Frequency	4GHz	16GHz	35GHz
Satellite Antenna Gain	constant (constant beamwidth required for coverage)		
Free Space Loss $\left(\frac{\lambda}{4\pi R}\right)^2$ (dB)	197	208.5	215.8
Ground Antenna Gain (dB)			
15-Foot	43	54.5	61.8
30-Foot	49	60.5	67.8
System Noise Temperature (dB)	28 TDA	28 TDA	32 Uncooled Paramp
Propagation Loss Maring (dB)	0.2	3.4	14.3*
Link Availability - 97% (weather only)	0.2	3.4	14.3*
Link Availability - 99%	0.4	10.9**	44.2**

* Due mainly to cloud cover attenuation. These may be reduced when better data on cloud density and coverage statistics is available.

** Use of geographic diversity at ground stations may significantly reduce these values. See Subsection 2.5.

*** These frequencies selected lie in the low propagation attenuation regions between water vapor and oxygen absorption frequencies.

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The first of these factors, free space loss, increases with the square of the wave length. If the size of the earth station antenna remains constant, the increased gain exactly cancels the increase in free space loss. However, comparative antenna costs indicate, for example, that a 15-foot antenna operating at 35 GHz doubles the price of the same size antenna designed for 4 GHz, thus placing an increased economic burden on the earth station. The additional loss factors, system noise, temperature, and propagation loss, can be offset by increasing the gain of the satellite antenna. This action, however, will result in a much narrower beam, thereby sacrificing area coverage. Another consideration toward offsetting these loss factors is to restrict the utilization of millimeter waves to high angles of arrival, thus reducing the effects of the earth's atmosphere.

In brief, extensive use of frequencies above 10 GHz appears promising under certain circumstances, i.e., point coverage, high arrival angles, and possibly geographic diversity. In any event, millimeter waves cannot be considered as a substitute for the better frequency bands below 10 GHz.

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SECTION 2

TECHNICAL DISCUSSION

2.1 SYSTEM PARAMETERS

2.1.1 System Assumptions

In the analysis that follows, the up-link (transmit) and down-link (receive) system trade-off parameters for TV and Communications Services (message operation) will be derived.

The developed equations, tables, and figures will then be utilized as a guide in establishing the engineering and economic design judgements for the various earth station models.

The assumptions used in the calculations are enumerated as required within each appropriate subsection of the analysis. However, some of the salient assumptions are:

a. Only synchronous geo-stationary satellites are considered. The Satellite transponder has an RF bandwidth exeeding 500 MHz, the exception being the color TV service system using Vestigial Sideband Amplitude Modulation (VSAM).

b. The frequencies used in the calculations are primarily the Comsat frequencies (Receive 3700 to 4200 MHz and Transmit 5925 to 6425 MHz). For the case of Vestigial Sideband Amplitude Modulation (TV service), the frequencies used are: receive 818-890 MHz, and transmit 1.5-1.572 GHz. These frequencies have been selected for modeling only; other frequencies in the 0.8 to 10 GHz band are not precluded.

c. All receivers will use either uncooled parametric amplifiers, TDA's, or other RF low-noise amplifiers.

d. The calculations for Preassigned Operation (multi-destination carrier or single destination carrier) use FDM/FM. The modulation technique used for Demand-Assigned Operation (one channel per RF Carrier) and TV broadcast operating in the commerical satellite frequency bands is SCC/FM.

e. Only conventional demodulators (limiter-discriminator) are used for FM demodulation. No Threshold Extension Demodulators are used for FM demodulation, since higher satellite effective isotropic radiated power (EIRP)* is postulated.

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*This is also called equivalent isotropic(ally) radiated power.

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2.1.2 System Parameter Calculations

2.1.2.1 General System Calculations

The discussion which follows is general and applies to all of the earth station models.

a. Path Loss

The classical communications equation* may be used to describe the up-link (the ground transmitter to the satellite) and down-link (the satellite to the ground receiver) path losses. The equation is:

$$\alpha = [\,36.6 + 20 \log f + 20 \log d\,]\ \text{dB} \qquad (2\text{-}1)$$

where

α = free space loss (dB)

d = distance between transmission points (e.g., transmitter and receiver) in miles

f = operating frequency in MHz

Only synchronous quasi-stationary satellite orbits are considered.

Therefore:

d = distance to satellite = 25,500 miles at a 5° slant angle at each end of the path (synchronous quasi-stationary orbit)

The RF frequencies considered and the corresponding path losses are listed in Table 2-1.

b. Antenna Gain

The gain of a parabolic dish is a function of diameter and frequency and is given by

$$G = \eta\ 10^{-5}\ D^2\ f^2 \qquad (2\text{-}2)$$

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*Reference Data for Radio Engineers, International Telephone and Telegraph Corporation, New York, 1956, p. 751.

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Table 2-1. Operating Frequency and Path Loss

Band	RF Frequencies	Path Loss
UHF - TV Reception VSAM Only (Last 12 channels)	818 - 890 MHz	183 dB @ 850 MHz
UHF - TV Transmission VSAM Only 12 channel	1.5 - 1.572 GHz*	188 dB @ 1.54 GHz
Comsat Receive Band FM - TV, Voice etc.	3.7 to 4.2 GHz	197 dB @ 4 GHz
Comsat Transmit Band FM - TV, Voice etc.	5.925 to 6.425 GHz	200 dB @ 6 GHz

*This frequency band has been selected as a frame of reference for model development. This does not preclude the use of other frequency bands in actual practice.

where

G = antenna gain

D = diameter in feet

f = operating frequency in MHz

η = antenna efficiency which is a function of surface tolerance, frequency of operation, aperture blockage, spillover, feedline losses, etc. The antenna efficiency varies from greater than 70 percent for large apertures (85 ft.) to less than 44 percent for smaller diameters (5 ft.). For the analysis that follows, an efficiency of 68 percent will be assumed as a frame of reference (68 percent is achievable for 30-foot dishes or greater).

In terms of dB, Equation (2-2) becomes:

$$G\,(dB) = 10 \log G = [-51.6\ dB + 20 \log D + 20 \log f] \qquad (2\text{-}3)$$

Using the above equation, Table 2-2 is developed showing the antenna gains in dB for the operating frequencies of interest.

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Table 2-2. Gain Over Isotropic Antenna

Antenna Paraboloid Diameter - ft	Efficiency %	Gain (dB)			
		@850 MHz	@1.5 GHz	@4 GHz	@6 GHz
5	68	21.0	26.0	34.5	38.0
8	68	25.0	30.0	38.5	42.0
15	68	30.5	35.5	44.0	47.5
30	68	36.5	41.5	50.0	53.5
40	68	39.0	44.0	52.5	56.0
60	68	42.5	47.5	56.0	59.5
85	68	45.5	50.5	59.0	62.5

c. G/T Ratio

The ratio of receiver-antenna gain G to system noise temperature T of the receiver will hereafter be called the G/T of the earth station. This ratio, which is also referred to as the figure of merit of the earth station, determines the sensitivity of the station. Throughout this discussion G/T is calculated at 5° antenna elevation. in most installations this is the elevation at which the ratio is a minimum and thus represents a worst case condition.

Specifically, G is the gain of the antenna and T is the system noise temperature, in degrees Kelvin (includes the noise figure of the preamplifier, antenna noise temperature, feeds, elevation angle, indigenous noise, etc.)

For the frequencies considered the following representative system noise temperatures will be used:

T_1 = 68° Kelvin (18.3 dB)* - Using cooled parametric amplifier

T_2 = 200° Kelvin (23 dB) - Using uncooled parametric amplifier

T_3 = 630° Kelvin (28 dB) - Using Tunnel Diode Amplifier (TDA)

*10 log T (°K)

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The receiving system sensitivity, or figure-of-merit, G/T is:

$$G/T\ (dB/°K) = G\ (dB) - 10 \log T\ (°K) \qquad (2\text{-}4)$$

where

G = antenna gain in dB

T = system noise temperature in degrees Kelvin

Table 2-3 gives the G/T ratios for typical receiving systems.

Table 2-3. G/T Ratio as a Function of Reflector Size, Frequency, and System Noise Temperature

Reflector Diameter - ft. (η = 68%)	G/T dB/°Kelvin				
	TDA @ T_3		Uncooled Paramp @ T_2		Cooled Paramp @ T_1
	@850 MHz	@4 GHz	@850 MHz	@4 GHz	@4 GHz
85	17.5	31.0	22.5	36.0	40.7
60	14.5	28.0	19.5	33.0	37.7
40	11.0	24.5	16.0	29.5	34.2
30	8.5	22.0	13.5	27.0	31.7
15	2.5	16.0	7.5	21.0	25.7
8	-3.0	10.5	2.0	15.5	20.2
5	-7.0	6.5	-1.0	11.5	16.2

d. Satellite Effective Isotropic Radiated Power (Down-Link)

The Satellite Effective Isotropic Radiated Power (EIRP) is expressed in dBW as:

$$EIRP\ (dBW) = P_t\ (dBW) + G_t\ (dB) \qquad (2\text{-}5)$$

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where

P_t = is the satellite transmitted power in dBW

G_t = is the satellite antenna gain in dB

The received signal strength is given in dBW by the following equation*

$$C = [\,EIRP - \alpha + G\,]\ dBW \qquad (2\text{-}6)$$

where

C = received carrier in dBW

α = path loss in dB.

Substituting T (dB) = 10 log T (°K) (system noise temperature) from both sides of Equation (2-6), we obtain

$$C - 10 \log T\ (°K) = EIRP - \alpha + G = 10 \log T(°K). \qquad (2\text{-}6a)$$

All the terms of Equations (2-6) and (2-6a) are in logarithmic form. Equivalently,

$$C - 10 \log T\ (°K) = 10 \log \frac{c}{T}, \qquad (2\text{-}6b)$$

where

c is now in watts.

To simplify the notation, the following accepted method will be used:

$$\frac{C}{T} = 10 \log \frac{c}{T} = C - 10 \log T\ (°K). \qquad (2\text{-}6c)$$

where

$\frac{C}{T}$ = carrier-to-total thermal noise in dBW/°K

---

*Circular polarization has been assumed, and hence the losses due to Faraday rotation have been neglected.

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Similarly,

$$\frac{G}{T} = 10 \log \frac{g}{T} = G - 10 \log T \ (°K), \qquad \text{(2-6d) (refer to Equation (2-4))}$$

where

g = gain as a ratio*.

Using this simplified notation, we obtain an expression for C/T from Equation (2-6a):

$$\frac{C}{T} = \left[EIRP - \alpha + \frac{G}{T} \right] \ dBW/°K \qquad (2-7)$$

Solving for EIRP we obtain

$$EIRP = \left[(\alpha + \frac{C}{T}) - G/T \right] \ dBW \qquad (2-8)$$

Examining Equation (2-8) we note that (α + C/T) is a constant depending on the grade of performance and α is determined by the path distance and operating frequency. Therefore, once (α + C/T) is established, the economic and performance trade-off between EIRP and G/T becomes evident. More will be said of this in the discussion that follows.

e. Up-Link (Earth Station Transmitter Power)

The received carrier level at the satellite (the preamplifier input) may be determined by adding the system gains to the transmission losses. Circular polarization is assumed and hence losses due to Faraday rotation can be neglected. The equation for the received carrier level in dBW for the up-link is:

$$C_u = [Ptg + G + G_t - \alpha] \ dBW \qquad (2-9)$$

*The notation derived in Equations (2-6c) and (2-6d) is an accepted form for expressing a ratio in dB. Elsewhere in this report this notation is used for other ratios, such as C/N and S/N.

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where

C_u = carrier level on up-link dBW

Ptg = ground transmitter power dBW

G = ground antenna gain

G_t = is the satellite antenna gain.

In terms of Carrier-to-Noise ratio, Equation (2-9) is modified as follows:

$$(C/N)_u = [\, Ptg + G + G_t - \alpha - N \,] \text{ dB} \qquad (2\text{-}10)$$

where

N = 10 log n in dBW

and

$$n = kT\, B_{if}$$

where

k = Boltzmann Constant 1.38×10^{-23} joules/°K

T = system noise temperature

2.1.2.2 Color TV Service

The TV performance using vestigial sideband amplitude and frequency modulation will be derived. Using these results the parameters for the earth terminals will be developed.

Vestigial sideband amplitude modulation will be used for UHF operation only (receive 818 to 890 MHz - transmit 1.5 to -.572 GHz). The audio program is on an FM subcarrier above the TV video information. The baseband frequency spectrum for TV video and TV audio is approximately 5 MHz.

FM operation will be used in the commercial satellite frequency bands (receive 3.7 to 4.2 GHz and transmit 5.925 to 6.425 GHz). A separate RF carrier for the TV video and program information is assumed. The audio (program) channel capacity is 24 voice channels (FDM/FM). The possibility of sending the program information

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above the video information via a subcarrier has not been considered; however, this approach should be considered, as it would eliminate an extra RF carrier. Use of the former approach is in accord with current INTELSAT practice.

Table 2-4 shows the TASO* TV performance for Service Grades 1 through 6. The table is based upon subjective evaluations by viewers observing a TV monitor.

Table 2-4. TASO TV Performance Characteristics*

Grade	Median Observer Signal-to-Interference Ratio (dB)	Impairment	Quality
1	44.5	None	Excellent
2	34	Perceptible	Fine
3	27	Not Objectionable	Passable
4	23	Somewhat Objectionable	Marginal
5	17	Definitely Objectionable	Inferior
6	-	——	Unusable

*G.L. Fredendall and W.L. Behrend, "Picture Quality - Procedures for Evaluating Subjective Effects of Interference," Proc. IRE, Vol. 48, pp. 1030-1034; June, 1960.
C.E. Dean, "Measurements of the Subjective Effects of Interference in Television Reception," Proc. IRE, Vol. 48, pp. 1035-1049; June, 1960.

For reception to cable heads (CATV) or interfacing with terrestrial microwave links for TV distribution, a peak-to-peak signal-to-rms noise ratio $(S/N)_o$ of 53dB has been selected as a representative value. This value allows for noise degradation by the terrestrial equipment, thus making it possible for the user to receive Grade 1 performance. The demodulated baseband of the earth station has a format similar to that which is currently used in terrestrial microwave terminals.

For reception directly to the home, a peak-to-peak signal-to-rms noise ratio $(S/N)_o$ of 33dB has been selected as a representative value, thereby making possible Grade 3 or better performance to the user.

The preamplifier used in the satellite is a TDA. A representative system noise temperature of 1000° Kelvin (30 dB) will be assumed.

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*Television Allocations Study Organization.

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Equation (2-10) will be used in calculating the earth terminal transmission (transmitter) requirements.

a. Vestigial Sideband Amplitude Modulation (VSAM)

(1) TV Video Reception (818 to 890 MHz)

The VSAM equation for TV video reception is:

$$(S/N)_o = \frac{W}{K}\left(\frac{C}{N}\right) = \frac{1}{K}\,\frac{C}{kTB_{if}}W \text{ (for high C/N ratio case)} \quad (2\text{-}11)$$

where

$(S/N)_o$ = output peak-to-peak signal-to-rms noise in dB

K = constant which depends on the detector efficiency and fade margin (assume K = 6 dB)

T = Equivalent receive temperature °Kelvin

k = Boltzmann constant 1.38×10^{-23} joules/°K (-228.4 dBW)

C = receiver rms carrier in dBW

B_{if} = IF Bandwidth (1.25 fm) ≈ 6 MHz (nominal television bandwidth with video and TV audio); fm ≈ 4.8 MHz upper baseband frequency

W = crest factor for the video carrier - peak-to-peak to rms (assume = 9 dB)*

∴ Substituting in Equation (2-11) and converting to dB yields:

$$(S/N)_o = \left(\frac{C}{T} - K + W + 160.4\right)\text{dB} \quad (2\text{-}12)$$

But

K = 6 dB and W = 9 dB.

*W can vary from 9 to 13 dB, since the signal exhibits noise-like characteristics.

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Therefore:

$$(S/N)_o = \frac{C}{T} + 163.4 \qquad (2\text{-}13)$$

Only $(S/N)_o$ = 53 dB and $(S/N)_o$ = 33 dB are considered. Calculation of the carrier-to-total noise temperature ratio (C/T — dBW/°K) using Equation (2-13) yields Table 2-5.

Table 2-5. VSAM Performance C/T Ratio for $(S/N)_o$ = 53 dB and 33 dB

	$(S/N)_o$ = 53 dB	$(S/N)_o$ = 33 dB
C/T dBW/°K	-110.4	-130.4

EIRP versus G/T ratio at 850 MHz is calculated for the two $(S/N)_o$'s using Equation (2-8), which is repeated here:

$$EIRP = [\,(\alpha + C/T) - G/T\,]\ dBW, \qquad (2\text{-}14)$$

where

$$\alpha = 183\ dB\ @\ 850\ MHz\ (From\ Table\ 2\text{-}1.) \qquad (2\text{-}15)$$

Therefore, we obtain Table 2-6.

Table 2-6. The Equations of EIRP as Function of G/T Using $(S/N)_o$ as a Fixed Parameter (VSAM)

Frequency of Operation	$(S/N)_o$ = 53 dB	$(S/N)_o$ = 33 dB
850 MHz	EIRP = (72.6 - G/T) dBW	EIRP = (52.6 - G/T) dBW

Using the equations derived in Table 2-6, the required EIRP for various G/T ratios for both $(S/N)_o$'s can be calculated. Tables 2-7 and 2-8 are sample calculations at 850 MHz. Graphical presentations of these tables are shown in Figures 2-1 and 2-2. These figures illustrate the system trade-offs between EIRP and G/T for the given grades of performance.

The earth station low-noise receivers (LNR) considered in the calculations were uncooled parametric amplifiers and TDA's.

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Table 2-7. Performance VSAM @ 850 MHz
$(S/N)_o$ = 53 dB for C/T = 110.4 dBW/°K
EIRP = (72.6 - G/T) dBW

EIRP dBW	Antenna Diameter ft	Gain* eff. = 68% dB	Effective Noise Temp. °K	G/T** dB/°K	Remarks
50.1	85	45.5	200 °K (23 dB)	22.5	Uncooled Paramp
53.1	60	42.5	200 °K (23 dB)	19.5	Uncooled Paramp
56.6	40	39.0	200 °K (23 dB)	16.0	Uncooled Paramp
59.1	30	36.5	200 °K (23 dB)	13.5	Uncooled Paramp
65.1	15	30.5	200 °K (23 dB)	7.5	Uncooled Paramp
55.1	85	45.5	630 °K (28 dB)	17.5	TDA
58.1	60	42.5	630 °K (28 dB)	14.5	TDA
61.6	40	39.0	630 °K (28 dB)	11.0	TDA
64.1	30	36.5	630 °K (28 dB)	8.5	TDA
70.1	15	30.5	630 °K (28 dB)	2.5	TDA

*From Table 2-2
**From Table 2-3

Table 2-8. Performance VSAM @ 850 MHz
$(S/N)_o$ = 33 dB for C/T = 124.4 dBW/°K
EIRP = (52.6 - G/T) dBW

EIRP dBW	Antenna Diameter ft	Gain* eff. - 68% dB	Effective Noise Temp. °K	G/T** dB/°K	Remarks
30.1	85	45.5	200 °K (23 dB)	22.5	Uncooled Paramp
33.1	60	42.5	200 °K (23 dB)	19.5	Uncooled Paramp
36.6	40	39.0	200 °K (23 dB)	16.0	Uncooled Paramp
39.1	30	36.5	200 °K (23 dB)	13.5	Uncooled Paramp
35.1	15	30.5	200 °K (23 dB)	7.5	Uncooled Paramp
35.1	85	45.5	630 °K (28 dB)	17.5	TDA
38.1	60	42.5	630 °K (28 dB)	14.5	TDA
41.6	40	39.0	630 °K (28 dB)	11.0	TDA
44.1	30	36.5	630 °K (28 dB)	8.5	TDA
50.1	15	30.5	630 °K (28 dB)	2.5	TDA
59.6	5	21.0	630 °K (28 dB)	-7.0	TDA

*From Table 2-2
**From Table 2-3

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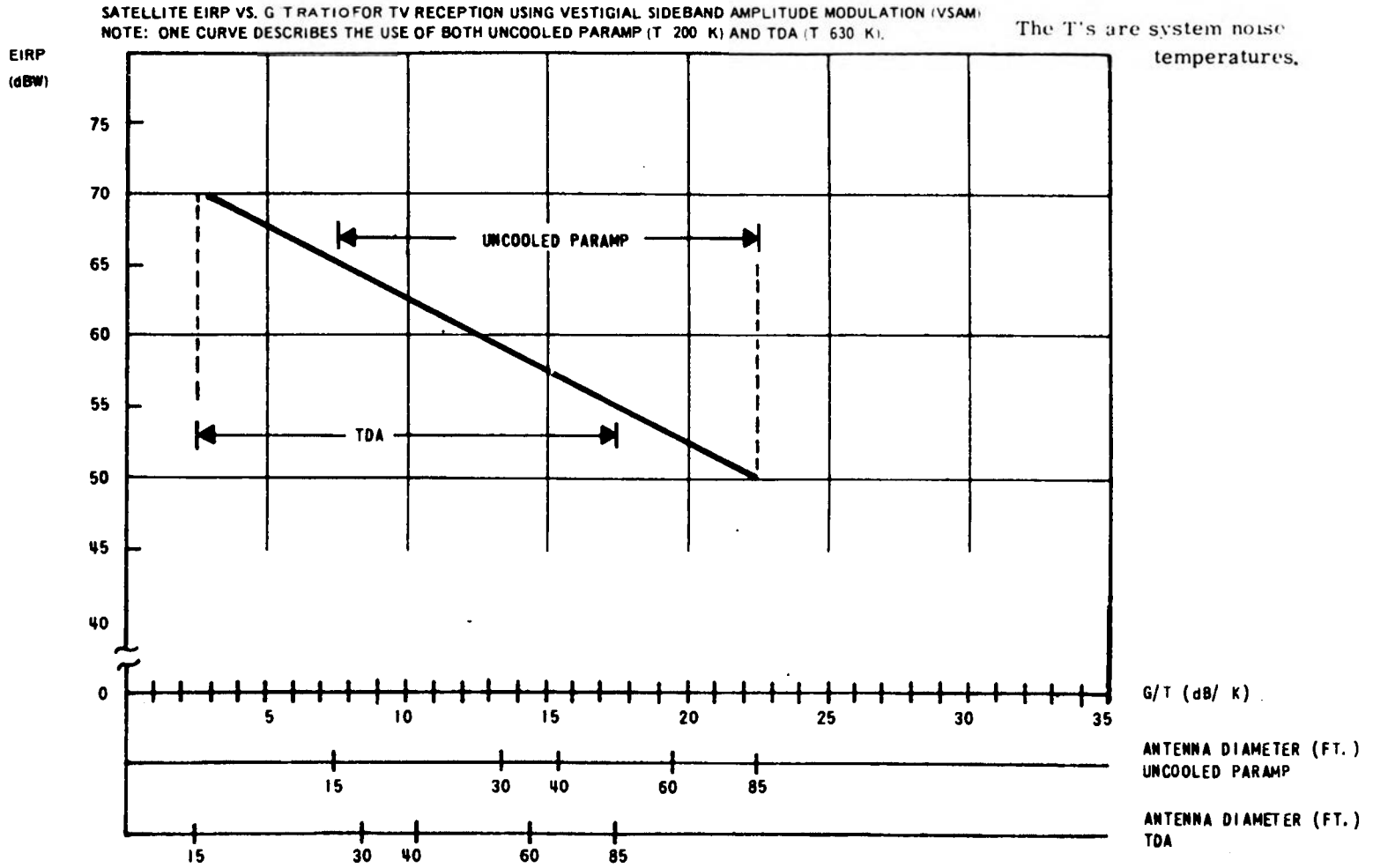


Figure 2-1. EIRP Versus G/T-VSAM @ 850 MHz, $(S/N)_o$ = 53 dB

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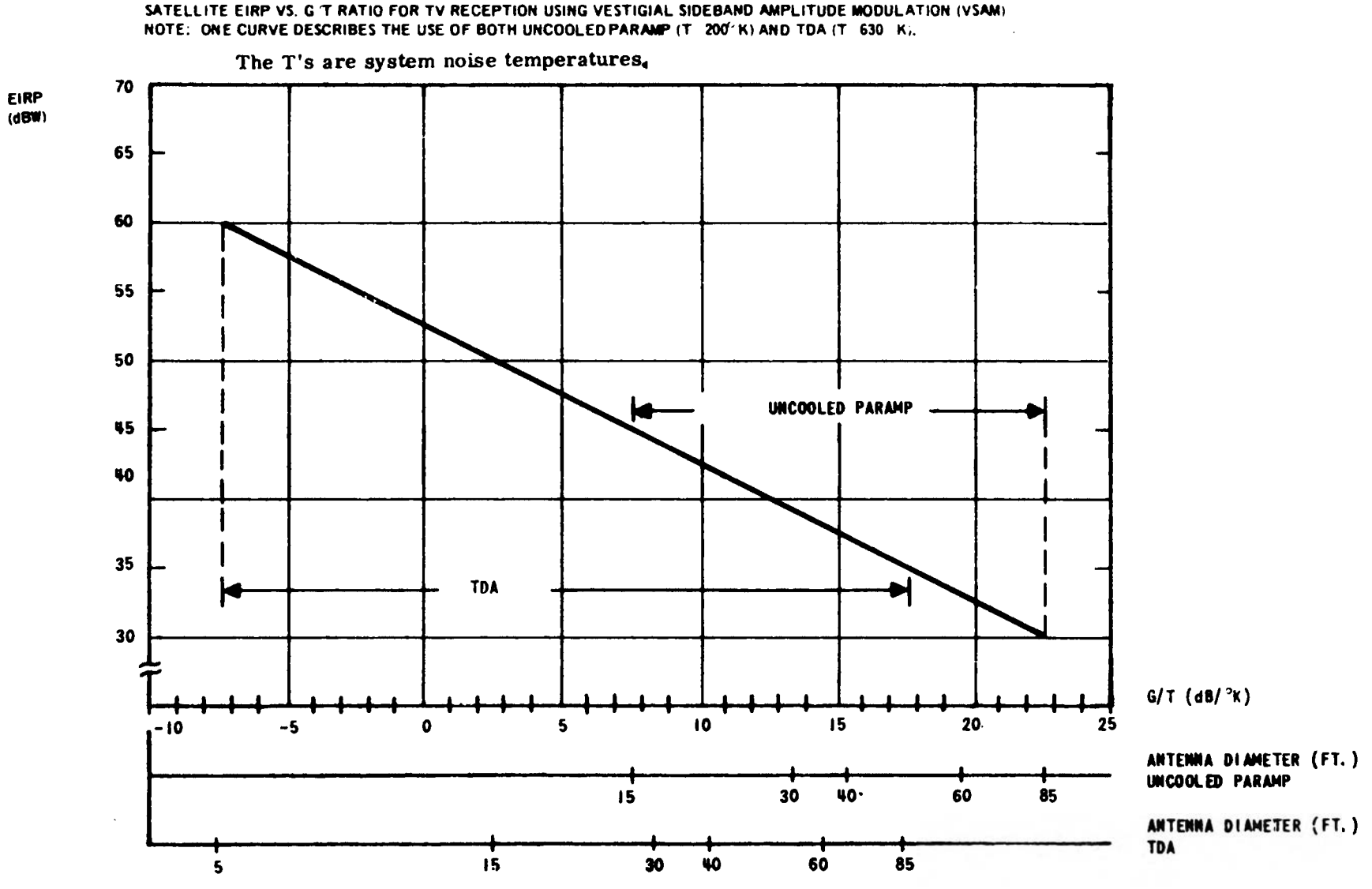


Figure 2-2. EIRP Versus G/T-VSAM @ 850 MHz, $(S/N)_o$ = 33 dB

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(2) TV Audio Reception

The TV Audio information is transmitted on an FM subcarrier at 4.5 MHz. Assume that the subcarrier FM deviation is 100 kHz peak-to-peak, and that the highest audio frequency is 15 kHz. Furthermore, assume that the first demodulation is linear, and that the TV audio is separated from the composite baseband (TV video and TV audio) via a bandpass filter located at 4.5 MHz with a bandwidth of 250 kHz nominal, followed by an FM demodulator (limiter discriminator). Then the signal-to-noise ratio of the demodulated audio is given by the following equation:

$$(S/N) = \left(\frac{C}{N}\right)' \left(\frac{B_{if}}{B_{if_2}}\right) \frac{3}{2} \left(\frac{f}{f_m}\right)^2 \left(\frac{B_{if_2}}{f_m}\right) \qquad (2\text{-}16)$$

where

(S/N) = output signal-to-rms noise

f = 25 kHz peak deviation

f_m = 15 kHz

B_{if_2} = 100 kHz (post second predetection bandwidth)

B_{if} = 6 MHz (post predetection bandwidth VSM detector)

$(C/N)'$ = rms carrier-to-rms noise ratio

Converting Equation (2-16) into decibels we obtain:

$$(S/N)_{audio} = \left(\frac{C}{N}\right)' \text{dB} + 10 \log\left(\frac{3}{2}\right) + 20 \log\left(\frac{f}{f_m}\right) + 10 \log\left(\frac{B_{if}}{f_m}\right) \qquad (2\text{-}17)$$

Solving the above equation for $(S/N)_{audio}$ in terms of $(C/N)'$ and using the above values for f, f_m, and B_{if}, we obtain:

$$(S/N)_{audio} = (C/N)' \text{ dB} + 32.2 \text{ dB} \qquad (2\text{-}18)$$

This equation can be related to the $(S/N)_{o\ video}$ as follows:

$$(C/N)' = (C/N) \text{ dB} - 9 \text{ dB}^* \qquad (2\text{-}19)$$

*Peak-to-peak-to-rms signal ratio (crest factor).

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But from Equation (2-11), we have:

$$(S/N)_{o\ video} = C/N + 3\ dB$$

Using Equation (2-19) and the above equation, we can solve for (C/N)':

$$(C/N)' = (S/N)_{o\ video} - 12\ dB.$$

Using Equation (2-18), we obtain:

$$(S/N)_{audio} = (S/N)_{o\ video} + 20.2\ dB \qquad (2\text{-}20)$$

Obviously, the $(S/N)_o$ video is the parameter of greater concern, since $(S/N)_{audio}$ exceeds $(S/N)_{o\ video}$ by a considerable amount (+20.2 dB). Thus, in specifying the model parameters for receive and transmit earth stations, we shall concern ourselves only with the TV video performance.

(3) TV Transmission (1.5 to 1.572 MHz)

The equation relating ground terminal transmitter power (P_{tg}) versus ground and satellite antenna gain will be derived.

Converting Equation (2-11) to dB, we obtain:

$$(S/N)_o = [\,W - K + C/N\,]\ dB \qquad (2\text{-}21)$$

But

$$(S/N)_o = 53\ dB \text{ and } W\text{-}K = 3\ dB$$

Therefore

$$(C/N)_D = 50\ dB \text{ (down-link)}$$

However, since we are concerned with the up-link carrier-to-noise ratio $(C/N)_U$, an additional 10 dB will be added to $(C/N)_D$. Thus

$$(C/N)_U = (C/N)_D + 10\ dB \qquad (2\text{-}22)$$

or

$(C/N)_U$ = 60 dB (the received carrier-to-noise ratio at the satellite receiver input.)

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The effect of adding the 10 dB to $(C/N)_D$ is to minimize the thermal noise contribution of the up-link path (ground to the satellite).

Equation (2-10) is repeated here:

$$(C/N)_U = \left[P_{tg} + G + G_t - \alpha - N \right] \text{ dB}$$

But

$$N = 10 \log n = -130.6 \text{ dBW},$$

where

$$n = kTB_{if} \text{ but } (B_{if} = 6 \text{ MHz})$$

$$(T = 1000\,^{\circ}\text{K})^*$$

and

$$\alpha = 188 \text{ dB @ } 1.54 \text{ GHz (From Table 2-1.)}$$

Thus solving for P_{tg} and substituting the known values, we obtain:

$$P_{tg} = [\, 117.4 - (G + G_t) \,] \text{ dBW} \qquad (2\text{-}23)$$

Equation (2-23) shows the system trade-off between P_{tg} and the hop (up-link) antenna gains $(G + G_t)$

b. Frequency Modulation

(1) TV Video Reception (3.7 to 4.2 GHz)

The FM equation for TV video reception is:

$$(S/N)_o = \frac{C}{N} \frac{3}{2} \left(\frac{f_p}{f_m} \right)^2 \left(\frac{B_{if}}{f_m} \right) \text{ WP} \qquad (2\text{-}24)$$

*System noise temperature of the satellite receiver.

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where

$(S/N)_o$ = peak-to-peak signal-to-rms noise in dB

f_p = peak frequency deviation MHz

f_m = nominal television bandwidth--assume 4.5 MHz

C = RF carrier level in dBW

k = Boltzmann's constant 1.38×10^{-23} joules/°K (-228.4 dBW)

T = equivalent receive temperature °Kelvin

W = relationship between peak-to-peak and rms signal, 13 dB*

P = emphasis, +3 dB

B_{if} = $2 (f_p + f_m)$--Predetection IF bandwidth (Carson's Rule)

N = kTB_{if} - Boltzmann's Equation

Since a conventional FM demodulator is assumed, the validity of Equation (2-24) depends on carrier-to-noise ratio (C/N) exceeding 10 dB, which is the typical FM threshold point. Therefore, C/N = 16 dB will be assumed, allowing for 4 to 6 dB of rain margin.

Only TV distribution ($(S/N)_o$ = 53 dB) will be considered here. Using this assumption, the peak deviation f_p will be calculated for this grade of service.. Knowing the peak deviation, the IF bandwidth B_{if} and the C/T ratio can be derived.

To simplify the calculation and the solving of a cubic equation, the following assumption will be made:

$$B_{if} \approx 2 f_p$$

$$\therefore (S/N)_o \approx \frac{C}{N} 3 \left(\frac{f_p}{f_m}\right)^3 WP \qquad (2\text{-}25)$$

*W can vary from 9 to 13 dB, since the signal exhibits noise-like characteristics.

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Let $M = \left(\frac{f_p}{f_m}\right)$ modulation index

Thus, converting Equation (2-25) to dB, and solving for M, we get:

$$10 \log M^3 = (S/N)_o \text{ dB} - \left(\frac{C}{N}\right)\text{dB} - 10 \log 3 - 16 \text{ dB} \qquad (2\text{-}26)$$

For Grade 1, C/T = ?

Using Equation (2-26) and $(S/N)_o$ = 53 dB we obtain:

$$10 \log M^3 = 16 \text{ dB}$$

$$M^3 = 40$$

$$\therefore M = 3.42 = \left(\frac{f_p}{f_m}\right)$$

Solving for f_p

$$f_p = 3.42 \times 4.5 = 15.2 \text{ MHz}$$

$$\therefore B_{if} = 2(15.2 + 4.5) = 39.4 \text{ MHz}$$

B_{if} = 40 MHz* and f_p = 15.2 MHz* will be used.

Thus

$$C/T = [\, C/N + 10 \log kB_{if} \,] \text{ dBW/°K}$$

$$C/T = -136.4 \text{ dBW/°K}$$

Substituting the calculated value for (C/T) in Equation (2-7) and referring to Table 2-1 for the path loss (α), the equation relating satellite EIRP versus G/T ratio is now developed. (See Table 2-9).

*Substitution of these assumed values into Equation (2-24) yields $(S/N)_o$ = 52.6 dB ≈ 53 dB.

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Table 2-9. Satellite EIRP as Function of G/T at 4 GHz for $(S/N)_o$ = 53 dB

Frequency of Operation	$(S/N)_o$ = 53 dB
4 GHz	EIRP = $(60.6 - \frac{G}{T})$ dBW

Table 2-10 is a sample calculation performed at 4 GHz for $(S/N)_o$ = 53 dB using the equation contained in Table 2-9.

A graphical presentation of Table 2-10 is shown in Figure 2-3. This figure illustrates the system trade-off between Satellite EIRP and G/T for the given grade of performance.

The figure also shows the maximum flux density allowed by current CCIR Standards (Recommendation 358, Oslo 1966).*

(2) TV Audio Reception (3.7 to 4.2 GHz)

A separate RF carrier for TV audio (program) is assumed. Its capacity is equivalent to 24 voice channels, and its performance requirements are discussed in Paragraph 2.1.2.3.a.

In Paragraph 2.1.2.3.a, it will be shown that the C/T ratio for audio is much lower than that for the TV video; hence, it will require a lower satellite EIRP. The TV video requirements will thus predominate in the choice of antenna size and low noise receiver type.

(3) TV Video Transmission (5.925 - 6.425 GHz)

The equation relating ground station transmitter power (P_{tg}) versus total (station plus satellite) antenna gain ($G + G_t$) will be derived.

In order to minimize the thermal contribution of the up-link path (ground to the satellite), 10 dB will be added to the carrier-to-noise ratio $(C/N)_D$ used in the down-link calculation (satellite to the ground). Therefore,

$$(C/N)_U = (C/N)_D + 10 \text{ dB} \qquad (2\text{-}27)$$

*For a 5° elevation angle at synchronous orbit the maximum flux density = 9.9 dBW/4kHz. For $(S/N)_o$ = 53 dB, flux density = 49.9 dBW/40 MHz

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where

$(C/N)_U$ = up-link carrier-to-noise ratio at the satellite receiver input.

But

$(C/N)_D$ = 16 dB (value used in paragraph 2.1.2.2.b(1))

Therefore, substituting in Equation (2-27), we obtain:

$$(C/N)_U = 26 \text{ dB}$$

Equation (2-10) is repeated here:

$$(C/N) = \left[P_{tg} + G + G_t - \alpha - N \right] \text{ dB}$$

But

$$N = 10 \log n$$

where

$$n = kT\, B_{if} \quad (B_{if} = 40 \text{ MHz}, \; T = 1000^\circ \text{K})$$

$$\therefore N = -122.4 \text{ dBW}$$

and

$$\alpha = 200 \text{ dB @ 6 GHz (From Table 2-1)}$$

Thus, solving for P_{tg} and substituting the above values into the Equation (2-10), we obtain:

$$P_{tg} = \left[103.6 - (G + G_t) \right] \text{ dBW} \qquad (2\text{-}28)$$

Equation (2-28) shows the system trade-off between P_{tg} and the hop (up-link) antenna gains $(G + G_t)$.

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Table 2-10. Performance FM Video @ 4 GHz; $(S/N)_o$ = 53 dB for C/T = 136.4 dBW/°K; EIRP = (60.6 - G/T) dBW

EIRP dBW	Antenna Diameter ft	Gain * eff. = 68% dB	Effective Noise Temp. °K	G/T** dB/°K	Remarks
24.6	85	59.0	200°K (23 dB)	36.0	Uncooled Paramp
27.6	60	56.0	200°K (23 dB)	33.0	Uncooled Paramp
31.1	40	52.5	200°K (23 dB)	29.5	Uncooled Paramp
33.6	30	50.0	200°K (23 dB)	27.0	Uncooled Paramp
39.6	15	44.0	200°K (23 dB)	21.0	Uncooled Paramp
45.1	8	38.5	200°K (23 dB)	15.5	Uncooled Paramp
29.6	85	59.0	630°K (28 dB)	31.0	TDA
32.6	60	56.0	630°K (28 dB)	28.0	TDA
36.1	40	52.5	630°K (28 dB)	24.5	TDA
38.6	30	50.0	630°K (28 dB)	22.0	TDA
44.6	15	44.0	630°K (28 dB)	16.0	TDA
50.1	8	38.5	630°K (28 dB)	10.5	TDA

*From Table 2-2
**From Table 2-3

(4) TV Audio Transmission (5.925 to 6.425 GHz)

A separate RF carrier is postulated for the transmission of the audio information. Its capacity is 24 voice channels and its allocated spectrum bandwidth is 3 MHz (from the analysis in Section 2.1.2.3.)

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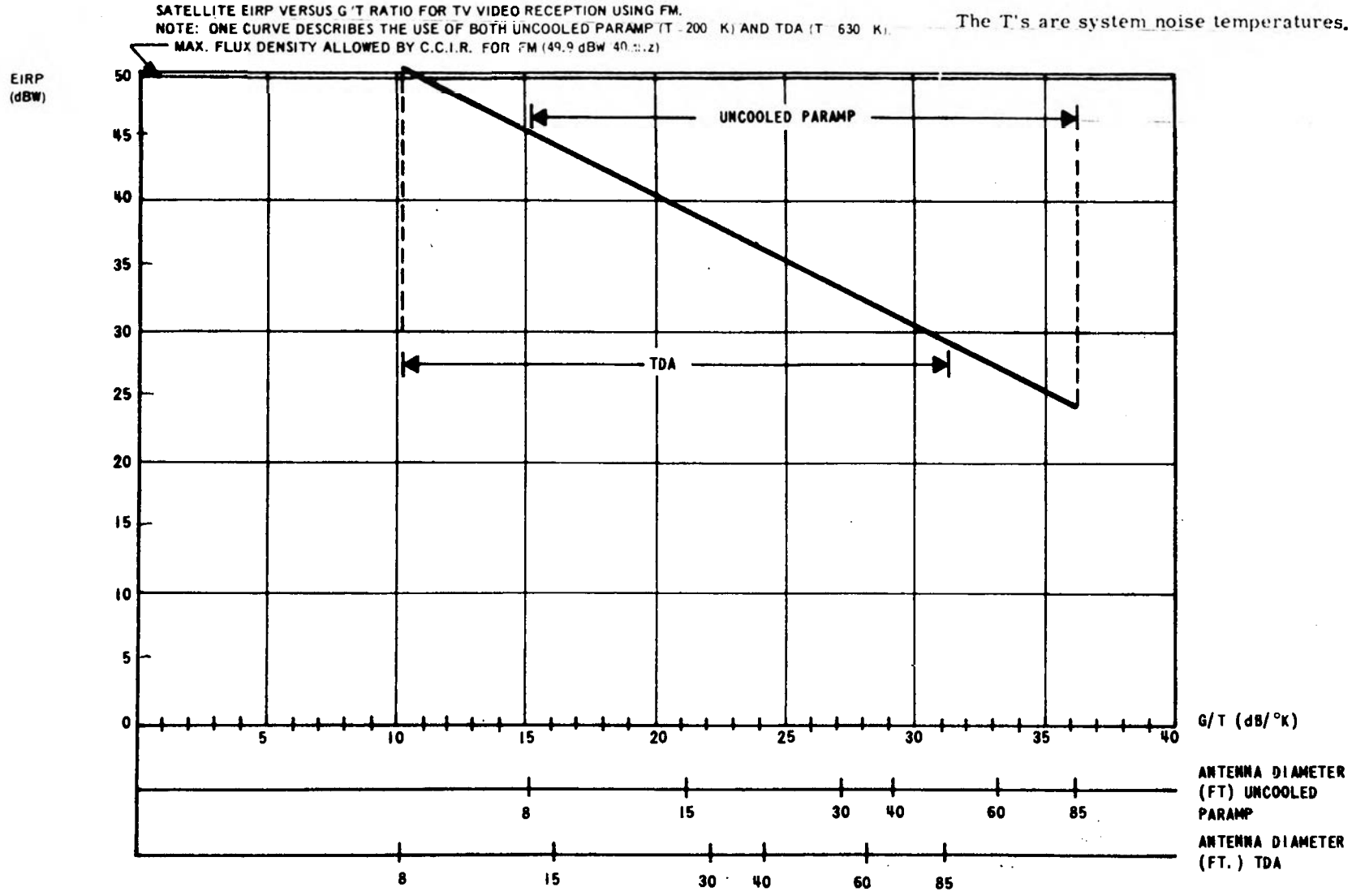


Figure 2-3. EIRP Versus G/T-FM Video @ 4 GHz, $(S/N)_o$ = 53 dB

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Performing a calculation similar to what was performed previously in Paragraph 2.1.2.2.b (3) of this Section, the Equation (2-28) is modified. We obtain:

$$P_{tg} = \left[91.4 - (G + G_t) \right] \text{ dBW} \qquad (2\text{-}29)$$

A common antenna and high power amplifier (HPA) are used for transmission for the TV Video and TV Audio Information. Examination of Equations (2-28) and (2-29) reveals that the TV video requirements predominate, and thus it dictates the choice of antenna size and HPA power output.

2.1.2.3 Communications Service

The Satellite Communications Service has duplex capability, as opposed to the Broadcast Service, which is one-way.

Frequency Modulation is used for both Preassigned and Demand-Assigned operation. The commercial satellite frequency bands (receive 3.7 to 4.2 GHz and transmit 5.925 to 6.425 GHz) will be used in the analysis. Also, only conventional (limiter-discriminator) demodulators are considered. The per-channel test tone deviation used will be 200 kHz rms maximum. This deviation used complements current CCIR standards for Terrestrial LOS Microwave links using FDM/FM. Therefore, in the case of FDM/FM, the effect will be a "softer" modulation as compared to current ICSC deviation requirements.

The Preassigned Model will use FDM/FM modulation with 24, 60, 132, 300 and 600 voice capacity per RF carrier. In the calculations that follow, the output signal-to-noise ratio (S/N) in an FDM/FM voice channel will be of toll quality (52 to 53 dB psophometrically weighted).

The Demand-Assigned Model will use a separate carrier for each voice channel. The modulation technique used is SCC/FM*. An RF spectrum of 100 kHz will be assigned to each message carrier. The (S/N) will be of toll quality.

The performance parameters and trade-offs, C/T versus number of voice channel, satellite EIRP versus G/T, earth station transmitter power versus total system antenna gain, etc. for both models will be calculated and used in the development of the specific earth station models. In connection with the Demand Assigned, only the analog voice channel will be analyzed.

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*Single Channel Carrier/Frequency Modulation

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a. Preassigned

(1) FDM/FM Reception (Down-Link) (3.7 to 4.2 GHz)

(a) Performance - Message Calculation

The FM equation as simplified for narrowband systems is

$$(S/N) = \frac{C}{N}\left(\frac{d\ rms}{f\ max}\right)^2 \frac{B_{if}}{bc}\ WP \qquad (2\text{-}30)$$

where

(S/N) = signal-to-rms noise ratio

D = peak deviation kHz

drms = rms single channel deviation

(C/N) = carrier-to-noise ratio in dB

fmax = maximum modulation frequency (kHz)

$B_{if} \approx 2\ (D + f_m)$ MHz

bc = voice channel bandwidth (3.1 kHz)

W = psophometric weighting factor (+2.5 dB)

P = emphasis (+4 dB)

L = CCIR loading plus peak factor

Expressing Equation (2-31) in dB form, we obtain

$$(S/N)\ dB = \left(\frac{C}{N}\right)dB + 20\log\left(\frac{d\ rms}{f\ max}\right) + 10\log\left(\frac{B_{if}}{bc}\right) + W + P \qquad (2\text{-}31)$$

The following is assumed:

(S/N) dB $\geq$ 52 dB (PSO)

peak factor = 13 dB

drms = 200 kHz for n = 60, 132, 300, or 600 voice channels

drms = 140 kHz for 24 voice channels

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Using Equation (2-31) and the above assumptions, the peak factor, the IF bandwidth (B_{if} nominal), the carrier-to-noise ratio (C/N), and the C/T ratio have been determined and tabulated (See Table 2-11).

(b) Satellite EIRP Requirements Per RF Carrier

Substituting the calculated values for (C/T) (see Table 2-11) into Equation (2-7) and referring to Table 2-1 for the path loss (α), the equations relating EIRP versus G/T ratio are developed, (refer to Table 2-12).

Table 2-13 contains sample calculations of satellite EIRP versus (G/T) for 24, 132, and 600 voice channels using the equations listed in Table 2-12.

A graphical presentation of Table 2-13 is shown in Figure 2-4. This Figure illustrates the system trade-offs between EIRP and G/T, using uncooled parametric amplifiers and TDA's.

Figure 2-4 also shows the maximum flux density allowed by current CCIR Standards* (Recommendation 358, Oslo 1966).

(2) FDM/FM Transmission (Up-Link) (5.925 to 6.425 GHz)

The equations relating ground station transmitter power (P_{tg}) versus total antenna gain (Terminal (G) plus Satellite (G_t)) will be derived.

In order to minimize the thermal contribution of the up-link path (ground to the satellite), 10 dB will be added to the carrier-to-noise ratio $(C/N)_D$ used in the down-link calculation (Satellite to the ground).

Therefore, repeating Equation (2-27), we have:

$$(C/N)_U = (C/N)_D + 10 \text{ dB},$$

---

*For a 5° elevation angle at synchronous orbit the maximum flux density = 9.9 dBW/4 kHz, or

For n = 24 voice channels
flux density = 38.7 dBW/3 MHz
n = 132 voice channels
flux density = 42.2 dBW/7 MHz
n = 600 voice channels
flux density = 45.6 dBW/15 MHz

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Table 2-11. FDM/FM Message Performance @ 4 GHz

Carrier Capacity Voice Channels	24	60	132	300	600
Baseband Frequency Range in kHz	12-108	12-252	12-552	60-1300	60-2600
Multichannel Loading, dB (CCIR)*	4.5	6.1	7.5	9.7	13
Peak Loading L = CCIR Loading +13 dB	17.5 dB (7.5)	19.1 dB (9)	20.5 dB (10.5)	22.7 dB (12.6)	26 dB (20)
4 kHz rms deviation in kHz (drms)	140	200	200	200	200
Peak Carrier Deviation in kHz (f x antilog $\frac{L}{20}$)	±1050	±1800	±2100	±2500	±4000
B_{if} in MHz Nominal	3.0	5.0	7.0	10	15
20 log $\left(\frac{drms}{fm}\right)$, dB	2.0	-2.0	-9	-16.3	-22
10 log $\left(\frac{Bif}{bc}\right)$, dB	29.8	32	34	35	37
(C/N), dB	13.7	15.5	20.5	26.8	31.5
will use (C/N) dB	15	16	21	27	31.5
(S/N) (PSO) dB	53	52.5	52.5	52.2	53
C/T dBW/^{o}K	-148.4	-145.4	-138.9	-131.4	-124.9

*It is recognized that future traffic trends will show a substantial increase in digital data traffic for both domestic and international communications links. Thus, modification to the loading factor is anticipated.

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Table 2-12. FDM/FM Message Performance @ 4 GHz

Satellite EIRP as a Function of G/T
For 4 GHz and (S/N) = 52 to 53 dB (PSO)

No. of Voice Channels	C/T dBW/°K	α @4 GHz dB	Equation
24	-148.4	197	EIRP = (48.6 - G/T) dBW
60	-145.4	"	EIRP = (51.6 - G/T) dBW
132	-138.9	"	EIRP = (58.1 - G/T) dBW
300	-131.4	"	EIRP = (65.6 - G/T) dBW
600	-124.9	"	EIRP = (72.1 - G/T) dBW

where

$(C/N)_U$ = Up-link carrier-to-noise ratio at the satellite receiver input

Table 2-14 is the tabulation of $(C/N)_U$ as a function of voice channel loading using the above equation (2-27) (Table 2-11 was used in finding the values for $(C/N)_D$).

Equation (2-10) is repeated here:

$$(C/N)_U = \left[P_{tg} + G + G_t - \alpha - N \right] \text{ dB},$$

where

$N = 10 \log kT^* B_{if}$

and

α = 200 dB @ 6 GHz (From Table 2-1).

*Assume T = 1000°K of the Satellite

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Table 2-13. FDM/FM Performance (Preassigned Operation)
(S/N) = 52 to 53 dB @ 4 GHz

n = 24 VC EIRP = (48.6 - G/T) dBW
n = 132 VC EIRP = (58.1 - G/T) dBW
n = 600 VC EIRP = (72.1 - G/T) dBW

EIRP dBW			Antenna Diameter ft	Gain* η= 68%	System Noise Temp.	G/T** dB/°K	Remarks
n=24	132	600					
12.6	22.1	36.1	85	59.0	200°K (23 dB)	36.0	Uncooled Paramp
15.6	25.1	39.1	60	56.0	200°K (23 dB)	33.0	Uncooled Paramp
19.1	28.6	42.6	40	52.5	200°K (23 dB)	29.5	Uncooled Paramp
21.6	31.1	45.1	30	50.0	200°K (23 dB)	27.0	Uncooled Paramp
27.6	37.1	51.1	15	44.0	200°K (23 dB)	21.0	Uncooled Paramp
33.1	42.6	56.6	8	38.5	200°K (23 dB)	15.5	Uncooled Paramp
17.6	27.1	41.1	85	59.0	630°K (28 dB)	31.0	TDA
20.6	30.1	44.1	60	56.0	630°K (28 dB)	28.0	TDA
24.1	33.6	47.6	40	52.5	630°K (28 dB)	24.5	TDA
26.6	36.1	50.1	30	50.0	630°K (28 dB)	22.0	TDA
32.6	42.1	56.1	15	44.0	630°K (28 dB)	16.0	TDA
38.1	47.6	61.6	8	38.5	630°K (28 dB)	10.5	TDA

* From Table 2-2
**From Table 2-3

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NOTE: ONE CURVE DESCRIBES THE USE OF BOTH UNCOOLED PARAMP (T=200°K) AND TDA (T=630°K)
The T's are system noise temperatures.

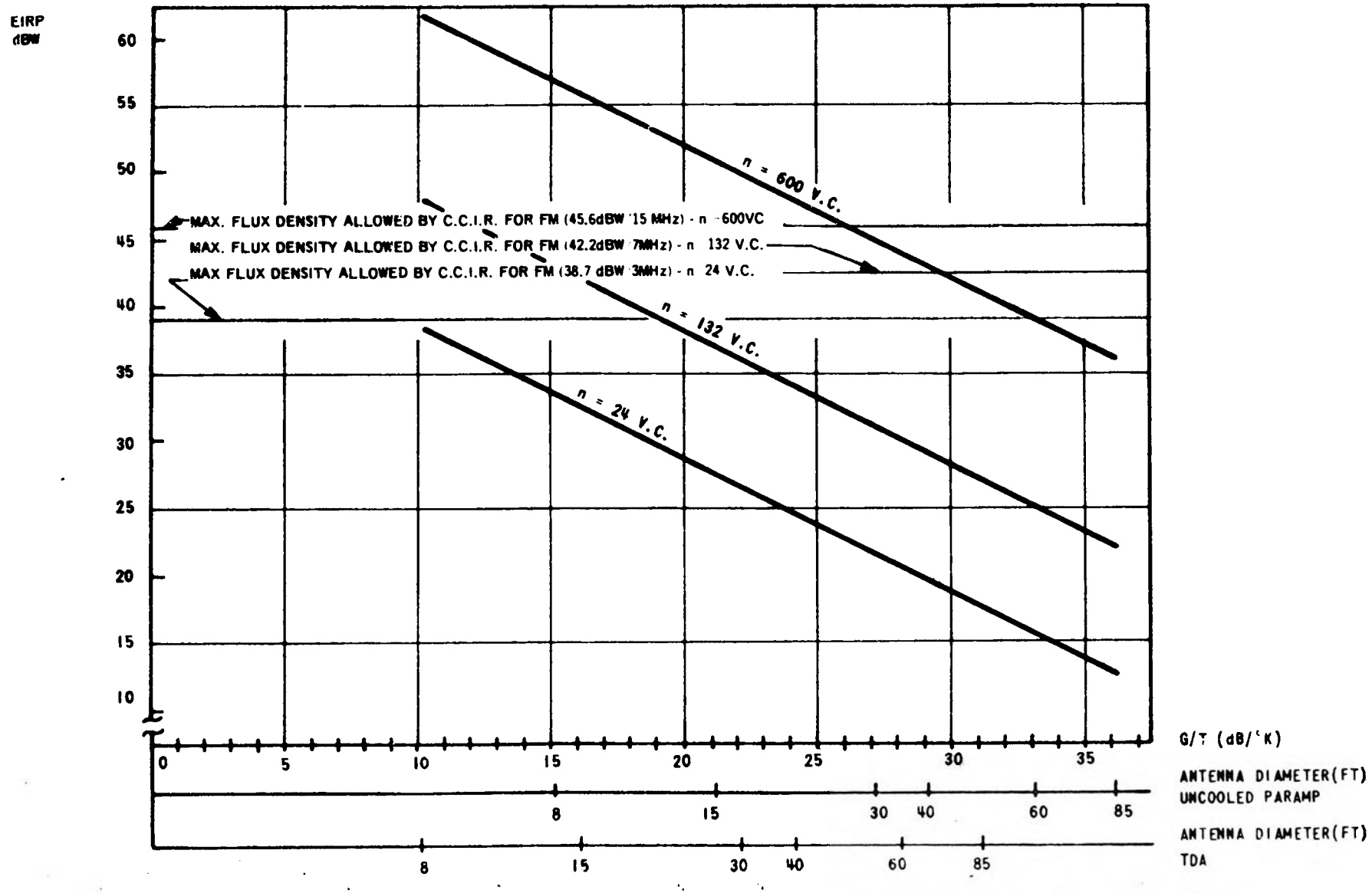


Figure 2-4. EIRP Versus B/T for FDM/FM Reception Using Various Voice Channel Loadings

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b. Demand-Assigned

(1) FM Reception (Down-Link) (3.7 to 4.2 GHz)

(a) Performance - One Voice Channel

The FM equation is:

$$(S/N) = (C/N)\left(\frac{f_p}{f_m}\right)^2 \frac{3}{2}\frac{B_{if}}{f_m} \quad WP, \tag{2-32}$$

where

(S/N) = signal-to-rms noise ratio

f_p = peak deviation kHz

$(C/N)_D$ = carrier-to-noise ratio

f_m = maximum modulation frequency (kHz)

B_{if} $\approx$ 2 $(f_p + f_m)$ MHz

W = psophometric weighting factor (+2.5 dB)

P = emphasis = 0 dB

Expressing Equation (2-32) in dB form, we obtain

$$(S/N)\ dB = (C/N)_D\ dB + 20 \log\left(\frac{f_p}{f_m}\right) + 10 \log\left(\frac{B_{if}}{f_m}\right) + W + P + 10 \log\left(\frac{3}{2}\right) \tag{2-33}$$

Let

$(C/N)_D$ = 16 dB (provides a 6-dB fade margin)

B_{if} = 100 kHz*

* Includes frequency stability of local oscillators.

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f_p = 30 kHz peak deviation

f_m = 4 kHz

Substituting the above values into Equation (2-32), the output signal-to-noise ratio is calculated.

$(S/N) = 51.7 \text{ dB} \approx 52 \text{ dB}$

(b) Satellite EIRP Requirement

The equation relating EIRP versus G/T ratio is:

$EIRP = [\alpha + (C/T - G/T)] \text{ dBW}$ (Equation (2-7))

The path loss α = 197 dB @ 4GHz (From Table 2-1). The value of (C/T) is given by the following relationship:

$$(C/T) = (C/N)_D + 10 \log k B_{if} \quad (2\text{-}34)$$

But

$(C/N)_D = 16 \text{ dB}$

and

$10 \log k B_{if} = -178.4 \text{ dBW}$ (B_{if} = 100 kHz)

$\therefore (C/T) = -162.4 \text{ dBW/°K}$,

or

$$EIRP = (34.6 - G/T) \text{ dBW} \quad (2\text{-}35)$$

Equation (2-35) relates EIRP to G/T for S/N_o = 51.7 dB.

Table 2-17 contains a sample calculation of Equation (2-35) using uncooled parametric amplifiers or TDA.

A graphical presentation of Table 2-17 is shown in Figure 2-5. This Figure depicts the system trade-offs between satellite EIRP and G/T.

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Table 2-16. Performance of SCC/FM (Demand-Assigned)

C/T = -155.4 dBW/°K @4GHz
Satellite EIRP = (34.6 - G/T)dBW

EIRP dBW	Antenna Diameter ft	Gain* η=68% dB	System Noise Temp. °K	G/T** dB/°K	Remarks
-1.4	85	59.0	200°K (23 dB)	36.0	Uncooled Paramp
11.6	60	56.0	200°K (23 dB)	33.0	Uncooled Paramp
5.1	40	52.5	200°K (23 dB)	29.5	Uncooled Paramp
7.6	30	50.0	200°K (23 dB)	27.0	Uncooled Paramp
13.6	15	44.0	200°K (23 dB)	21.0	Uncooled Paramp
19.1	8	38.5	200°K (23 dB)	15.5	Uncooled Paramp
3.6	85	59.0	630°K (28 dB)	31.0	TDA
6.6	60	56.0	630°K (28 dB)	28.0	TDA
10.1	40	52.5	630°K (28 dB)	24.5	TDA
12.6	30	50.0	630°K (28 dB)	22.0	TDA
18.6	15	44.0	630°K (28 dB)	16.0	TDA
24.1	8	38.5	630°K (28 dB)	10.5	TDA

*From Table 2-2
**From Table 2-3

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NOTE: ONE CURVE DESCRIBES THE USE OF BOTH UNCOOLED PARAMP (T=200°K) AND TDA (T=630°K).
The T's are system noise temperatures.

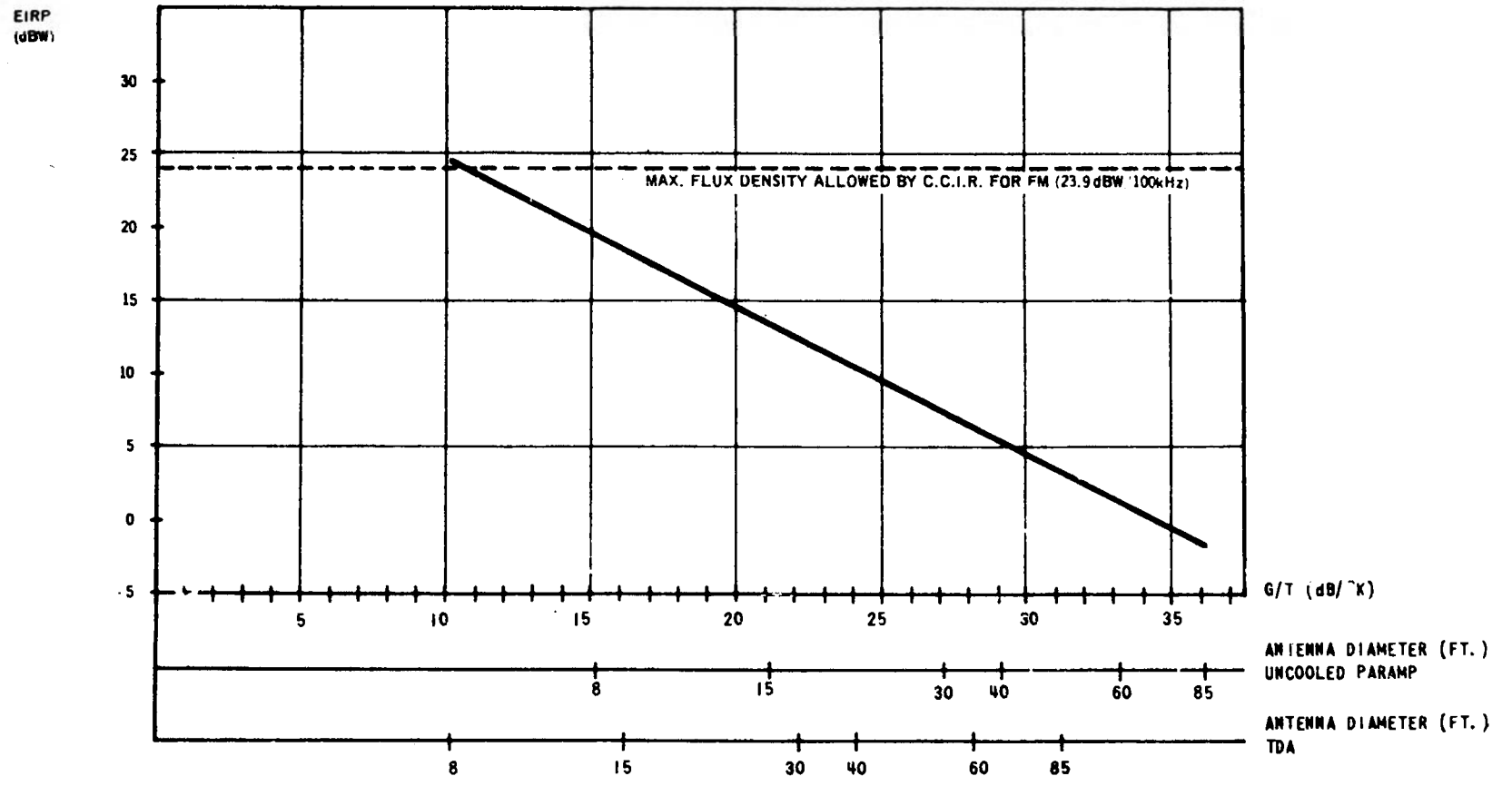


Figure 2-5. EIRP Versus G/T for FM Reception per RF Carrier for one Voice Channel (Demand-Assigned)

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The Figure also shows the maximum flux density allowed by current CCIR Standards* (Recommendation 358, Oslo, 1966).

(2) FM Transmission - Up-Link (5925 to 6425 MHz)

The general equation relating ground station transmitter power P_{tg} to total system antenna gain (station (G) plus satellite (G_t) is:

$$P_{tg} = \left[(C/N)_U + \alpha + N - (G + G_t)\right] \quad \text{(From Equation (2-10)).}$$

But

$$(C/N)_U = (C/N)_D + 10 \text{ dB},$$

$$(C/N)_U = 26 \text{ dB},$$

$$\alpha = 200 \text{ dB @ 6 GHz (From Table 2-1), and}$$

$$N = 10 \log kT B_{if} = -148.4 \text{ dBW},$$

where

$$T = 1000°K \text{ (30 dB)},$$

$$B_{if} = 100 \text{ kHz, and}$$

$$10 \log k = -228.4 \text{ dBW}.$$

Therefore,

$$P_{tg} = [\ 77.6 - (G + G_t)\ ] \text{ dBW}. \qquad (2\text{-}36)$$

*For a 5° elevation angle at synchronous orbit, the maximum flux density =9.9 dBW/4kHz, or 23.9 dBW/100 kHz

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2.2 EARTH STATION MODELS

The block diagrams and the tabulated performance characteristics for the various earth station models will be developed. The earth station models considered are:

a. Color TV Service

(1) TV Reception

(a) National Stations - multiple TV channels (FM and VSAM)
(b) Regional Stations - single TV channel (FM and VSAM)
(c) Direct service to the home (VSAM)

(2) TV Transmission

(a) Regional Stations (FM and VSAM)

b. Communications Service (Message Traffic)

(1) Preassigned (FDM/FM)

(a) Multi-Destination Carrier (MDC)
(b) Single-Destination Carrier (SDC)

(2) Demand-Assigned (FM - one RF Carrier per Channel) - for developed and developing nations.

The rationale used in the model development is:

a. For multipoint TV and Communications Services, the price of the earth stations must be reduced in order to decrease the total system cost. To effect this cost reduction, the Satellite Effective Isotropic Radiated Power must be increased sufficiently to minimize earth station G/T ratio for the given grade of service. The trade-off to find the optimum point between EIRP and G/T ratio of the earth stations is a study effort in itself and depends on the objectives of the particular system; it has not been considered herein.

b. The satellite(s) will provide U.S. continental coverage via multiple antenna beams. The increase in required Satellite Effective Isotropic Radiated Power (EIRP) will be achieved using greater satellite antenna gains rather than by means of kilowatt actual power. Satellite 3-degree time-zone coverage is assumed (antenna gain $\approx$ 34.6 dB).

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c. The most expensive portions of current earth stations are: the antenna subsystems and associated tracking requirement; the cryogenically cooled low-noise receiver subsystems; the high-power amplifier subsystem; the interfacility link; and the multiplex equipment. It is in these areas that economies are initiated in the model development.

d. All models use small antennas (30 feet or less in diameter); the advantage is possible roof-top operation and minimum real estate requirements for antenna diameters (15 feet or less). The resulting broader antenna beams will result in minimal tracking requirements. All antennas considered are fixed-position ground antennas and have manual tracking capabilities (a number of discrete positions). The disadvantage of using smaller antennas, aside from the loss of gain, is the problem of interference that may result with both terrestrial microwave links and other satellites operating on the same frequencies. However, performance curves of EIRP versus G/T ratio for a particular grade of performance have been developed for each model system (Figures 2-1 through 2-5), thus allowing for system trade-off.

e. The frequencies used in the model developments are primarily the commercial satellite frequencies (receive - 3700 to 4200 MHz, and transmit - 5925 to 6425 MHz). For the case of Vestigial Sideband Amplitude Modulation (TV service), the frequencies used are: receive - 818 to 890 MHz, and transmit - 1.5 to 1.572 GHz. These frequencies have been selected for modeling only; other frequencies in the 0.8- to 10-GHz band are not precluded.

f. The modulation techniques employed in the models do not preclude the use of other modulation techniques, but are simply used as a basis for establishing a frame of reference. Regardless of which modulation technique is used, the antennas, low-noise receivers, and power amplifiers would not change markedly.

g. All receivers would use either uncooled parametric amplifiers, TDA's, or other RF low-noise amplifiers.

h. No threshold extension demodulators are required for FM demodulation, since higher satellite EIRP's are postulated.

i. The satellite transponder(s) has (have) an RF bandwidth exceeding 500 MHz, the exception being the systems which use Vestigial Sideband Amplitude Modulation.

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2.2.1 Color TV Service

The TV performance parameters using vestigial sideband amplitude and frequency modulation have previously been derived (see paragraphs 2.1.2.2.a and b). The results will now be employed.

For reception to cable heads (CATV) or interfacing with terrestrial microwave links for TV distribution, a peak-to-peak signal-to-rms noise ratio $(S/N)_O$ of 53dB has been selected as a representative value. This value allows for noise degradation by the terrestrial equipment, thus making it possible for the user to receive Grade 1 performance. The demodulated baseband of the earth terminal has a format similar to that currently utilized in terrestrial microwave terminals.

For reception directly to the home, a peak-to-peak signal-to-rms noise ratio $(S/N)_O$ of 33dB has been selected as a representative value, thereby making possible Grade 3 or better performance to the user.

2.2.1.1 Vestigial Sideband Amplitude Modulation (VSAM)

a. Reception (818 to 890 MHz*)

(1) Regional and National Earth Stations - $(S/N)_O$ =53dB. Figures 2-6 and 2-7 are block diagrams of Vestigial Sideband Amplitude Modulation TV receive earth stations with RF protection. Both single (regional) and multicarrier (National) TV receive stations are shown.

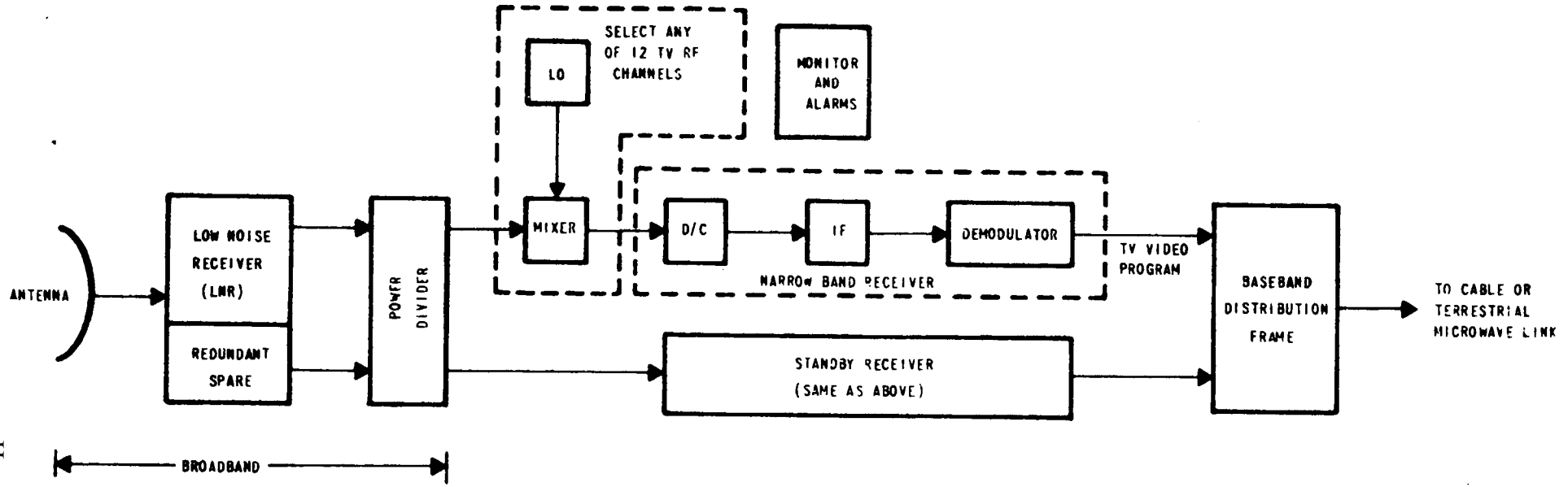
The 30-foot diameter antenna, the redundant low-noise receiver (LNR), the power splitter, and the first mixer are all broadband (100 MHz or greater). The narrowband receiver that follows, as the name implies, is narrowband: it has a predetection bandwidth of 6 MHz. A double-heterodyne technique is depicted; the function of the first mixer is to allow for ease of tuning to any of 12 TV RF channels.

The format of the demodulated signal is an FDM signal with the TV video occupying a band from 20 Hz to 4.0 MHz, and the TV audio (program) on an FM subcarrier at approximately 4.5 MHz.

The reception characteristics of the model systems are represented in Table 2-17.

* Last 12 channels of the TV video UHF band.

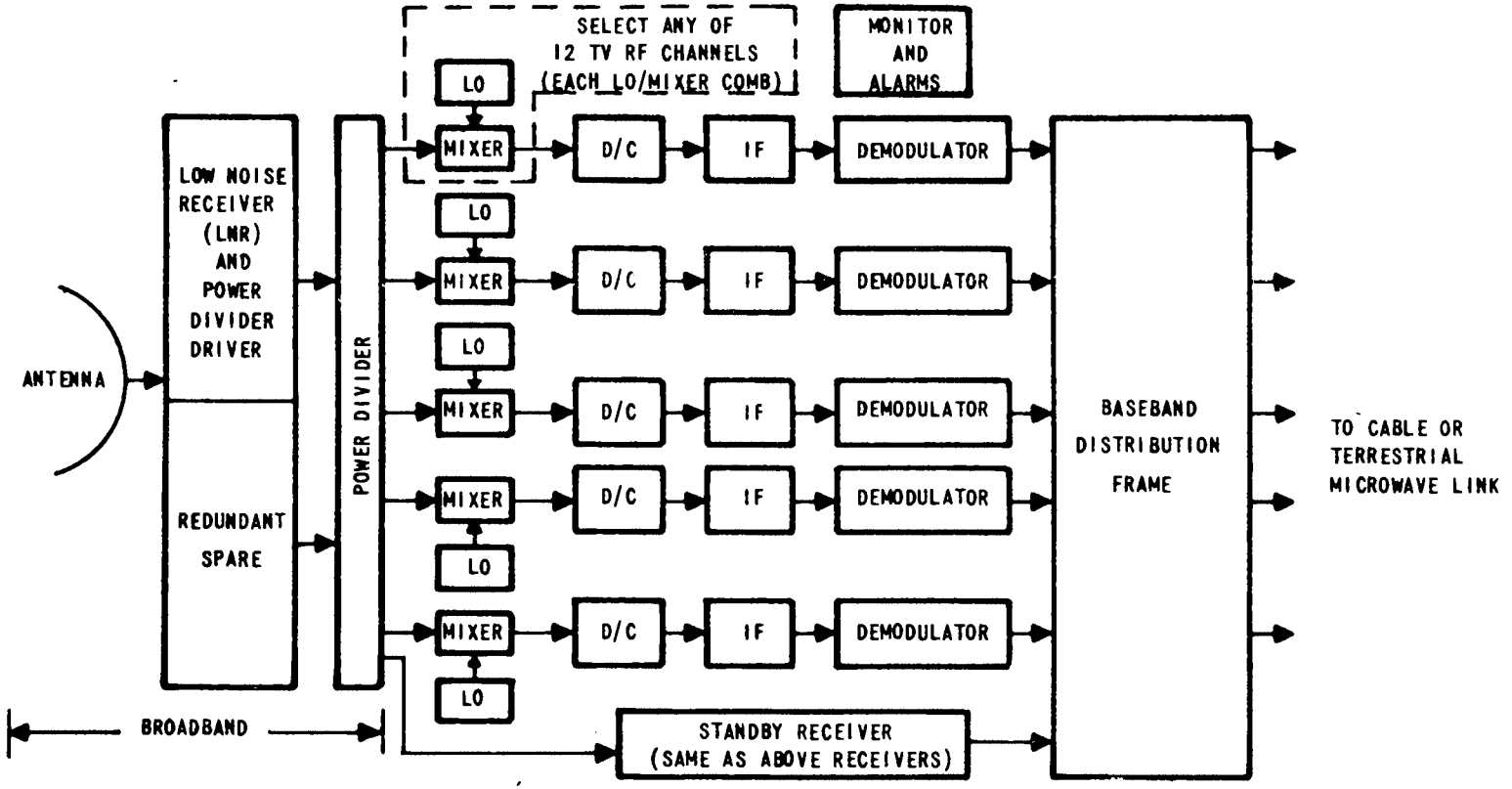
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NOTE: D/C IS DOWN-CONVERTER WITH LO.
IF IS IF AMPLIFIER AND FILTER.
SPARE (STANDBY) EQUIPMENT CAN BE SWITCHED IN AND OUT BOTH MANUALLY AND AUTOMATICALLY.

Figure 2-6. Simplified Block Diagram of a Regional Receive Earth Station Using Vestigial Sideband Amplitude Modulation for TV Video and Audio Reception (With 1:1 Backup)

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NOTE: D/C IS DOWN-CONVERTER WITH LO.
IF IS IF AMPLIFIER AND FILTER.
SPARE (STANDBY) EQUIPMENT CAN BE SWITCHED IN AND OUT BOTH MANUALLY AND AUTOMATICALLY.

Figure 2-7. Simplified Block Diagram of a National Receive Earth Station Using Vestigial Sideband Amplitude Modulation for TV Video and Audio Reception (Provides 1:5 Backup) (Reception of Five Different RF Carriers Containing TV Video and Audio (Program)

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Table 2-17. Regional and National TV Reception Characteristics for Earth Stations Using Vestigial Sideband Amplitude Modulation (Figure 2-6 and Figure 2-7)

Parameters	Description
RF Frequency Range	818 to 890 MHz (allocation for 12 TV channels)
Tunability	Tunable to any one of the 12 allocated TV video channels.
Modulation Technique	Vestigial Sideband
Predetection IF Bandwidth	6 MHz
Capacity	
(a) Regional Block Diagram, Figure 2-6 (with 1:1 back-up)	One TV Video plus TV program (sound) at baseband
(b) National Block Diagram, Figure 2-7 (with 1:5 back-up)	Five different TV Video plus TV program (sound)
$(S/N)_o$ (peak-to-peak signal-to-rms noise)	53 dB (TV Video)
(S/N) (signal-to-rms noise)	73.2 dB (TV Program)
Carrier-to-Total Noise Temperature, C/T	-110.4 dBW/^oK
Antenna Diameter	30 ft (mechanical tracking only)
Antenna Gain	36.5 dB at 850 MHz
Equivalent Noise Temperature	200° Kelvin (uncooled paramp front end)
Figure of Merit of the Earth Station G/T	13.5 dB/^oK
Satellite EIRP (from Figure 2-1)	59.1 dBW per TV channel

Assume Satellite 3-degree time-zone coverage - antenna gain ≈ 35 dB
∴ Satellite Transmitter Power = 24.1 dBW (approximately 600 watts) per channel.

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(2) Directly to the Home - $(S/N)_o$ = 33dB
Figure 2-8 is a block diagram of TV service directly to the home. A 5-ft diameter antenna with a TDA front end has been assumed. The receiver that follows is a commercial television set.

The reception characteristics of the model system are shown in Table 2-18.

b. Transmission (1.5 to 1.572 GHz*)

Figure 2-9 is a block diagram of a Vestigial Sideband Amplitude Modulation TV Video and Audio Transmit Earth Station. One-for-one RF protection is provided.

The narrowband transmitter converts the baseband input to Vestigial Sideband Amplitude Modulation via the modulator. The signal is then up-converted to RF by the up-converter. By changing the local-oscillator (LO) frequency associated with the up-converter, the RF frequency of operation can readily be changed to select any one of the 12 video channels.

The subsystems which follow the transmitter/exciter are broadband - 100 MHz or greater; this includes the redundant high-power amplifier (HPA), the antenna, etc.

A National Transmit TV Earth Station would be made up by using as many of these Transmit Earth Stations as required. Each station would carry a different TV video program. A separate HPA is used for each RF carrier to avoid intermodulation problems. However, a common antenna could be used to transmit more than one RF carrier.

The transmission characteristics of the model system are depicted in Table 2-19.

Refer back to Equation (2-23), which is repeated here:

$$P_{tg} = [117.4 - (G + G_t)] \text{ dBW};$$

but from Table 2-12,

$$G = 41.5 \text{ dB (30 ft diameter at 1.5 GHz)},$$

* This frequency band has been assigned as a frame of reference for model development.

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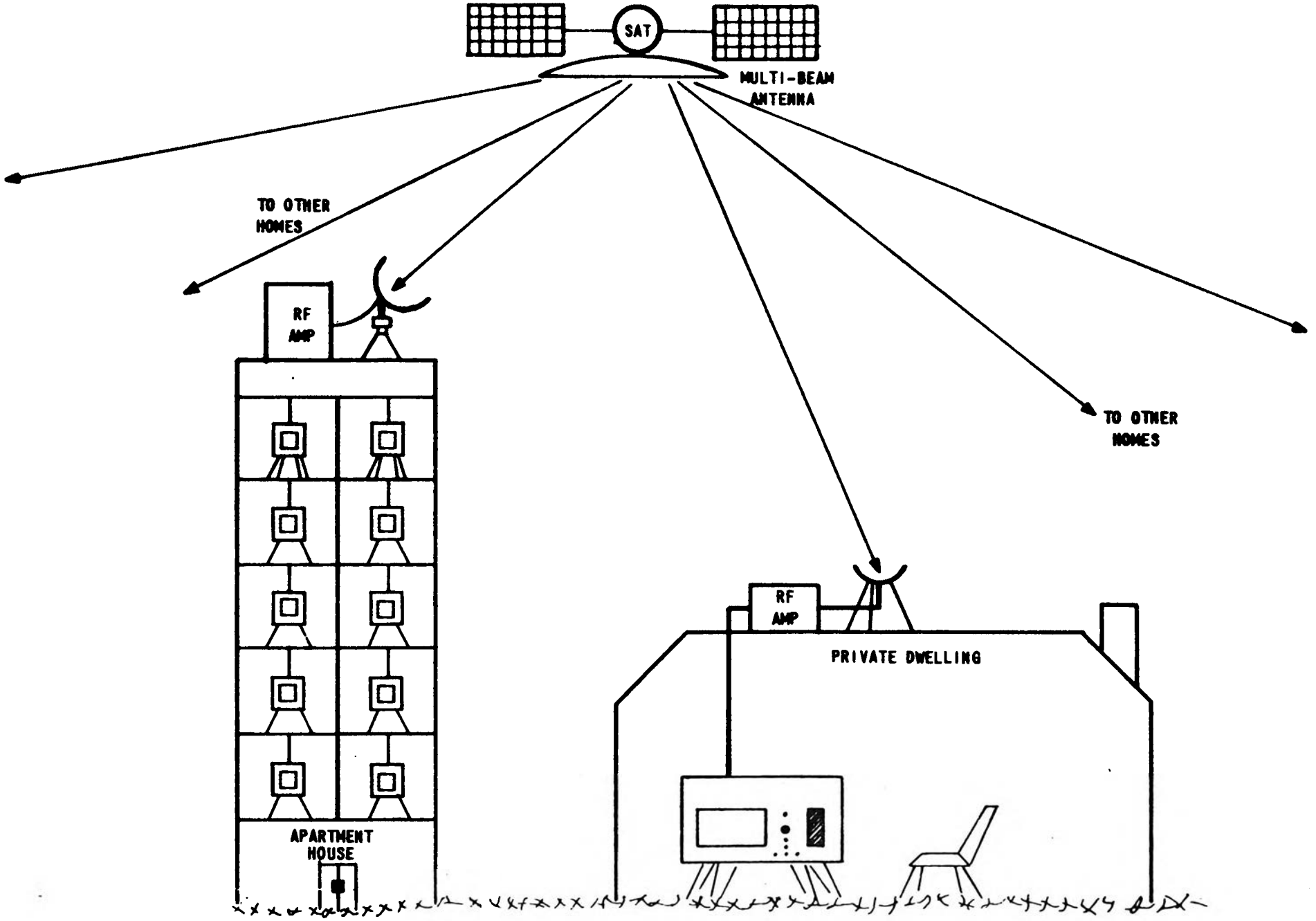
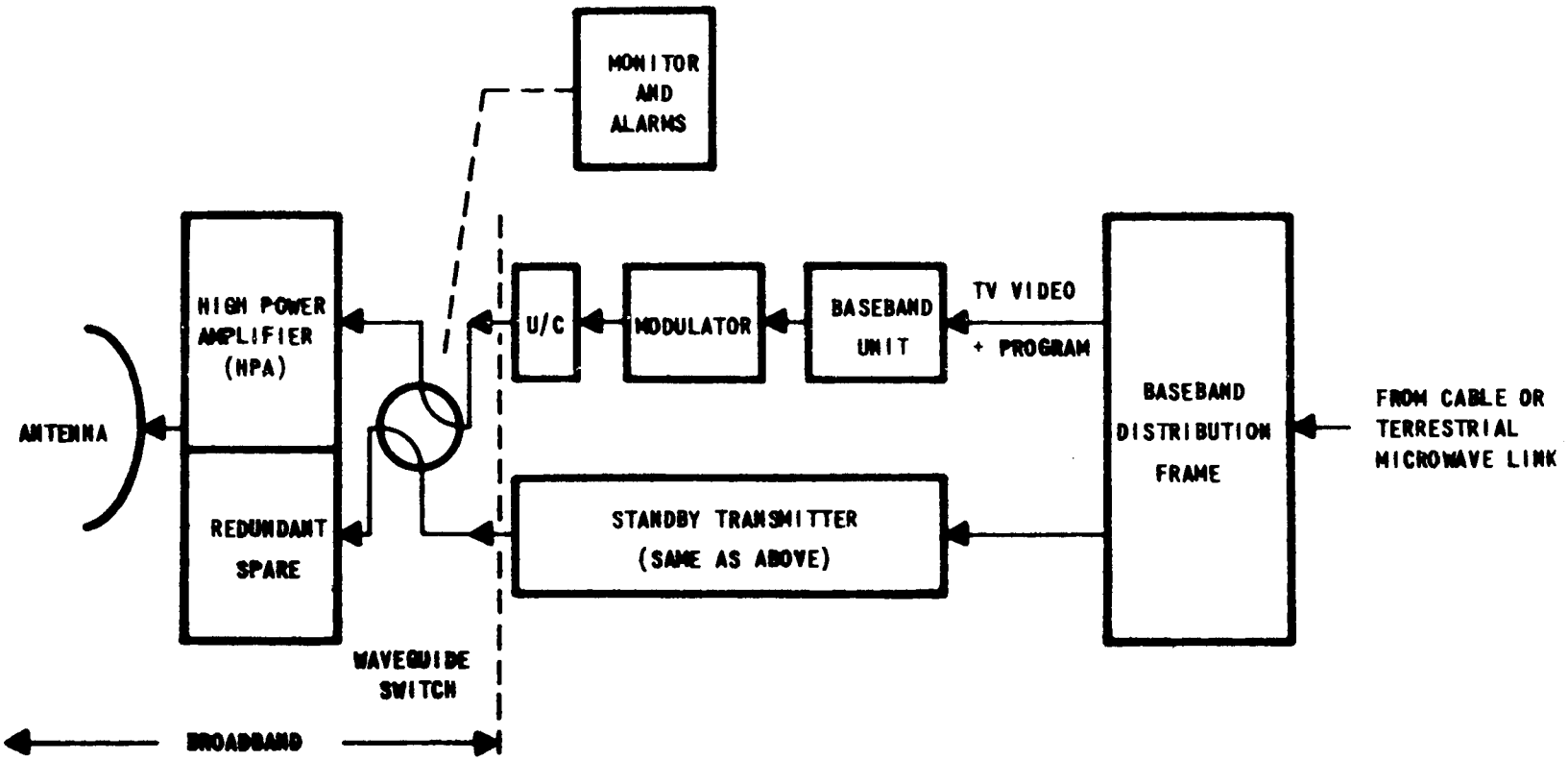


Figure 2-8. Block Diagram of TV Service Directly to Private Dwellings from Satellite (VSAM $(S/N)_O$ = 38dB)

Table 2-18. TV Service Directly to the Home Using Vestigial Sideband Amplitude Modulation (See Figure 2-8)

Parameters	Description
RF Frequency Range	818 to 890 MHz (12 TV channels)
Modulation Technique	Vestigial Sideband
Predetection IF Bandwidth	6 MHz
Capacity	One TV Video plus TV Program (sound) at baseband
$(S/N)_o$ (peak-to-peak signal-to-rms noise)	33 dB (TV Video)
(S/N) (signal-to-rms noise)	53.2 dB (TV Program)
Carrier-to-Total Noise Temperature	-130.4 dBW/^oK
Antenna Diameter	5 ft (mechanical tracking only)
Antenna Gain	21 dB at 850 MHz
Equivalent Temperature Noise	630^oK (TDA or equivalent RF amp front end)
Figure of Merit of the Earth Station, G/T	-7 dB/^{o} Kelvin
Satellite EIRP (from Figure 2-2)	60 dBW per TV channel

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NOTE: U/C IS UPCONVERTER WITH LO.
SPARE (STANDBY) EQUIPMENT CAN BE SWITCHED IN AND OUT BOTH MANUALLY AND AUTOMATICALLY.

Figure 2-9. Simplified Block Diagram of Transmit Earth Station Using Vestigial Sideband Amplitude Modulation for TV Video and Audio Transmission (Provides 1:1 Backup)

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Table 2-19. Regional and National TV Transmission Characteristics for Earth Station Using Vestigial Sideband Amplitude Modulation (See Figure 2-9)

Parameter	Description
RF Frequency Range	1.5 to 1.572 GHz (allocation for 12 TV channels)
Tunability	Tunable to any one of the 12 allocated TV video channels
Modulation Technique	Vestigial Sideband
Predetection IF Bandwidth	6 MHz
Capacity Block Diagram, Figure 2-6 (with 1:1 back-up)	One TV Video plus TV program (sound) at baseband
Antenna Diameter	30 ft (mechanical tracking only)
Antenna Gain	42 dB at 1.5 GHz
HPA Power Output Bandwidth	 12 kW 100 MHz Nominal
Satellite Antenna Gain	34.4 dB Minimum at 1.5 GHz *

* Obviously, if the satellite does not have this antenna gain, the ground-terminal antenna or the HPA power must be increased.

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and

$$P_{tg} = 41 \text{ dBW (12 kW)}.$$

Therefore, solving the above equation for G_t (satellite antenna gain), we obtain:

$$G_t = +34.9 \text{ dB}. \quad \text{(Time Zone Coverage)}$$

2.2.1.2 Frequency Modulation (TV Performance)

a. Reception (3.7 to 4.2 GHz)

Figures 2-10 and 2-11 are block diagrams of Regional and National FM TV Receive Earth Stations.

In the case of the Regional Earth Station, one-for-one RF carrier backup is provided. However, for the National Earth Station one-for-five backup is used.

A separate RF carrier is depicted for the TV video and the TV audio (program) information. The possibility of sending the audio information via a subcarrier has not been considered. However, this approach should be considered, as it would eliminate an extra RF carrier. Use of the present approach is consistent with current earth station practices.

The 15-foot diameter antenna, redundant low-noise receiver (LNR), the power splitter, and the first mixer are all broadband - 500 MHz or greater. The receiver that follows is narrowband - 40 MHz for the TV video and 3.0 MHz for the TV audio. A double-heterodyne technique is shown; the function of the first mixer is to allow for ease of tuning to any of the 12 TV RF channels.

The demodulated signal consists of TV video and the TV audio signals. This signal can then be distributed to either a cable head or a terrestrial microwave link.

The reception characteristics of the system are shown in Table 2-20.

b. Transmission (5925 to 6425 MHz)

Figure 2-12 is a block diagram of a Regional FM TV Transmit Earth Station. One-for-one RF protection is provided.

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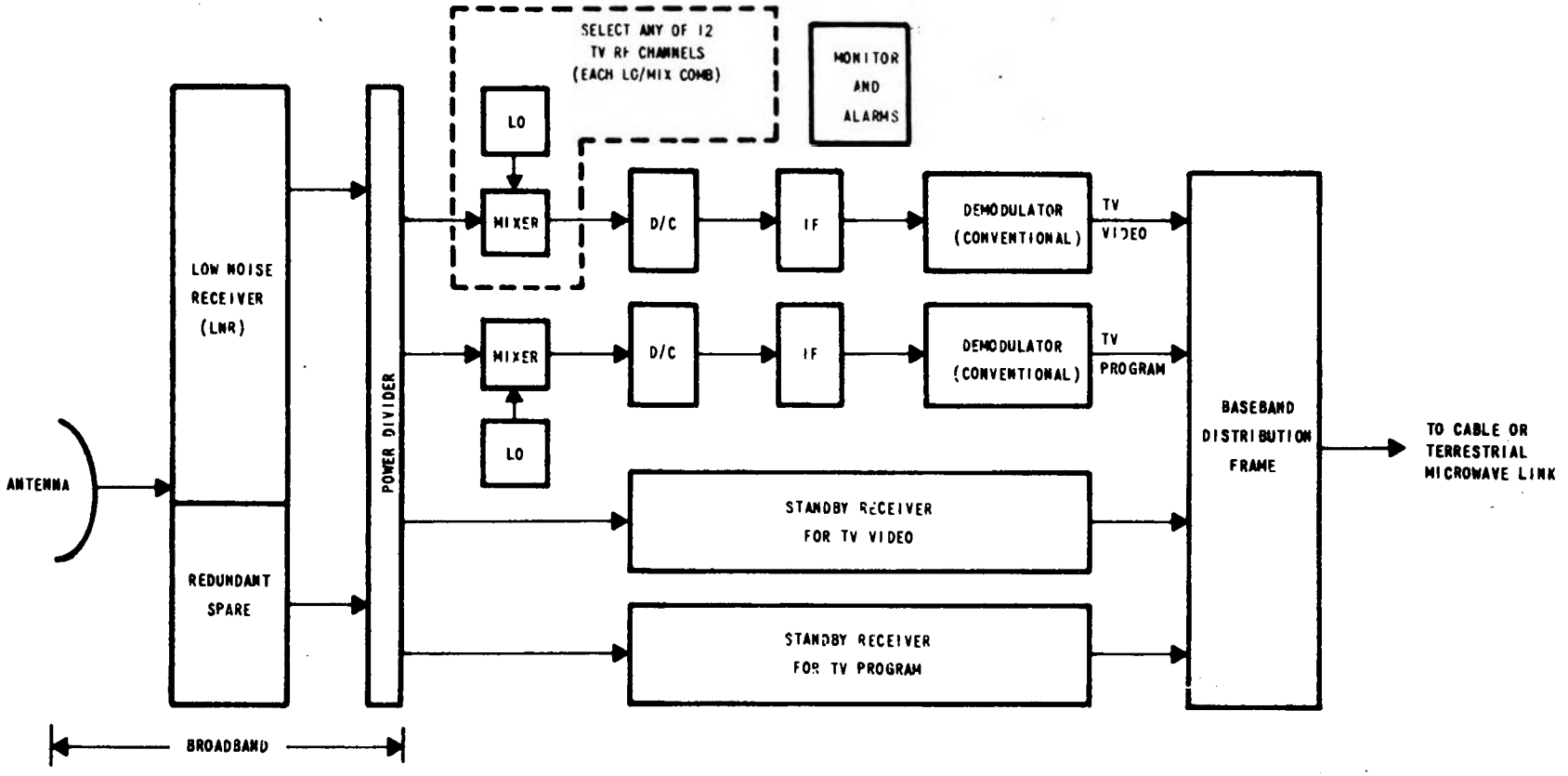


Figure 2-10. Simplified Block Diagram of a Regional Receive Earth Station Using FDM/FM for TV Video and Audio Reception (With 1:1 Backup for Video and Audio Chains)

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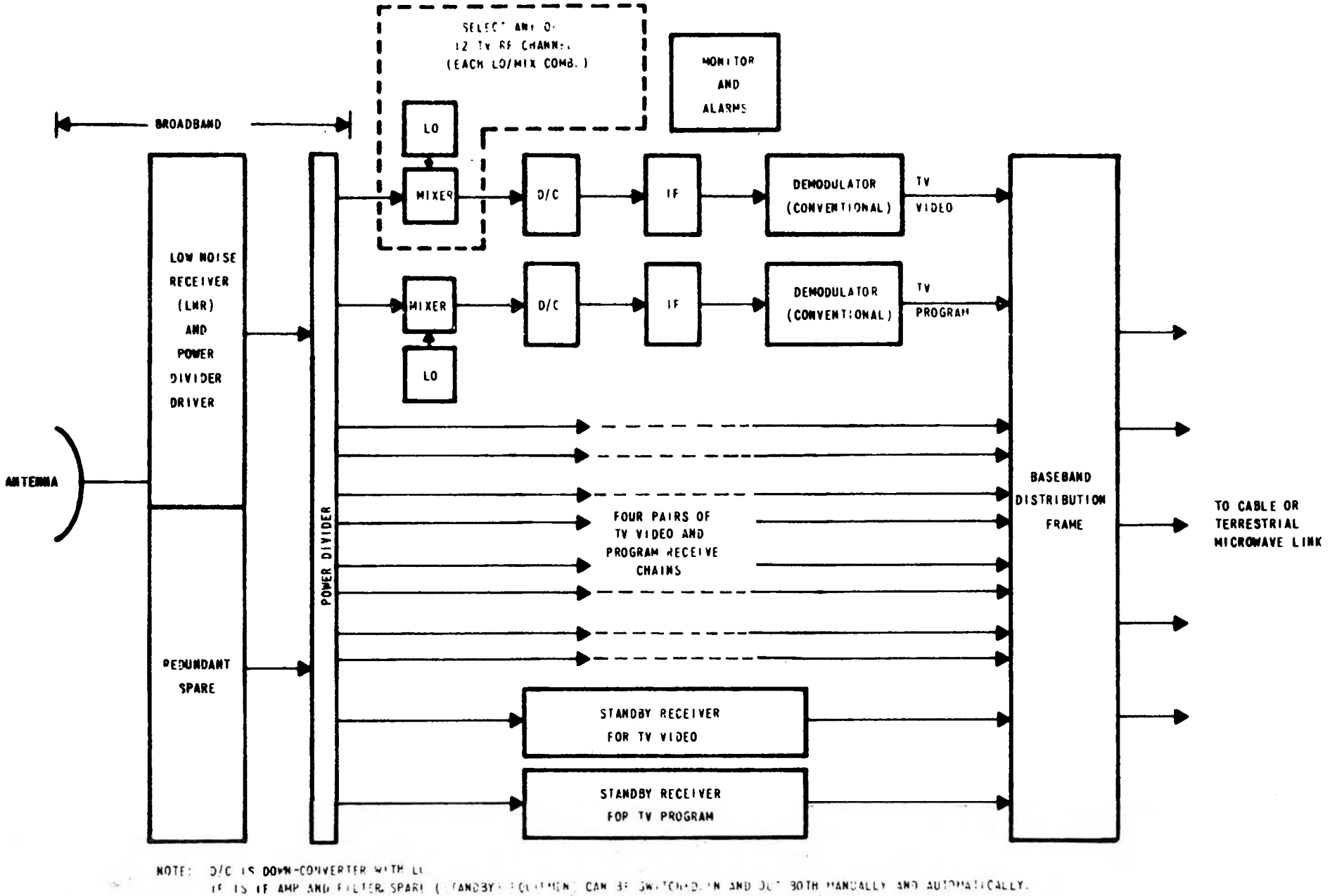


Figure 2-11. Simplified Block Diagram of a National Receive Earth Station Using FDM/FM for TV Video and Audio Reception (Provides 1:5 Backup)
(Reception of 10 Different RF Carriers: Five Which Contain TV Video and Five Which Contain TV Audio)

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Table 2-20. Regional and National TV Reception Characteristics for Earth Stations Using Frequency Modulation (Figures 2-10 and 2-11)

Parameters	Description
RF Frequency Range	3.7 to 4.2 GHz (can accommodate 12 TV channels)
Tunability	Tunable to any of the 12 allocated TV video channels.
Modulation Technique	FM
Capacity	
Block Diagram Figure 2-10 (with 1:1 Back-up)	1 TV Video Carrier 1 TV Sound Carrier (24 voice channels per carrier)
Block Diagram Figure 2-11 (with 1:5 Back-up)	5 TV Video Carriers 5 TV Sound Carriers (24 voice channels per carrier)
TV Video	
$(S/N)_O$ (peak-to-peak to rms noise)	+53 dB
Peak Deviation	15.2 MHz
Predetection IF Bandwidth	40 MHz
Carrier-to-Total Noise Temperature, C/T	-136.4 dBW/^{O}K
C/N	≥16 dB
Antenna Diameter	15 ft.
Antenna Gain	44.0 dB
Equivalent Noise Temperature	200°K (uncooled paramp)

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Table 2-20. Regional and National TV Service Characteristics for Earth Stations Using Frequency Modulation (Figures 2-10 and 2-11) (Continued)

Parameters	Description
Figure of Merit of the Earth Station G/T	21.0 dB/^{o}K
TV Audio	
(S/N) (signal-to-rms noise)	53 dB
Number of Voice Channels	24-voice channel capacity
Single-Channel Test-Tone Deviation	140 kHz rms
Predetection IF Bandwidth	3.0 MHz
Carrier-to-Total Noise Temperature	-148.4 dBW/^{o}K
C/N	15 dB
Satellite EIRP (From Figure 2-3) (From Figure 2-4)	+39.6 dBW per TV channel +27.6 dBW per TV channel program (audio)

Assume Satellite 3-degree time-zone coverage - antenna gain ≈ +35 dB

∴ Satellite Transmitter Power Requirements are:

4.4 dBW (2.8 watts) TV Video
-7.6 dBW (0.174 watt) TV Audio (Program)

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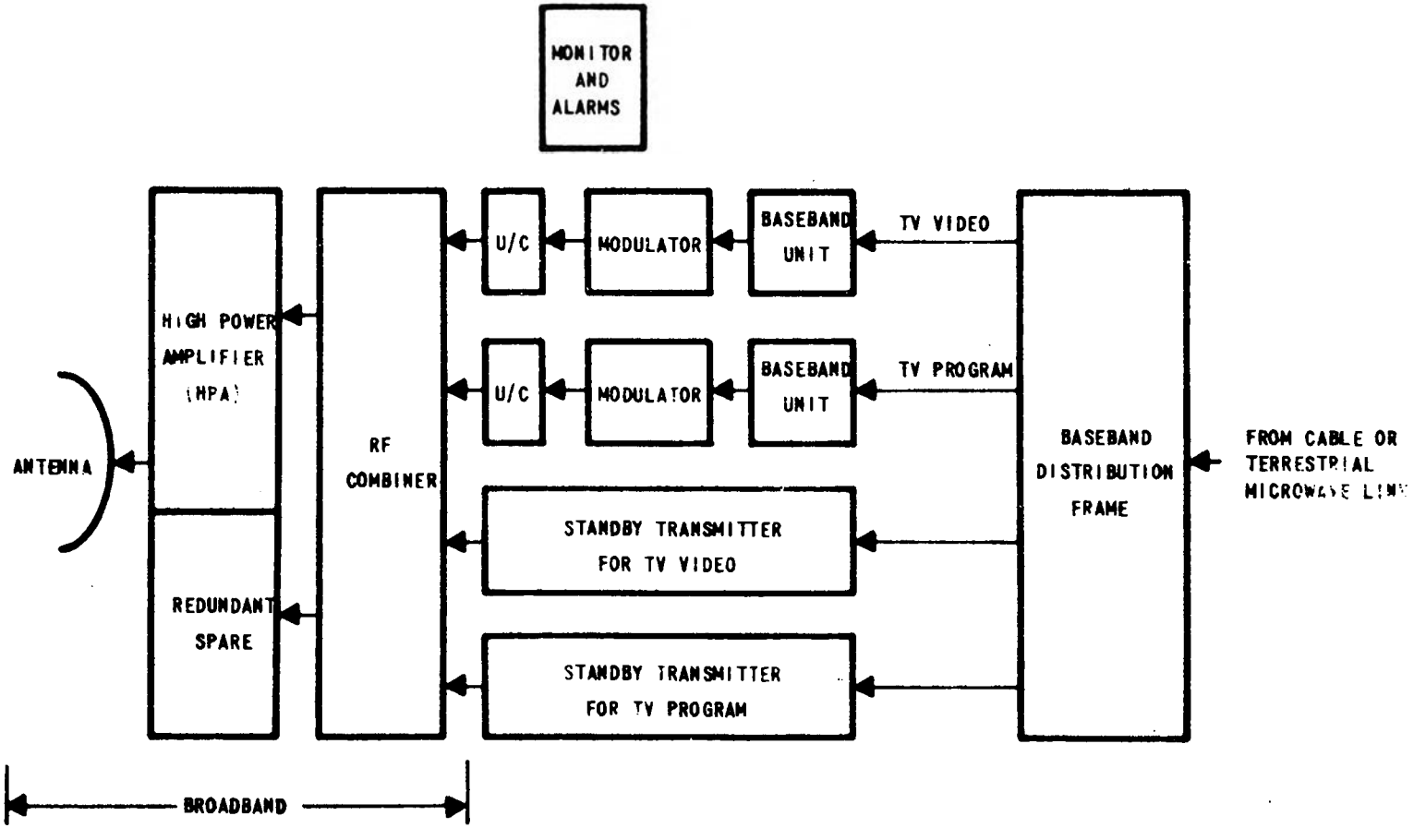


Figure 2-12. Simplified Block Diagram of Transmit Earth Station Using FDM/FM for TV Video and Audio Transmission (Provides 1:1 Backup)

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A separate RF carrier is used for the transmission of the TV video and the TV audio information.

The baseband input is applied to the FM modulator where it is converted to an FM signal; following this, the signal is then up-converted to RF by the up-converter. The frequency of operation can readily be changed via the LO frequency associated with the up-converter.

The subsystems which follow the transmitter/exciter are broadband - 500 MHz or greater; this includes the RF combiner, the common redundant HPA, the antenna, etc.

A National Transmit TV Earth Station would look similar except that RF transmitter pairs, one for TV video and one for TV audio, would be added to accommodate the different TV programs. The RF combiner, the HPA, and the antenna would all be common.

The transmission characteristics of the model systems are depicted in Table 2-21.

Refer back to Equation (2-28), which for informational purposes is repeated here:

$$P_{tg} = [103.6 - (G + G_t)] \text{ dBW};$$

but, from Table 2-12,

$$G = 47.5 \text{ dB and}$$

$$P_{tg} = 27 \text{ dBW (for Regional Station with back-off for TV program).}$$

Therefore, solving the above equation for G_t (satellite antenna gain), we obtain:

$$G_t = +29.1 \text{ dB.}$$

This is greater than time zone coverage.

2.2.2 Communications (Message) Service

The Communications Service has duplex capability, as opposed to the TV Distribution Service, which is one-way.

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Table 2-21. TV Transmission Characteristics for Regional and National Earth Stations Using Frequency Modulation

Parameters	Description	
RF Frequency Range	5925-6425 MHz (can accommodate 12 TV channels)	
Tunability	Tunable to any one of 12 allocated TV video channels.	
Modulation Technique	FM	
Deviation	TV Video: 15.2 MHz peak TV Audio Program: 140 kHz rms	
	Regional (Block Diagram Figure 2-12)	National
Capacity		
Baseband Input	1 TV Video Carrier 1 TV Sound Carrier (24-voice-channel capacity per sound carrier)	3 TV Video Carriers 3 TV Sound Carriers (24-voice-channel capacity per sound carrier)
Narrowband transmitters		
TV Video Carriers	1	3
TV Audio Program	1	3
TV Video Carriers (Back-up)	1	1
TV Audio Program (Back-up)	1	1
Antenna		
Diameter	15 ft	30 ft *
Gain	47.5 dB at 6 GHz	53.5 dB at 6 GHz

* Allows for back-off for multiple carrier operation at the HPA input.

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Table 2-21. TV Transmission Characteristics
for Regional and National Earth Stations
Using Frequency Modulation
(Continued)

Parameters	Description	
HPA		
Power Output	+30 dBW (1 kW)	Can handle 3 TV carriers plus 3 TV audio carriers
Bandwidth	500 MHz	nominal
Satellite Antenna Gain	+29.1 dB min.	

The Preassigned Models will use FDM/FM modulation with a message (voice channel) capacity of 24, 60, 132, 300, 600 or TV per RF carrier. Multi-Destination Carrier (MDC) and Single-Destination Carrier (SDC) models will be considered. In the case of MDC, TV video capability will also be enumerated. The two models developed differ from current earth stations in the following ways:

a. Uncooled front ends are used.

b. Smaller antennas can be used.

c. Tracking requirements will be minimal (e.g., manual tracking).

d. Requirements of the interfacility link are eliminated.

e. Only conventional demodulators (limiter-discriminators) are used.

f. A greater number of voice channels can be transmitted per RF carrier.

g. Lower per-channel test-tone deviation (for message operation) similar to that currently used on terrestrial LOS microwave links (200 kHz rms per channel deviation) can be used; this yields higher satellite channel-handling capacity.

Obviously, to initiate these changes, the satellite must become more sophisticated and have increased EIRP capability. The output signal-to-noise will be of

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toll quality (52 to 53 dB psophometrically weighted). The performance parameters have previously been enumerated (see Paragraphs 2.1.2.3.a and b). In particular, the results of Table 2-11, the graphical results of Figure 2-4 (EIRP versus G/T ratio), and the equations shown in Table 2-15 will be used. For TV transmission the results are derived in Paragraph 2.1.2.2.f.

The modulation technique used in the Demand-Assigned Model is a form of SCC/FM. An RF spectrum of 100 KHz will be allocated to each message carrier. The output signal-to-noise ratio will exceed 52 dB. The performance parameters are derived in Paragraphs 2.1.2.3.b(1) and (2).

2.2.2.1 Preassigned

a. Multi-Destination Carrier (MDC)

The Multi-Destination Carrier model is a type of multiple-access communications satellite system currently in use. In this approach maximum use is made of the broadband satellite transponder by using multi-destination carriers, which results in each earth station transmitting fewer RF carriers than it receives. The RF channels at a particular earth station destined for several other earth stations are FDM'd on a single outgoing FM carrier, with each distant earth station required to receive and demodulate the complete carrier and then extract the channels destined for it. Consequently, the quantity and characteristics of the baseband-to-RF and RF-to-baseband equipment in any earth station will depend on the quantity and kinds of communications service required. This technique can be used for both developed and developing nations, the difference being the voice-channel capacity, or number of destinations (number of RF receive carriers), or both.

Figure 2-13 is a block diagram of a Multi-Destination Carrier Earth Station. The station has the facilities for the transmission of three carriers and the reception of seven carriers with a spare for back-up.

The typical capacity of this type of earth station is as follows:

Transmit	3 RF Carriers:	One TV video One TV audio (program) One redundant telephone (300-voice-channel capability)

The redundant telephony RF channel can be used as back-up for the TV video or TV audio channel.

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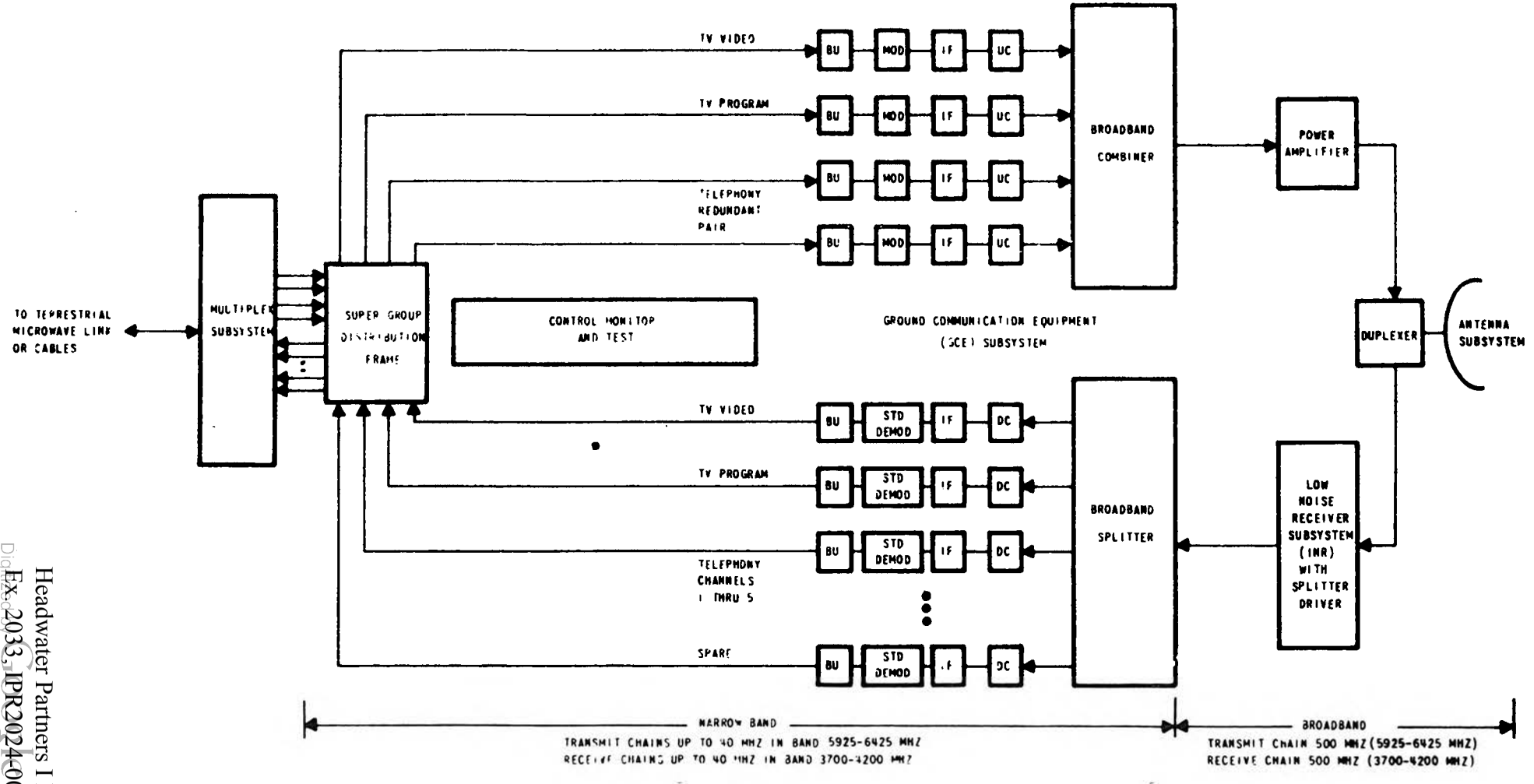


Figure 2-13. Multi-Destination Carrier Satellite Communications Earth Station Model

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Receive	7 RF Carriers	Five telephone channels (300-voice-channels capacity) One TV video One TV audio (program) One spare; provides 1:7 back-up

The reception and transmission characteristics are shown in Tables 2-22 and 2-23 respectively. The performance requirements for other voice channel loadings are depicted in Table 2-11 (Paragraphs 2.1.2.3.a and b); this supplements the existing Comsat requirements for a "softer" modulation technique.

The TV video performance is a hard modulation approach as compared to the telephony which is softer*. Hence, for 300 voice channels or greater, the voice channel satellite EIRP requirements predominate and will govern the earth station antenna size. This also holds true in the selection of the HPA for transmission.

b. Single-Destination Carrier (SDC)

This type of communications system is a special case of the MDC system. It is designed primarily for developed nations and is intended for heavy loaded point-to-point systems covering large distances, e.g., an east coast location (Washington, D.C.) to West Europe (Brussels) or to the west coast (San Francisco).

An 1800-voice channel FDM/FM capacity is assumed per earth terminal (see Figure 2-14). This capacity is accomplished by means of three RF carriers. Each carrier handles 600-voice channels.

The total bandwidth required is approximately equal to that required for one TV video channel. One-for-three RF back-up is provided.

At a current cost of approximately $1,000 a voice channel, the cost of the multiplex equipment alone exceeds 1.8 million dollars. This is probably the most expensive subsystem of the earth station, and cost economics must be exercised in this direction.

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* Obviously, if the satellite EIRP is available, the TV modulation can also become softer and utilize less bandwidth. The problem is simply one of bandwidth exchange versus EIRP.

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Table 2-22. MDC Receive Performance Characteristics, FDM/FM

Parameters	Description	
Carrier Frequency Range	3700 to 4200 MHz	
Modulation Technique	FDM/FM	
Capacity	7 carriers 1 TV Video 1 TV Program (audio) 5 Telephony (300 voice channels)	
TV Video	Grade 1	
$(S/N)_O$ peak-to-peak signal-to-rms noise	53 dB	
C/T carrier-to-total noise temperature	-136.4 dBW/°K	
$(C/N)_D$	16 dB	
Peak Deviation	15.2 MHz	
Predetection IF Bandwidth	40 MHz	
Satellite EIRP (from Figure 2-3)	33.6 dBW/carrier	
Telephony	n =24*	n =300
(S/N) signal-to-rms noise	53 dB	52.2 dB
C/T carrier-to-total thermal noise	-148.4 dBW/°K	-131.4 dBW/°K
drms per channel rms deviation	140 kHz	200 kHz
Predetection IF Bandwidth	3.0 MHz	7.0 MHz
C/N	15 dB	27 dB
Satellite EIRP (from Figure 2-4)	21.6 dBW/carrier	38.6 dBW/carrier

* TV Program

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Table 2-22. MDC Receive Performance Characteristics, FDM/FM (Continued)

Parameters	Description
Antenna	
Diameter	30 ft (mechanical tracking only)
Gain	50.2 dB at 4 GHz
Equivalent Receive Noise Temperature	200° K (23 dB) Using uncooled paramps
Figure of Merit of Earth Station G/T	27.0 dB/° K

Table 2-23. MDC Transmission Performance Characteristics, FDM/FM

Parameters	Description
Carrier Frequency Range	5925 to 6425 MHz
Modulation Technique	FDM/FM
Capacity	3 Carriers 1 TV Video 1 TV Program (audio) 1 Telephony (300 voice channels)
Deviation	TV Video: 15.2 MHz peak TV Audio (Program): 140 kHz Telephony: 200 kHz
Antenna	
Diameter	30 ft (mechanical tracking only)
Gain	53.5 dB
HPA**	
Power Output	2 kW (33 dBW)
Bandwidth	500 MHz
TV/carrier *	+23.6 dBW (235 watts)
TV program/carrier *	+11.4 dBW (13.8 watts)
Telephony/carrier *	+28.6 dBW (720 watts)

* Satellite antenna gain of approximately 26.5 dB is assumed; this corresponds to continental coverage - 7.5° satellite beamwidth. (Equation (2-28) and Table 2-15)

** The common HPA enumerated above has more than enough capacity for back-off.

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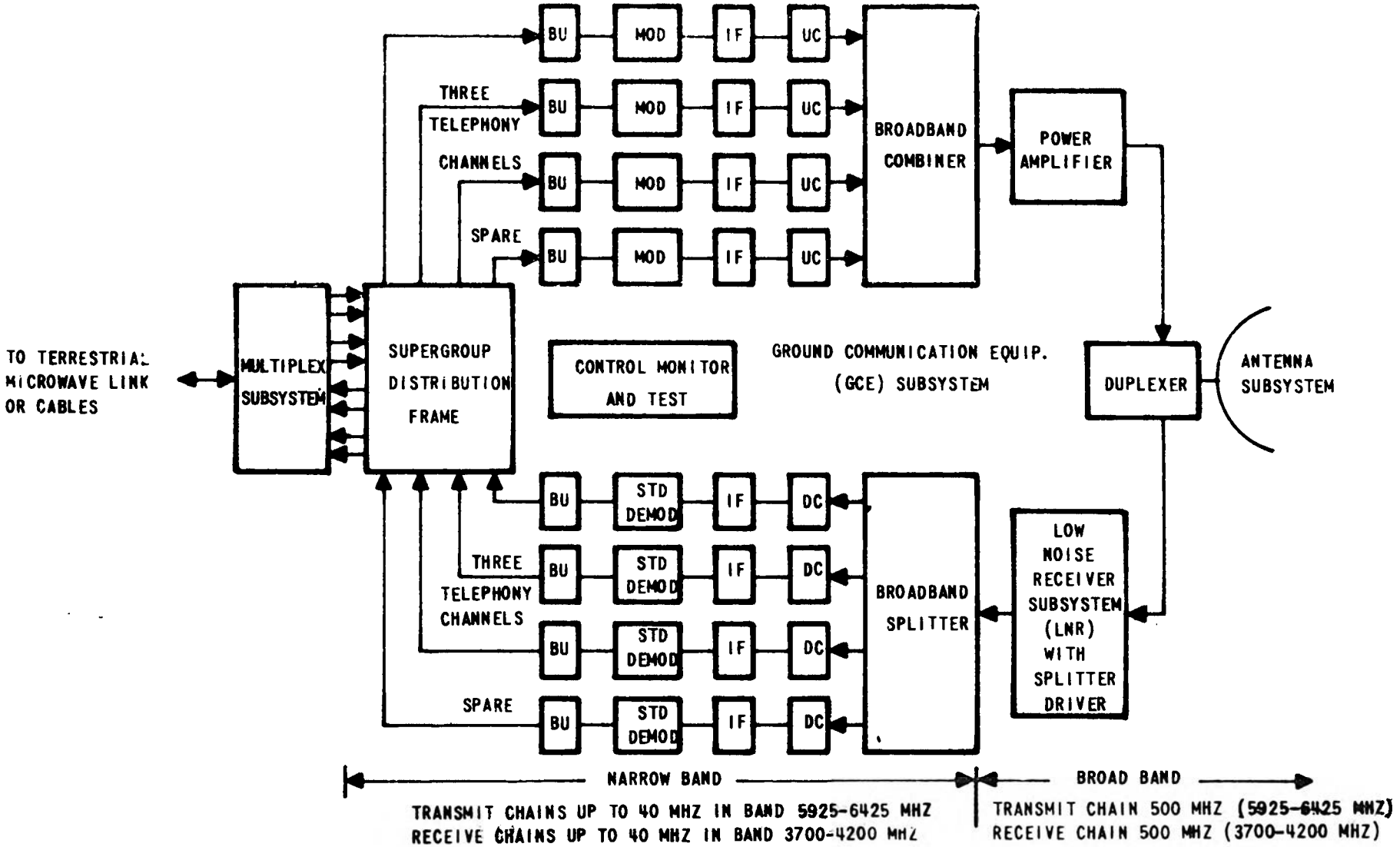


Figure 2-14. Single-Destination Carrier Satellite Communications Earth Station Model (1:3 Backup)

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The receive and transmit performance characteristics are depicted in Table 2-24.

Table 2-24. Point-to-Point Heavy Message Loading (1800 Voice Channels) Performance Characteristics (Figure 2-13)

Parameters	Description
A. Receiver Performance	
Carrier Frequency Range	3700 to 4200 MHz
Modulation Technique	FDM/FM
Capacity	3 carriers (600 voice channels per carrier)
(S/N) Signal-to-rms Noise	+53 dB
Predetection IF Bandwidth	15 MHz nominal
Single-Channel Test-Tone Deviation	200 kHz rms
C/T (Carrier-to-Total Noise Temperature)	-124.9 dBW/° K
C/N	+31.5 dB
Satellite EIRP per Carrier (from Figure 2-16)	45.1 dBW per carrier
Antenna	
Diameter	30 ft (mechanical tracking only)
Gain	+50.5 dB
Equivalent Noise Temperature	200° K (uncooled paramp front end)
Figure of Merit (G/T)	+27.0 dB/° K
B. Transmitter Performance	
Carrier Frequency Range	5925 to 6425 MHz
Modulation Technique	FDM/FM
Capacity	3 carriers (600 voice channels per carrier)
Single-Channel Test-Tone Deviation	200 kHz rms

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Table 2-24. Point-to-Point Heavy Message Loading (1800 Voice Channels) Performance Characteristics (Figure 2-13) (Continued)

Parameters	Description
Antenna	
Diameter	30 ft (mechanical tracking only)
Gain	+53.5 dB at 6 GHz
HPA	
Power Per Carrier	500 watts per carrier *
Power Output of Common Power Amplifier	1 to 2 kW
Bandwidth	500 MHz nominal

* Satellite antenna gain of approximately 34.6 dB is assumed; this corresponds to time-zone coverage - satellite antenna beamwidth of 3°.

2.2.2.2 Demand-Assigned Model

The model used will be a modified STAR* system. The designation STAR system is derived from Satellite Telecommunications with Automatic Routing.

In this system, which is a form of SCC/FM, each voice channel frequency modulates one carrier, and the carriers are arranged within the transmission bandwidth of the satellite.

The channel capacity of the system is limited not only by the bandwidth of the satellite, but also by its output power and the performance of each earth station which is linked to one another by means of the common satellite.

Voice channels through the satellite are not assigned to each earth station, but are assigned on a demand basis. This on-demand assignment is the so-called automatic routing operation.

*M. Marita, T. Fukami, and S. Yamoto, "Project STAR", Telecommunications, October 1967, Volume 1, No. 2 pp. T22-T25.

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In an operating voice channel, the carrier is not continuously transmitted; that is, a technique in which the wave is emitted only for the time in which a voice is present, and in which the wave (signal) is cut off for the period during which no voice is presented, is the so-called Start-Stop function. Using this approach, the number of usable channels is increased by utilizing the limited output power of a satellite most effectively, and the interference to other channels is minimized by cutting off the unmodulated waves.

The earth stations are always connected through the routing center by means of data transmission links for channel assignment. Time-division multiplex is used for the data link. However, the voice channels are transmitted using frequency modulation. Thus, each earth station has an analog system for voice-channel transmission, and a digital system for voice-channel demand assignments.

The system consists of many earth stations which use a common satellite. Associated with this network is a separate earth station, whose function is the automatic routing of the voice channels. This station is the Routing Center. Figure 2-15 is a block diagram depicting this system.

Figures 2-16 and 2-17 are block diagrams of a Demand-Assigned Earth Station and the Routing Center.

A system for developed and developing nations is proposed. The essential difference between the two is the earth station channel capacity and the application of the Start-Stop function. Thus, conversion from developing to developed nation earth terminals is readily accomplished.

Each demand channel has been allocated a 100-kHz spectrum, thereby accommodating a single voice channel.

The satellite has a bandwidth of 500 MHz; therefore, 5000 voice channels are available. The number of earth stations that can be accommodated by the satellite is a function of the expected traffic (data, voice, etc.) the allowable delays, etc., and is a traffic engineering problem.

Obviously, many earth stations can use the satellite. The applications of the Start-Stop function further decrease the activity factor, thereby reducing the average power requirement in the satellite.

The reception and transmission characteristics for the Message Earth Station and the Routing Center are depicted in Table 2-25, Table 2-26, and Table 2-27.

Paragraphs 2.1.2.3.b (1) and (2) are the calculated results used in establishing the model parameters.

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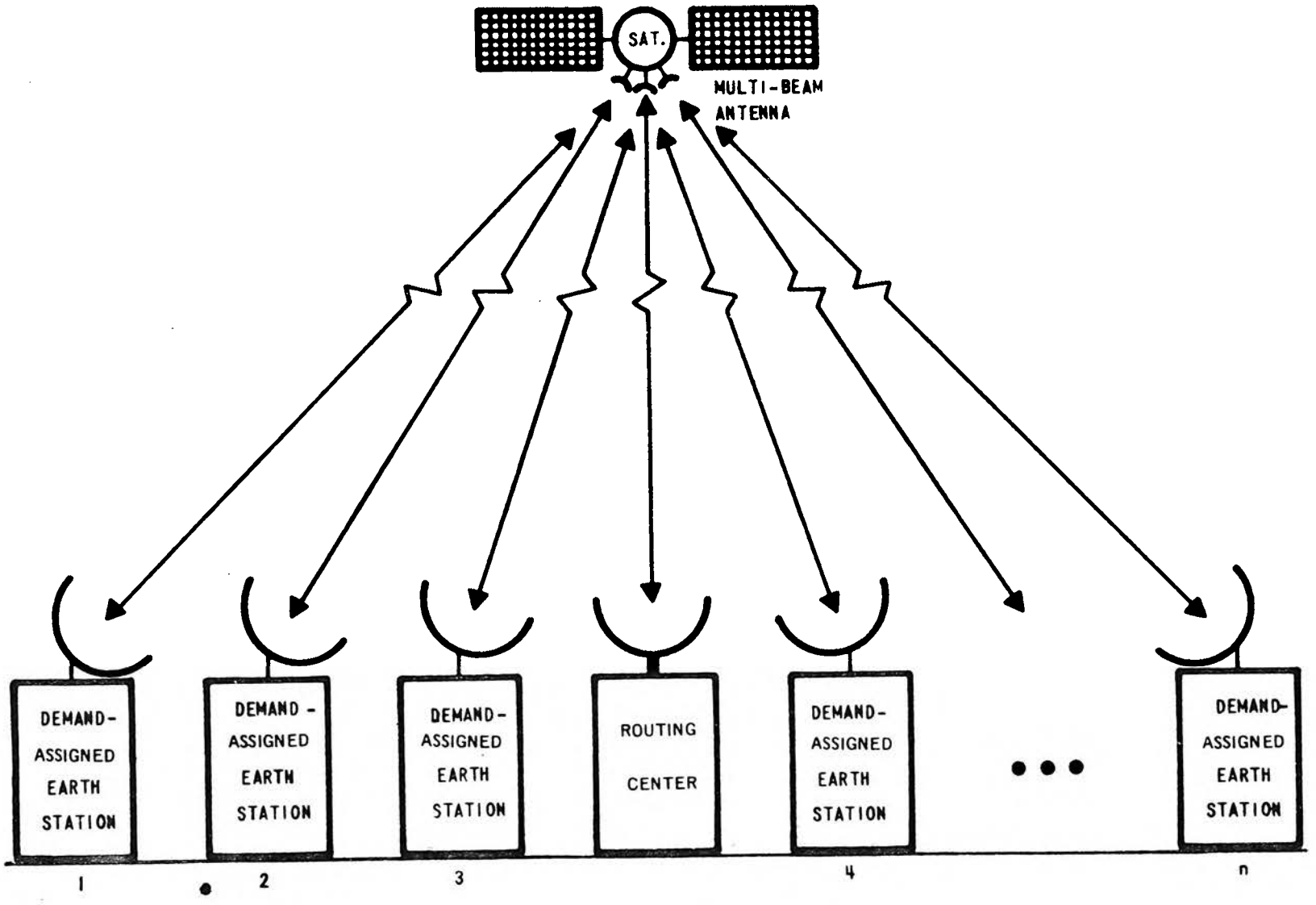
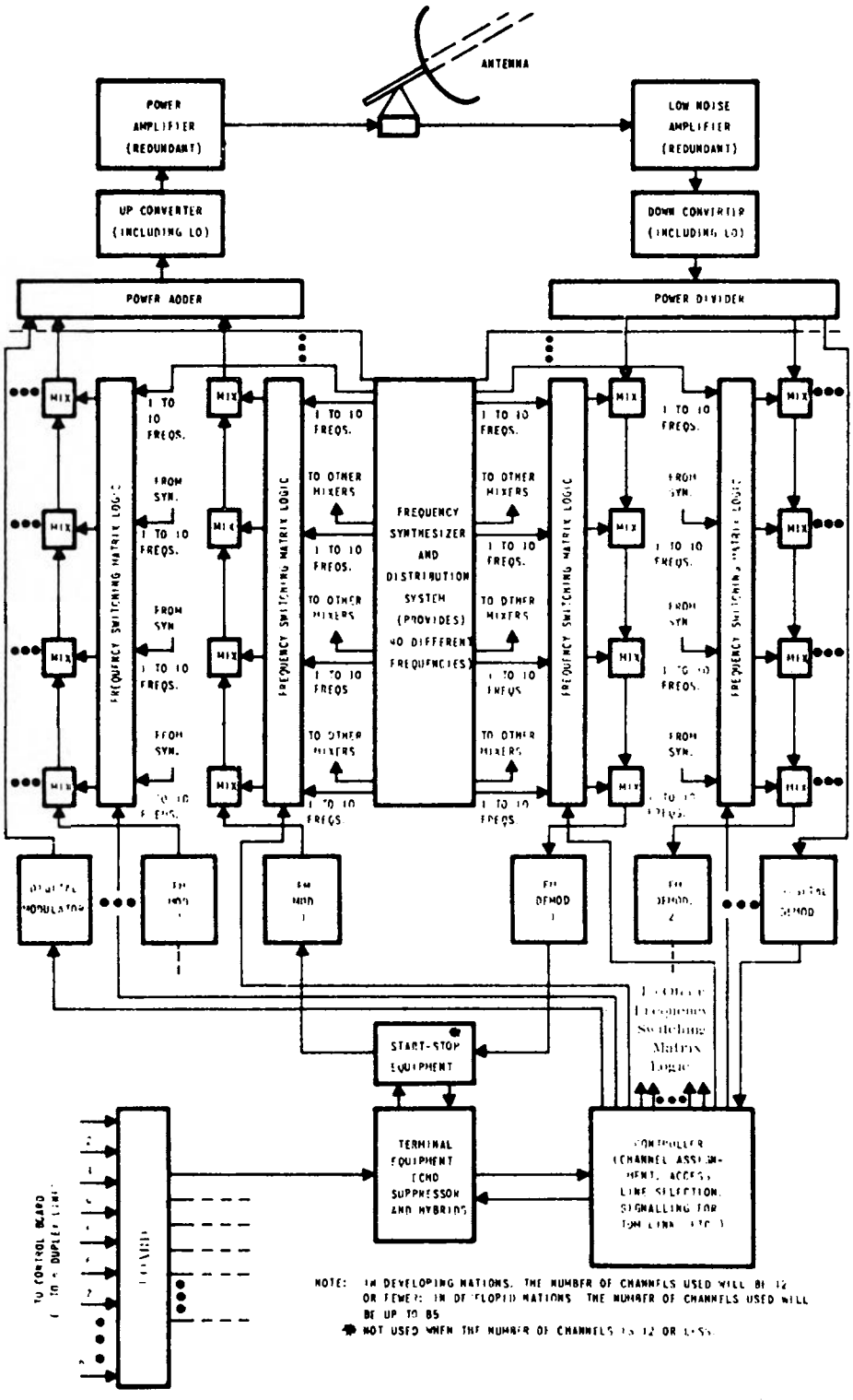


Figure 2-15. Block Diagram of Demand-Assigned Communications System

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NOTE: IN DEVELOPING NATIONS, THE NUMBER OF CHANNELS USED WILL BE 12 OR FEWER; IN DEVELOPED NATIONS THE NUMBER OF CHANNELS USED WILL BE UP TO 85

* NOT USED WHEN THE NUMBER OF CHANNELS IS 12 OR LESS.

Figure 2-16. Block Diagram of Demand-Assigned Earth Station

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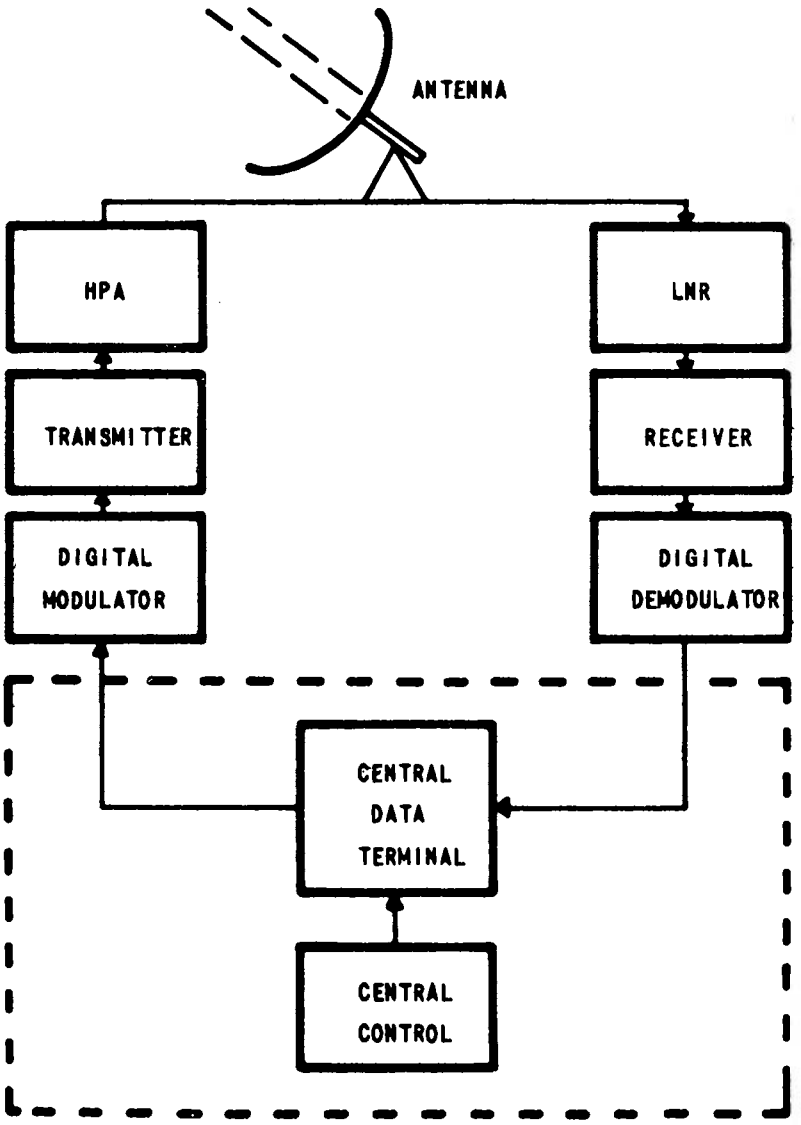


Figure 2-17. Block Diagram of Routing Center

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Table 2-25. Demand Assigned Receiver Performance Characteristics
(Figure 2-16)

Parameters	Characteristics
A. Message	
RF Frequency	3700 to 4200 MHz
Modulation	SCC/FM
Channel (Single Carrier) Predetection IF Bandwidth	100 kHz nominal
Capacity	Developing nations: 12 carriers Developed nations: 85 carriers (each carrier can receive one voice channel)
(S/N) (signal-to-rms Noise)	52 dB
Carrier-to-Noise Ratio	16 dB
Equivalent Noise Temperature	200°K (uncooled paramp)
Carrier-to-Total Noise Temperature	-162.4 dBW/°K
Antenna Diameter Gain	 15 ft. (mechanical tracking only) +44.2 dB at 4 GHz
Figure of Merit (G/T)	21.0 dB/°K
Satellite EIRP (from Figure 2-5)	13.6 dBW per carrier
B. TDM Receive Channel	
RF Frequency Range Modulation	4100 to 4200 MHz TDM
Predetection Bandwidth	1.0 MHz nominal
Capacity	1 carrier
Data Capability	1.0 Megabit (binary)
Carrier-to-Noise Ratio	+16 dB
Satellite EIRP	+24.2 dBW per carrier

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Table 2-26. Demand-Assigned Transmission Performance Characteristics (Figure 2-17)

Parameters	Characteristics
A. Message	
RF Frequency Range	5925 to 6425 MHz
Modulation	SCC/FM
Channel (Single Carrier) Predetection Bandwidth	100 kHz
Capacity	Developing nations: 12 carriers Developed nations: 85 carriers
Antenna	
Diameter	15 ft. (mechanical tracking only)
Gain	47.5 dB
HPA	
Power Required per carrier	13W (11.1 dBW) per carrier*
Power Output (Common P.A.)	1.0 kW
Bandwidth	500 MHz nominal
B. TDM Transmit Channel	
RF Frequency	6325 to 6425 MHz
Modulation	TDM
Capacity	1 carrier
Data Capacity	1 Megabit (binary)
Bandwidth Allocation	1 MHz nominal

* Satellite antenna gain of approximately 19 dB; this corresponds to global coverage — 18° satellite beamwidth.

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Table 2-27. Performance Characteristics of Routing Center

Parameters	Characteristics
RF Frequency	
Transmit	6325 to 6425 MHz
Receive	4100 to 4200 MHz
Modulation	TDM
RF Bandwidth Allocation	1.0 MHz Nominal
Data Capability	1.0 Megabit (Binary)
Capacity	One duplex channel
Carrier-to-Noise Ratio	16 dB
Equivalent Noise Temperature	200°K (uncooled paramp)
Antenna	
Aperture	15 ft.
Gain	44.2 dB at 4.1 GHz 48 dB at 6.3 GHz
Figure of Merit (G/T)	+21.0 dB/°K
Satellite EIRP	+24 dBW per channel
HPA (6325 to 6425 MHz)	
Power	20 Watts
Bandwidth	5.0 MHz minimum

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2.3 COST MODELS

Figure 2-18 is a block diagram of a typical multidestination carrier Comsat type of earth station that complements the Intelsat III satellite type. This type of earth station will be used in the 1968 to 1976 time frame, and will be used as the cost model.

The typical capacity of this type of earth station is as follows:

Transmit	3 RF carriers:	one TV video; one TV audio (program) one redundant telephony (132 voice channel capability).
Receive	7 RF carriers	five telephony (132 voice channel per RF carriers); one TV video; one TV audio (program) One spare, provides 1:7 back-up.

This type of station will be used as the standard for price comparison and hereafter will be referred to as the standard earth station.

The current earth stations require system G/T ratios exceeding 40.7 dB and a top voice channel signal-to-noise ratio of 52 dB. To accomplish this, 85-foot dishes with cooled parametric and threshold extension demodulators are used. However, in the case of TV video, a standard limiter-discriminator is used. The TV reception characteristics are similar to those depicted in Table 2-20, except that the G/T ratio exceeds 40.7 dB.

Table 2-28 shows the current Intelsat III transmission parameters for message traffic.

The cost range of the equipment which makes up a current standard type of earth station is shown in Table 2-29. The prices developed reflect the cost received from vendors in the U.S. and other countries over the past 18 months.

This information has been utilized in deriving Table 2-30, which is the equipment cost breakdown of the MDC earth station shown in Figure 2-28. The cost of the earth stations range from $2,650,000 to $5,173,000, the mean value being $3,911.500.

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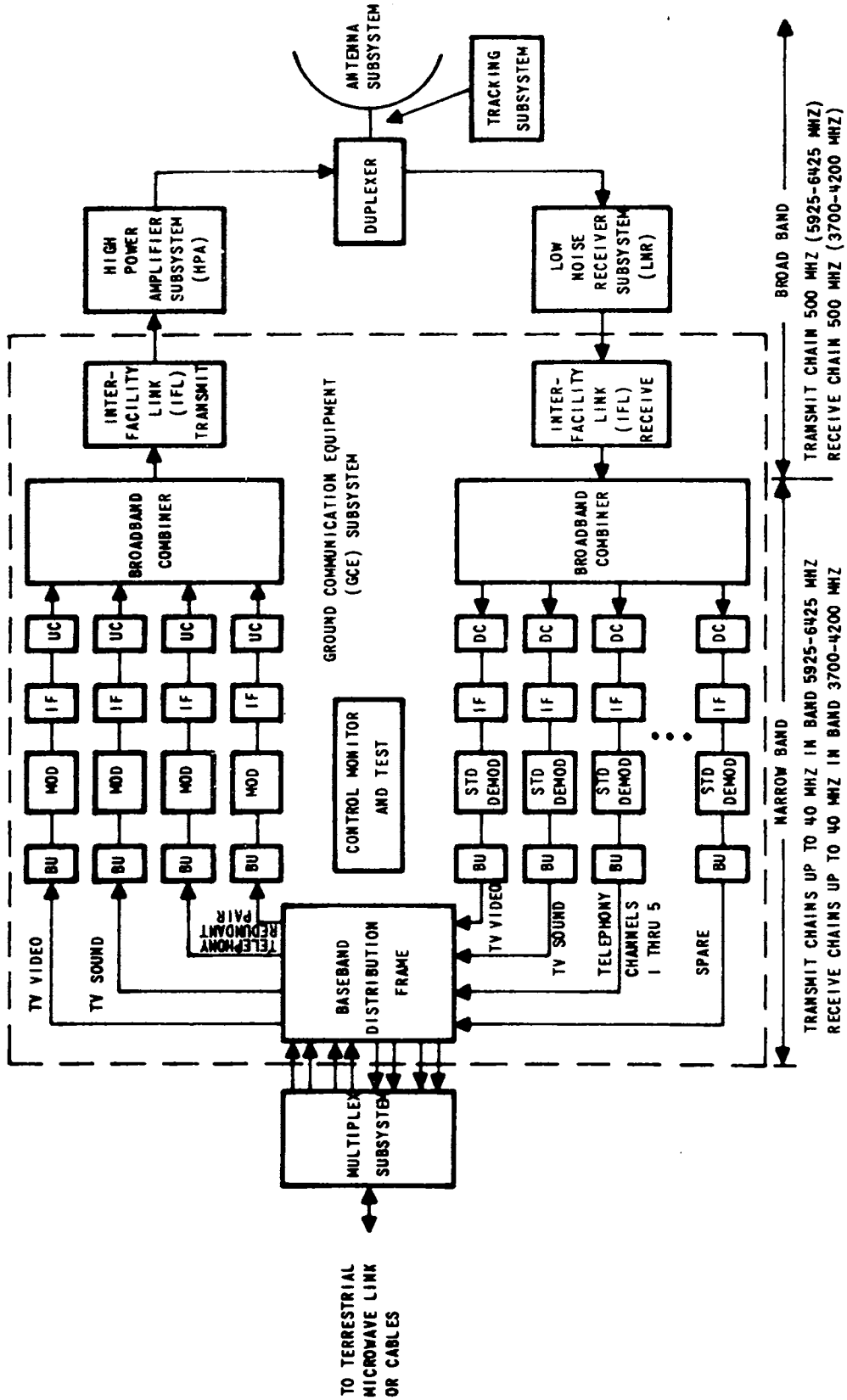


Figure 2-15. Satellite Communications Earth Station (Standard)

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Table 2-28. Intelsat III Transmission Parameters

Parameters	Symbols	Units	Values		
1. Carrier Capacity	n	Voice Channels	24	60	132
2. Allocated Satellite Bandwidth	b_a	MHz	5	10	20
3. Bottom Baseband Frequency	fb	kHz	12	12	12
4. Top Baseband Frequency	fm	kHz	108	252	552
5. Demo Test Tone Deviation	fr	kHz	250	410	630
6. Multi-channel rms Deviation	fmc	kHz	420	830	1490
7. Satellite Bandwidth with 268 Guardband	bsg	MHz	5.0	10.0	18.2
8. Carrier-to-Total Noise Temperature Ratio	$\frac{C}{T}$	dBW/^oK	-154.8	-151.3	-148.5
9. Satellite Bandwidth without Guardband	bs	MHz	3.95	7.95	14.4
10. IF Bandwidth	Bif	MHz	2.9	5.8	10.5
11. Earth Station Received Flux Density		dBW/m^2	159.0	-155.5	-152.7
12. Excess Margin	E	dB	4.0	4.0	4.0
13. Rain Margin	M	dB	6.0	6.0	6.0
14. Satellite EIRP (10^0EL)	EIRP sat	dBW	4.4	7.9	10.7
15. Satellite EIRP (10^0EL)	EIRP sat	W	2.75	6.2	11.8
16. Satellite EIRP per channel	EIRP sat	mW	115	103	89
17. Satellite Illumination	$Wsat_n$	dBW/m^2	-89.8	-86.3	-83.5
18. Earth Station Transmit EIRP (10^0EL)	EIRP es	dBW	73.6	77.1	79.9

The Cost Model price used for the cost analysis will be $4.0 million. This price will be used as the frame of reference.

The cost analysis will consist of comparing the mean cost of the earth stations developed previously (Section 2.2) using 1972 to 1980 as the time frame for cost, with the Cost Model. The costs developed will be expressed as a percentage of the Cost Model ($4.0 million) price.

Tables 2-31 and 2-32 shows the result of the analysis for color TV and communications services respectively. Furthermore, the cost of the antennas and the multiplex equipment, where applicable, are expressed as percentages of the particular earth stations.

In addition, the equipment lists for the various models are depicted Tables 2-33 through 2-45. These tables were used in the cost analysis for equipment cost estimation.

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Table 2-29. Current Earth Station Equipment Cost Range

Item	Equipment	Descriptions	Cost *
1.	Antenna System	Includes the antenna pedestal, structure, reflector, the feed, duplexer, subreflector, and dual servo drive	$1.25M to 2.0M
2.	Dual Low Noise Receiver	Cryogenically colled low noise parametric amplifier (20 degee Kelvin); provides a minimum of 33 dB of gain	$175k to 250k
3.	Interfacility Link (Transmit and Receive)	Is completely redundant, includes TWT amplifiers (low noise or intermediate type), waveguide runs from antenna complex to control building, waveguide switches, pilot tone injection, etc.	$30k-50k (Receive or Transmit)
4.	Dual High Power Amplifier	A dual high power TWT amplifier in the 8kW range complete with power supply, heat exchanger/monitor, control and switching equipment.	$200k to 280k
5.	a. Power Divider	Power divider, reception (Low Level) 1:16	$2k to 5k
	b. Power Combiner	Low level, transmission 1:4	$1k to 3k
6.	Narrowband Transmitter	Low level, includes power supply, modulator, baseband unit, and upconverter	$18k to 25k

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Table 2-29. Current Earth Station Equipment Cost Range (Continued)

Item	Equipment	Description	Cost *
7.	Narrowband Receiver		
	A. Message	Message service assembly with power supply, threshold extension demodulator, baseband unit and down-converter.	$20k to 25k
	B. TV	Television service assembly with power supply, conventional demodulator, baseband unit and down-converter.	$18k to 22k
8.	Baseband Distribution Frame	Provides the baseband coupling and switching between the MUX and the narrowband receivers and transmitters	$25k to 50k
9.	Alarms/Monitor Control Equipment Plus Test Equip.	Depends on customer requirements	$100k to 275k
10.	Multiplex	The multiplex price is based on redundant frequency generation equipment from group up, but no terminations, signaling and conditioning equipment. A 132 channel consisting of one transmit path and voice receive paths is assumed.	$100k to 150k
11.	Installation Cost	Includes engineering, site preparation, cost of land, etc.	$500k to 1.75M

*In cost figures k = thousands, M = millions } of dollars

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Table 2-30. Estimated Cost Breakdown of a Typical MDC Earth Station

Items No.	Equipment	Qty.	1968-1972 Unit Cost: Thousands of Dollars Range	1968-1972 Cost in Thousands of Dollars Range
1	Antenna System	1	1,250 - 2,000	1,250 - 2,000
2	Dual Low Noise Receiver	1	175 - 250	175 - 250
3	a) IFL Transmit (Redundant)	1	30 - 50	30 - 50
	b) IFL Receive (Redundant)	1	30 - 50	30 - 50
4	a) Power Divider (1:16)	1	2 - 5	2 - 5
	b) Power Combiner (Low Level, 4:1)	1	1 - 3	1 - 3
5	Dual High Power Amplifier	1	200 - 280	200 - 280
6	a) Narrow Band Transmitter	4	18 - 25	72 - 100
	b) TV Baseband Unit (To convert redundant mess. to video operation)	1	2 - 4	2 - 4
7	Narrow Band Receiver (Low level)			
	a) Message	7	20 - 25	140 - 175
	b) TV Video	1	18 - 23	18 - 23
	c) Spare Standard Demod. & TV Baseband Unit plus IF Filters, Etc.	1	5 - 8	5 - 8
8	Baseband Distribution Frame	1	25 - 50	25 - 50

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Table 2-30. Estimated Cost Breakdown of a Typical MDC Earth Station (Cont)

Items No.	Equipment	Qty.	1968-1972 Unit Cost Thousands of Dollars Range	1968-1972 Thousands of Dollars Range
9	Multiplex (Message 132 voice channels)	1	100 - 150	100 - 150
10	Control Monitor & Test (Alarm/Monitor Control Equipment plus test equip.)	1	100 - 275	100 - 275
11	Installation Cost	1	500 - 1500	500 - 1750
	Total Cost			$2,650 - $5,173
	Mean Value			$3,911,500.

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Table 2-31. Cost Analysis of Color TV Earth Stations

Description	Block Diagram Figure No.	Grade of Service	Equip. List Table No.	Capacity	User	Cost**	Antenna Cost Normalized
A. Reception							
Regional (VSAM) **@ 850 MHz**	2-6	No. 1	2-33	One channel	Commercial*	2.0%	40%
National (VSAM) **@ 850 MHz**	2-7	No. 1	2-34	Five channels simultaneously	Commercial*	5.0%	20%
Home (VSAM) **@ 850 MHz**	2-8	No. 3.5	2-35	12 channels	Home	.01%	10%
Regional (FM) @ 4 GHz	2-10	No. 1	2-37	One channel	Commercial*	2.0%	14%
National (FM) @ 4 GHz	2-11	No. 1	2-38	Five channels simultaneously	Commercial*	5.0%	6.0%
B. Transmission							
Regional (VSAM) **@ 1.5 GHz**	2-9	No. 1	2-36	One channel	Commercial*	5.0%	20%
National (VSAM) **@ 1.5 GHz**	---	No. 1	2-36	Transmits three channels simultaneously	Commercial*	13%	7.0%
Regional (FM) @ 6 GHz	2-12	No. 1	2-39	One channel	Commercial*	3.0%	10%
National (FM) @ 6 GHz	---	No. 1	2-40	Transmits three channels simultaneously	Commercial*	5.0%	20%

** The ratio of the particular earth station to the Cost Model expressed in percent

* Cable head or interfaces with terrestrial microwave for distribution by TV stations.

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Table 2-32. Cost Analysis of Communications Service Earth Stations

Description	Block Diagram Figures	Grade of Service	Equip. List Table No.	Capacity	User	Cost*** Comparison	Antenna Cost Normalized	Multiplex Cost Normalized
A. Preassigned	2-13	TV-No. 1 Message-Toll quality (S/N=52dB)	2-41	Ties in with a network of five ground stations-300 voice capacity plus one TV channel	Developed or Developing* Nations	12%	7	30%
1. Multi-Destination Carrier (FDM/FM Station)								
2. Single Destination carrier (FDM/FM Station)	2-14	Message-Toll Quality (S/N 52dB)	2-42	1800 voice channels point to point	Developed Nations (e.g., USA to Europe	30%	3%	72%
B. Demand Access								
1. SCC/FM System**	2-16	Toll Quality or Better	2-43	85 demand access voice channels		15%	3%	60%
2. SCC/FM System**	2-16	Toll quality or better	2-44	12 demand access voice channels		6%	1%	30%

*** Ratio of the particular earth station to the Cost Model in percent.

** The cost of the routing earth station is counted with the cost of the satellite. (See Table 2-45 for est. cost).

* Could reduce cost by having a multiplex of lower capacity, e.g., 132 voice channels.

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Table 2-33. Regional TV Receive Earth Station Equipment List
(Figure 2-6)
VSAM

Item No.	Equipment	Description	Qty.
1	Antenna	30 ft diameter, mechanical tracking	1
2	LNR	Redundant Uncooled Paramp.	1
3	Power Divider	1:2	1
4	Receiver Equipment	LO, Mixer, D/C, IF, Demodulator, and Power Supply	2
5	Baseband Distribution Frame	Video Amps, Processors, etc. (accommodates 2 channels)	1
6	Monitoring and Alarms		1
7		Installation Cost	1

Table 2-34. National TV Receive Earth Station Equipment List
(Figure 2-7)
VSAM

Item No.	Equipment	Description	Qty.
1	Antenna	30 ft diameter, mechanical tracking	1
2	LNR	Redundant Uncooled Paramp with Power Supply	1
3	Power Divider	1:6	1
4	Receiver Equipment	LO, Mixer, D/C, IF, Demodulator, and Power Supply	6
5	Baseband Distribution Frame	Video Amps, Processors, etc. (accommodates 6 channels)	1
6	Monitoring and Alarms		1

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Table 2-35. Home TV Receive Earth Station Equipment List
(Figure 2-8)
VSAM

Item No.	Equipment	Description	Qty.
1	Antenna	5 ft diameter mechanical tracking	1
2	RF Amplifier		1
3	TV Receiver	Color, reception of UHF channels 71-83 only	1
4		Installation Cost	1

Table 2-36. Regional and National TV Transmit Earth Station Equipment List
(Figure 2-9)
VSAM

Item No.	Equipment	Description	Qty.*	
			R	N
1	Antenna	30 ft diameter mechanical tracking	1	1
2	High Power Amplifier	Redundant Amplifier, 12 kW, 100 MHz. Bandwidth, with Waveguide Switch	1	3
3	Transmitter Equipment	U/C, Modulator, and Baseband Unit	2	6
4	Baseband Distribution Frame	Video Amps, Processors, etc. (accommodates 2 channels)	1	3
5	Monitoring and Alarms		1	3
6		Installation Cost	1	1

*R = Regional
N = National

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Table 2-37. Regional TV Receive Earth Station Equipment List
(Figure 2-10)
FM

Item No.	Equipment	Description	Qty.
1	Antenna	15 ft diameter, mechanical tracking	1
2	LNR	Redundant Uncooled Paramp	1
3	Power Divider	1:4	1
4	Receiver Equipment	LO, Mixer, D/C, IF, Demodulator, and Power Supply	4
5	Baseband Distribution Frame	Video Amps, Processors, etc. (accommodates 4 channels)	1
6	Monitoring and Alarms		1
7		Installation Cost	1

Table 2-38. National TV Receive Earth Station Equipment List (Figure 2-11)
FM

Item No.	Equipment	Description	Qty.
1	Antenna	15 ft diameter, mechanical tracking	1
2	LNR	Redundant Uncooled Paramp	1
3	Power Divider	1:12	1
4	Receiver Equipment	LO, Mixer, D/C, IF, Demodulator, and Power Supply	12
5	Baseband Distribution Frame	Video Amps, Processors, etc. (accommodates 12 channels)	1
6	Monitoring and Alarms		1
7		Installation Cost	1

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Table 2-39. Regional TV Transmit Earth Station Equipment List
(Figure 2-12)
FM

Item No.	Equipment	Description	Qty.
1	Antenna	15 ft diameter, mechanical tracking	1
2	High Power Amplifier	Redundant Amplifier, 1 kW, 500 MHz Bandwidth	1
3	RF Combiner	4:1	1
4	Transmitter Equipment	U/C, Modulator, Baseband Unit	4
5	Baseband Distribution Frame	Video Amps, Processors, etc. (accommodates 4 channels)	1
6	Monitoring and Alarms		1
7		Installation Cost	1

Table 2-40. National TV Transmit Earth Station Equipment List FM

Item No.	Equipment	Description	Qty.
1	Antenna	30 ft diameter, mechanical tracking	1
2	High Power Amplifier	Redundant Amplifier, 1 kW, 500 MHz Bandwidth	1
3	RF Combiner	8:1	1
4	Transmitter Equipment	U/C, Modulator, Baseband Unit	8
5	Baseband Distribution Frame	Video Amps, Processors, etc. (accommodates 8 channels)	1
6	Monitoring and Alarms		1
7		Installation Cost	1

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Table 2-41. MDC Satellite Communications Earth Station Equipment List (Figure 2-13)

Item No.	Equipment	Description	Qty.
1	Antenna Subsystem	30 ft diameter, mechanical tracking with Duplexer	1
2	LNR	Uncooled Paramp with splitter driver	1
3	HPA	1-2 kW, 500 MHz nominal bandwidth	1
4	Broadband Splitter	1:8	1
5	Broadband Combiner	4:1	1
6	Receivers		
	a) TV Video	DC, IF, STD Demod, baseband unit	1
	b) Telephony	DC, IF, STD Demod, baseband unit	7
	c)	TV Baseband unit, IF filter (to convert spare rec.)	1
7	Transmitter/Exciters		
	a) TV Video	Baseband unit, mod, IF, UC	1
	b) Telephony	Baseband unit mod, IF, UC	3
	c)	TV Baseband unit (to convert redundant telephony to TV video	1
8	Super Group Distribution Frame	Amps, Processors, etc.	1
9	Multiplex Subsystem	300 VC Capacity	1
10	Control Monitor and Test Equip.		1
11		Installation Cost	1

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Table 2-42. SDC Satellite Communications Earth Station Equipment List
(Figure 2-14)

Item No.	Equipment	Description	Qty.
1	Antenna Subsystem	30 ft diameter, mechanical tracking with Duplexer	1
2	LNR	Uncooled Paramp with Splitter Driver	1
3	Power Amplifier	1-2 kW, 500 MHz nominal bandwidth	1
4	Broadband Splitter	1:4	1
5	Broadband Combiner	4:1	1
6	Receiver Equipment	D/C, IF, Std-Demodulator, Baseband Unit	4
7	Transmitter Equipment	U/C, IF, Modulator, Baseband Unit	4
8	Super Group Distribution Frame	Amps, Processors, etc. (accommodates 4 channels)	1
9	Multiplex Subsystem	Handles 3 carriers (600 voice channels per carrier)	1
10	Control Monitor and Test Equip.	- - -	1
11	- - -	Installation Cost	1

Table 2-43. Demand-Assigned Earth Station for Developed Nations Equipment List
(Figure 2-16)

Item No.	Equipment	Description	Qty.
1	Antenna	15 ft diameter, mechanical tracking	1
2	Power Amplifier	Redundant, 1 kW, 500 MHz Bandwidth	1

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Table 2-43. Demand-Assigned Earth Station for Developed Nations Equipment List (Cont)
(Figure 2-16)

Item No.	Equipment	Description	Qty.
3	Low Noise Amplifier	Redundant Uncooled Paramp	1
4	Transmitter Equipment	Up Converter, LO, Power Adder (85:1)	1
5	Receiver Equipment	Down Converter, LO, Power Divider (1:85)	1
6	Transmitter Chain	FM Modulator, Mixers (4), Frequency Switching Matrix Logic	85
7	Digital Modulator		1
8	Receiver Chain	FM Demodulator, Mixers (4), Frequency Switching Matrix Logic	85
9	Digital Demodulator		1
10	Frequency Synthesizer and Distribution System	Provides 40 different frequencies	1
11	Start-Stop Equipment		85
12	Terminal Equipment	Includes Echo Suppressor and Hybrids	85
13	Controller	Channel Assignment, Access Line Selection, Signalling for TDM Link, etc.	1
14	Board	(Switchboard)	1
15		Installation Cost	1

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Table 2-44. Demand-Assigned Earth Station for Developing Nations Equipment List (Figure 2-16)

Item No.	Equipment	Description	Qty.
1	Antenna	15 ft diameter, mechanical tracking	1
2	Power Amplifier	Redundant, 1 kW, 500 MHz Bandwidth	1
3	Low Noise Amplifier	Redundant Uncooled Paramp	1
4	Transmitter Equipment	Up Converter, LO, Power Adder (12:1)	1
5	Receiver Equipment	Down Converter, LO, Power Divider (1:12)	1
6	Transmitter Chain	FM Modulator, Mixers (4), Frequency Switching Matrix Logic	12
7	Digital Modulator		1
8	Receiver Chain	FM Demodulator, Mixers (4), Frequency Switching Matrix Logic	12
9	Digital Demodulator		1
10	Frequency Synthesizer and Distribution System	Provides 40 different frequencies	1
11	Terminal Equipment	Includes Echo Suppressor and Hybrids	12
12	Controller	Channel Assignment, Access Line Selection, Signalling for TDM Link, etc.	1
13	Board	(Switchboard)	1
14		Installation Cost	1

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Table 2-45. Routing Center Equipment List
(Figure 2-17)

Item No.	Equipment	Description	Qty.
1	Antenna	15 ft diameter, mechanical tracking	1
2	HPA	20 W, 5 MHz Bandwidth (min.)	1
3	LNR	Uncooled Paramp	1
4	Transmitter	TDM	1
5	Receiver	TDM	1
6	Digital Modulator		1
7	Digital Demodulator		1
8	Central Equipment	Data Terminal and Control	1
9		Installation Cost	1

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2.4 EARTH STATION ANTENNA ECONOMICS

2.4.1 Introduction

Since the satellite transmitting powers and operational frequencies during the next 10 to 15 years may change considerably over that of today or of those assumed for purposes of this report, it is of interest to consider the cost of antennas between the sizes of 5-foot to 105-foot diameter and for operational frequencies from 1 GHz to 35 GHz. The present-day costs of basic materials used in antenna fabrication are shown in Table 2-46. It is anticipated that the materials shown in Table 2-46 will continue to be used for a large number of the commercial antennas that will be built within the next 15 years. Since the type of material and fabrication techniques used depends upon the type and size of antenna, it is convenient to consider three classes of antennas:

a. Large (over 30-foot diameter) steerable antennas.

b. Large nonsteerable antennas

c. Small nonsteerable antennas

Table 2-46. Basic Fabrication Costs for Large Antennas

Metal Castings	$0.80 - 1.00/lb
Structural Steel	$0.25 - 0.30/lb
Structural Aluminum	$0.75 - 0.90/lb
Reflector Panels *	$5.50/ft^2
Concrete **	$0.50 - 3.00/cubic foot
Reinforced Concrete **	$3.50 - 4.50/cubic foot
Lead (used in counterweights)	$0.20/lb
Fiberglass	
Laminate 181 glass cloth	$0.25/ft^2
Impregnated with resin	$0.15 - 0.25/ft^2
Polyurethane Foam	$0.80/lb

* Solid panels includes initial tooling and painting

** Includes cost of installation

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2.4.2 Antenna Reflector Surface Considerations

The most important aspect of a reflector antenna is the reflector surface itself. The performance and cost of the antenna is highly dependent upon the type and quality of reflector surface that is used. The quality of the reflector surface is normally given in terms of its root-mean-square deviation from the desired surface. The required surface accuracy depends upon the highest radio frequency to be used.

It can be shown that the gain/loss is given by the following expression: *

$$\text{Power/gain/loss in decibels} = 5.555\ (\sigma f)^2 \qquad (2\text{-}37)$$

where: f is the RF frequency in GHz

σ is the effective standard deviation (root-mean-square) in inches of the surface errors relative to desired surfaces.

A common rule of thumb is that the rms surface tolerance should be less than $\lambda/12$, where λ is the radio-frequency wavelength. This is based upon the fact that the maximum gain of the antenna is achieved when the operating frequency wavelength is 12 times that of the rms surface tolerance.

This maximum gain is

$$G_{max} = \frac{\eta}{43} \left(\frac{D}{\sigma}\right)^2 \qquad (2\text{-}38)$$

and is 4.3 dB less than the gain that would have been obtained with a perfect reflector. The frequency at which the maximum gain occurs is called the gain-limit frequency. Figure 2-19 illustrates the relationship between the gain-limit frequency and the σ/D ratio of a reflector.

2.4.3 Large Steerable Antenna Costs

2.4.3.1 Introduction

A number of factors determine the cost of large steerable antennas. The important factors are:

a. The antenna reflector surface

b. The wind environment

c. The type of mount

d. The type of servo drive system

* John Ruze. "Antenna Tolerance Theory - A Review," Proceedings of IEEE, Volume 54, No. 4, April 1966

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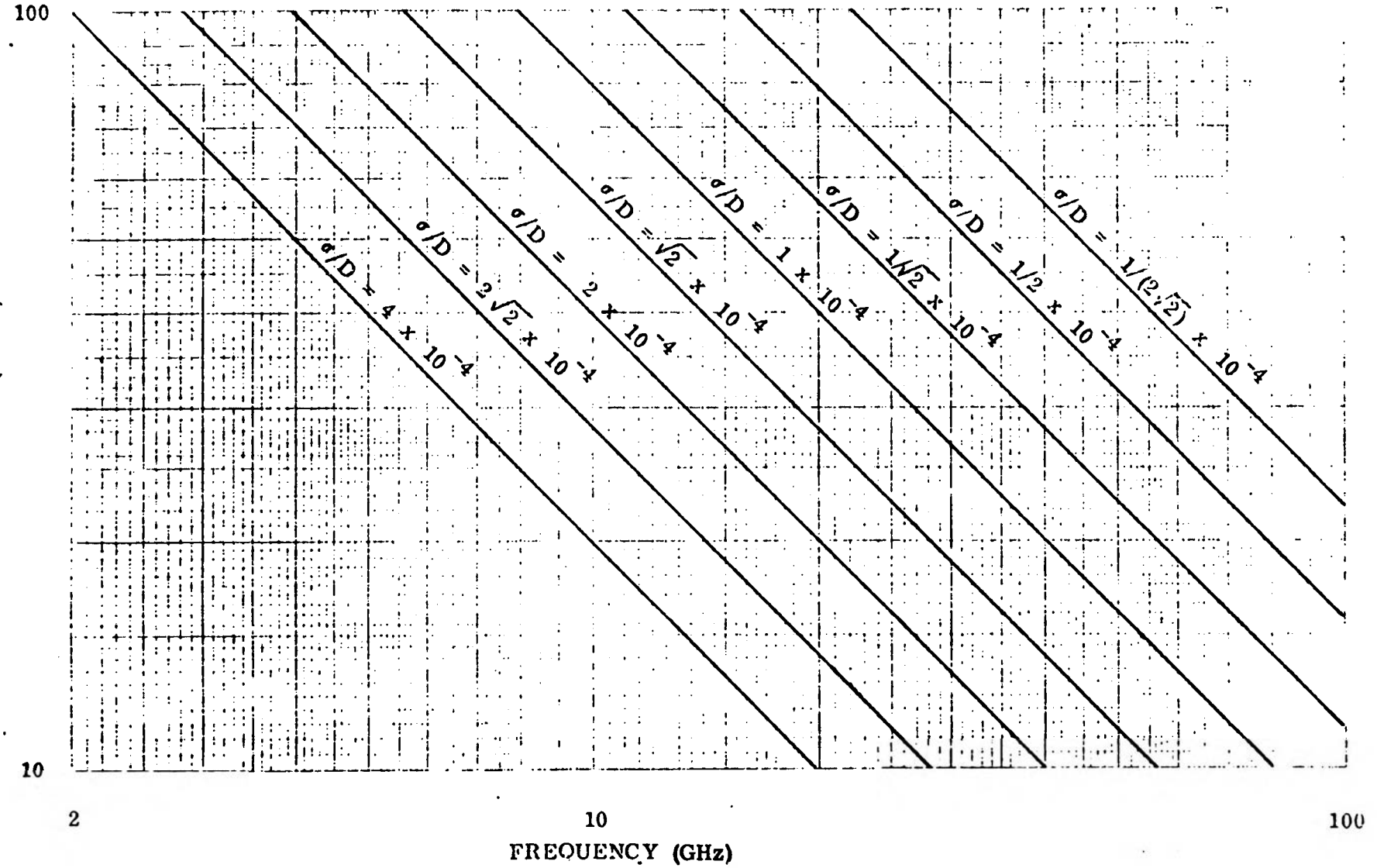


Figure 2-19. Gain Limit Frequency

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Large reflector antenna surfaces are normally made up of individual accurately contoured panels. The panels in turn are usually supported by adjustable mounts on a rigid back-up support structure. This approach permits the back-up structure to be designed for strength and overall rigidity without requiring precision dimensional control in the structural members. This approach, in general, has proven to result in the lowest cost in fabricating large reflectors for commercial use.

The panel design involves optimization of several design parameters which affect the cost of the panels as well as the cost of the back-up support structure. For operating frequencies below 3 GHz it is common practice to use mesh-surface panels, since this reduces the weight of the reflector panels and the wind loading of the entire reflector structure. The higher the radio frequencies the smaller the required hole size of the mesh. For example, at 850 MHz, 1/4-inch hole sizes are acceptable, whereas at 2.3 GHz 3/16-inch hole sizes are common.

A variety of materials and fabrication techniques have been used to construct low-cost, light-weight and rigid reflector surface panels. Many of these have been described in the literature[1]. The most common type of solid-surface reflector panel is the framed-skin type where a contoured sheet of metal is bonded to a light-weight rigid panel frame. However, the use of plastic materials has been increasing in recent years. The cost and weight per square foot for three of the most common panel construction techniques are compared in Table 2-47.

Table 2-47. Approximate Relative Costs of Typical Solid-Surface Reflector Panels[2]

	Honeycomb Sandwich	Framed Skin	Foam Sandwich
Weight	1.05 lb	1.5 lb	2.0 lb
$/ft^2 - Qty. 1	21	18	10
$/ft^2 - Qty. 10	15	13	3
$/ft^2 - Qty. 40	12	1.05	7
$/ft^2 - Qty. 100	10.5	9	6

The above costs can vary by a factor of two depending upon the size, shape accuracy and quantity. The cost of mesh type of reflector surface panels is typically 1/2 to 1/3 that of solid-surface panels.

1 S. Pugh & D.E. Walker "Reflector Surfaces for Communication and Radar Aerials" Design & Construction of Large Steerable Aerials, IEE Conference Publication Number 21, June 1966

2. "A Proposal for a Very Large Array Radio Telescope" Vol. II Chapter 11 prepared by the National Radio Astronomy Observatory, January 1967

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2.4.3.2 Effect of Wind on Antenna Costs

The wind distorts the reflector surface, offers additional resistance to the antenna drive system, and attempts to overturn the antenna. Thus, the wind environment affects the cost of the reflector back-up structure, the drive system, the pedestal and foundation. The wind loading in turn depends upon whether or not the reflector surface is solid or mesh. Figure 2-20 illustrates the typical reduction in wind loading with mesh reflector panels. The wind loading also depends upon the antenna pointing angle. This is illustrated in Table 2-48.

Table 2-48. Relative Effect of Antenna Pointing Angle on Cost[1]

Elevation angle	0	10°	20°	25°	30°
Wind drag loading	1.0	0.96	.91	.88	.70
Wind moment at ground	1.0	.90	.67	.58	.51
Counter weight	1.0	.87	.80	.73	.70
Tower structure weight	1.0	.88	.74	.66	.60
Pedestal cost	1.0	.938	.885	.848	.825

The effect of wind on the required drive torques at the antenna axes is illustrated in Figure 2-21.

2.4.3.3 Drive System Costs

The type of antenna drive and control system used also influences the antenna costs. The two basic drive systems used are electric motor and hydraulic motors. It has been reported[2] that at 10 hp the cost of a hydraulic drive is about half that of the electric equivalent. At 100 hp the cost of a hydraulic drive is about two-thirds of the electric equivalent. For hydraulic drives up to 20 hp, valve control is considered to cost less. Above 20 hp pump control is slightly less costly. For 100 hp hydraulic drives, the pump control costs are approximately 15 percent less than the valve control equivalent. Figure 2-22 shows the relative cost of servo drive systems as the horsepower requirements vary for a static SCR bidirectional drive amplifier, with dc drive motors arranged in a parallel antibacklash configuration and servo electronics. The servo electronics is assumed to have multiple mode selections, automatic acquisition, position follow-ups, remote and/or computer control and/or

1. Ibid VLA Proposal

2. K.N. Hastings and J.G. Chaplin "Drives For Steerable Aerials - Hydraulics Versus Electromechanical "Design and Construction of Large Steerable Aerials, British IEE Conference Publication Number 21, p. 135-139.

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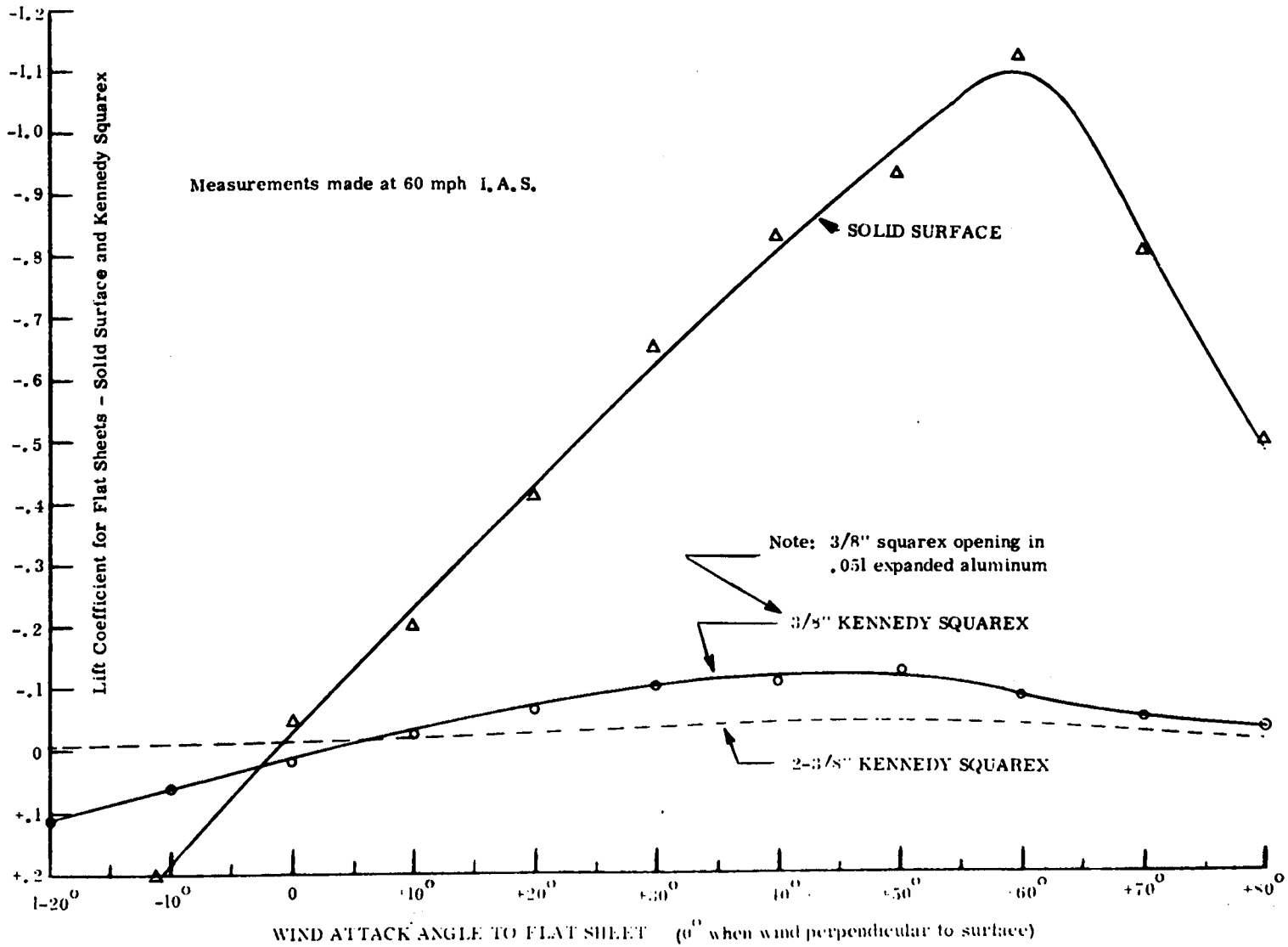


Figure 2-20. Wind Tunnel Measurements by MIT-Lincoln Lab (Aug. 1956) (MIT Test Report No. 950)

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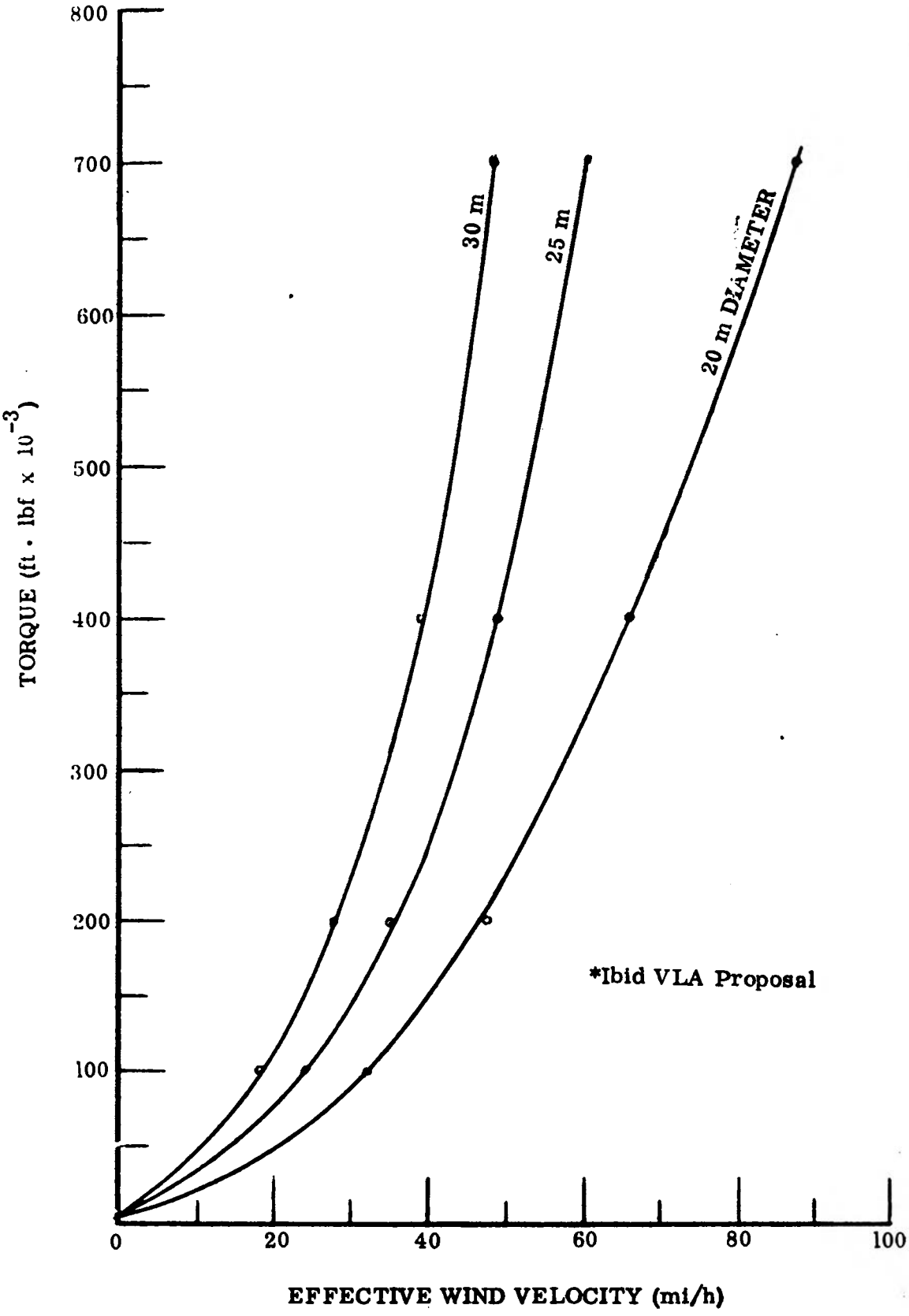


Figure 2-21. Torque Requirements Versus Wind Velocity For Different Size Reflectors*

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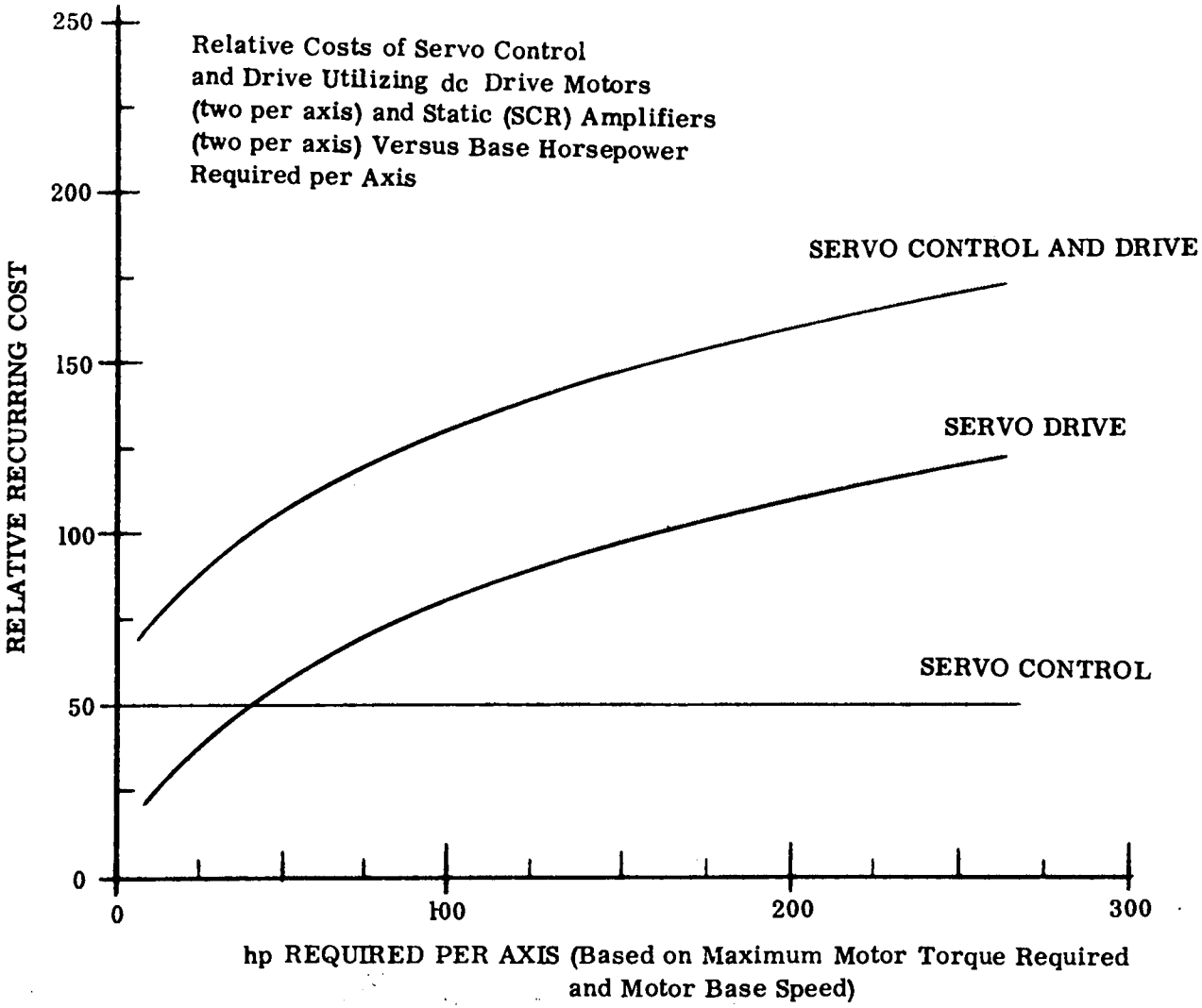


Figure 2-22. Relative Cost of Servo Drive Systems Versus Power Requirements

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monitoring capabilities. Non-recurring costs depend highly on the amount of dynamic analysis and interfacing required to integrate the servo control and drive into the system, and can easily vary by a factor of two.

The base horsepower is defined as the maximum required continuous torque (greater than one minute) times the base speed of the dc motors. Motor overloads of 150 percent of the maximum required continuous torque are allowable as long as the rms horsepower is below the base horsepower and the overload is not sustained continuously longer than one minute.

2.4.3.4 Parametric Relationship of Large Steerable Antenna Costs

As indicated in previous sections the antenna cost is a function of the size of the antenna, the wind environment and the required surface tolerance. It has been shown [1, 2, 3] that the costs of large steerable antennas can be expressed in the following form:

$$C = C_o V^n f^m D^k \qquad (2\text{-}39)$$

where

C_o is a proportionality constant

D is the diameter of the antenna

k is a constant whose value is between 2.7 and 3.1

v is the wind velocity

f is the highest operational radio frequency

m is a constant whose value is approximately 1/3

n is a constant whose value is approximately 2/3.

---

1. W.K. Victor, "Ground Equipment for Satellite Communication" J.P.L. Tech Report No. 32-137 Oct. 30, 1961

2. R.N. Bracewell, Swarup and Seeger, Nature 142, Vol. 193, pp. 412-416

3. P. Blacksmith and A.C. Schell "A Comparison of Three Antenna Techniques in Terms of Cost vs Performance" Design & Construction of Large Steerable Aerials, British IEE Conference Publication Number 21. P. 135-139.

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The cost includes the foundation and drive system as well as erection costs. The proportionality constant depends upon the type of antenna mount. Figures 2-23 and 2-24 illustrate how the costs vary with size of the antennas, type of reflector surfaces and type of mounts.

2.4.3.5 Effect of Reliability Requirements on Antenna Cost

Communications Satellite Antennas will normally be required to provide for continuous 24 hr/day operations. For steerable antennas, this means a cost of approximately 1.5 times greater than the same size of steerable antennas which do not operate continuously, such as radio astronomy antennas.* This increase in cost is partly due to the quality of materials required for greater reliability, but is primarily due to the requirement to continue operation under practically all weather conditions.

The need for continuous operation requires that the antenna-mounted equipment must be readily accessible. To illustrate, many of the large present-day earth-terminal antennas are equipped with large equipment rooms with near-laboratory ambient conditioning. Some are even equipped with elevators to ferry the electronic technicians back and forth.

For use with synchronous satellites, a steerable autotracking antenna can spend a considerable amount of time rocking back and forth on one or two gear teeth. Gear failure rates are normally rated under the assumption that all of the gear teeth over the lifetime will be loaded approximately the same percentage of time. Where this is not the case, higher stress gears are required.

One way which has been suggested to reduce the wear on the gear teeth is to stop the antenna drives and turn them on only when needed to correct the antenna pointing for satellite drift. For most drive systems, the wear and tear of starting and stopping a great number of times is many times greater than if they were permitted to run continuously.

*P. Potter, W. Merrick and A. Ludwig "Large Antennas and Arrays for Deep Space Communications," JPL Technical Report 32-348, November, 1965.

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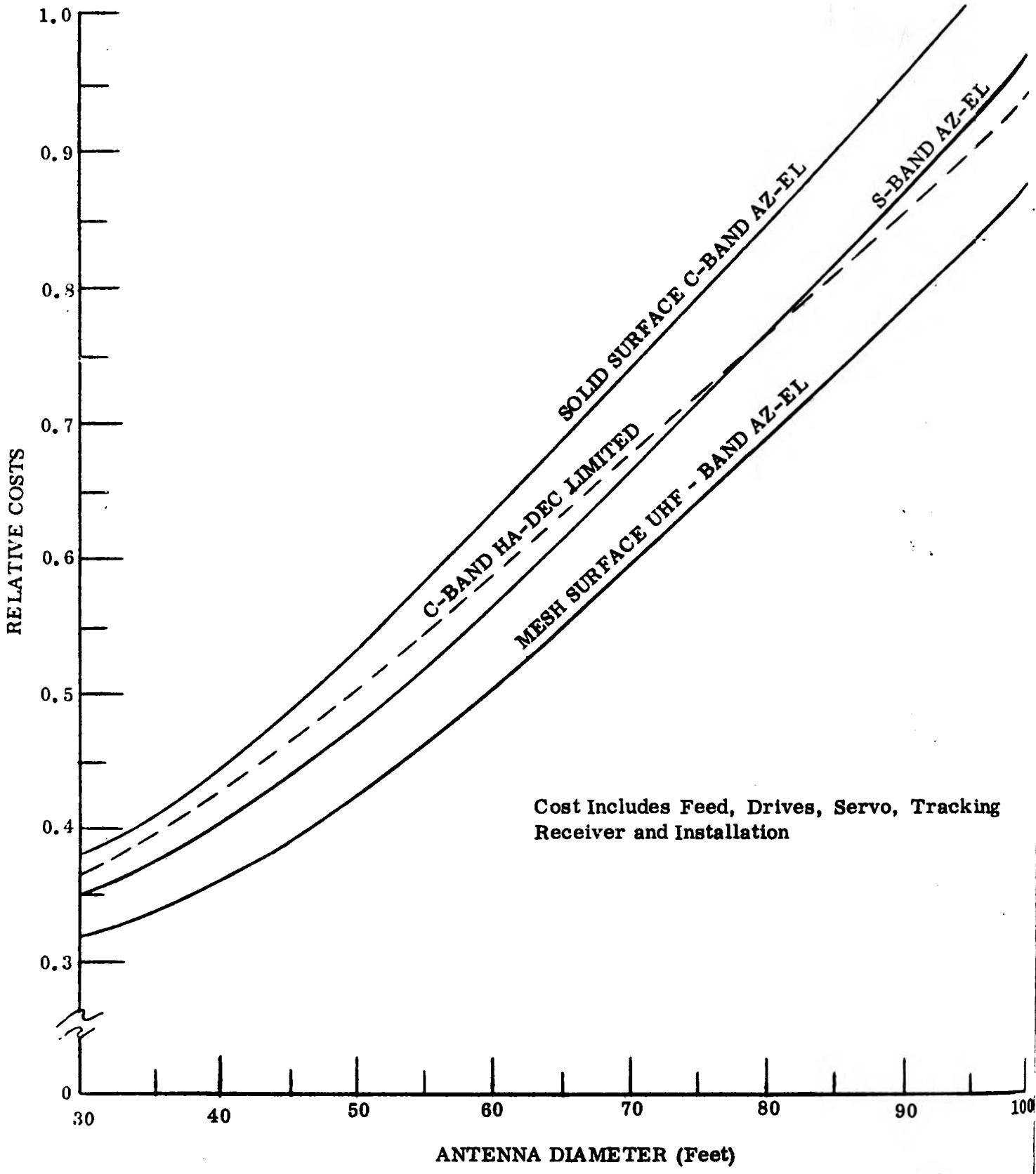


Figure 2-23. Steerable Antenna Costs Versus Diameter

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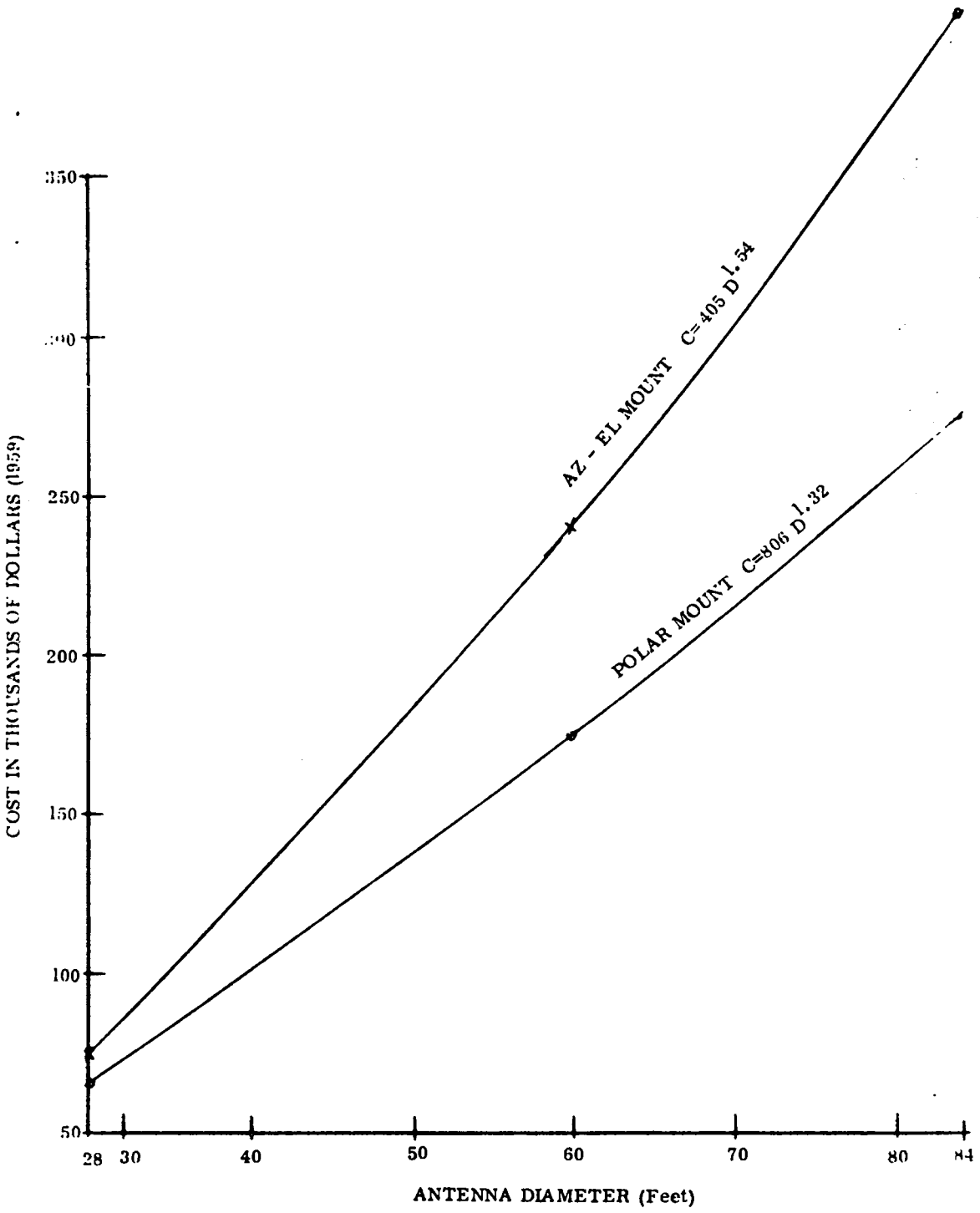


Figure 2-24. D. S. Kennedy Mesh Surface Steerable Antenna F.O.B. Factory Costs With Electric Drive and Front-Fed Feed

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2.4.4 Large Non-Steerable Antenna Costs

It has been reported [1, 2] that the cost of large fixed mesh-surface reflector antennas is about $9.40 per square foot. Hutchinson[2] has estimated that the increased cost of a solid reflector surface suitable for 4 GHz is threefold. He further concludes that an 80-foot diameter fixed reflector antenna would cost one-half that of a fully steerable 60-foot antenna. Other studies [3, 4] have indicated that the cost ratio between fixed reflectors and limited motion reflectors at 4 GHz and in sizes from 10 to 60-foot diameters is 0.7 to 0.8.

2.4.5 Small Reflector Antenna Costs

The most common technique for manufacturing solid-surface parabolic reflectors up to 15 feet in diameter is the spin-shaping technique. This technique forces a spinning section of heavy sheet metal to conform to a parabolic shaped mandrel. On occasions this technique is also extended to reflectors up to 25 feet in diameter.

More recently plastic antenna reflectors to which a metallic skin or coating is applied to form the reflecting surface have been gaining in popularity. Metal-coated plastic reflectors up to 30 feet in diameter are currently in use. This technique has been applied successfully for millimeter wave types of antennas. For millimeter-wave type of applications the low cost of the material and its excellent thermal stability make it very competitive with metal antennas.

The costs of small conventional microwave relay antennas and tropospheric antennas are known and are illustrated in Figure 2-25. It was indicated in earlier sections that the majority of the earth station costs remained fixed regardless of the antenna. When a large number of stations are contemplated, techniques which reduce the antenna costs even when the antenna is not the dominant cost item of the station can become significant. Some of the possibilities in this direction have been explored by the

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1. Ibid, P. Blacksmith and A.C. Schell, "A Comparison of Three Antenna Techniques in Terms of Cost Vs. Performance, "Design & Construction of Large Steerable Aerials British IEE Conference Publication Number 21, p. 135-139.
2. G.L. Hutchinson, "A Review of Microwave Problems in the Designs of Large Steerable Aerials" presented at the Conference on Design & Construction of Large Steerable Aerials, London, June 21, 1966.
3. R.D. Swenson, "Economic Comparisons of Domestic Satellite Television Distribution System"
4. "An Approach to Low Cost, High Performance Antenna Systems for Satellite Communications Ground Stations," Andrew Corporation Report dated March 1967.

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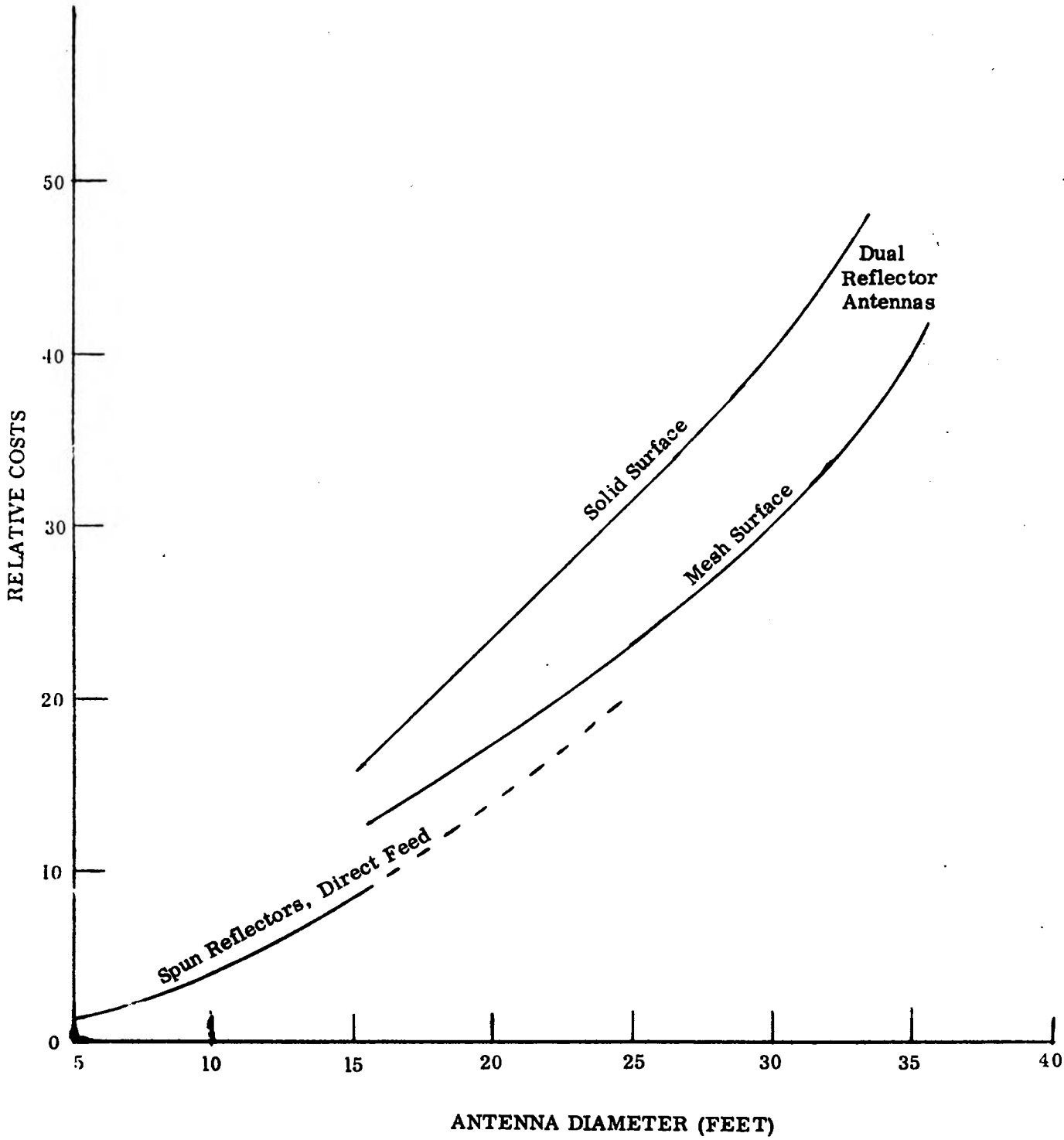


Figure 2-25. Fixed Commercial Antenna Costs Versus Diameter (Cost Includes Feed and Installation)

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engineering students at Stanford*. Their estimated fabrication costs for a large number of small reflectors range from $18 for a four-foot reflector to $55 for an eight-foot reflector.

2.4.6 Antenna Feed Costs

The antenna feeds currently used for commercial communications satellite earth terminals are fairly sophisticated. This is primarily because current earth-terminal antennas are 85 feet to 105 feet in diameter. For these sized antennas autotracking is normally required. In addition, the sophistication of the antenna feed system can be justified by the savings in the size of the antenna.

A recent survey of the antenna feed suppliers indicates that the present-day price for feed systems varies from $95,000 to $200,000. All of these feeds are capable of low-noise high-efficiency reception and autotracking in the 3.7 to 4.2 GHz frequency band, while simultaneously transmitting up to 10 kilowatts of power in the 5.925 to 6.425 GHz frequency band. All of these feeds are capable of operating in linear or circular polarization modes. When using the linear polarization mode, the feeds are equipped for positioning of the polarization orientation.

A variety of fabrication techniques are employed, such as casting, machining, electroforming, dip-brazing, etc. All of the fabrication processes require a great deal of individual attention by a skilled craftsman. In addition, a great deal of mechanical and electrical testing is required, which again requires highly skilled craftsmen, technicians, and engineers. The net result, much like that of the communications satellites, is a high cost per pound. Thus, as long as sophisticated antenna feed systems are used, the price will not significantly decrease.

Most of the sophistication is in the communications portion of the antenna feeds so that elimination of the autotracking requirements will result in, at most, moderate reductions in the feed cost, i.e., 5 to 15 percent. In the communications portion of the feed system, more effort is directed towards optimizing the receive performance so that elimination of the transmit requirement would only result in 10 to 15 percent reduction in the cost of the feed system.

To achieve similar sophistication as present-day feeds at other frequency bands requires $100,000 to $350,000 in development costs. The only way to anticipate a reduction in feed costs within the next 10 to 15 years is to anticipate a reduction

*ASCEND - Advanced System For Communications and Education in National Development. Final Report Space Systems Engineering Report, Stanford University June 1967.

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in the sophistication. This can be achieved through improved satellites and relaxation of the accessibility requirements. To illustrate, commercial microwave communications antenna feeds which are designed to feed the parabolic reflector from the front cost anywhere from $500 to $2,000.

Present-day earth-terminal feeds are designed to feed the reflector from the rear by means of a subreflector. This permits the low-noise receiver to be mounted behind the main reflector in an equipment room. This technique uses a secondary reflector whose cost alone is about $600 per foot in diameter. Subreflector diameters are typically 0.1 to 0.15 of main reflector diameter. The use of a subreflector permits improved G/T performance but it also requires a large feed system. For example, the feed systems for present-day earth-terminals weigh on the order of 3500 to 6000 pounds, compared to 50 to 150 pounds for a front-fed feed.

2.4.7 Receiving System Cost Tradeoffs

From the previous sections it would appear that the reduction of the antenna diameter by a factor of two could result in reducing the cost of large steerable antennas by a factor of 6.5 to 8.5. The net cost savings depends upon the amount of expenditure required to achieve the more sophisticated design; i.e., the net cost savings is approximately equal to:

$$\Delta C = \Delta C_a + \Delta C_e \tag{2-40}$$

where

$$\Delta C_a \tilde{=} C_o \left(\frac{D_1}{D_2} \right)^k$$

and

ΔC_e is the extra cost to achieve the more sophisticated design.

It should be noted that the cost ΔC_e is, for all practical purposes, independent of the size of the antenna.

System design engineers try to use the smallest antenna diameter with the highest antenna efficiency possible to meet the system requirements, since this usually results in the lowest cost. This is particularly true in the case of a quantity of antennas. There is, of course, a limit to the increase in antenna gain that can be achieved by increasing the efficiency. Most microwave parabolic antennas can be designed to produce an efficiency of 55 percent by cookbook methods. Table 2-49 compares the

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Table 2-49. Comparison of Performance of Different Types of Large Microwave Antennas at 4 GHz

Feed System	Maximum Theoretical Efficiency (Percent)	Typical Maximum Efficiency (Percent)	Anticipated Maximum Efficiency (Percent)
Primary Focus Conventional 10 dB Taper	75.0	52.5	58
Primary Focus Conventional 20 dB Taper	71.6	50	55
Primary Focus Shaped-Beam 20 dB Taper	71.6	60	65
Conventional Cassegrain	81-85	55	6
Cassegrain with Shaped Subreflector	81-85	62	67
Shaped Dual Reflector	81-85	72	80
Dielguide	81-85	68	73
Horn-Reflector	91-95	77	87
Spherical Reflector With Corrective Subreflector	60	40	50

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relative efficiency of various types of antennas. Thus, the maximum reduction in antenna diameter that is theoretically possible (i.e. 100 percent efficient) is a factor of 0.74 over one that is 55 percent efficient. It is believed that the upper limit for a physically realizable parabolic reflector antenna is 85 percent, allowing a reduction in the antenna diameter by a factor of 0.804. The differential cost reduction, ΔC, which results from an increase in efficiency, ΔN, is given by the following expression:

$$C = C\ (1 - \alpha^{k}) \tag{2-41}$$

where

α = antenna diameter reduction factor

$$\alpha = \left[\frac{N}{N + \Delta N}\right]^{1/2} \simeq \left[1 - \frac{\Delta N}{N}\right]^{1/2} \tag{2-42}$$

$$\frac{\Delta C}{C} \simeq \frac{k}{2} \qquad \frac{\Delta N}{N} \quad (\text{if } \Delta N/_{N} \text{ less than } 0.1)$$

The above equation assumes that the gain of the antennas is the same in both cases, and C is the cost of the larger antenna. Table 2-50 illustrates the differential antenna costs predicted by the above expression compared to a 55 percent efficient antenna while holding the antenna gain constant.

Of course, part of the above savings must be applied to the cost of achieving the additional antenna efficiency. If the reference antenna already has a high efficiency (say 65 percent), it may cost more to increase the efficiency significantly than can be saved by reducing the antenna diameter accordingly.

If the quotient of antenna gain/noise temperature (G/T) is the prime figure of merit, a similar cost and antenna performance tradeoff may be performed by reducing the antenna noise temperature. If the antenna noise temperature is reduced without affecting the antenna efficiency (which is rarely the case in practice) and the antenna cost follows Equation 2-42, then

$$C = C\ (1 - B^{k})$$

where

B = antenna reduction factor

$$B = \left[1 - \frac{\Delta T}{T}\right]^{1/2} \tag{2-43}$$

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Table 2-50. Theoretical Antenna Cost Reduction For Improving Antenna Efficiency Above 55 Percent

Efficiency In Percent	Diameter Reduction Factor	$\frac{\Delta C}{C}$ k = 2.7	$\frac{\Delta C}{C}$ k = 2.8	$\frac{\Delta C}{C}$ k = 2.9	$\frac{\Delta C}{C}$ k = 3.0	$\frac{\Delta C}{C}$ k = 3.1
55	1.000	.000	.000	.000	.000	.000
60	.957	.111	.115	.119	.122	.126
65	.920	.202	.209	.215	.222	.228
70	.886	.278	.287	.295	.304	.312
75	.856	.342	.352	.362	.372	.382
80	.829	.397	.408	.419	.430	.441
85	.804	.444	.456	.468	.480	.491

$$\frac{\Delta C}{C} \cong \frac{k}{2} \quad \frac{\Delta T}{T} \qquad \left(\text{if } \frac{\Delta T}{T} \text{ less than } 0.1\right) \tag{2-44}$$

Table 2-51 illustrates the differential costs predicted by Equation 2-43 compared to an antenna having a noise temperature of 50°K while holding the gain constant.

2.4.8 High Power Amplifier and Antenna Tradeoffs

The required Effective Isotropic Radiated Power (EIRP) from the ground-based station depends upon the modulation, the satellite receiver characteristics, and the quality of service. The EIRP is given by the product of the antenna gain and the transmitter power output, i.e.:

$$\text{EIRP} = GP = \eta \left(\frac{\pi D}{\lambda}\right)^2 \beta P_t \tag{2-45}$$

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where

G is the antenna power gain

P is the transmitting power

η is the antenna gain efficiency

D/λ is the antenna diameter-to-wavelength ratio

P_t is the transmitter saturation power

β is the transmitter back-off factor to minimize the intermodulation.

Table 2-51. Theoretical Antenna Cost Reduction For Improving Antenna Noise Temperature

Antenna Temperature Degrees Kelvin	Diameter Reduction	$\frac{\Delta C}{C}$ k = 2.7	$\frac{\Delta C}{C}$ k = 2.8	$\frac{\Delta C}{C}$ k = 2.9	$\frac{\Delta C}{C}$ k = 3.0	$\frac{\Delta C}{C}$ k = 3.1
50	1.000	.000	.000	.000	.000	.000
49	.990	.027	.028	.209	.030	.031
48	.980	.054	.056	.057	.059	.061
47	.970	.080	.083	.086	.089	.091
46	.959	.106	.110	.114	.118	.121
45	.949	.133	.137	.142	.146	.151
44	.938	.159	.164	.169	.174	.180
43	.927	.184	.190	.196	.202	.208
42	.917	.210	.217	.223	.230	.237
41	.906	.235	.243	.250	.257	.265
40	.894	.260	.268	.276	.284	.292
39	.883	.285	.294	.303	.211	.320
38	.872	.310	.319	.328	.337	.346
37	.860	.334	.344	.354	.363	.373
36	.849	.358	.369	.379	.389	.399
35	.837	.382	.393	.404	.414	.425

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The cost of the high-power amplifier increases as its saturated (maximum output) power output increases. The cost also depends upon a number of other factors, such as bandwidth requirements, operating frequency, etc.

Narrow-bandwidth (1 to 3%) high-power microwave amplifiers usually employ klystron amplifiers and are suitable for single-carrier transmission. Wide-bandwidth (10% to 15%) high-power microwave amplifiers usually employ Traveling-Wave-Tubes (TWT) and are suitable for multiple-carrier operation (with a suitable backoff).

Although the cost of a high-power amplifier increases with the increase in its saturated output power, the cost per unit of output power decreases as the saturated power output increases. This is illustrated below.

Table 2-52. Relative Cost Per Unit of Power for Microwave High-Power Amplifiers*

Saturated Output Power	Type of Amplifier	
	Klystron	TWT
100 watts	$70/watt**	$100/watt
1000 watts	$20/watt	$ 35/watt
10,000 watts	$ 6/watt	$ 11/watt

* L.L. Fisher, "High Power Wideband TWT Power Amplifier Systems," presented at 1968 IEEE Region 6 Conference.

**extrapolated

From Table 2-52 it appears that the high-power amplifier costs are inversely proportional to the square root of the saturated power level.

2.4.9 Satellite Orbital Spacing Versus Earth Station Antenna Diameter

Dramatic increase in satellite EIRP is projected in the 1970's. This increase in EIRP will be attained by increased satellite transmitter power coupled with the use of higher-gain satellite antennas (national, regional, "pencil beam" coverage). With this increase in EIRP, the cost of the earth terminals served can be drastically reduced from the current range of 2.65 million to 5 million to under 0.5 million dollars. This cost reduction is achieved primarily by having earth stations with smaller antennas (mechanical positioning only) and uncooled low-noise receivers. (The result is an earth terminal with a lower station figure of merit, (G/T) ratio.) The latter does not affect the separation between satellites operating at common frequencies. However, as the earth terminal antennas are reduced in size, the antenna beamwidth gets wider and the spacing between satellites must be increased to maintain a tolerable interference level.

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Figure 2-26* is a plot of a family of curves that shows the earth antenna diameter changes in discrete steps, while maintaining 4,350 picowatts each for thermal noise and for interference from the adjacent satellites. The figure further shows that as the earth terminal antenna gets smaller, the satellite EIRP must increase, as would be expected, to maintain the same quality of performance.

We have postulated that achieving the required satellite EIRP in the 1970's is a fact of life and is within our technological grasp. The adverse effect of reducing the earth station antenna diameter is that the channel capacity per orbital degree decreases. The curves substantiate this fact and, indeed, show that changing the antenna diameter from 85 feet to 30 feet changes the channel capacity per orbit degree (at the peak of the curves) from approximately 22,500 channels per orbital degree to 8,000 per orbital degree. Further reducing the earth antenna diameter from 30 feet to 15 feet leads to a change of 8,000 channels per orbital degree to 4000 channels per orbital degree. Thus, the relationship between channel capacity per orbital degree and antenna diameter is a linear one, and can be expressed as such:

$$C = KD \tag{2-46}$$

where:

C is the channel capacity per orbital degree

K = performance constant

D = antenna diameter

The point of this discussion is to show that the reduction in channel capacity per orbital degree as a function of antenna diameter is a linear one. However, the economic cost savings by using smaller antenna sizes in the earth station has been shown to be more dramatic. Obviously a tradeoff point exists, and this itself depends on the particular circumstances.

*Figure is extracted from a communique between Dr. Samuel G. Lutz of Hughes and Mr. Paul Bachar of ITT. This communique was an attachment to the Minutes of TR-34 Committee on Space Telecommunications Equipment and Systems, dated April 24, 1968.

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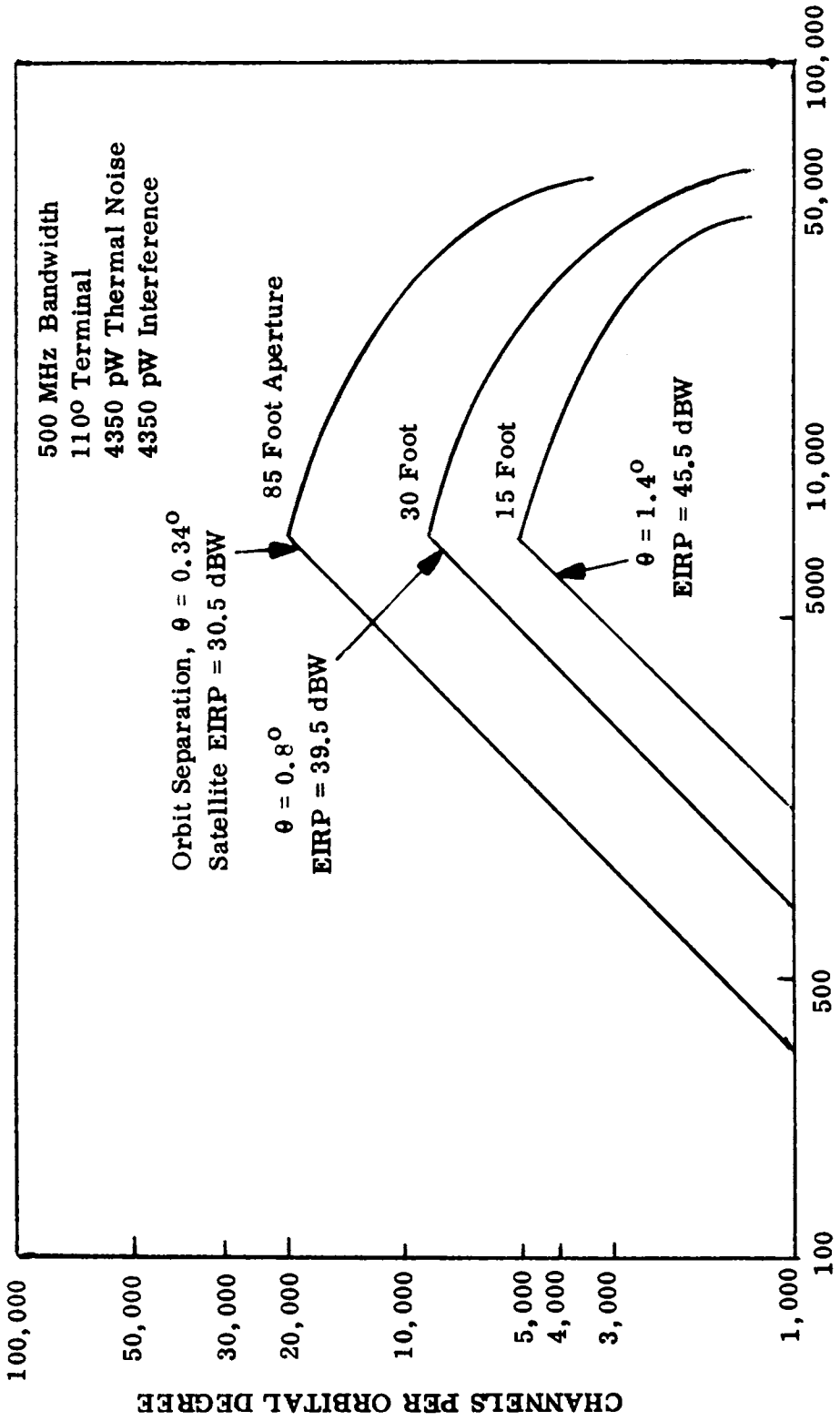


Figure 2-26. Channels per Orbital Degree Versus Channels per Satellite (With Earth Station Aperture Size as a Parameter)

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2.5 EFFECTS OF OPERATING AT MILLIMETER WAVE FREQUENCIES

2.5.1 General

This subsection compares the factors which will affect satellite communications above and below 10 GHz. The frequencies selected for comparison are 16 GHz, 35 GHz, and 94 GHz. These frequencies were selected because they lie in the low propagation attenuation regions between water vapor and oxygen absorption frequencies.

Table 2-53 below summarizes the link loss factors which are sensitive to frequency. If the satellite beamwidth is fixed (constant antenna gain) to provide the same earth coverage from synchronous altitude, the increase in ground antenna gain as the frequency is increased (for a fixed antenna size) exactly cancels the increase in free-space loss. Thus the only changes in the link calculations are in the receiver noise temperature (which gets worse with increasing frequency), and in the increase in attenuation through the atmosphere due to rain, cloud, oxygen, and water vapor absorption. To maintain the same satellite EIRP, increased transmitter power in the satellite is required.

As the table shows, the margins required for 35 GHz and 90 GHz become quite large. The propagation loss margins shown are estimates of the values required to provide the link availability values shown. For instance, the margins shown in Table 2-53 for a 97-percent link availability are values which would be exceeded only three percent of the year (12 days) for a ground station with a 15-degree elevation angle and 100 cm/yr average annual rainfall. The major propagation uncertainty at this time results from a lack of statistics on the frequency, extent, density, and thickness of cloud cover. The cloud attenuation for a high-availability link at 35 GHz or higher can be a significant factor, as shown in Figure 2-29.

Table 2-53. Link Loss Factors

Frequency	4 GHz	16 GHz	35 GHz	90 GHz
Satellite Antenna Gain	Constant (constant beamwidth required for coverage)			
Free-Space Loss $\left(\frac{\lambda}{4\pi R}\right)^2$ (dB)	197	208.5	215.8	224
Ground Antenna Gain (dB)				
15-Foot	43	54.5	61.8	70
30-Foot	49	60.5	67.8	76

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Table 2-53. Link Loss Factors (Cont)

Frequency	4 GHz	16 GHz	35 GHz	90 GHz
System Noise Temperature (dB)	28	28	32	35
	TDA	TDA	Uncooled Paramp	Mixer
Propagation Loss Margin (dB)				
Link Availability - 97% (weather only)	0.2	3.4	14.3*	90.2*
Link Availability - 99.9% (weather only)	0.4	10.9	44.2**	203.5**

*Due mainly to cloud cover attenuation. These may be reduced when better data on cloud density and coverage statistics is available.

**Use of space diversity at ground stations may significantly reduce these values.

Figure 2-27 shows a graph of relative antenna costs (including pedestal, servo, and reflector) for 15-foot and 30-foot antennas at 4 GHz and 35 GHz. The data is insufficient to obtain any general trends, but does indicate that 35-GHz antennas are on the order of twice as expensive as an equivalent size antenna at microwave frequencies.

2.5.2 Propagation Considerations

Rain, snow, and fog introduce an absorption in the atmosphere which depends on the amount of moisture and the operating frequency. In addition to the effect of condensed water vapor, some selective absorption will result from the oxygen and water vapor in the atmosphere.

In earth-to-satellite communications, the effective atmospheric path length is a function of the angle of elevation of the transmission path and of the depth of the atmosphere in which most of the radio attenuation occurs. Since most of the absorption above a frequency of one GHz occurs in the lower levels of the atmosphere, there is less attenuation from mountain-top sites.

In the case of attenuation resulting from heavy rain storms, considerable improvement can, in general, be obtained by the use of space diversity: two earth stations spaced several miles apart being employed.

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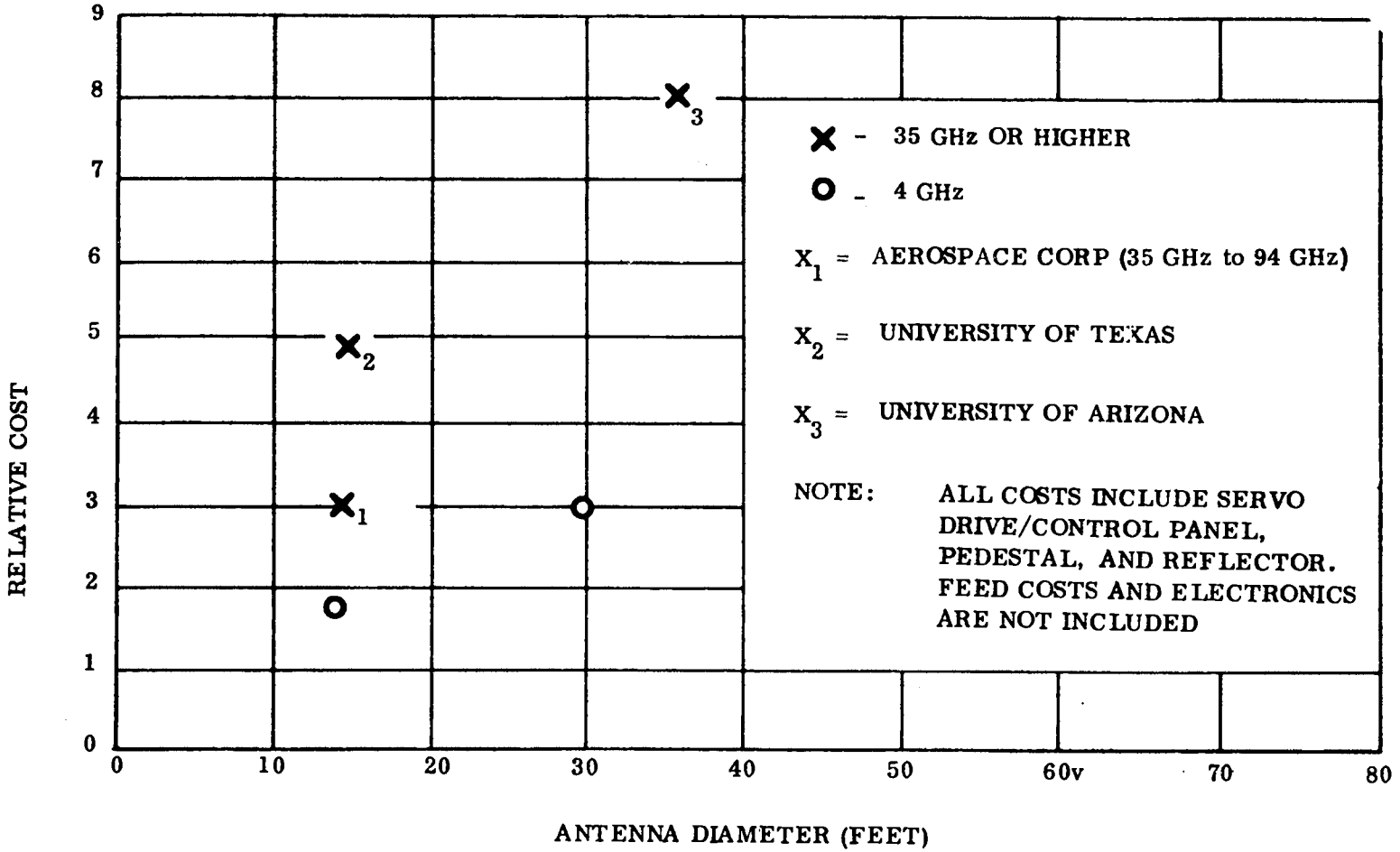


Figure 2-27. Relative Antenna Costs, 4 GHz Versus 35 GHz

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2.5.2.1 Rain Attenuation

Normal Rain Storms - The rate of absorption A of rain in dB/km may be expressed in terms of the rainfall rate R, in millimeters per hour, by[1]:

$$A = KR^a$$

The values of the functions K and a for four frequencies are given below:

GHz	K	a
8	9×10^{-3}	1.27
16	5.6×10^{-3}	1.20
35	$3.2. \times 10^{-1}$	0.92
94	2.5	0.82

In earth-to-satellite communications, the effective path length depends on the elevation angle of the transmission path. Under normal rainfall conditions, most of the rainfall occurs below an altitude of 2 km. It has been estimated that the effective path length for rain attenuation, as a function of elevation angle, is as follows:

Elevation Angle (degrees)	Effective Path Length (km)
5	20
10	8
90	2

Long-term cumulative distribution of rain absorption has been estimated from statistics analyzed by Bussey[2]. The cumulative distribution of instantaneous path surface rainfall rates depends on how the rainfall rate varies with height above the earth's surface and upon the correlation of rainfall with distance along the path.

The rainfall attenuation has been estimated for a central U.S. site having an average annual rainfall of 74 cm. The rain attenuation exceeded for only 0.01 percent of the year has been estimated assuming elevation angles of 5, 15 and 90 degrees. Figure 2-28 shows the rain attenuation at this site as a function of frequency for three elevation angles.

---

1. National Bureau of Standards, Technical Note 101.

2. Bussey, H.E., "Microwave Attenuation Statistics Estimated from Rainfall and Water Vapor Statistics," IRE, P 281-285, July 1950.

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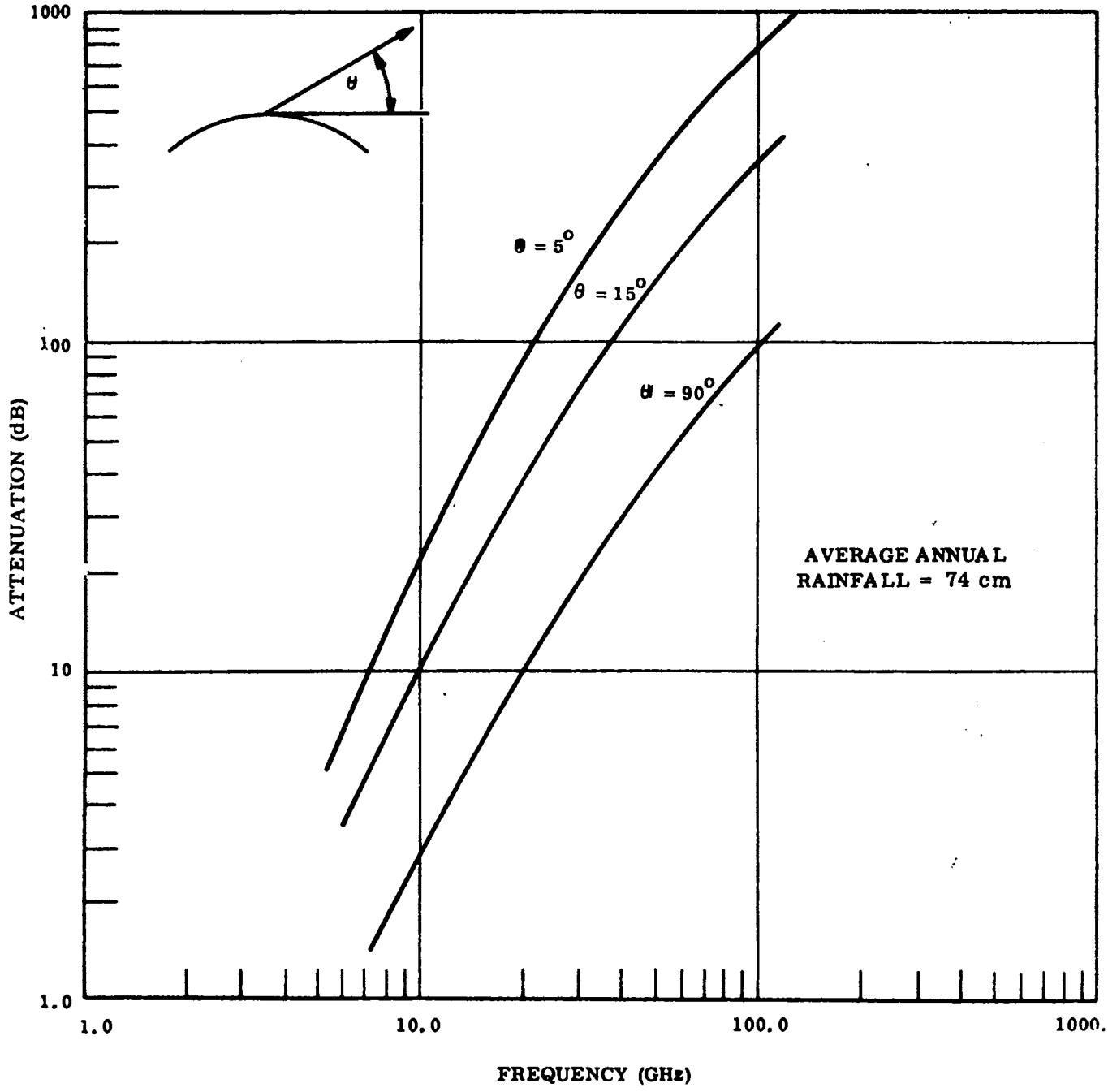


Figure 2-28. Rain Attenuation Versus Frequency

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2.5.2.2 Cloud Attenuation[1,2,3,4,5]

The attenuation of radio waves by fog or clouds increases rapidly with increasing frequency, and is proportional to the liquid water content. Water concentration in clouds generally ranges from 1 to 2.5 g/m^3, although isolated instances have reported values as high as 4 g/m^3. The attenuation of water clouds increases with decreasing temperature, but ice clouds give attenuations about two orders of magnitude smaller than water clouds of the same water content.

Figure 2-29 shows the attenuation of clouds as a function of frequency for four values of water content. The attenuation shown assumes an elevation angle of 15 degrees, a temperature of 0°C, and a uniform water cloud extending from an altitude of 3 km to 5 km.

At 10°C, cloud attenuation in $dB/km/g/m^3$ at 9 GHz is about 0.78 and, at -8°C, 1.35 times the attenuation at 0°C. The visibility in cloud of 1 g/m^3 is about 175 feet, and a cloud of 2.5 g/m^3, about 90 feet.

2.5.2.3 Oxygen and Water Vapor Attenuation[1,2]

The attenuation of radio waves by suspended water droplets and rain usually exceeds the combined oxygen and water vapor absorption. The absorption of oxygen reaches a peak of about 10 dB/km at 60 GHz, but decreases rapidly to about 0.015 dB/km at 10 GHz. The absorption by water vapor reaches a first peak of about 0.2 dB/km at 24 GHz, but decreases very rapidly to about 0.002 dB/km at 10 GHz. At frequencies below 10 GHz, the sum of the attenuation resulting from oxygen and water vapor is thus chiefly due to oxygen absorption.

---

1. National Bureau of Standards, Technical Note 101.

2. Bean and Dutton, Radio Meteorology.

3. Handbook of Geophysics and Space Environments, Air Force Cambridge Research Laboratories, McGraw Hill 1965.

4. Bertoni, "Clear Line of Sight from Aircraft," AFCRL 67-0435.

5. Solomon, "Estimated Frequencies of Specified Cloud Amounts Within Specified Ranges of Altitude," Tech. Report 167; Air Weather Service, USAF.

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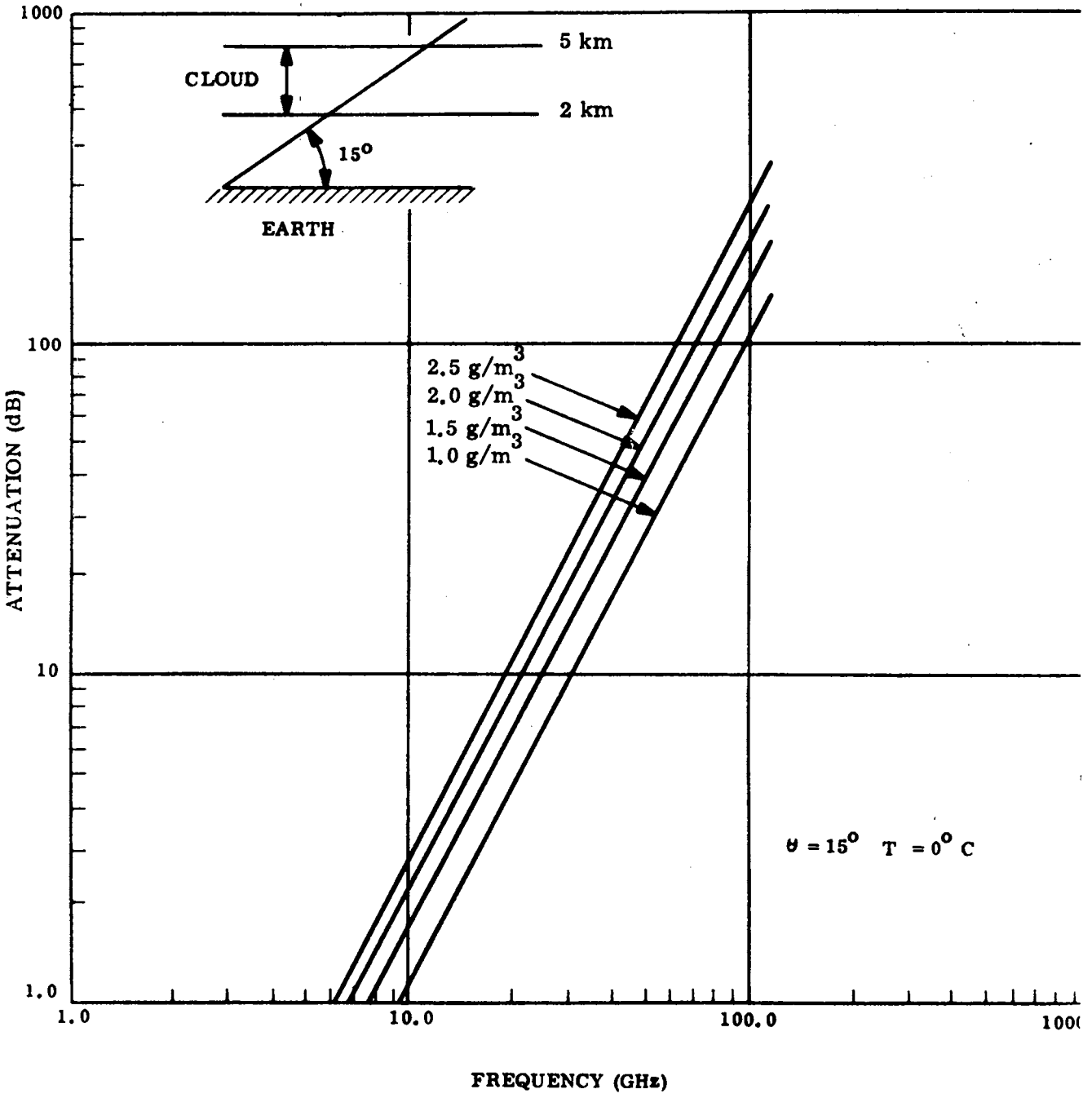


Figure 2-29. Cloud Attenuation Versus Frequency

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2.5.2.4 STATISTICS[1,2,3,4]

Adequate meteorological statistics are not available to enable accurate estimates to be made of the rain and cloud attenuation which will be exceeded for a small percentage of the year. However, from the limited data available, approximate estimates can be made of the magnitude of rain and cloud attenuation likely to be exceeded for only 0.01 percent of the time, or about one hour per year, on an earth-to-satellite transmission path in a given area.

Cumulative distribution of rain attenuation may be estimated from statistics analyzed by Bussey[1] who relates the cumulative distribution of instantaneous path average rainfall rates for 25, 50 and 100 km paths, respectively, with the cumulative distributions for a single rain gauge of half-hour, one hour and two-hour mean rainfall rates recorded for a year. If no space diversity is used, then, for example, the total attenuation during the worst hour of the year will be the sum of the rain, cloud, oxygen and water vapor attenuation during the worst hour. However, with space diversity, the maximum rain attenuation will be reduced considerably, and perhaps also the cloud attenuation to some extent. It has been shown by Hogg[5] that the rain attenuation in dB was reduced by about one-half by the use of the diversity system having a spacing of 2 km, located near Bedford, England, where the annual rainfall is about 63 cm.

High rainfall rates are usually of only limited extent, rarely exceeding 15 km. The rate of rainfall may be associated with a particular extent of rain by the empirical relationship[6]:

$$\text{Extent in km} = 41.4 - 23.5 \log \text{mm/h} \qquad (2\text{-}46)$$

---

1. Bussey, H.E., "Microwave Attenuation Statistics Estimated from Rainfall and Water Vapor Statistics," IRE, P281-285, July 1950.

2. Handbook of Geophysics and Space Environments, Air Force Cambridge Research Laboratories, McGraw Hill, 1965.

3. Bertoni, "Clear Line of Sight from Aircraft," AFCRL 67-0435.

4. Solomon, "Estimated Frequencies of Specified Cloud Amounts Within Specified Ranges of Altitude," Tech. Report 167; Air Weather Service, USAF.

5. Hogg, "Path Diversity in Propagation of Millimeter Waves through Rain," P 410-415, AP-15-May 1967.

6. International Conference on Satellite Communication, London, Nov. 1962.

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hus at a worst-case U.S. site, where it is estimated that a rainfall rate of 48 mm/h is only exceeded for 0.01 percent of the year, the extent of such a rainfall rate would be only about 1.7 km. In the case of cloud, some statistics are available for the time and space distribution of clouds at various altitudes[1,2].

2.5.3 Conclusion

The following table shows the estimated attenuation for link availabilities of 99.99 percent (~ 1 hour per year outage) and 99.9 percent (~ 10 hours per year outage) and 97 percent (~ 12 days per year outage) at a site having an annual average rainfall of 100 cm.

Table 2-54. Estimated Attenuation

Link Availability		Frequency (GHz)			
		4	16	35	90
99.99%	Rain (dB)	0.5	26.4	105	320
(48 mm/h)	Clouds (2 g/m^3, 0°C) (dB)	0.5	5.6	24	150
	Oxygen and Water Vapor (dB)	-	0.3	0.8	3.5
	Total (dB)	1.0	32.3	139.8	573.5
99.9%	Rain (dB)	0.1	6.6	26.4	80
(12 mm/h)	Clouds (1.5 g/m^3, 0°C)(dB)	.3	4.0	17	120
	Oxygen and Water Vapor (dB)	-	0.3	0.8	3.5
	Total (dB)	0.4	10.9	44.2	203.5
97%	Rain (dB)	-	0.4	1.5	4.7
(0.7 mm/h)	Clouds (1.0 g/m^3, 0°C)(dB)	.2	2.7	12	82
	Oxygen and Water Vapor (dB)	-	0.3	0.8	3.5
	Total (dB)	0.2	3.4	14.3	90.2

1. Bertoni, "Clear Line of Sight from Aircraft," AFCRL 67-0435.

2. Solomon, "Estimated Frequencies of Specified Cloud Amounts Within Specified Ranges of Altitude," Tech. Report 167; Air Weather Service, USAF.

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ORGANIZATION OF THE UNITED STATES INTERNATIONAL COMMUNICATIONS INDUSTRY - APPENDIX - REPORT OF THE PANEL ON SATELLITES AND OTHER LONG-HAUL TRANSMISSION MODES OF THE NATIONAL ACADEMY OF ENGINEERING

Eugene V. Rostow

President's Task Force on Communications Policy
Washington, D. C.

June 1969

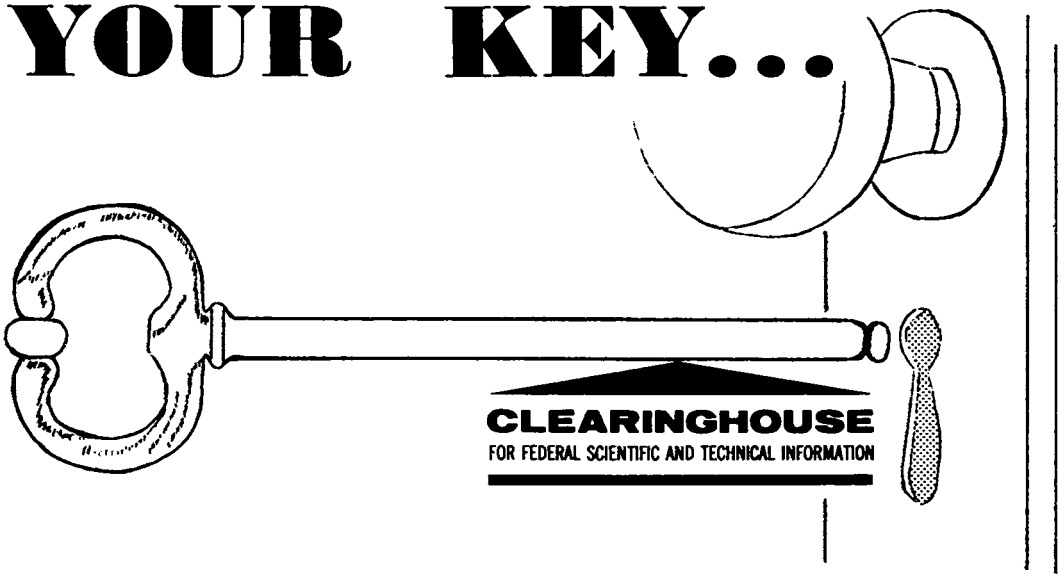
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ORGANIZATION OF THE U.S.
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I. INTRODUCTION

A. The President's Mandate

The purpose of this staff paper is to examine the structure of the U.S. international communications industry with a view to determining whether the present division of ownership continues to be in the public interest. The posture of our nation's international communications industry was a central theme in the President's Message to Congress on Communications Policy. The President noted that unlike most other nations, the U.S. has no "chosen instrument" to handle its international communications, and that while our "normal instinct is to favor the existence of multiple companies in each commercial field . . . there is a legitimate question as to whether the present division of ownership in our international communications industry continues to be in the public interest."*/

*/ The discussion here should be considered in the light of our studies, in other papers, of U.S. policy toward INTELSAT, the global communication satellite consortium, of the promise and prospects of advanced technology for meeting the communications needs of less developed countries, of domestic telecommunications policy, and of domestic applications of communication satellite technology.

B. Why We Are Concerned

The impact of satellites on communications was a central theme of President Johnson's Message to Congress of August 14, 1967. The development of satellite communications by INTELSAT since 1964 and the unmistakable future of satellites are transforming the environment for international communications. This advancing technology, and the foreign policy environment in which it operates, justify re-examination in depth of the structure of our international communications industry.

A fundamental criterion of any national policy is its consistency with national goals. Two national goals seem especially important and relevant to this study. The first is the objective of satisfying the international communications requirements of U.S. users -- personal, business, and governmental (including military) -- for various types of reliable, high quality service at low cost, consistent with efficient and progressive operation. The second goal is to foster certain foreign policy-related objectives of the United States. These include encouraging the peaceful use

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of outer space through international cooperation; building bridges to Communist nations; maintaining cordial relations with other countries; assisting the developing countries; and, in general, promoting world harmony and U.S. security and prosperity.

In examining the nation's international communications posture in the light of these goals, we shall focus on several major current issues of national policy, all of which are related to a common theme: the desirability of some form of consolidation of the U.S. international communications industry.

For many years, it has been urged in some governmental and other quarters that the structure of our international communications industry should be simplified.*/ In 1966, the Intragovernmental Committee on International Telecommunications, composed of the Chairman of the FCC and the Director of Telecommunication Management and officials of the Departments of State, Justice, and Defense, recommended

*/ The history of consideration of this question prior to 1966 is described generally in the "Study of International Telecommunications Policies, Technology and Economics," prepared by the Stanford Research Institute for the 1966 Intragovernmental Committee on International Telecommunications, Annex 1, at p. 199 (May 1966) (hereinafter "SRI Report").

that the Communications Act of 1934 be amended to authorize the FCC to approve a merger of two or more of the international record carriers, or their facilities, or of those carriers plus the domestic Western Union company, or of the international record carriers with AT&T's overseas facilities and with or without Comsat if, after appropriate proceedings, the FCC found any such combination to be in the public interest. Congress has given the FCC authority to confer antitrust immunity by authorization of a merger of domestic telephone and telegraph carriers, but such authority does not extend to restructuring of the international communications industry.

The Intragovernmental Committee did not expressly endorse a merger, although some participants in the study strongly favored the notion that a restructuring of the industry was desirable. The Committee recommended merely that the FCC be permitted to consider and decide upon merger proposals. The Committee's report was submitted to Congress. But no legislation was proposed by the Administration or considered by the Congress.

What concerns may lie behind the Committee's recommendations?

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1. Separation of ownership by technologies

As discussed more fully below, the central concern today is with the separation of ownership by technologies of the dominant transmission facilities used for international communications. The international voice and record carriers own cables, while Comsat is limited to the satellite mode. This division is at the root of many recent disputes in the industry.

The TAT V-INTELSAT IV question (discussed more fully below), involving cable-satellite rivalry, illuminates the issue. TAT V is a 720 voice circuit transatlantic cable to be jointly owned*/ by AT&T, the principal U.S. international record carriers, and communications entities of Spain, Portugal, and Italy.**/ Some observers feel that the

*/ AT&T and the U.S. international record carriers have ownership in 403 whole circuits and Spain and Italy each have ownership in 6 whole circuits. These circuits have been reserved for service via the cable system. It is contemplated that half interests in these circuits will be granted (by indefeasible right of use or otherwise) to other countries which will use TAT V facilities for their communications.

**/ The FCC, with State Department consent, announced conditional approval of the carriers' application. Memorandum Opinion, Order and Authorization, FCC 68-569 and 68-570, May 22, 1968. Commissioner Johnson issued a dissenting opinion, and Commissioner Cox issued a concurring statement. The TAT V issue is considered more fully infra, p. 33 et seq. A similar controversy involved a proposed cable from Florida to the Virgin Islands. See infra, p. 55 et seq.

Commission authorized a cable facility substantially more costly than available satellite alternatives (although the cost comparison was obscured by uncertainty about rates), and that the incident (along with others) reveals the difficulty of achieving system optimization and avoiding uneconomical expansion of the international communications plant, given the present separation of cable and satellite ownership under a regime of indirect, regulated competition. Others feel that TAT V might have been proposed by an integrated enterprise in any event, and that the incident highlighted the unattractiveness of Comsat's present rates in comparison with today's costs for new cable circuits.

2. Status of the international record carriers. International record carriers are substantially insulated from the competition of AT&T and Comsat by virtue of the historical separation of voice and record services*/ and FCC rulings in the "TAT IV"**/ and "authorized user"***/ decisions. This insulation is a matter of continuing controversy.

*/ See infra, p. 11 et seq.

**/ See infra, p. 13

***/ See infra, p. 19 et seq.

Some contend that the record carriers no longer have a sufficiently necessary or important function in international communications to justify the privileged position with respect to the services they provide -- record and combined voice-data (AVD). Others recognize the diminished technological significance of the voice/record separation, but believe that the benefits of competition among the record carriers continue to outweigh the detriments. Still others believe that while one or another of the merger alternatives that have been suggested might diminish competition among the carriers, a merger might be justified if it resulted in more vigorous competition between voice and record services and perhaps direct competition in the provision of combined voice/record services between AT&T and a strengthened record carrier. Finally, it has been suggested that while legislation enabling a consolidation of the record carriers' transmission and switching operations may be justified, the legislation should not apply to their service, or retail functions, lest competition be unnecessarily stifled.

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3. Role of Comsat. Controversy over the status and future of Comsat has not abated since its creation in 1962. The foremost issue affecting it concerns the evolution of the industry structure, and whether Comsat should have a role in a consolidation involving the international carriers.

Comsat's interlocking directorate with the carriers has also been a source of dispute. Experience suggests that Comsat has interests that may conflict with those of the voice and record carriers. Despite the FCC's authorized user decisions, which insulate them from direct competition, the voice and record carriers and Comsat are rivals in a very real sense.

In addition, there is concern about the degree of balance in Comsat's capital structure. Comsat has no long-term debt, and only about one-third of the $200 million that it raised by an initial stock offering is now invested in productive communications assets.

Comsat has been involved in a series of controversies before the FCC on issues that vitally affect the corporation's future. These include satellite earth station ownership,

Comsat's authority to deal directly with ultimate users of satellite services, and whether and in what directions Comsat should be permitted to expand or diversify its activities. One aspect of the last-mentioned issue is the domestic satellite question, treated more fully in a separate staff paper and in the Task Force Report.

In view of the government's role in Comsat's creation and the corporation's position and significance in international communications, these questions are of public, not merely of private, concern.

4. Effective government regulation and achievement of national policy objectives. Doubts have been expressed about the FCC's rulings in resolving the frequent disputes that have marked the history of the international communications industry. Some have criticized the thrust of certain regulatory decisions as designed to protect the weaker firms in the industry, to the detriment of users of communications facilities. It is also said that, given the existing separation of ownership by technologies of the dominant modes of international transmission, the regulatory body cannot

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examine investment plans in a comprehensive and consistent manner, free from partisan claims by participants dependent upon maintaining a particular technology.

Still another view is that the ability of the Executive Branch to secure adequate international communications for military and other governmental services, and to advance U.S. foreign policy objectives, has been impaired by the plurality of firms in the industry. It is alleged that under the present structure, foreign government-controlled communications entities may play one U.S. entity against another, while a unified U.S. carrier presenting a consolidated U.S. position in transmission matters would be in a stronger negotiating position with foreign entities.

C. Plan of This Study

We first examine the evolution of the U.S. international communications industry, including the emergence of Comsat, and describe how the industry now operates. Next, we examine the principal problems, already noted briefly in this introduction. Finally, we examine possible correctives. Of the various alternatives, a consolidation into

a single entity to perform the basic international transmission functions now performed by Comsat and the U.S. international voice and record carriers is, in our view, the only comprehensive solution. We believe it is feasible and attractive, provided certain safeguards and conditions are attached, and we describe it in some detail.

The problems of divided ownership of our international communications plant have not reached crisis proportions. But effective policy should anticipate problems, treat them before they become severe, and seize opportunities that could benefit the nation substantially. Restructuring the U.S. international communications industry to create a single transmission entity would appear to achieve these objectives.

II. EVOLUTION OF THE U.S. INTERNATIONAL COMMUNICATIONS INDUSTRY

A. Early History

The present organization of the U.S. international telecommunications industry is the product of long technological evolution and many government decisions.

Invention of the submarine telegraph cable made transoceanic telecommunications possible. The first

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transatlantic cable was laid over 100 years ago by a consortium of British and U.S. interests. In the following years many more cables were laid by U.S. and foreign interests in the Atlantic, Caribbean, and Pacific. The dominant U.S. entities in the industry were Western Union, All American Cables and Radio, Inc., the Commercial Cable Co., and Commercial Pacific Cable Co.*/

Telegraph cables carried telegram and other record traffic, but they had insufficient bandwidth to provide voice-grade circuits for telephony. During World War I, the use of radio for both voice and record communications was perfected, and in 1927 the Bell System inaugurated transatlantic radiotelephone service. Transatlantic radiotelegraph service had been started somewhat earlier by RCA, followed by ITT subsidiaries and smaller companies. Its quality was poorer than that of submarine cable, but it also involved a smaller investment cost; and competition forced the cable companies to lower their rates.**/

*/ The latter three companies were subsequently acquired by International Telephone and Telegraph Corporation.

**/ For a useful early study, see Herring and Gross, Telecommunications Economics and Regulation (1936).

The Mann-Elkins Act in 1910 had extended the Interstate Commerce Commission's powers to regulation of the rates and practices of wire communications companies. The Federal Communications Commission succeeded to this authority upon its creation in 1934. It also took over the radio licensing function of the Federal Radio Commission.

Telegraph cables and radio dominated the U.S. international communications industry until the invention of the voice-grade submarine cable in the early 1950's. The first transatlantic voice cable (TAT I) was laid in 1956. The new technology enabled AT&T to provide transatlantic telephone service of much better quality than previously, and enabled telegraph circuits to be derived at a much lower cost than through telegraph cables. The record carriers soon began to phase out their telegraph cables and to lease circuits from AT&T in the new cables. At the same time the offering by AT&T of a combined voice-record service (AVD - alternate voice data) and to some extent the availability of high-quality telephone service in transoceanic communications threatened grave inroads into the record carriers' business and profits. A merger of the record carriers was urged with

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renewed vigor as necessary to assure the continued economic viability of the record industry. */

The Commission's "TAT IV" decision in 1964 provided a regulatory framework in which the record carriers could expect to maintain profitable operations. The Commission held, first, that the record carriers were entitled to a share of the ownership of TAT IV and subsequent trans-oceanic cables, an investment in the modern cables which they could include in their rate bases. It is said that this decision enabled the record carriers to reduce their costs by substituting ownership for much higher cost leases. Second, the Commission held that AT&T would be barred from further offerings of AVD service. Thus, except for service already provided by AT&T, which it was permitted to retain, AVD was to be provided only by the record carriers and the Hawaiian Telephone Company. **/

See, e. g., Hearings Before the Interstate and Foreign Commerce Committee, U.S. Senate, 86th Cong., 1st Sess., on a proposal to amend the 1934 Communications Act to permit merger of the international record carriers.

*/ American Telephone and Telegraph Co., Memorandum Opinion and Order, 37 F.C.C. 1151 (March 17, 1964).

B. Emergence of Comsat

The early 1960's also saw the advent of satellite communications. The existing common carriers urged that communication satellites, like voice-grade submarine cables, should be a joint venture of the carriers. A bill introduced by Senator Kerr in January 1962 would have created a new communications satellite corporation with ownership limited to authorized U.S. common carriers.

Other groups, citing the immense governmental investment in space technology that lay behind the development of the communication satellite, urged that satellite communications be made a government monopoly. In February 1962, Senator Kefauver introduced a bill which would have established a Communications Satellite Authority as an agency of the government to own and operate the U.S. ground stations and the U.S. portion of a global satellite system.

A middle ground was sought when, early in 1962, President Kennedy sent to the Congress a proposed bill, introduced in the Senate by Senators Kerr and Magnuson, and in the House by Representatives Harris and Miller,

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that contained the germ of the 1962 Communications Satellite Act. It provided for a privately owned communications satellite corporation in which stock ownership would be shared by the carriers and the public. The 1962 Act, as finally adopted, entrusted U.S. participation in a projected global communications satellite system to a new private corporation, the Communications Satellite Corporation. The entity would be subject to close government regulation, have 3 Presidentially appointed directors, and 12 others representing common carriers and other stockholders.*/

The 1962 Act reserved 50% of the Corporation's common stock to those common carriers that the FCC (upon a finding of public interest, convenience, and necessity) might authorize to own shares in the corporation. Pursuant to this provision, AT&T and the international record carriers were authorized to purchase shares in Comsat. AT&T today has about 29% of the corporation's common stock, and the remaining authorized carriers about 13%. The carriers

*/ For analyses of the 1962 Act, see Note, The Communications Satellite Act of 1962, 76 Harvard Law Review 388 (1962) and Levin, "Organization and Control of Communications Satellites," 113 University of Pennsylvania Law Review 315 (1965).

elect 6 of the 15 members of Comsat's board of directors.*/ The non-carrier, or public, stockholders also elect 6 directors.

The global system envisaged by Congress in the Satellite Act began to take shape in 1964, when the INTELSAT Interim Arrangements (in which 63 nations have now joined) were negotiated. They created an international joint venture (the International Telecommunications Satellite Consortium, or INTELSAT) of operating entities to own the space segment -- the satellites and related facilities -- of a global commercial communications satellite system. Comsat was made Manager of INTELSAT. The earth stations were left to the ownership and control of the nations in which they were located. Members were to invest in and own the space segment in proportion to quotas established on the basis of traffic projections. In accordance with this formula, Comsat now owns a 53% share of the system.

*/ It should be noted that, under existing law, the carriers may elect 6 members of Comsat's board of directors even though their stock holdings fall substantially below 50% of its common stock. Proposed legislation is now under consideration to revise the formula specified in the Act for carrier representation on Comsat's board of directors.

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The present INTELSAT arrangements are tentative, with definitive arrangements to be negotiated in 1969.

To finance its share of the global system, Comsat raised some $200 million by an initial issuance of stock. The size of the issuance was based on an expectation that a quite expensive system involving a relatively large number of medium-altitude random-orbiting satellites might be required to provide global coverage, and that large amounts of foreign capital might not be forthcoming. In fact, a less expensive system employing a relatively few snychronous satellites proved feasible. Moreover, through INTELSAT, foreign entities have furnished almost half of the capital investment required for the space segment. Consequently, the bulk of Comsat's original capital remains in cash or securities -- although a substantial amount will be used for planned INTELSAT programs.

Early Bird, INTELSAT's first satellite, was launched in April 1965. Four INTELSAT satellites, each with an equivalent capacity of about 240 high-quality voice circuits, are now in operation in the Atlantic and Pacific regions.

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The circuit capacity of the two satellites over the Atlantic is already slightly greater than that of the four trans-atlantic voice-grade cables, including TASI. Extensive further development of the global satellite system (involving the INTELSAT III and the recently contracted for INTELSAT IV series) may be anticipated in the coming years. At present 19 earth stations are operating in 14 countries. By 1970 more than 40 earth stations are expected to be in operation, with still others planned or under construction.

The advent of commercial satellite communications caused further perturbation in the U.S. international industry. Comsat's proposed rates for Pacific satellite service were far below those of the carriers. In the "30 circuits" case the Department of Defense contracted directly with Comsat for a block of circuits for AVD communications in INTELSAT's Pacific satellite. The record carriers' initial bids had ranged from $10,000-12,500 per half circuit per month; Comsat's was $4,000. In its authorized user inquiry the FCC ruled in 1966 that Comsat was a "carrier's carrier" precluded from serving the government directly except in "unique or national interest circumstances," as

determined by the Commission.*/ In response to this FCC decision, Comsat and the Administrator of General Services requested reconsideration, contending the Commission had adopted an unduly restrictive interpretation of the 1962 Satellite Act. On reconsideration the Commission modified its earlier position. While continuing to regard Comsat's authority to provide service directly to the Government as dependent on the existence of unique national interest requirements, the Commission indicated that it would look to the Director of Telecommunications Management (DTM) as the "focal point for the judgment of the Executive agencies as to the national interest."**/

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*/ The Commission also ruled that, while Comsat was not legally precluded from providing direct service to non-government users, it would only authorize such direct service in unique or exceptional circumstances, as where the service must be tailored to the particular needs of the customer and cannot be provided within the terms and conditions of a general public tariff offering -- or where the conventional carriers fail or refuse to meet reasonable demand for satellite service. Authorized Users, Memorandum Opinion and Statement of Policy, 4 FCC 2d 421, 431-32 (July 20, 1966).

**/ Authorized Users, Memorandum Opinion and Order, 6 FCC 2d 593 (Feb. 1, 1967).

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Although Comsat's proposed tariff for the Government lease of the 30 circuits from Hawaii to the Far East was considerably below existing cable rates, the carriers proposed a substantial reduction, on a "composite rate" basis, if the 30-circuit contract were assigned to any of them. The Department of Defense calculated that the contract coupled with the new rate structure would be substantial, since the lower rate proposed by the carriers -- $7,100 per half circuit per month from Hawaii to certain Far East points -- would apply to all circuits leased by Defense in the Pacific. Therefore, Defense requested assignment of the contract to the carriers. The FCC ordered that the service should be so assigned and that carriers would provide satellite and cable service at the so-called "composite rate."*/ After some delay, caused by the need to obtain concurrence of foreign communications entities, the contract was eventually transferred.

The "30 circuits" case lends focus to a number of difficult issues, all related to the question of Comsat's

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*/ ITT World Communications Inc., et al. ("30 Circuits") Memorandum Opinion, Order and Certificate, 6 FCC 2d 511 (Feb. 1, 1967).

role as a satellite entity in an industry which must serve the needs of users through different transmission facilities -- primarily undersea cables and satellites. The challenge for public policy is difficult, and a principal consideration is one of economics: How should the benefits of the new satellite technology be shared in the public interest, in the spirit of the Satellite Act? This raises the question of the effect on overall service and rates for small as well as large users, of allowing direct access to the satellite entity by the government and other large users. Then, too, comparisons of proposed investment decisions and tariffs of Comsat and the U.S. voice and record carriers' costs are complicated by the need to consider the probable impact at the foreign end, since the foreign carriers' costs also influence the rates of U.S. users. Quotations by Comsat and the other U.S. carriers, viewed in isolation, do not indicate the comparable economies at the foreign end.

A further example of the impact of the new satellite entity on the industry relates to satellite earth stations. Five INTELSAT-standard U.S. earth stations have been

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established in Maine, Hawaii, West Virginia, the state of Washington, and Puerto Rico; one more in California is nearing operational readiness. A sharp dispute arose between Comsat and the other carriers over who should own the stations in the southeastern United States and in Puerto Rico and where they should be placed. The FCC in 1966*/ reversed an initial ruling**/ which had given Comsat sole ownership of the three original U.S. earth stations, and authorized the international carriers to own a 50% share

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*/ F.C.C. Second Report and Order: Amendment of Part 25 of the Commission's Rules and Regulations with respect to Ownership and Operation of Initial Earth Stations in the United States, 5 F.C.C. 2d 812 (Dec. 8, 1966).

**/ Report and Order: Amendment of Part 25 of the Commission's Rules and Regulations with respect to Ownership and Operation of Initial Earth Stations in the United States, 38 F.C.C. 1104 (1965); modified, 2 F.C.C. 2d 658 (Feb. 25, 1966). In the 1965 Report and Order, the Commission also adopted certain rules under which the earth station complex, which was to be under the direction and control of the interim earth-station licensee, would be defined to include terrestrial facilities between the earth station and the "gateway" centers where international traffic is normally processed for overseas handling, as well as associated multiplex and demodulation equipment at those centers. In reversing the latter determination in February, 1966, the Commission held that the "point of interface" between the earth-station licensee and its customers should be at the earth station itself.

of the three earth stations then built and three others then planned, with Comsat to own the other 50% and to be manager. The 1966 ruling is tentative, however, and is to be re-examined in 1969.*/

The earth station controversy is said to have delayed construction of a second east coast earth station. Located in West Virginia, it was only put into service in the fall of 1968, perhaps resulting in costs for routing some U.S.-destined traffic through a Canadian station located in Nova Scotia that may have been avoidable.

A more recent example of difficulty related to an earth station for Guam, first proposed by RCA Global Communications and later supported by the three principal international record carriers in a joint filing with the FCC. Initially, Comsat said the station was not needed, but that if it was to be constructed, Comsat should serve as manager and part owner. Later, general agreement was

*/ For a detailed examination of the authorized user and earth station decisions, see Schwartz, "Comsat, the Carriers and the Earth Stations: Some Problems with 'Melding Variegated Interests'," 76 Yale L.J. 441 (1967).

reached on the need for a Guam station, but efforts to reach agreement between Comsat and the international record carriers over joint ownership failed, and Comsat filed its own construction application for the station.

The question of responsibility for providing television service by satellite was hotly disputed by the U.S. carriers in 1965. The FCC adopted a policy under which television provided through INTELSAT facilities would be handled under a "carrier of the week" arrangement, with the international voice and record carriers providing the service in rotation pursuant to a joint tariff. This arrangement has given rise to a number of questions, particularly the role played by the voice and record carriers, and we understand the FCC staff is actively reviewing it.

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C. How the Industry Operates Today.

As a result of these technological developments and regulatory rulings, the following pattern of operation in the U.S. international communications industry */ has emerged. Message telephone traffic travels over domestic telephone lines to cable heads, satellite earth stations, or high-frequency radio stations. This traffic is then carried to distant points on voice-grade cables (mainly by AT&T)**/ on INTELSAT satellite circuits or -- to a decreasing extent -- by high frequency radio .

Record and mixed voice-record (alternate voice/data, or AVD) traffic is carried by domestic telephone or Western Union lines to the office of the international record carriers in gateway cities (principally New York and San Francisco).

*/ We follow conventional practice and include in our discussion of the industry communications between the continental U.S. and U.S. overseas points (e.g., Hawaii), as well as communications between the U.S. and foreign countries. We exclude, however, U.S. Government-owned (e.g., Department of Defense) systems.

**/ Two smaller telephone companies, Hawaiian Telephone (a subsidiary of GT&E) and AACR (a subsidiary of ITT), provide overseas voice service in Hawaii and Puerto Rico, respectively. RCA Global Communications, basically a record carrier, provides overseas voice service in Guam.

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thence to cableheads, earth stations, and radio stations. It is then carried to distant points on voice-grade cables, INTELSAT satellite circuits or -- again to a decreasing extent -- by high-frequency radio.

The international voice and record carriers (together with their foreign counterparts) own the voice-grade cables used for transatlantic service. They obtain INTELSAT satellite circuits by lease through Comsat and share ownership of the U.S. earth stations with Comsat. The voice and record carriers also own their own high-frequency radio facilities.

The principal record carriers are ITT World Communications (a subsidiary of ITT), RCA Global Communications (a subsidiary of RCA), and Western Union International (separated from the domestic Western Union Company in 1963). A smaller record carrier, Tropical, provides service to Latin America. */ These carriers perform a switching function between the domestic and international transmission links. They monitor the international circuits to maintain or improve signal quality (although in Hawaii, for example, they have hired out the conditioning function to the Hawaiian Telephone Co.).

*/ RCA Communications has announced plans to acquire Tropical, subject to FCC approval. Two other small carriers, French Cable Co. offering limited worldwide service, and United States-Liberia Radio Corp. offering service with Liberia, are also licensed as international record carriers by the FCC.

They also subdivide voice-grade channels to obtain the number of usable telegraph communications channels. In the gateway cities, they maintain public offices and provide user-terminal equipment. They also provide service advice to their customers.

Comsat had a small operating profit in the last quarter of 1967 and again in the first quarter of 1968. Western Union International, the smallest of the major record carriers, had a net income after taxes in 1967 of $2.8 million, on a total stockholders' equity on January 1, 1967, of $6.2 million (of which $3.8 million represented earned surplus accumulated since 1963). Despite its rapid growth, the international industry is still quite small compared to the domestic, with total revenues in 1966 of $267 million, of which $121 million represented record-carrier revenues. In contrast, the domestic revenues of AT&T alone are more than $12 billion annually. Table 1 gives some idea of the current situation.*/

But the current growth of the industry should not obscure the fact that the advent of commercial satellite communications, the changing environment of international operations, and

*/ See page 27

TABLE 1

International Revenues and Income (in millions)

Carrier	1965			1966			1967		
	Revenues	Net Income	Net Plant	Revenues	Net Income	Net Plant	Revenues	Net Income	Net Plant
AT&T - Toll	84.5			106.8			120.1		
Leased	9.2			9.0			7.7		
Totals	93.7	*	180.0	115.8	*	180.0	127.8	*	183.0
RCAC - Telegram	25.1			25.0			24.5		
Telex	11.0			13.4			15.3		
Leased	11.4			15.6			15.8		
Other	3.6			4.8			5.5		
Totals	15.1	10.1	71.9	57.8	12.4	76.7	61.1	12.5	91.6
ITT - Telegram	15.3			16.4			16.4		
Telex	7.5			9.5			11.6		
Leased	6.0			8.9			9.4		
Other	1.0			2.3			2.5		
Totals	29.8	5.2	43.7	37.1	5.2	54.7	39.9	8.8	61.3
WUI - Telegram	12.3			12.1			12.8		
Telex	2.7			4.3			6.6		
Leased	1.9			4.2			5.7		
Other	1.2			1.3			1.6		
Totals	18.1	2.2	11.8	21.9	2.8	16.2	26.7	5.1	20.1

* - FCC statistics do not disclose AT&T's net income from its international operations.
(Source - FCC)

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recent regulatory decisions have had a serious impact on the industry.

III. MAJOR PROBLEM AREAS

A. Separation of Ownership by Technologies

1. Difficulty of achieving sound system choices and avoiding overbuilding. The present structure of the U.S. industry largely divides international communications by type of traffic and mode of transmission. But the old distinction between voice and record services has lost its technical significance; both voice and record transmission are now largely carried by identical facilities. And the growing capacity and resultant economies of scale of new modes of transmission set a major challenge to our existing compartmentalized industry structure.

In determining the proper role of competition, regulation, and monopoly in the U.S. international communications industry, the most critical factor is that the principal means of transmission -- terrestrial facilities and satellites -- are owned by different entities. The international voice and record carriers own the former (mainly voice-grade submarine cables), and Comsat has an exclusive commitment to the latter.

The international voice and record carriers have interests which, in some important respects, diverge from those of Comsat. As the industry is organized today, these divergent interests provide incentives for basing investment decisions in new transmission facilities on considerations that impede the best combination of satellite and cable facilities to serve the nation's needs and, particularly to avoid overbuilding. A major concern of policy should be to protect users from having to bear the burden of unwarranted investments in communications facilities.

As elaborated more fully in the subsequent TAT V-INTELSAT IV analysis, voice and record carriers have a number of reasons for preferring investment in new cables to the leasing of additional satellite circuits from Comsat, some of which may not be congruent with overall system optimization.

To be sure, this preference is weakened insofar as (a) direct price competion does not exist between Comsat and other carriers due to the authorized-user rulings, (b) the carriers have a financial stake in satellite communications

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stemming from their stock interest in Comsat and their part ownership of the U.S. satellite earth stations, and (c) some of the carriers (AT&T, ITT World Communications, and RCA Communications) have affiliates that manufacture satellite-system components.

Nonetheless, in a number of respects the carriers have reason to feel threatened by the growth of Comsat and satellite technology generally. Large-scale substitution of leased-satellite for owned-cable facilities would erode the carriers' international rate base; and more than one-half of their net plant investment is in cables. * / Moreover, Comsat remains a potential competitor, since the authorized-user rulings could be reversed or modified at any time. And two of the carriers (AT&T and ITT World Communications)have cable-manufacturing affiliates. Were the carriers to meet the bulk of their needs through leased rather than owned circuits, they would lose control over a major part of the communications service and become relegated to a purely terminal function. In that event, their role in the international industry would be much smaller than it is today.

* / SRI Report, Tables 14 and 15, at 101-102.

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Other considerations may include actual or putative differences between self-costs (for cables) and lease costs (for satellites), and operator confidence in their own ability to establish and maintain service with cable.

Comsat, on the other hand, has an exclusive commitment to satellites and an incentive to discourage further cable laying, in which it cannot participate and which diverts traffic fron INTELSAT's currently small (although growing) traffic base.

Serious problems arise from a compartmentalization of technologies whereby the voice and record carriers may not launch satellites (although they may lease satellite circuits from Comsat), nor Comsat lay cables, regardless of the relative merit of each technology in meeting a particular transmission need. No single firm is in a good position to make the complex decisions among alternative transmission technologies required to meet projected requirements on operational and economic grounds. The voice and record carriers deal directly with users and presumably know their needs. But for reasons such as those discussed above they may not always arbitrate objectively the competing alternatives of cables and satellites in making their investment decisions. With virtually no direct customers nor cable interests, Comsat is in no better position.

The FCC normally acts as a reviewer, not an initiator, of investment decisions. It is, in any case, difficult to make the requisite comprehensive long-range and systematic judgments on the basis of sporadic filings by interested parties. Nor is the Executive Branch charged with this latter function.

Some doubt has been expressed as to whether this problem is authentically serious. It is argued that the practices of the international voice and record carriers up to now may have reflected the fact that satellite circuits were not significantly cheaper because of satellite pricing policy. Were decisive cost advantages soon to appear on the side of the satellites, as many anticipate, the preference might be countered by appropriate regulatory action. The present structure has been said to have some advantages in the pressure on carriers to expose for government decision competing choices and considerations, and to pass on economies to the public in the form of lower rates and diversity of service. Giving due weight to such considerations, we are nevertheless persuaded that the central problems in the industry cannot be adequately dealt with in the absence of a fundamental restructuring of the industry.

Under the industry's present organizational structure, there is reason to believe that investment decisions may be made and traffic divided arbitrarily on the basis of compromises deemed fair and equitable to industry claimants, rather than on the basis of least social cost. On balance, cable-satellite rivalry under today's conditions does not seem to promise sufficient social benefits to outweigh the dangers of uneconomical investment decisions.

The TAT V-INTELSAT IV discussion in the following section shows the problems that have arisen in maintaining rivalry between satellite and cable interests under conditions of regulation, and it illustrates the difficulty of achieving sound system choices and avoiding overbuilding in the context of the divided and compartmentalized organizational structure we have today.

2. TAT V-INTELSAT IV question. As noted earlier, TAT V is a 720 voice-circuit transatlantic cable which will connect southern Europe with the United States. Its estimated cost of construction is $70 million, estimated useful life at least 20 years, and planned date of completion 1970. The Communications Act required FCC approval of

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such an installation; and under the Cable Landing Act of 1920, State Department consent is required. Accordingly, in late 1967 the carriers filed an informal application for permission to participate in construction of TAT V. Comsat opposed, claiming that the cable represented an uneconomical investment that would only divert traffic from satellites.

The carriers argued that demand might outstrip transatlantic capacity by 1970 and that TAT V represented the most economical means of closing the gap between demand and capacity. Existing transatlantic capacity is about 1,000 voice-grade circuits -- 468 in the four cables, 480 in the two INTELSAT II satellites. Assuming the launching of two INTELSAT III satellites, already approved and funded, satellite capacity will rise to about 2,000 circuits by 1970. With U.S. participation and encouragement, INTELSAT has also approved a long-term program of satellite development that contemplates the launching of an INTELSAT IV satellite with a design capacity of about 5,000 circuits in the first half of 1971 to replace the two INTELSAT III's.

On the basis of traffic estimates provided by Comsat and the carriers, an FCC/State/DTM/NASA working group evaluated the circuit requirements for the Atlantic Basin through 1972

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and concluded that, in the absence of INTELSAT IV, capacity could fall short of demand sometime around 1970. These estimates are subject to substantial uncertainty. Furthermore, to describe an excess of demand over capacity as a "shortage" may overstate the gravity of the situation. Should a gap emerge it would be reflected in customer queues, building up during peak periods of the day, much as one observes at present. Since it is clearly not economical for any industry to build enough capacity to forestall all queues, the costs of providing additional capacity across the Atlantic in 1970-1971 must be weighed against the benefits from speedier (or less costly) service during peak periods.

Once INTELSAT IV is launched, all Atlantic requirements until the middle 1970's can probably be met with one satellite, and certainly with two. After that, systems of even greater capacity should be available to meet additional increments of demand. Should INTELSAT IV be delayed by one year the then existing capacity may still be sufficient. But if INTELSAT IV slips by more than a year, a sizable shortage is likely. However, even assuming a substantial likelihood that INTELSAT

IV would be so long delayed as to create a real shortage (not merely a short additional delay at peak hours), TAT V represented only one possible response. There were other methods of filling the gap, using satellites, to be considered. One was to replace the second programmed INTELSAT III, scheduled for launch in 1969, with a III-1/2, thus providing almost 1,000 additional circuits -- enough to fill any shortage likely to arise before 1972 -- at an additional cost of $10-20 million (in contrast to the $70 million for TAT V). Another possibility was to launch a third INTELSAT III with a capacity of about 1,000 circuits to plug the gap. No additional earth stations would have to be built, although extra antennas might have to be added to some existing stations and perhaps a new routing plan adopted. Even if complete new earth stations were necessary, the total investment might not exceed $40 million. In addition to a cost saving, this solution might also have involved a slightly shorter lead time than TAT V.

To be sure, the foregoing cost comparisons give no weight to the fact that the cable will provide 720 channels for 20 years, whereas the useful life of an INTELSAT III or

III-1/2 is estimated to be only 5 years. Aside from diversity considerations, however, TAT V was primarily defended as a stopgap facility to meet a possible condition of shortage in the early 1970's. By 1972, at the latest, INTELSAT IV should be in operation with adequate capacity to satisfy all transatlantic needs; existing facilities (including TAT V and any INTELSAT III's) will be redundant. Viewed as a stopgap, a proper cost comparison is between TAT V and any alternative facility that, regardless of having a shorter life, would function long enough to fill the gap. Moreover, a 20-year lifetime is not an unalloyed advantage when the trend in technology is toward substantial reductions in cost per circuit of new transmission facilities at 5-7 year intervals.

Under any assumptions about the duration of the shortage, TAT V appears substantially less attractive in terms of investment cost per channel than the satellite alternatives. We asked a distinguished Panel of the National Academy of Engineering (NAE) to compare the engineering cost of establishing a single point-to-point transmission link across the North Atlantic by satellite

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and by cable. The NAE report, appended in pertinent part to this paper, was based on the technology expected to be available by 1970 -- a 720 circuit transistorized cable, compared with a modified INTELSAT III satellite using a 2-spot beam configuration yielding 10,000 circuits and working with one "dedicated" earth station on each side of the Atlantic. Since the cable would have a 20-year life, it was matched by four identical 5-year lifetime satellites.

Table 2 summarizes the comparison of the cable system cost and the satellite system cost (in millions):

TABLE 2

Satellite-Cable Cost Comparisons
(in millions)

	Cable System	Satellite System (including 2 earth stations)
Annual cost (including interest on investment at 10% per year)	$9.3	$8.1
Point-to-point capacity (circuits)	720	10,000
Cable system:		
Total initial cost		$70.4
Annual operating and maintenance cost		0.99
Annual amortization - 10% interest		8.26

Satellite system

The annual cost of this system is comprised of three parts: amortization of the space segment cost, amortization of the earth station cost, and annual operating and maintenance cost. The annual O.& M. cost of each earth station is assumed to be 10% of the first cost of the station. The first cost for each station is assumed to be $5 million with a 10-year life expectance. Thus the annual cost of the two earth stations is $2.6 million for an interest rate of 10%.

To determine the space segment cost the following assumptions were made:

(a)	expected life-time, years	5
(b)	probability of successful launch	0.8
(c)	development cost, million	$7.5
(d)	satellite cost, million each	$3.5
(e)	launch cost, million each	$5.0
(f)	six space craft would be purchased in order to have an in-orbit spare.	

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(Table 2 Continued)

With an appropriate launching sequence including one failure, the annual cost of the space segment is $5.5 million. The total satellite system annual cost of $8.1 million includes the $5.5 million space segment and the $2.6 million ground segment. The 10% interest rate employed here is the "standard" rate used by the Department of Defense in its cost-benefit analyses.

Thus, the satellite system would have a somewhat lower total annual cost than the cable system. Moreover, on a per circuit basis, the cost advantage of the 10,000-circuit satellite is enormous in comparison with the 720-circuit cable. */

It is appropriate to consider why the U.S. international voice and record carriers sought authorization to build TAT V. One reason may have been that investment in a cable is includable in the carriers' rate bases, on which their allowable profits are computed, and leased satellite circuits are not. Also, the carriers argued that their

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*/ It should be noted that the satellite capacity is derived on the basis of 4 KHz per voice channel. The cable would provide only 3 KHz per voice channel. If capacity comparability were based on 4 KHz for both satellite and cable circuits, the cable would provide 540 circuits, rather than 720.

self-costs for the cable were less than the cost to them of leasing from Comsat.

Comparisons between the self-costs to the carriers of the cable and the cost of leasing satellite circuits from Comsat are difficult to make, because they and Comsat use different methodologies in computing costs, rate base, and revenue requirements.

A useful indication may be provided by a comparison of Comsat's monthly rate per half-circuit with those of AT&T and the record carriers for private-line service. When the TAT V controversy was decided by the FCC, AT&T's monthly rate for New York-Madrid voice service was $6,500, while Comsat's U.S.-Europe rate was $3,800. */ AT&T agreed to make a 27% rate reduction when TAT V was operational. But even then, AT&T's rate would exceed Comsat's rate by about 25%. While the carriers must add to the Comsat rate a sum sufficient to cover their own added expenses in "retailing" the service to the public, the available figures do not

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*/ Comsat's rate covered termination at the earth station, rather than at New York City. However, the monthly cost of the link from earth station to New York City was under $500.

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provide a sufficient basis for concluding that the carriers' self-costs for cables (including TAT V) would be less than their lease costs for satellite circuits. */ Moreover, these comparisons are based on the assumption that Comsat's rates would have remained unchanged. In fact, the INTELSAT III and IV programs may enable substantial reductions in Comsat's present rates.

On the other hand, as noted earlier, it is misleading to consider only the half-circuit costs of Comsat and the voice and record carriers. Account must also be taken of the costs and charges at the foreign end, and of the reductions that may be possible -- or perhaps even delayed -- by the use of one or another transmission mode.

Another reason why the international carriers sought the cable may have been greater assurance of available transmission capacity, and of other elements of control, over owned rather than leased facilities -- a consideration quite

*/ The international record carriers' leased line rates for U S.-Europe service were identical to AT&T's rates, and they agreed to make rate reductions of about 25% when TAT V became operational. Thus, the discussion in the text is also applicable to these carriers, and the conclusions substantially the same.

important to communicators. Moreover, it is the carriers who deal directly with the actual communications users and who therefore feel responsible in the first instance for meeting the users' demands. They may feel more confident in constructing their own facilities to meet new increments of demand than they would in leasing from Comsat -- a new company, with no direct responsibility to the user and an exclusive commitment to satellite technology. It is also relevant that the choice in the TAT V-INTELSAT IV question was between an existing, proven cable technology and a satellite mode still in the process of development.

Still another reason given for the carriers' preference for TAT V involves the question of service integrity or reliability. Reliability has two aspects: redundancy (i.e., spare capacity in case of failure) and diversity (i.e., spare capacity in a different mode). While redundancy seems not to have been an issue in the consideration of TAT V and INTELSAT IV, diversity is a different matter. Satellites are relatively new and their effectiveness not wholly tested. Some believe they may be more vulnerable in certain respects than cables. It is therefore desirable to retain a "mix" of the two modes. Diversity is an important consideration, and we suspect that for some time

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to come the United States will not want to rely totally on satellites for transatlantic communications. However, we now have four transatlantic cables in service, providing almost 500 circuits; how much more cable insurance we need and what price we should pay for it are matters of judgment. Considering the vulnerability of submarine cables to being damaged by trawlers, some question whether providing 720 additional circuits of cable capacity across the Atlantic justified an investment of $70 million that might otherwise have been avoided.

Other factors, of peripheral interest in the consideration of TAT V and INTELSAT IV, included the time delay aspect of satellite transmission and spectrum conservation. Being 24,000 miles from earth, synchronous satellites introduce a significantly greater time delay factor than a cable. However, the added delay is apparently not serious except for "two-hop" voice connections.*/

*/ Time delay can also have an effect on certain kinds of data transmission. It has been suggested that some users might wish to pay a premium for minimizing delay in certain situations, but we understand that there are no insurmountable engineering obstacles to adapting existing compensating techniques to satellite use, and that equipment should be available for commercial use at a reasonable cost in the early 1970's. Moreover, there is no evidence that data traffic is likely to exceed the capacity of the four cables in place today at any time in that period.

So far as we have been able to determine there would be relatively little traffic requiring two rather than one satellite hop and with proper routing of this limited traffic over existing cables, capacity would be sufficient without further cable building until at least 1973.

The issue of radio spectrum conservation arises from the fact that cables, unlike satellites, do not radiate energy through the atmosphere, and therefore do not draw on potentially scarce spectrum resources. However, congestion of spectrum use would likely pose no serious difficulties over the Atlantic Ocean. And at the earth station location, potential harmful interference between earth stations and nearby microwave relay links is avoidable by locating the earth stations in areas of low-density microwave routes (remote, sparsely populated areas) where congestion is not a problem in the foreseeable future.*/ Cables are not entirely free of spectrum interference problems in their own right. The critical factor would, in any event,

*/ Furthermore, by appropriate design measures, it may be possible to locate future earth stations much nearer the dense microwave relay routes without harmful interference to either service.

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be the final link into areas of large spectrum use.

It is not our purpose to debate whether TAT V, or INTELSAT IV, or both, were justified. Rather, we seek to understand whether the organizational setting for investment decisions best serves the public interest, by ensuring efficient, low-cost, and reliable service. This means, among other things, avoiding unnecessary construction of facilities, or put more positively, rationally programming future investment decisions for the best mix of transmission facilities over time to meet our needs.

Many observers feel that, under direct competition, the voice and record carriers would not have risked building the TAT V cable, a facility which might soon become obsolete. But the voice and record carriers might have calculated that the FCC would not prevent the carriers who invested in TAT V from including that investment in their rate base during its 20-year useful life just because satellite circuits become much cheaper. One may question whether, in making the decision to go ahead with a fifth transatlantic cable at this time, these carriers were in a position to weigh alternative choices in a balanced, impartial manner in order to achieve "system optimization." As noted above,

various additional factors may have weighed heavily in their decision, some of which are of questionable relevance from the standpoint of achieving sound system choices.

There was neither the "unseen hand" of competition nor a single manager free to deploy any and all technologies as he saw fit to meet the various demands placed on the system.

Special reasons were pressed for granting conditional approval of TAT V, notably that the carriers were willing in exchange to reduce transatlantic rates by 25-30% upon completion of the cable and that cable approval, strongly desired by certain European administrations, */ might win support from them for our INTELSAT policies. An issue of equity also arose. Having sought before Congress the opportunity to diversify into the new technology of satellites, and been denied it (at least with respect to the satellites themselves), the carriers could argue that it

*/ The strong support for TAT V by the European communications entities may be attributable to several factors, including: (a) greater familiarity with cable technology; (b) greater control--including a higher percentage of investment--in a small cable consortium than they enjoy in the larger INTELSAT body; and (c) concern about their capacity to compete effectively for INTELSAT procurement of advanced satellites. It is notable that most of the European countries affected by the cable already have satellite earth stations in operation.

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would be unfair to prevent their further growth using the only technology in which Congress permits them to invest directly. Moreover, AT&T said it would not continue further research and development in submarine cables unless TAT V were approved.

There were also strong pressures for a prompt start on INTELSAT IV, particularly because of our special sense of interest in developing the INTELSAT system, and more generally, the satellite mode.

However, if both the cable and satellite facilities are placed in operation as now scheduled, the Atlantic Basin will, for some time at least, have a total communications capacity considerably in excess of the highest responsible estimate of demand. */

In summary, given the present structure of the industry and the nature of regulatory practices, one has good reason to be concerned lest continued separation of cable and satellite ownership lead to distortion of the optimal mixture of technologies and of system choices, and to

*/ As shown in our Staff Study on Technology, Demand and New Services, the highest estimate of Atlantic Basin demand in 1970 is 4,032 circuits; with TAT V and INTELSAT IV, the capacity to meet that demand will be about 6,200.

overbuilding.

3. Feasibility of unfettered cable-satellite competition

Direct and open competition between cable and satellite entities might theoretically produce optimal development of rival technologies, but establishing such an environment in practice in a regulated industry of so few firms would be very difficult, if not highly unlikely to achieve. It is improbable that the balanced transmission plant needed to achieve national security and foreign policy objectives would result from direct and open competition between competing technologies premised primarily on cost.

The cost gap between satellites and cables over long distances seems likely to grow during the next decade. TAT V, the first of the transistorized cables to be laid across the Atlantic, will have a capacity of 720 voice circuits. But, by the time it is laid in 1970, satellites expected to have a 1000-circuit capacity (the INTELSAT III series) will already be in service; and by 1975, when a 2500-3000 circuit cable is expected to be available, satellites of the INTELSAT IV and possibly subsequent series with capacities in the 5,000-10,000 circuit range will have been in operation for several years. At both

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stages of development, the cost per satellite circuit (including associated earth-station costs) should be appreciably lower than that of cable. */

Furthermore, technical differences between the services -- with the single exception of multiple-hop satellite circuits for high-quality voice -- should not be significant. And satellites will provide a more flexible communications capability, for they are able to connect a number of different points, not just two points as a cable, and to be moved to different orbital slots as replacements for or supplements to other satellites.

This is not to say that the existing voice-grade cables will or should be abandoned, since investment is a sunk cost and operating expenses are very low. Nor does it mean that any further cable building will be unjustified; quite apart from the uncertainties of technological prognostication, other reasons may exist for maintaining some diversity of modes. However, even if we are willing to pay a premium for a composite system, it seems likely that

*/ In its Report on Satellites and Other Long Haul Transmission Media the NAE Panel compared the two technologies, and concluded that, in the Atlantic Basin, estimated demand in the 1975-1985 time frame could be met at minimum cost by the use of satellites only in new installations. Appendix A.

satellites will have the lion's share of the Atlantic Basin traffic. */

Were future development to occur in a context of direct competition between cable and satellite carriers, the former could be financially hard pressed. The sharp decline in circuit costs with increased satellite capacity may permit low marginal-cost pricing on competitive routes. Should satellite prices drop to a point where the cable carriers could not amortize their existing cable investment, their stockholders would suffer. In any event, further growth of the carriers would be halted. Yet, however destructive such competition might be to the private interests involved, and however unfair it might seem to have locked the companies into an obsolete technology, the social costs of the competition would probably not be great. The superior technology would triumph and the obsolete technology would be phased out by the end of its economically useful life.

However, the competitive conditions that would produce such a result are unlikely to emerge in the foreseeable

*/ The NAE Panel calculated that, assuming a 20% annual growth in demand over the period 1976-1985, the extra cost of installing cables to meet 10% of the circuits installed during that period would be $3.3 million per year, or 14% of the average annual cost for all facilities in the period. Appendix A, p. 15.

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future. To recommend removing the protective mantle of regulation and forcing the cable and satellite entities to compete directly would seem to be both unrealistic and unfair. Reversal of the authorized-user rulings would probably expose the record carriers to serious jeopardy. Moreover, while Comsat might well best the record carriers in open competition, effective competition with AT&T would be difficult to imagine so long as AT&T controlled most originating traffic, unless compulsory interconnection were required. And, in any event, a question of equity would be presented, as noted earlier, if the carriers are prevented from using satellite technology to compete with Comsat in such an environment.

In noting the problems raised by a separation of cable and satellite ownership, we are mindful that modal separation (e.g., separate trucking and railroad companies) is a traditional feature of public utility regulation, notably in the transportation field. Although one may question whether experience in that industry has demonstrated the wisdom of the policy, of central relevance here is the fact that the precedent may not be applicable to the international communications industry.

Trucks and railroads, barges and pipelines, and buses and airlines provide quite different services. With the widely varying speed, handling, and other critical characteristics that are offered, different classes of commodities and passengers are attracted to the modes that best satisfy their needs. Thus, even in the face of a sudden steep decline in the cost of air travel, the intercity bus industry would be protected against disastrous inroads into its traffic by such factors as settled consumer preference for a familiar mode, the inconvenient location of many airports, the uncertainty and delays of air travel under adverse weather conditions, and the fear that some travelers have of air travel. */

In contrast, satellites are, in one sense, a new technique for performing the communications function heretofore performed by terrestrial facilities--the submarine telephone cables and, before them, high-frequency radio and the telegraph cables.

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*/ In addition (and here there may be a limited parallel to the cable-satellite situation), buses might well remain substantially cheaper on the very short routes.

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If one technology achieves a cost breakthrough, firms committed to the other would find it difficult to keep customers, who would be able to obtain essentially the same service elsewhere at a lower cost. In particular, the distinct possibility exists that a single satellite will soon have sufficient capacity to handle all of the traffic on several international routes (perhaps even whole ocean basins), probably at lower cost than alternative techniques. The pendulum may well swing the other way, and an advanced cable obtain a decisive cost advantage. But competition in such circumstances would be so unstable that we would expect the regulatory authority to be disposed to shield the regulated firms from its consequences, thus postponing the displacement of old technology by new.

Our thesis that competition between cables and satellites is not a viable organizing principle of the international industry does not depend on a conclusion that voice cables, like telegraph cables, are obsolete for transoceanic communications. What we have said would hold if cables were an equally or more promising technology. Suppose that cables (or some more advanced terrestrial technique, such as laser pipes) were or became demonstrably more

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economical than satellites; the FCC would still be under great pressure to authorize continued satellite building by Comsat, because international satellite communications--not international communications simpliciter--is what that company was created to do.

Aware of the uncertainties of open competition, and fearful of the mutually destructive force it would have, we believe that firms in the industry are likely to renounce such competition, preferring instead a policy of "live and let live." Rather than the life and death choices that the market makes in truly competitive situations, the pattern in our opinion would likely be one of parallel development of the separate technologies, to some degree independent of economic justification.

As an example of the effects of parallel development, we might note the FCC's decisions in 1966 approving separate applications to build an earth station in Puerto Rico and a transistorized cable to the Virgin Islands. */ The cable would add 720 voice circuits to an existing cable capacity serving the Puerto Rico-Virgin Island area of some 400

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*/ ITT Cable and Radio Inc. Puerto Rico et al., Memorandum Opinion and Order, 5 F.C.C. 2d 823 (December 7, 1966).

circuits. At the time of the Commission's action, the actual number of circuits being used for service to Puerto Rico was well under 200. (Traffic to the Virgin Islands is only about 15% of Puerto Rican traffic.) Estimated Puerto Rican demand in 1970 is about 350 circuits; to meet the demand, more than 1,000 cable circuits alone are available. Although the cable will provide interim capacity for service between North and South America and the Caribbean area, even if the highest responsible estimate of demand for 1970 materializes, it is evident that either the 720-circuit cable or the earth station will turn out to have been a redundant facility. */ Yet, the cable and satellite applicants did not oppose each other. In granting both applications, the Commission stipulated that new traffic was to be allocated 50/50 between satellite and cable circuits.

The social costs of policies designed to maintain some rough parity between cable and satellite communications are not trivial. TAT V will involve an initial investment of

*/ The demand projections for U.S./Puerto Rico traffic cited in the text are extrapolations from the Atlantic Basin demand projections cited in our staff study on Demand, Technology and New Services.

some $70 million and require revenues of some $250 million over its useful life. Should satellite capacity alone be adequate in the near future to accommodate all transatlantic traffic at comparable or lower costs, a prospect which appears quite likely, these cable revenue requirements may be quite burdensome to users. The possibilities of a TAT VI having a 2,500 circuit capacity are under discussion. If cables are to be permitted to grow irrespective of the existence of adequate and lower-cost satellite capacity--and vice versa-- one may anticipate the expenditure of perhaps hundreds of millions of dollars for unneeded transoceanic capacity. This sum is large not only in absolute terms, but also in relation to the total plant and revenues of the international industry. The burden of these added costs could be borne by the users of international communications in the form of substantially higher rates than actually necessary.

Of course, cable-satellite competition could not fairly be premised purely on considerations of cost. Other factors, such as diversity of transmission modes and foreign policy objectives, are also entitled to weight. But such factors could strengthen the prevailing tendency to find an

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agreed compromise and complicate the task of fostering genuine competition between cables and satellites.

4. Economies of scale and the practicality of bimodal competition. Rejection of separate ownership of cables and satellites as a salutary organizing principle does not necessarily mean that competition should not be permitted in international transmission.

Although airlines are not confined to either prop or jet technology, competition does exist among airlines free to operate either type of aircraft or both.

Accordingly, one alternative to the present system would be to foster the emergence of competing bimodal entities. One way to establish such a competitive environment would be to permit the terrestrial carriers to build and operate satellites and earth stations if they desired, or to participate in INTELSAT ownership, and to permit Comsat to lay cables if it desired. The authorized-user doctrine would be repealed, permitting some direct competition among the various communications companies. Probably, some additional steps might also be desirable to create a truly competitive environment. These would include divestiture by

the cable companies of their stockholdings in Comsat, so that they could not influence its policies and separation of AT&T's international from its domestic operations to ensure against the possibility that it might seek to channel the lion's share of the international market to its own facilities.

This hypothetical solution would raise difficult problems: Allowing separate U.S. entities to compete with one another by satellite for international traffic would be difficult to reconcile with our commitment to the INTELSAT concept of a global satellite system, in which a single entity--Comsat--represents the United States in the global system.

We also doubt the practicality of competing bimodal entities because the capacity of existing and projected transmission facilities will be large in relation to demand. In the face of such a relationship between capacity and demand, it is unrealistic to expect effective competition in international transmission--whether between satellite and cable companies, or between bimodal entities. It is no exaggeration to say that in international transmission we may be faced with conditions of a true "natural monopoly."

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In the words of two distinguished students of antitrust policy:

> In the economic sense, natural monopoly is monopoly resulting from economies of scale, a relationship between the size of the market and the size of the most efficient firm such that one firm of efficient size can produce all or more than the market can take at a remunerative price, and can continually expand its capacity at less cost than that of a new firm entering the business. In this situation, competition may exist for a time but only until bankruptcy or merger leaves the field to one firm; in a meaningful sense, competition here is self-destructive. */

Such conditions are rarely encountered in the real world. The transmission segment of transoceanic communications may, however, be one area where they are present. Beginning in the early 1970's, the economies of scale in transoceanic transmission--given projected demand-- appear too great to permit effective competition.

We are aware that today's most optimistic technological forecasts and highest estimates of future demand for international communications services may prove to be inaccurate. Accordingly, it would be imprudent to base important policy decisions today solely on prognostications about future technology and demand. It may be useful, nonetheless, to

*/ Kaysen & Turner, Antitrust Policy (1959), at p. 91.

examine some of the projections that have been made.

The ITU's World Plan Committee projected Atlantic basin growth in demand for the period 1968-1975 at approximately 18% per year. In the NAE Panel Report on Satellites and Other Long Haul Transmission Media, comparisons of the engineering costs of meeting Atlantic Basin requirements through 1985 by satellites and cables were made on the basis of further expansion of demand along two projected growth curves--one at 10% a year, the other at 20% a year.

Even if Atlantic Basin demand for two-way voice circuits (including TV, data, and voice) grew at the highest suggested rate--20% a year, by 1980 less than 20,000 circuits would be needed to meet all circuit requirements in the Basin. Yet, the NAE Panel, relying on "rather conservative technology forecasts," */ postulated a series of modified INTELSAT IV satellites which, operational no later than 1976, could each provide 20,000 circuits. It follows a fortiori that on other intercontinental routes, also, no more than one satellite

*/ Appendix A, p. 15.

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would be required. */

The trend toward facilities of greatly increased capacity at sharply reduced costs per circuit is a general characteristic of communications technology. It is by no means limited to satellites. Economies of scale in submarine-cable technology are also considerable. The largest transatlantic cable in operation today has a capacity of only 138 circuits. At less than twice the total installed cost, TAT V will have 720 circuits--nearly a sixfold increase in capacity; by the middle 1970's cables with 3,000-circuit capacity are expected to be available--affording a further reduction in per circuit cost.

Of course, it would be possible to have several facilities share the traffic of a single route. However, if

*/ While the NAE Panel postulated the future use of such large-capacity satellites, some believe that satellites of this character are not the most economical; rather that the requirements of the Atlantic Basin could more cheaply be met by two or more smaller satellites, one perhaps to handle the very dense transatlantic traffic between the developed countries and the other to provide global coverage in the region. This outcome would not disturb our conclusion that satellite technology offers very large economies of scale, for even under this model only one satellite is used for the most dense international route--U.S.-Europe. Two satellites would be used to meet the needs of the entire oceanic basin, but on non-competing routes.

predictions as to economies of scale are roughly accurate, costly and unnecessary duplication of facilities is a dangerous possibility. Not only more satellites, but more complicated earth-station configurations, would be required. Thus, any attempt to create a true bimodal competitive structure could impede efforts to reduce existing rates for international communication services, and even increase the cost of providing those services.

Furthermore, the resulting excess capacity could engener "cutthroat" competition. Each entity would be under pressure to sell additional circuits at their very low marginal cost. However, given the large economies of scale, the sum of the marginal costs would not equal the total costs, and the industry might end up operating at a loss and seek government subsidy. At this point a consolidation might even seem inevitable.

Most important, to the extent that the service provided by each entity is essentially the same, there would be little reason to select the facility of an entity whose marginal costs were just a shade higher than that of the competing entity's. The user would have no reason to pay even slightly more for the service of a particular facility--

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the service being essentially the same -- and there would be no capacity limitation compelling use of the higher-cost facility. In these extremely unstable conditions, the pressures would be very great for enforced rate uniformity, for an allocation of traffic according to formula, and for a tacit agreement to follow the "quiet life" and refrain from destructive competitive forays. As a result, and if the thrust of regulatory policy is along present lines, the social costs of duplicating facilities would probably not, in practice, be offset by corresponding competitive benefits.

In considering today's international communications industry structure, it is appropriate to compare earlier experience. When transoceanic radio communications became feasible in the 1920's, the existing telegraph carriers (which had previously operated exclusively by means of submarine cables), provided the conditions concerning competition of the Radio Act (embodied in Section 314 of the Communications Act) were not violated, were permitted to diversify into the new technique. Eventually all of the international record carriers except Western Union International had both cable and radio facilities. ITT World Com, for example, is the product of the consolidation of several pure radio, pure

cable, and cable-radio carriers. To have insisted on a separation of cable and radio would most probably have resulted in overbuilding and excess capacity.

As a further example, suppose that AT&T had been confined to radio-telephony on its international routes and forbidden to lay voice-grade cables, with the right to exploit the new cable technology given to a new entity. Healthy competition would probably not have been fostered. Rather, the phasing out of high-frequency radio in international telephony and the full exploitation of the new technology would have been delayed.

B. Future of the U.S. International Record Carrier Industry

Aside from the separation of technologies, of concern above, two other issues were of principal focus in prior studies, including the extensive study resulting in the 1966 Intragovernmental Committee Report: First, should the international record carriers be consolidated in order to promote more efficient operations, or would possible gains in efficiency be outweighed by the loss of competitive benefits? Second, does the existence of a record carrier industry, insulated from effective competition by other firms, impose unnecessary cost on the public?

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1. Role of the record carriers in international communications. The international record carriers offer three basic kinds of service: telegram (equivalent to the domestic Western Union public message service); teletypewriter exchange (equivalent to domestic TWX and Telex); switched narrowband and broadband data (computer-to-computer); and leased-line service, either pure record or mixed voice-record (AVD).

In public message service anywhere in the United States outside of "gateway" cities, an individual desiring to send a telegram overseas contacts the local Western Union office which transmits the message over its lines to an international record carrier switching center in the appropriate gateway city for transmission overseas. If the individual does not specify a particular international record carrier to handle his message Western Union will transfer it to a carrier in accordance with current quotas established under a formula pursuant to the Communication Act of 1934. The record carriers maintain their own public offices (similar to domestic Western Union's local offices) only in the gateway cities.

Public message has accounted for a steadily declining portion of the record carriers' revenues. If domestic experience is any guide, the prospects for growth of this service are not bright. Domestically, the sharp decline in long-distance telephone rates has cut deeply into the telegram business. The predicted sharp decline in overseas telephone rates could have similar (although in view of time and language differences perhaps less drastic) impact upon international telegram services. On the other hand, Telex and leased-line services are of growing importance to the profit positions of the record carriers.

For switched teletypewriter data services, the "hinterland" (i.e., non-gateway) customers are with few exceptions subscribers to Western Union's Telex or AT&T's TWX service who also use their instruments for international service. (The record carriers are interconnected with both TWX and Telex though, as mentioned, not with each other.) To make an overseas connection, the subscriber dials the record carrier of his choice which provides the overseas transmission. Automatic Telex (customer dialing) is available with an increasing number of overseas points. In gateway cities, the international record carriers furnish teletypewriters

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or data sets to their tieline customers. They buy these instruments from equipment manufacturers (both affiliates and non-affiliates), frequently foreign ones.

For leased services, which are not switched, the international record carriers provide the overseas transmission and a domestic carrier provides the tieline from the customer's office to the international record carrier's office where it is monitored and tested. The record carriers derive usable communications channels from the transmission capacity available through the cable or satellite and supply the equipment to maintain signal quality over long distances. They also furnish terminal equipment used by their leased-line customers.

2. Consolidation of the record carriers: an economic analysis. To decide whether the maintenance of a plurality of record carriers is preferable to consolidation, the benefits of competition must be weighed against the detriments of a fragmented industry structure. At present, the area of effective competition in the international industry is limited. Competition between the

record carriers as a group and the voice carriers (mainly AT&T) is at best indirect, since the two groups do not sell identical services. */ Also, the authorized user doctrine effectively protects the record carriers from competition by Comsat. The only significant direct competition is among the record carriers, and even there it is somewhat limited. On major routes, the record carriers and AT&T use the same cable or satellite facilities for the international leg; this trend will, if anything, accelerate. The domestic legs are provided over lines of AT&T (or other telephone companies) and Western Union in this country, and over a foreign carrier's lines at the other end.

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*/ An exception is AVD service to Hawaii, which is offered by AT&T and Hawaiian Telephone Company as well as by the record carriers.

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Nevertheless, the study conducted by Stanford Research Institute (SRI), in connection with the 1966 Intragovernmental Committee Report, suggests that some significant competitive pressures remain. Despite the nominal separateness of their services, the record carriers may exercise a partial competitive check on AT&T, since their AVD service as well as recently filed tariffs for voice-teleprinter circuits seem reasonably close substitutes for AT&T's leased voice-only service. Also the record carriers are not completely dependent on other carriers' plants. As of 1964 they had $50 million (out of a total net plant of $120 million) invested in switching and other terminal plant (including user terminal equipment). Of this amount some $18 million apparently represented investment in electronic switching equipment.* According to SRI the record carriers have competed vigorously in modernizing their plant and improving the efficiency of its use.

More important, substantial service competition exists among the record carriers. Areas of such competition include the proper maintenance of facilities, the quality of proposals outlining new services for a customer, terminal equipment

*SRI Report, p. 101.

alternatives, and in dealings with foreign correspondents as a representative of the customer for the establishment of leased circuits. Medium-sized users, at least, have probably benefitted from this competition. Some government officials have attested to the existence of concrete benefits in their own relations with the record carriers.

In addition, at least some rate competition exists among the record carriers, e.g., in the introduction of high-speed services like DATEL. Occasionally (indeed, several times in 1968) one or another of the carriers files a special low tariff to win a particular segment of the business, e.g., a U.S. Government or airline account. And competition can be quite vigorous with respect to leased circuits. Moreover, the fact that the rates charged by all carriers on a given route are identical is not conclusive evidence that rate competition is negligible. It may mean only that any price change initiated by one carrier is immediately matched by its

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competitors. This has been the case (at least sporadically) in the airline industry, where price competition has occasionally been intense even though at any given point in time the rates charged by all airlines over a given route are usually identical.

However, these competitive benefits must be viewed against certain detriments. First, it is alleged that on occasion the plurality of U.S. carriers has made more difficult effective bargaining with foreign entities; bargaining for more favorable terms seems more likely, the fewer the U.S. entities involved. Secondly, the existence of several international record carriers may lead to substantial unnecessary duplication of facilities and manpower. If true, substantial cost savings (and resultant rate reductions) could be obtained by consolidation; and perhaps some of the existing barriers to competition could be removed as well. If a consolidation of the record carriers enabled the record-carrier industry to survive without the protections afforded by the FCC in the TAT IV and authorized user rulings, the resulting gain to competition might outweigh the competitive loss from eliminating intra-record rivalry. The answer depends primarily on whether the record

carriers need consolidation in order to operate at an efficient scale.

At first blush, it would appear that whatever economies of scale are possible in transoceanic transmission have already been realized. The only transmission facilities not shared today are the radio facilities, and no reason appears why they could not be shared as readily as cables and satellites. In any event, most of these facilities will be phased out as technology advances, regardless of whether a consolidation takes place.

Nevertheless, the SRI report concluded that consolidation would enable substantial cost savings (amounting to some $50 million annually by 1975)* with transmission being the principal source of potential savings. It estimated that a merged entity would have required 25% fewer circuits than the record carriers needed in 1965 (although only 12% fewer in 1975 than the three carriers separately would then require.**

As the SRI report indicates, the reason that the record carriers' individual exceed their group circuit requirements lies in their inability or unwillingness to share transmission circuits which they have leased or to which they have inde-

* Supplement C, Tables C-16 and 18, at pp. 261, 264. The figure cited in the text is based on an assumption that two major rate reductions take place between 1964 and 1975.

** Id. at pp. 245-46.

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feasible rights of use.*** Perhaps it is true that even with out a merger competing entities could share the use of commonly owned or leased facilities more efficiently than at present; in principle, when a particular carrier finds its own circuits overloaded it should be able to quickly obtain additional circuits from AT&T or from the other record carriers if at the same time some of the circuits allocated to these other carriers are not being used. However, while some improvements in meshing the peaks and troughs in demands facing individual carriers may be possible in the future, the heart of the problem seems to be that each carrier has its own switching plant. Without a consolidation of switching, traffic cannot be fully adjusted among the circuits allocated to each carrier in a particular cable to meet variations in each carrier's demand. It would seem to follow that switching, like transmission, should be a common, shared function.

Additional support for this conclusion is provided by the report's calculation that the net terminal plant (including switching) of a single, consolidated record carrier should after one year of consolidation be reduced by 20% (or

*** Supplement A, pp. 32-34

by $10 million) relative to the net terminal plants of the carriers separately.* Although SRI gave no exact basis for this figure, it did observe that new switching facilities then being installed by any of the record carriers could probably handle the message traffic for all three at little added cost.**

Since switching equipment is more than 50% of the carrier's total terminal plant, consolidation could conceivably result in a reduction of at least 33-1/3% (2/3 of 50%) in the total.*** The discrepancy between this figure and the report's 20% estimate may reflect a judgment that the older facilities would be phased out gradually.

SRI does not indicate the extent to which a consolidation of the record carriers might enable cost savings in user terminal equipment, sales offices and sales forces, and other terminal or service facilities. It seems quite likely that a consolidation would enable some savings in these respects, particularly in duplicative telegram offices. Thus, we know that in gateway cities customers must frequently obtain three teletypewriters in order to communicate with all overseas

* Supplement C, at p. 257
** Supplement A, at p. 33
*** Supplement C, at p. 247

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points, since the record carriers are not inter-connected. But we do not know the magnitude of this terminal duplication or whether it could feasibly be eliminated by means short or merger, such as compulsory interconnection. The SRI report calculates that the carriers' annual expense of conducting operations (the largest expense item by far) would range from 3% to well over 20% lower if there were a consolidation, on the theory that the consolidated carrier would have a more modern and efficient plant than would the individual carriers operating separately.* However, no explanation of this assumption is offered.

We conclude that the available date is insufficient to determine whether consolidation of the record industry is necessary to achieve substantial economies of scale. Major economies appear to lie in transmission, and they could be fully exploited by a partial consolidation which merely unified the transmission facilities and operations of the record carriers, leaving them otherwise free to compete. The extent to which significant added economies would be achieved by a more comprehensive consolidation, involving switching and

*Assuming two major rate reductions. See supplement C, at pp. 261, 264, 265.

other terminal facilities or service operations, is unclear. While some added economies would certainly be possible by a broader consolidation (particularly of switching facilities) that left the record carriers otherwise free to compete, a serious question might be presented as to their willingness to do so if the separate entities were shorn of a substantial role in the communications process, apart from their sharing of joint facilities.

C. Future of Comsat

Despite the authorized-user doctrine -- which insulates the voice and record carriers from direct competition by Comsat -- Comsat and the other carriers are in a very real sense rivals. The fact that representatives of the voice and record carriers sit on Comsat's board of directors -- one is chairman of the corporation's finance committee -- would appear to create a potential conflict of interest. Although the carrier-appointed directors do not control Comsat's board, they exercise influence within it; and even though they seek not to participate in Comsat board decisions affecting their own company, they could conceivably use their position to obtain private information potentially detrimental to Comsat's interests. While hard evidence in this area

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is of course elusive, there is some reason to believe that, as a result of the carriers' presence on Comsat's board and their control of the user's access to the satellite system, the corporation sometimes feels reluctant to take positions adverse to the carriers' interests.* Then too, since the carriers account for some 42% of Comsat's stockholders, Comsat is in the anomalous position of owing them a fiduciary obligation.

While many potential dangers of conflict of interest may be rather remote, the carriers' influence over Comsat can be expected to have a concrete impact on the development of satellite services. In a sense, such development poses a threat to the carriers because it may mean large-scale substitution for their own transmission plant of satellite facilities which are not includable in their rate bases. This consideration could influence the carriers to be less enthusiastic than they otherwise would be about the development and introduction by Comsat of advanced satellite communication techniques and uses.

*See e.g., Congressional Quarterly, Fact Sheet on Communications Controversy, March 13, 1968, at 1.

These various issues are all affected by the basic structure of our international communications industry; and in the final analysis, the future of Comsat will rest on decisions made about changing the industry's structure.

D. Improving Government Regulation and Furthering Objectives of National Policy

We have already noted areas in which regulating a plurality of international carriers under today's fragmented industry structure has proved difficult. There are also aspects of this problem which relate to Executive Branch concerns.

The role of the Executive Branch international communications has traditionally been twofold: (1) to secure adequate communications for military and other governmental services; and (2) to advance foreign-policy objectives, including support for U.S. carriers in negotiations with their foreign counterparts. On occasion these functions have been made more difficult by the plurality of U.S. international communications entities. Five companies -- AT&T, Comsat, ITT World Communications, RCA Communications, and Western Union International, to name only the principal entities -- are involved in U.S. overseas communications.

Recent examples of these problems may be summarized

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briefly as follows:

The Guam-Philippine Cable. At the urging of the Defense Department, AT&T agreed in 1963 to construct a cable between Guam and the Philippines in conjunction with its own subsidiary (Transpacific) and a GT&E affiliate Philippine Long Distance telephone (PLDT).* PLDT and AT&T then agreed to allocate some of the channels on the cable to American Cable and Radio (AC&R), then parent of ITT World Com. After the necessary licenses had been obtained from the FCC and (provisionally) from the Philippines Public Utilities Commission, a dispute arose between AC&R and PLDT. AC&R -- acting through another subsidiary, Globe Wireless Limited (Philippines) sued before the Philippines Commission contending that Transpacific and PLDT lacked authority to lay the cable and were discriminating against it and in favor (among others) of RCA Communications in the provision of circuits. The Commission thereupon suspended authority to lay the cable. AC&R then proceeded against AT&T before the FCC on similar grounds.

Defense intervened in both proceedings, arguing that they were delaying an urgently needed facility. The Secretary of State interceded with the President of the Philippines. Eventually, 5 months late because of the legal disputes among the carriers, the cable was laid.

* GT&E has since disposed of its interest in PLDT.

The Philippine Earth Station. Early in 1966, the Philippine Government began to evidence serious interest in satellite communications. In February it requested ITT World Com, RCA Communications, and PLDT, to make a joint proposal for an earth station to be owned partly by the carriers and partly by the Philippine Government. However, in November the Philippine Government reversed its earlier position and announced formation of the Philippines Communications Satellite Corporation (Philcomsat) to be owned partly by the Government and partly by a newly created telephone company wholly owned by Philippine nationals. Philcomsat sought (and received) technical assistance from Comsat, but ITT and the other U.S. carriers protested their exclusion from earth-station ownership to the Philippine Government -- which in turn protested to the U.S. Embassy that the carriers' maneuverings were delaying the earth-station program.

Eventually, an earth station was installed by Comsat, acting under Philcomsat's initiative and direction. However, dispute soon arose again when, pursuant to the authorized-user decision, Comsat was directed to relinquish its contract to furnish ten satellite circuits required by Defense in the Philippines to WUI, ITT World Com, and Hawaiian Telephone.

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Philcomsat refused to agree to this transfer, stating its desire to deal directly with Comsat. Shortly afterwards the Philippine Undersecretary of Defense protested to the U.S. State Department concerning the "strong pressure" which the carriers were allegedly exerting on Philippine Government decisions. After further difficulties, the Philippine Government approved the transfer of the circuits as requested by the United States in January 1968.

The Thailand and Japan Disputes. As mentioned earlier, in accordance with the outcome of the "30 circuits" case, Comsat was directed to assign its contract to the carriers. ITT World Com, RCA Communications, Western Union International, and Hawaiian Telephone were each to have several circuits to each country involved. However, difficulty arose when the Japanese carrier refused to deal with WUI and the Thai authorities refused to deal with any carrier except RCA Communications. After extended exploration of the questions at high levels in both the U.S. and foreign governments, it was agreed that Thailand's preference for RCA Communications would be respected on the understanding that dealings would involve no permanent exclusive arrangement. It was also decided that if the Thai and Japanese positions were adhered to, other circuits

in the Pacific would be reallocated so that, overall, the U.S. carriers would receive equal treatment. As a result of this and other controversies, transfer of the 30 circuits from Comsat to the other carriers was a lengthy process. Moreover, disputes have arisen between Comsat and the carriers over the proper allocation of certain initial costs incurred in providing the service.

The Northeast Power Failure. As noted earlier, the only portion of the actual international transmission provided by the record carriers consists of loops in the gateway cities running through the record carriers' offices. During the northeast power failure of November 1965, the power supplying these loops failed. The emergency backup power facilities of the record carriers were inadequate, resulting in outages of various lengths. The record carriers were able to reroute some of the traffic through other facilities, but substantial interruptions of overseas traffic (including important though non-essential government communications) occurred. With its substantial backup power facilities and extensive alternate routing AT&T was largely unaffected. A unified international transmission network

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could have been less vulnerable and better equipped to handle important traffic on a priority basis during the outages than the record carriers, depending on various factors including the availability of electric power to operate teleprinters in customers' offices.

IV. ALTERNATIVE SOLUTIONS

The preceding discussion has highlighted the fact that separation of cable and satellite ownership, in the presence of substantial economies of scale, is a central problem of the industry -- a problem exacerbated by two factors: the rapid deployment of communication satellites and the development of transistorized undersea cables, each with vastly greater (and continually growing) capacity than earlier modes of transmission, and at far lower per circuit costs.

The goal of policy in international communications should be a system which permits such investment choices to be made on sound economic grounds, including appropriate consideration of the claims of defense and other national interest and foreign policy requirements. An efficient international communications system will increasingly require a careful meshing over time of the various methods of transmission -- submarine cables, high-frequency radio, satellites and their attendant earth stations, and doubtless other future techniques as well. Each method has both advantages and disadvantages; different patterns of costs and benefits; different capacities, service characteristics,

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vulnerabilities to accidental or hostile disruption, useful lifetime and building times. To approximate the best blend of facilities in international transmission will necessarily involve complex investment decisions among alternative transmission technologies for meeting new demands.

In light of the discussion thus far, one may question whether the existing industry structure adequately serves these objectives. It is now appropriate to examine alternative solutions.

A. Merger of the International Record Carriers

Our earlier analysis of this solution raised a question about the desirability of a record carrier merger going beyond a limited consolidation of certain of their facilities and operations, since the available data did not indicate the extent to which substantial added economies would be realized by a comprehensive merger of the record carriers. The benefits of such a broader merger of the record carriers might not outweigh the loss of benefits available today as a result of competitive pressures created by the existence of a plurality of record carriers. For it has not been suggested that the record carriers are too weak to compete with each other. In the last few years, at least,

they have been quite prosperous. Nor has a case been made for the proposition that, if the record carriers were merged, effective competition between Comsat and the consolidated record carrier would be possible. The evidence is simply lacking.

Moreover, proponents of the record carrier merger have not shown that it would enable effective competition between AT&T and the new merged entity. In fact, the SRI report states that the privileged position with respect to AVD now enjoyed by the record carriers would continue to be required. */ AT&T undoubtedly would continue to have great strategic advantages -- related to its size and to its position in the domestic market -- over the record carrier industry. While a record carrier merger might enable somewhat greater rate reductions and more efficient service than the existing industry, a unified record carrier -- still a quite modest entity with no domestic base -- may not be materially stronger vis-à-vis AT&T than today's plurality of record carriers.

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*/ SRI Report, p. 184.

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Some believe that a more effective competitive environment would be created if a consolidation of the international record carriers also included domestic Western Union. */ Such a consolidation, it is said, would strengthen the industry's bargaining positions vis-à-vis foreign administrations, and also its research and development capability, and would enable greater economies (mainly in gateway city operating and administrative expenses). SRI suggested that such an integrated domestic/international record carrier would have a stronger competitive position vis-à-vis the Bell System, but conceded that the record carriers' position with respect to international operations would still be necessary for the new record carrier, at least for a trial period.

On balance, we are skeptical about the feasibility of breaking down existing barriers to an added measure of competition between international record carriers on the one hand and AT&T and/or Comsat on the other -- either by merging the record carriers alone or with domestic Western Union. More significantly, neither merger approach

*/ See SRI Report, pp. 185-188.

would deal with the central issue we perceive to be raised by the existing fragmented U.S. international communications industry structure, namely, the separation by technologies of the ownership of the principal transmission facilities. Comsat would still be wedded to satellites, and AT&T and the other carriers prevented from entering the satellite field directly (except for earth station ownership and operation) to meet their international communications requirements. If, as we believe, this compartmentalization of technologies is today a questionable organizing principle of the industry, merger alternatives that exclude Comsat fail to come to grips with the central issue. Comsat's future would remain clouded, and more effective government regulation and achievement of our national policy objectives would remain in doubt.

B. Allow the Terrestrial Carriers to Participate More Directly in Satellites

We have seen that a major difficulty with the existing industry structure is that the firms may be committed or inclined toward a particular technology. Accordingly, one suggested alternative is to permit the international voice and record carriers to obtain indefeasible rights of use (IRU's) in satellites. Some suggest that this would

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effectively neutralize the specific factors that give rise to problems of system optimization under the present fragmented ownership structure of cables and satellites. In return for permitting them to have a direct financial interest in the space segment, the carriers might be required to give up their stock interest in Comsat.

We doubt the merit of this proposal. In essence, it substitutes a consortium or cartel of carriers enjoying practical dominance of the satellite entity, presumably to avoid the anticompetitive consequences of a consolidation. But very little competition would remain once the carriers were secure in being insulated from Comsat's potential competition and owned a substantial portion of Comsat's facilities -- indeed, implicit in the proposal is a desire to substitute a sense of "partnership" between cable and satellite entities for the present rivalry. Moreover, the consortium approach would create added problems in the minds of many by increasing the role and influence of AT&T in international communications. Further, since some carriers have manufacturing affiliates, problems presented by vertical integration might persist. A joint venture of AT&T, ITT World Com, RCA Communications, Western Union International,

several smaller carriers, and Comsat would be administratively cumbersome. It would drastically curtail Comsat's international role, aggravate its problems, and raise a fundamental question as to its future raison d'être. Moreover, it would be tantamount to a repeal of the Satellite Act of 1962, which gave ownership of the space segment to Comsat, rather than the alternative approach of vesting ownership of the satellite mode in the existing carriers as we proposed at that time.

C. Seek to Create a Structure of Workable Competition

It has been suggested that public policy should seek to create a workable competitive model in our international communications industry. The model would keep separate cable and satellite entities for the time being, but take steps to correct the existing barriers to effective competition. Such a solution would, it is said, maximize whatever competitive stimulus may be provided by the separation for at least 10 years more, and possibly much longer. Under this view, international transmission could be carried out by two separate entities: an international satellite company (e.g., Comsat) and an international cable company. These companies would not provide customer services directly. Rather, they would lease channels a) to common carriers who

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would, in effect, acquire circuits at wholesale and provide international message and channel services, terminal facilities, etc.; and b) to others, not acting as common carriers, who have sufficient need to utilize entire international circuits (large users like the broadcast companies, private carriers or groups which use line-sharing techniques).

We see several difficulties with this approach. First, it seems quite unlikely today that private enterprise would invest in an international cable company subject to such conditions; and from the point of view of public policy, it may appear inequitable to decree unfettered competition in such fashion when one mode may prove most attractive only in a distinctly supplementary role. Second, as a practical matter we think that the structural changes necessary to make the model work -- especially, severing AT&T's international operations -- would be quite difficult except (for reasons noted below) in the context of a fundamentally different approach to the industry's problems, discussed in the next section of this paper. Third, the competitive model may be questioned in light of the circumstances of international transmission, including economies of scale, that in our judgment preclude effective competition under regulation.

D. Create a Single Entity for U.S. International Transmission

We are persuaded that there is one comprehensive approach to the problems noted earlier that is both feasible and attractive. A new single entity would be created for the basic international transmission and switching functions now performed by Comsat and the international voice and record carriers. It would involve a consolidation of the international transmission plant of the international voice and record carriers, Comsat's satellite investments, the U.S. earth stations now operating or planned for operation with INTELSAT satellites, and such switching and other equipment as may be justified to realize economies of scale.

Conceivably, steps short of industry restructuring could go far in coping with the problems arising under the present structure. For example, the rates of the international voice and record carriers could be set on the basis of the most efficient and lowest cost transmission medium regardless of ownership; government review could be strengthened to enable rigorous scrutiny and evaluation of adversary proposals for new facilities and choices which

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avoid overbuilding; and these carriers could be subjected more rigorously to the test of the market by giving more direct access to international circuits through modification of the authorized-user rulings.

Apart from questions concerning the practicality of such steps, experience under the present structure demonstrates the limited benefits resulting from the diversity of ownership in international transmission facilities. As noted, the carriers are increasingly using joint transmission facilities. Such benefits as are provided by competition are largely, therefore, in terminal equipment and in arrangements for special communications services and not in transmission facilities. And some competition in service and terminal arrangements can be maintained and fostered by providing users, carriers, and, prospectively perhaps, specialized service companies, with more flexible access to the international transmission facilities.

We are mindful of the risks inherent in a single entity being entrusted with such broad power, even in a defined sector of the communications industry. But, for the reasons elaborated below, we have concluded that such

risks are worth taking, provided that appropriate safeguards are established. */

1. Advantages of the single transmission entity

a. A sounder framework for wise system choices. The single entity would not be committed to any particular technology, It would have an opportunity denied the present participants in international transmission to make impartial and balanced system choices between available technologies and to exploit fully the available economies of scale.

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*/ We have also examined a variant of this approach, which would involve the creation of regional bimodal transmission entities -- most likely one for the Atlantic and one for the Pacific, since the needs of those two regions cannot possibly be served by a single satellite. These entities would not compete directly, but they would offer greater diversity in terms of corporate policy toward innovation, rates and service; a potential basis for FCC regulation on a yardstick basis; and a more competitive market for the equipment suppliers. Despite such potential attractions, we think this alternative on balance undesirable. It might greatly complicate our INTELSAT arrangements. It would also be very difficult to implement; it would be difficult enough to consolidate existing facilities without then splitting them in two again.

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System optimization is an especially important requirement in the transmission sector of our international communications. Major decisions involve the selection at relatively infrequent intervals among a broad range of system designs, often involving different technologies, costs, capacities, lead times and useful lives, to meet estimated demands that are subject to considerable uncertainty. In the absence of an effective competitive mechanism, this suggests the desirability of a centralized system manager.

Thus, in considering the merits of TAT V and INTELSAT IV the single entity could have explored the range of possibilities open to it for meeting predicted growth in transatlantic demand. It could have appraised the tradeoffs between the probability of a shortage in the early 1970's, the costs (determined on a consistent basis) of meeting it by a variety of satellite configurations vs. the costs of various cable systems, the desirability of diversity, the advantages and disadvantages of facilities having very long life in a situation of rapid technological change, the choices based on existing technology as well as

expectations about future technology, and other relevant considerations.

For the single entity, the degree of control of cables and satellites should be roughly comparable. To be sure, any satellites in its system would be part of the INTELSAT system. However, international cables are not wholly owned by U.S. carriers. There are always foreign partners, who usually have an equal measure of ownership and control. Comsat's role in INTELSAT probably gives it at least as great a voice over satellites as AT&T and the record carriers have over cables. Particular foreign administrations may continue to prefer cables because their share in ownership of the global satellite system will remain relatively small, and this preference may affect the views of the U.S. transmission entity. But a single entity should be able to resist the pressure of foreign administrations for a particular mode of transmission better than the several U.S. carriers now can.

b. Helps resolve questions concerning future of international record carrier industry. We discussed earlier the central questions raised about the future of the record industry -- protective regulatory restrictions

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that, in the view of some, are perpetuating a costly and unnecessary "middleman function," and a fragmented structure that may involve costs as well as some competitive benefits. Both issues could be resolved by the formation of a single U.S. international transmission entity.

To be sure, it is theoretically possible to remove the protection now afforded the record carriers without forming a single entity. But it is far easier to contemplate such a change as part of a complete restructuring of the international industry in which the record carriers are offered the option to dispose of all their assets and franchises at a fair price. We do not foreclose the possibility that the record carriers will prefer arrangements retaining some role for them in international communications. But if they choose to dispose of all their assets and franchises, their non-transmission, non-switching properties and personnel could then devolve upon the domestic companies which would succeed them in performing their functions at the service end.

The governing principle for the structure of a single international transmission entity would be that applicable generally to all situations where public policy has found

the need for a public utility monopoly -- to confine the monopoly to the functions which in their nature require unity of operations.

A single transmission entity would permit the elimination of inefficient or duplicative transmission and switching operations without necessarily foreclosing competition in other areas. The principal areas where competitive offerings exist today in the international record business are in leased-line service, switched teletypewriter and public message service, and the provision of terminal equipment.

The public message service is not, in any event, an attractive candidate for competitive offering and, if the record carriers choose to dispose of their assets and franchises, might well devolve upon domestic Western Union. With respect to leased-line service and switched teletypewriter service, competition need not be eliminated. AT&T and domestic Western Union, perhaps strengthened by the acquisition of international record carrier properties and personnel at the service end, might well provide competitive services. Of course, the existing record carriers should be free to maintain terminal and service offerings,

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using circuits obtained from the single entity, if they choose to do so. Moreover, competitive elements will be added by permitting the single entity to deal directly with large users where no "customizing" of the transmission service is involved or where the user can do it himself. Finally, where feasible, other firms should be permitted to enter the customer-service international market and provide remote accessing of computers, message switching, subdividing or channelizing of leased circuits, and terminal gear to users as needs for such specialized services develop, and provided that appropriate procedures can be established where necessary for dealing with foreign entities.

One avenue which deserves exploration is a possible consolidation involving terminal facilities of the international record carriers with domestic Western Union to form a strengthened service capability which would permit effective competition with respect to services from which AT&T is presently barred. This is a difficult question which will require further study and considerable exploration with the parties involved.

There may be a market for firms to provide remote accessing of computers, message switching, subdividing or

channelizing of leased circuits, and terminal gear to users. We do not exclude the possibility of new entrants in some of the markets now served by the international record carriers. Roughly comparable to freight forwarders in the railroad business, these firms would employ the common communications network to provide services differentiated by customer requirements -- furnishing user terminal equipment, advising customers on their communications needs, designing services tailored to particular needs, and perhaps deriving additional communications channels from leased circuits. Not common carriage in the traditional sense, this kind of customer service function would appeal principally to the medium-sized business user. It would resemble what the computer time-sharing companies propose to do -- use the common communications network to furnish unique services utilizing specialized terminal equipment. */ And, as this example suggests, such a service need not be a negligible function. The function might devolve very largely on the regulated domestic carriers, though at least with regard to computer services we see a promising role for the specialist firm.

*/ Indeed, the same companies may seize the opportunity to diversify into international service. Already, the international record carriers have begun to offer computer services similar to some recent domestic offerings.

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Freer entry into the service end of the international communications business would raise questions about negotiations with foreign entities. If any service firm were free to make its own arrangements for obtaining circuits from foreign carriers, certain advantages of the single entity approach from the foreign policy point of view -- discussed below -- might be lost. Moreover, foreign carriers are accustomed to dealing with substantial and responsible U.S. international communications entities. They would be reluctant to deal with a large number of small service companies. But it may well be possible to establish procedures under which the U.S. international entity would make the necessary arrangements with foreign entities.

What then, is likely to be the net impact of the single-entity approach on competition with respect to the U.S. international record carriers? It may be mixed. Consolidation of transmission, switching, and to a lesser extent perhaps, some terminal facilities such as telegraph offices in gateway cities can be expected to yield significant cost savings. Moreover, modification of the authorized-user limitations will benefit the large communications users by offering them an opportunity to deal directly with the transmission entity.

One drawback is the possible curtailment of the competitive alternatives of the medium-sized communications user -- the telex or datel customers who today can choose among the international record carriers. There is likely to be a lack of interest on the part of the international record carriers in remaining in that business after their international transmission and switching plant is absorbed by the single entity. But some competition could continue between domestic carriers at the service end and opportunities may develop for competitive diversity at the service end -- competition in deriving additional circuits, in furnishing terminal equipment, and in deriving specialized computer-based services.

It has been argued that the ability of large users to deal directly with the international entity could affect adversely the position of small international users who would be denied the joint economies of sharing facilities with large users. We doubt this will be a serious problem. The small users are, of course, most numerous, and their traffic demands would be accumulated by the domestic common

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carriers in many geographic areas, along with purely domestic traffic, so that substantial joint economies in international transmission could still be achieved. While it is true that such small users might even be better off if large users were also forced to share facilities with them, we question the wisdom of denying large users (particularly the government) the economies that they are able to obtain for themselves, through their own efforts. We believe that, in the context of a dynamic and continually expanding industry it should be possible to protect adequately the interests of all classes of users while permitting more flexible opportunities for service and cost saving for those users who can benefit from them.

On balance, while a consolidation to create a single international transmission entity would reduce the existing pattern of competition in the international record business, we feel there are grounds for concluding that in some important areas, at least, effective competition could be maintained.

c. Helps resolve the uncertainties and anomalies of Comsat's present role and functions. Of all

the alternatives we have considered thus far, none is as attractive as the single international transmission entity, in terms of providing a framework within which Comsat can realize its full potential. As we have seen, it now faces serious problems and anomalies.

Comsat's participation in a fair plan of consolidation involving the international transmission and switching plant of the voice and record carriers should prove attractive to the corporation in terms of its capital structure. Creation of the single entity would also provide an opportunity for resolution of the conflict-of-interest problems created by the carriers' participation in Comsat. In the circumstances prevailing in 1962, there may have been no practical alternative to carrier participation in Comsat and to an interlocking directorate. The formation of a single entity would be an auspicious occasion to end such arrangements. A clearly appropriate condition for creating a single entity would be to forbid all other carriers to hold a stock interest in, or be represented on the board of, the new entity.

Since the single entity would own U.S. earth stations now used or planned for use with INTELSAT satellites, the

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problems associated with divided ownership of these stations would also disappear. Comsat's isolation from large ultimate users of communications, as a consequence of the FCC's authorized-user rulings, would also end, since the special circumstances in the record business that gave rise to those decisions would be changed.

Given a viable and well-defined role, the single entity could not persuasively contend that it was entitled to more generous regulatory treatment, as in allowable rate of return, than normally received by regulated firms.

Finally, a decision to create a single international entity involving Comsat would help resolve uncertainties regarding its domestic role. As discussed below, we would expect the new entity to relinquish any claim to the domestic satellite field save as necessary to permit completion of a pilot domestic satellite program (in which Comsat might participate).

d. Would improve the effectiveness of government regulation and supervision. The formation of a single U.S. international entity should appreciably simplify and improve the functioning of government in

relation to the U.S. international communications industry. With a single entity, regulation of the international industry should be more manageable. With the number of firms providing international transmission reduced to one, there would be no occasion to adopt regulatory policies designed to protect the weaker firms. The regulatory body could examine investment plans in a comprehensive and consistent manner, free from certain claims by participants dependent upon the maintenance of a particular technology. The regulator could insist on an explanation of the full range of possibilities open to the single entity. It would no longer be under pressures on equity grounds to authorize a facility the need for which was not clear. Nor would the regulator have any basis for programming the introduction of new facilities on essentially arbitrary grounds -- as by approving 50-50 sharing arrangements between entities tied to different transmission modes in order to ensure an adequate increase of traffic in a particular facility.

Moreover, the single entity would constitute a relatively manageable operation from the regulatory standpoint. Lacking domestic interests, manufacturing affiliation,

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and terminal service functions now performed by the international record carriers, a single entity would be, in effect, a transmission highway or pipeline having relatively few major facilities and assets. In comparison with the total U.S. domestic and international industry which has net assets of some $40 billion (the vast bulk of which belong to AT&T), the single entity would have net assets of less than $1/2 billion, at least in the early years. It would have easily identifiable costs and a simple rate structure. So radical a simplification of the industry could materially improve the prospects for effective regulatory supervision.

The international industry would also be quite small by domestic standards -- its annual revenues would be less than 5% of the annual revenues of the domestic industry. The problems of regulation would thus be presented on a far smaller scale. Major responsibilities of the regulator would be rate review and the authorization of new transmission facilities. Since important investment decisions would involve relatively infrequent, long-life, high-cost programs dependent on long-term demand projections and a

variety of economic and non-economic factors, effective government overview may prove fairly straightforward.

A final point is that our international communications industry represents an important point of contact between the United States and foreign nations. A single international transmission entity should help to minimize differences with foreign governments and entities; facilitate broad efforts at international cooperation in such arenas as INTELSAT and the International Telecommunication Union; and, more generally, provide a hospitable framework for the achievement of our foreign policy and national security objectives.

For example, as the INTELSAT system moves into an era of advanced development -- one where global coverage is achieved -- a single entity would be in a better position than Comsat is today to reflect an overall and consistent U.S. view in the consortium. Comsat's mandate is to promote only satellites. A single entity with both cable and satellite interests would necessarily reflect a more balanced

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interest in efficient communications. */ Faced with a single U.S. transmission entity, foreign administrations would not be in a position to "play off" rival cable and satellite entities; in particular, a single entity would be better able to deal with foreign preferences for either satellites or cables.

2. Objections to the single entity approach

a. Quality and reliability of service.

Some have argued that a carrier with a monopoly of transmission but without responsibility for the entire communications service would be insensitive to customer needs, complaints, and demands. However, most users of international communications (save those, like the U.S. Government, large enough to purchase transmission capacity directly from the transmission entity and do their own conditioning) would not deal directly with the transmission entity. It would deal mainly with carriers and large users.

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*/ The single entity solution would raise questions with respect to present policy concerning the Manager of INTELSAT -- now entrusted to Comsat. But that issue does not seem significant in light of the benefits to be derived from reorganization of the U.S. international industry as described herein. And in any case, evolutionary steps are already under way further to "internationalize" the INTELSAT managership.

Lacking face-to-face relations with many customers, the single transmission entity, it is argued, might conceivably be insufficiently sensitive to service quality and customer needs and complaints. However, it would have some direct purchasers. And we suspect that the entity's principal carrier customer -- AT&T, representing most domestic users of international telephone communications -- would be quite able to elicit adequate performance from it. In any case, end-to-end control has never been a possibility in the international communications business. One end is always under foreign control.

It has also been suggested that a split between domestic and international telephone service could endanger the quality of overseas calling from the U.S., which now derives benefits from the scientific achievements of the Bell Laboratories and the design and engineering skills of Western Electric. To be sure, overseas calling has always been an extension of domestic service (the message network is used commonly for both domestic and international traffic), and by the early 1970's customers in the U.S. will be dialing

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most overseas calls just as they now dial directly distant points within this country. This will bring almost complete integration of domestic and international telephone service over a single, integrated message network.

Again, the creation of a single entity should not significantly alter existing relationships between domestic and international telephone service. With the growth of international satellite communications, the transmission links of our international telephone communications are already subject to divided responsibility between Comsat on the one hand and AT&T on the other. Given the projected future growth of satellites as a means of international transmission, the bulk of our international telephone circuits is likely to be carried by satellites. Thus, even in the absence of a restructuring of the industry, the international transmission links of those circuits would not be the responsibility of the domestic telephone carrier. Nor would a restructuring to form a single entity for international transmission otherwise affect the present pattern of responsibility for international telephone service.

The message network commonly used for domestic and international calls would continue to be the responsibility of the domestic carrier. Appropriate arrangements for dealing with foreign entities on operational matters remain to be worked out among the parties and interests involved.

b. Loss of competitive benefits. A more fundamental objection to the single entity solution is that the new entity would not be sufficiently motivated to optimize between technologies, reduce rates, and operate efficiently -- that the pressures now exerted by competition, however imperfect, would be eliminated. The absence of competitive pressures, rate-base considerations, and the fact that the entity might have less control over satellites owned by INTELSAT than over cables would, it is argued, lead to distortions similar to those created by the present system.

Past rivalry between Comsat and the other carriers may well have produced a more rapid pace of innovation and rate reductions than might otherwise have been obtained. It is probably true, for example, that Comsat's low bid in the "30 circuits" case stimulated the record carriers to reduce their rates.

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However, such pressures by Comsat are indirect today in view of the FCC's authorized user rulings; and whatever the beneficial competitive tensions created by separate ownership, they must be weighed against the dangers of increased cost imposed on the system and borne ultimately by the users.

We recognize that, lacking direct competitive pressures, the single entity might be slow to grasp opportunities for system optimization and, more generally, for efficient and economical operations. What assurance is there that the single entity would have adequate incentives to make socially optimal, efficient and economical choices? To the extent that it may be impossible to assure an entirely satisfactory set of incentives, can we rely on government regulation and supervision to supply the missing impetus?

(1) Incentives. So long as the rate-base method of regulation is retained (and we can imagine no sound regulatory theory in which that method would not play a major role), there may always be some incentive toward capital-intensive operation, all other things being equal.

However, there will be contrary influences at work -- influences toward minimizing capital as well as operating costs. To the extent that demand for international communications is perceived to be responsive to price decreases, the single entity will have a financial stake in reducing rates -- and therefore in discovering methods of reducing costs so as to enable rate reductions. Although public utilities have traditionally been cautious and hesitant about testing elasticity through rate reductions, we believe our studies demonstrate that the demand for international communications at the present high rates (compared to U.S. domestic service) is in fact price elastic. */ More venturesome pricing policies by the international industry should be encouraged. If the government can expand its capability to make studies of demand conditions it will be in a position to consider the possibility of promotional price reductions.

The prospect of greater revenues might not operate as an incentive if regulation were completely effective in

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*/ See our Staff Paper on Demand, Technology and New Services

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limiting profits to a predetermined rate. But it is not. Rate-making proceedings, especially in the communications industry, are infrequent; and if through successful cost cutting or rate reductions the regulated firm can derive above-normal profits at its allowed rates in the interim that those rates remain in effect, it will be able to retain those profits even though they exceed the allowed rate of return. */

Rate-base considerations are only one element of the incentives possibly tempting today's international carriers to seek to build particular facilities. Another stems from the fact that two of the carriers, AT&T and ITT, own cable-manufacturing enterprises. This factor will be eliminated

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*/ Proposals have been made to strengthen this incentive to greater efficiency by formalizing the "regulatory lag" -- for example, by fixing rates for a fairly generous period, say five years, and expressly permitting the regulated company to keep any "excess" profits it might earn in this period by reducing its costs. But there are dangers under this approach: windfall profits in an area of rapidly declining long-haul transmission costs; and temptation to the regulated firm to postpone the introduction of cost-saving innovations until new rates for the next period have been set.

under our proposal since, as discussed below, an essential condition of forming a single U.S. international transmission entity is that it have no manufacturing affiliations.

Another potential influence for large-scale cable building regardless of actual economic justification is said to be the conservatism of communicators experienced in cable communications. Consolidation would force such individuals, as members of a combined cable-satellite entity, to confront actual investment choices between these modes. To be sure, this advantage might be lost, at least temporarily, if the personnel of the new entity were predominantly wedded to one technology or the other; but care can be taken in the formation of the entity to ensure that its leadership is primarily concerned with the highest performance possible, regardless of technology.

A potentially more serious problem involves INTELSAT's policy of setting rates on a worldwide average basis, so that traffic on the less dense routes is subsidized by the lucrative transatlantic trade. The U.S. entity may have an incentive to construct cables across the Atlantic (whether or not economically justified) in order to "skim

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the cream" created by INTELSAT's pricing policy. Whatever the results of a review of INTELSAT's pricing policies, it should be easier to prevent the single entity from building cables that undermine our INTELSAT policies than it is to prevent cable building by entities that have no stake in the global satellite system. At the same time, a single entity, not being financially dependent solely on satellites as Comsat is today, would be in a position more effectively to urge INTELSAT to reconsider its pricing policies in troublesome cases.

Two additional factors should generate incentives working in the right direction: large, sophisticated users such as government agencies and AT&T; and the manufacturing level of the communications industry. The satellite manufacturers have been responsible for the major advances in communication satellite technology. The importance of military and other government space programs as a spur to innovation in the communications field is also, and should remain, exceedingly significant. The history of commercial satellite communications supports the view that the manufacture of satellites is a progressive, and, despite the rather small number of manufacturers, a reasonably

competitive industry. It should become more so with the development of a substantial foreign capability in satellite design and manufacture. Manufacturers can be expected to compete vigorously in the development of advanced satellite facilities and to press for their acceptance. In the face of such intensive and informed advocacy, the single entity might find it difficult to justify a failure to welcome new facilities that promised service at appreciably lower cost than existing or alternative facilities, especially if, as suggested below, the government's own capability in system design and analysis in this area is strengthened. Competition at the manufacturing level can thus be expected to counteract, at least to some extent, any tendency of the transmission entity or INTELSAT to act sluggishly in improving its facilities.

This is not to suggest that a single entity will fail to exploit opportunities for undersea cable expansion, if they are economically attractive. Inheriting extensive undersea cable investments, it will have no inherent reason or motivation to neglect cable technology. While some stimulus for continued cable research and development may be lost if a single entity is created, ample pressure should

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remain from cable manufacturers and foreign administrations for more cable building. Accordingly, we do not expect that undersea cable technology will be prematurely abandoned. In this regard, policy should ensure that Western Electric faces no legal inhibitions to serving as a competitive supplier of the single entity in the cable manufacturing field.

(2) Government regulation and supervision. There would, of course, be a need for vigilant and improved regulation by the government of the entity's major decisions. On balance, we believe the prospects for such regulation are generally good.

To be sure, if the present fragmented ownership structure in the industry were modified by creating a single entity owning both cables and satellites, the regulatory agency might lack the benefits of an adversary presentation with respect to applications for new construction. However, one may question the amenability of investment decisions in this industry to thorough review in such adversary proceedings if the present structure is continued.

In some cases, proponents of cable and satellites may not contest each other's applications vigorously. And, in any event, the long-term system planning required does not lend itself easily to examination in contests over specific investments. Moreover, AT&T and other major customers of a single transmission entity should be fully capable of vigorously representing their interest in efficient low-cost international communications before the FCC even if adverse to the single entity's interest; and if competition is preserved at the manufacturing level, cable and satellite manufacturers can be expected to promote new cost saving technology with equal vigor.

Nevertheless, strengthened regulation can and should be a prime consideration. In particular, we would strongly urge that the government's existing capability for systems engineering, technological forecasting, economic analysis and long-range policy planning in the communications field be greatly augmented. Strengthening the existing Executive Branch capability, as proposed in another staff paper, should assist in making available to the regulatory body the kind of expert advice necessary to examine critically

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the major investment decisions of the international transmission entity. We believe such a strengthening is feasible, particularly as part of a larger package of proposals for restructuring the communications industry and reorganizing the pertinent government functions.

Nor do we believe that the government can or should fail to exercise such responsibilities merely because the actual operation of our international communications facilities is entrusted to private enterprise. While favoring private ownership of commercial communication satellites, Congress took obvious pains in the 1962 Satellite Act to ensure that the government had the requisite power to regulate and supervise the new corporation. The FCC was given comprehensive regulatory authority, including such responsibilities as approval of the technical characteristics of the satellite system and earth stations and ensuring that substantial additions of facilities meet the test of public interest, convenience, and necessity. Likewise, the President was given extensive supervisory responsibility over the new corporation. If this legislative mandate is to be fulfilled, the government cannot avoid considering questions that in another industry would be matters of unfettered business judgment.

The very important role of the government as a user dependent on our commercial international communications facilities, */ and the unique foreign policy and national security implications of international communications, make the government's concern all the more appropriate.

This is not to say that the government need be involved in the day-to-day affairs of the single entity. Such involvement has not been the experience under the 1962 Satellite Act. Nor would the government have to duplicate, at unjustifiable expense, much of the work of the single entity. Rather, the government's principal role should be to engage in long-range economic and technological forecasting, delineation of technical and service standards, and review of rates and major system design and investment decisions of the single entity.

c. Reliance on technical and economic prognostications. A final objection to the single entity solution is that it is based on technical prognostications about the future -- e.g., about economies of scale in

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*/ In 1966 the international record carriers had revenues of $28.7 million from private line services of which 65% was obtained from Federal Government contracts.

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international transmission, about demand for international communications services, and about satellites superseding cables. History demonstrates that predictions based on such factors can be quite inaccurate; care must be taken in relying on them for making policy decisions about our international communications. We are, of course, aware of and sensitive to these problems.

However, any well-conceived evaluation of international services in the face of growing demand necessarily requires some prognostication of the future.

In considering questions of industry restructuring, it is particularly important to have reliable technical data. In this industry, the notable technological factor is the presence of large economies of scale in transmission -- regardless of mode. We should not fail to take account of this factor merely because there is some uncertainty as to which, if any, technological development will eventually prevail.

3. Necessary conditions to adoption of a single entity approach. The discussion thus far indicates the desirability of restructuring the international communications industry to create a single international transmission

entity. However, it also underscores the vital importance of ensuring that certain conditions are attached to the creation of such an entity. We turn now to consider these conditions.

a. Limited to functions where economies of scale indicate effective competition is unlikely. Large economies of scale exist in satellites, in the ground stations that serve them, in cables, to a lesser extent in high-frequency radio facilities, and in switching facilities; but to a lesser extent, if at all, in sales offices, sales forces, and other terminal facilities and functions of the record carriers. Competition may or may not be workable in these latter areas -- in buying basic transmission capacity, conditioning and subdividing it to provide usable communications channels; in supplying terminal equipment (e.g., teletypewriters) tailored to particular business needs in the pickup and delivery of cablegrams; and in other specialized customizing functions for the user of international communications. Stanford Research Institute's massive study for the Intragovernmental Committee on International Telecommunications does not

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indicate, for example, whether substantial economies of scale could be realized in the performance of such functions. However, that question need not be resolved at this juncture.

It is unnecessary now to define the precise interface between the domestic and international communications industry, or decide the exact structure which would emerge in the user service (as contrasted with transmission) function in international communications. To encourage competition in certain functions at the service end, the retail service function should not be provided by the single entity. The entity would sell only transmission capacity to users.

It will be recalled that, under the 1962 Communications Satellite Act, only Comsat and authorized carriers may be granted authorizations to construct and operate earth stations used in the global satellite system. The single entity would assume responsibility for the U.S. earth stations now in operation or planned for operation with INTELSAT satellites. This should not foreclose eventual authorization by the FCC of user-owned and operated stations, should they prove justified; we would recommend

legislation if needed to ensure that this matter is left to the wise judgment of the regulatory body.

While liberal policies toward new entry into international transmission would be rather irrelevant in the foreseeable future in view of the large economies of scale in transoceanic communications, the new entity should not be led to believe that its status is necessarily permanent. The government need not and should not decree that there shall always be one entity and no more -- the "chosen instrument" approach. Circumstances may change. The emergence of competing international transmission sources may some day be practical and consistent with our commitments to INTELSAT -- perhaps as a byproduct of the development of domestic satellite systems (a satellite used primarily for domestic communications could conceivably direct a pencil beam to a European gateway city, or even effect a direct traffic exchange in space via inter-satellite relay). Although there is no present indication that demand will rise to such levels that several systems can operate economically side by side, such an eventuality should

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not be foreclosed by granting a single transmission entity a perpetual or irrevocable franchise.

b. Not engage in manufacturing that can be provided by the competitive marketplace and have no manufacturing affiliations. Diversity of approach is an important factor in successful innovation. Accordingly, the creation of an international transmission entity makes all the more vital the preservation of competition at other levels, such as manufacturing. The satellite systems manufacturing industry today is highly competitive. If it remains so one can expect that satellite manufacturers, vying among one another for INTELSAT contracts, will add stimulus to vigorous and rapid technological development and application by the single entity. Several companies here and abroad also engage in cable research and development and manufacturing; and yet other techniques for international transmission may hold promise in the more distant future.

In a rapidly developing area of advanced technology, every encouragement should be given to competition among firms and technologies, all with equal access to the purchaser of

communications facilities. The technical staff of the entity should be capable of organizing and maintaining close and continuous relations among research, manufacturing and operating personnel in the field, so that the lessons of operating experience may be made fully available to those who design equipment and who study the more fundamental aspects of international communications. For these reasons, in areas where development and production capability is available in the competitive marketplace, we deem it an indispensable condition that the single entity be forbidden to engage in manufacturing, directly or indirectly (although we assume it would wish to undertake serious programs of research). The entity should be required to deal completely at arm's length with its suppliers and pursue competitive procurement policies under appropriate governmental regulation and supervision.

c. Not provide domestic service, and have no domestic carrier affiliations. It would be undesirable to accentuate an arbitrary distinction between domestic and international communications. To be sure, development of satellite communications tends to blur the technical distinction between domestic and international communications and in

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time this may well compel a re-examination of the matter. But for the present and foreseeable future, particularly in view of our INTELSAT policies, there is greater value in continuing to distinguish between our domestic and international communications. One benefit will be to ensure diverse sources of commercial satellite communications development. Hence, we would favor confining the single entity to the international arena, save as may be necessary to permit completion of the pilot domestic satellite program, as discussed below. We do not, however, suggest foreclosure of the possibility of the international entity making application to the FCC for the establishment of additional inland earth stations for more economical origination and receipt of international traffic.

Our judgment that the domestic and international sectors can and should remain separate is supported, therefore, by the objective of maintaining the maximum diversity in communications common carriage as is consistent with efficient systems planning and operation. We therefore reject a solution whereby AT&T would become the single U.S. international transmission entity. Given AT&T's size and

complexity, such a solution would, in any case, be the antithesis of creating a simple international operation that would facilitate effective government regulation. It would impede competition in satellite manufacture, and complicate our INTELSAT relationships. Moreover, Congress confronted this choice in 1962 and clearly rejected it.

As discussed in our staff paper dealing with domestic uses of satellites, much concern has been expressed that ownership patterns not be frozen in the domestic satellite field as a consequence of an early pilot program. This concern has given rise to objections to allowing Comsat to play a major role in the pilot domestic satellite program, even though it may be the best qualified candidate for the job in the short run. An appropriate condition to adoption of a single entity approach is that the single entity have no domestic affiliations save as necessary to permit completion of the pilot domestic satellite program. Thus, if Comsat were to participate in the formation of the single entity, its participation in the domestic satellite pilot program as a trustee or steward would facilitate the preservation of complete flexibility as to subsequent ownership of domestic satellites.

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The existence of separate domestic and international entities, both in the business of developing satellite technology, would help to stimulate innovations in satellite technology by furnishing opportunities for comparisons. In contrast, allowing the single entity to provide domestic service would complicate regulation of both sectors and could foster policies of accommodation. Thus, maintaining a clean domestic/international separation seems desirable at this stage of technological development.

It would not follow from Comsat's vacating the domestic field that AT&T should obtain a monopoly of domestic satellite communications. There are attractive possibilities for specialized domestic satellite applications outside the common carrier public message telephone network, as well as within that network, and we think it premature to define now the future role of AT&T in domestic satellite communications, although it is clear that AT&T will have a major interest in satellite uses within the public message telephone network.

As noted earlier, the justification advanced in 1962 for allowing the carriers to own stock in Comsat and to sit on its board of directors would disappear with the formation

of a single international transmission entity. Such interlocking ownership and control should be eliminated in order to avoid conflicts of interest, and to avoid blurring the relationship between customer and supplier of transmission service.

d. Strengthened government regulation and supervision. The 1962 Satellite Act adapted the framework established by the 1934 Communications Act to conform to contemporary approaches to government regulation and supervision, as well as to the needs of the new communications mode. The more comprehensive scheme of the 1962 Act provides appropriate guidance for government regulation and supervision of the new single entity, in view of the entity's unique status and relation to sensitive national concerns.

The regulatory body should thus be given comprehensive power over financing, additions and abandonment of facilities, rates and service, accounting practices, interconnection and procurement by the single entity. In addition, as discussed earlier, existing techniques and resources of regulation can and should be improved and regulatory resources devoted to the international communications industry should be increased.

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We assume that the duties imposed on the Executive Branch by the Satellite Act of 1962 with regard to Comsat would continue, or would be strengthened, if Congress were to authorize a single international transmission entity. Furthermore, the capability of the Executive Branch to engage in economic analysis and system design in the communications policy field should be augmented substantially, so that it can assist the FCC on long-term planning and design of international transmission facilities. As explained in greater detail in our paper on the Federal roles in telecommunications, we urge creation in the Executive Branch of a high-level staff of economists, engineers, and management experts to engage in long-range economic planning, communications systems analysis, demand forecasting, and other operations essential to informed and effective policy guidance with respect to the efficiency of the international industry.

4. Implementation of the single entity approach. If the formation of a single entity for U.S. international transmission subject to the conditions outlined above is accepted as a goal of U.S. policy, the question arises as to how best to achieve it. We have not attempted to lay

out a detailed plan for carrying out such a program. Legislation would, of course, be required. It should embody the following general principles:

-- that an appropriate opportunity be afforded for full hearing and for the submission of views by interested parties;

-- that the single entity be subject to a requirement, similar to that contained in the Communications Satellite Act, that effective competition be maintained to the extent feasible in its procurement of apparatus, equipment, and services;

-- that the single entity not engage in manufacturing that can be provided in the competitive marketplace, and that it have no manufacturing affiliations;

-- that the single entity be forbidden to provide terminal or service functions now offered by the international record carriers, but be permitted to deal directly with users as well as carriers;

-- that users or carriers obtaining leased circuits from the single entity be entitled to appropriate interconnection and other arrangements with domestic carriers enabling them to make use of such international facilities;

-- that the provision of the 1962 Communications Satellite Act prescribing Executive Branch responsibilities to protect the national interest and further U.S. foreign policy apply with equal force to the single entity;

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-- that the terms of all agreements among the interested parties, as well as the capitalization and financing of the single entity, be subject to government approval.

In addition to these conditions, reflecting the earlier discussion, provisions should be made for appropriate protection of labor. A detailed study of this aspect of the question of consolidation of the international industry is contained in the SRI report, */ which concluded that, of various alternatives for industry restructuring, a merger of the international transmission facilities of the existing carriers should provide maximum opportunity to cope with work force changes through attrition, transfer and retraining. Some 7,000 workers were employed by the international record carriers in 1967 -- a minor proportion of the labor force of the entire U.S. communications industry, estimated at almost 700,000 persons. **/ About 70% of the labor force of the international record carriers work

*/ Vol. III, Annex B-8, at B-231.

**/ AT&T's employees engaged in providing international services are part of the company's domestic bargaining unit and, in fact, frequently are assigned to jobs involving both international and domestic services.

within the continental U.S. The vast majority of the domestic workers perform the kinds of functions most likely to be affected by any industry changes that increase productivity. A substantial portion of these employees are represented by labor unions -- either the American Communications Association or the Communications Workers of America. The SRI study noted a general and consistent downward trend in employment by the industry -- despite the marked increase in revenues during the postwar period. */ On the other hand, the growth of new services may increase employment prospects in the future. Also, while technological advances may reduce the number of operating personnel required in the industry, such advances may lead to market expansion that would offset overall reduction in employment.

*/ By 1967, total employment by the international record carriers had fallen more than 30% since 1950. The 1967 figures cited in this discussion were supplied by the Department of Labor.

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In the past, industry spokesmen have taken the position that consolidation of the international carriers would not be detrimental to the workers involved, but the two predominant labor unions have opposed a merger.

Section 222(f) of the 1934 Communications Act provides extensive protection for the interests of all employees affected by consolidations or mergers which the FCC was authorized to approve under the Act. Enabling legislation for the single international transmission entity should also ensure appropriate protection. The legislation might provide that, as a condition of approval of any consolidation, the Commission must require fair and equitable arrangements with respect to all affected employees, to be determined jointly with the Secretary of Labor. */

Such protective arrangements would include provisions necessary to preserve rights, privileges, and benefits (including continuation of pension rights and benefits)

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*/ Beyond this, it may be necessary for the government to give continued attention to the possible adverse effects on labor due to technological change in this as well as other areas of communications.

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under existing collective bargaining agreements or otherwise; continue collective bargaining rights; protect individual employees against a worsening of their positions with respect to their employment; insure employment to employees of any carrier and priority of re-employment of employees terminated or laid off; and to insure paid training or retraining programs.

It would be useful in this regard to give close attention to related action taken by government in other fields as in the Transportation Act of 1940 and Mass Transportation Act of 1964. */

Another matter meriting special discussion concerns the terms of any consolidation, which should in any event be subject to government approval. The basic financial question would be how acquisition costs should be treated.

*/ It may also be useful for the government to begin promptly to determine the exact displacement effects that would be brought about by the single entity solution and propose the kind of employment security and adjustment assistance that is realistically needed on a case-by-case basis. This might include severance pay; retraining; relocation expenses; advance warning before layoff; preferential hiring, transfer, seniority rights, etc.; attrition clause for job security; allowing disputes on technological change to be arbitrable; and a possible industry-wide tax, to provide a financial underpinning for these kinds of assistance.

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Generally, the FCC calculates rate base at no more than the original cost of property at the time it was first dedicated to public use. Following this approach, it would not matter whether such cost was incurred by the operating entity or a predecessor. Therefore, if the formation of a single entity involved acquisition of plant from any carrier in excess of the depreciated original cost, such excess would not be includable in the single entity's rate base. This theory ensures that the general public is not unnecessarily saddled with the costs of any industry restructuring.

Substantial modifications in the present international communications industry structure and regulatory scheme may not be feasible except in the context of a consolidation that created a single entity.

However, if a single transmission entity is not implemented, steps should be taken to improve the performance of the industry under the present structure. Better regulatory methods and appropriate competitive pressures can further enhance the pricing, service, and investment decisions of the existing international communications industry. Augmenting the regulatory agency's capabilities should improve

its appraisal of carrier proposals and enable it better to make the difficult choices between competing applications for transmission systems and, if necessary, disallow unneeded facilities. Among other steps to be considered by the regulatory agency are development of rate-making criteria related to optimal plant, and modification of the authorized-user policy to allow broader direct access to the satellite entity.

We believe that these would be useful steps in improving the performance of the international industry. But they fall short of what we believe is necessary and we doubt how helpful they will be except in the context of a single-entity solution.

We recognize that modification of aspects of the FCC's TAT IV decision with respect to mixed voice-record traffic and its authorized-user decisions would have a serious impact on the record carriers. However, in the interest of ensuring the nation efficient and economical international communications service in the future if our recommendation for a single entity is not implemented, these decisions should be reconsidered. In such a context we would favor Congressional action to divest the international voice and record carriers of their ownership of Comsat's stock and representation on its board of directors.

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We do not suggest that the Administration seek a more limited consolidation (e.g., limited to the record carrier). It would be unobjectionable, however, to give the Commission the authority to approve such consolidations when found to be in the public interest. For reasons already discussed, we are not persuaded that such a consolidation, without going further, would substantially alleviate the problems of the international industry. Moreover, our discussions with the record carriers indicate no general enthusiasm about such a consolidation. While a record-carrier merger might have some appeal as a first step toward a single-entity solution, we fear that consolidation might stop there. Furthermore, a two-step approach to a single-entity solution could entail considerable delay and added expense. The goal of a single entity is most likely to be achieved by a direct approach, rather than one which sees a record-carrier merger as a necessary way-station.

5. The question of government ownership. Public ownership was rejected (albeit in a somewhat different context) in 1962, when Congress passed the Satellite Act, and the decision may well be regarded as a definitive indication of preferred Congressional policy. Nonetheless, we have re-examined the question.

Public ownership might be established by creating a federally owned corporation for international communications -- an International Communications Authority (ICA), which would purchase the assets of Comsat and the pertinent equities of the other international carriers, under appropriate safeguards to assure necessary independence, operating efficiency, continuity and pertinence of research and development programs, reflection of the national interest in international communications decisions, and responsiveness to national security and foreign policy objectives. On behalf of such a proposal, one could argue that experience since 1962 indicates that international, inter-government involvement in communications satellite programs will loom quite large -- particularly in spectrum and orbital management, and in technical standardization and coordination. It seems most unlikely that any major decision on satellite design, implementation, or control will be possible without close government participation and coordination -- a situation quite unlike that in other areas of communications, such as domestic microwave relay facilities. The synchronous technology now in use by INTELSAT underscores the importance of close coordination among governments, since specialized communication satellite

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systems serving various small areas of the globe may well prove feasible. Prospects are also increasingly apparent for extensive international, inter-governmental cooperation with respect to the use of satellites in areas other than communications. Meteorological, navigational aid, and earth-resource satellites are among the leading candidates. Finally, our national policies in international communications are not based solely on the goal of providing U.S. users with reliable, low-cost and improved service. A variety of foreign policy and national security goals also enter the picture. For example, the 1962 Act expresses concern for the interest of developing countries.

A separate argument for government ownership stresses the extent of the Federal Government's involvement in space. It has been, and will probably continue to be, the nation's principal investor in space, both in terms of research and development as well as operational programs. Without the vast Federal research and development and manufacturing programs, and the government's facilities for launch vehicles, it is unlikely that commercial communication satellites would have proved viable. Since the U.S. taxpayer has contributed so substantially to the development of communication satellites

and will continue to do so, some believe that government ownership is the best way to ensure that the entire nation benefits. Whatever the force of this argument, it is not a new one; it was fully argued to the Congress in 1962.

Proponents of public ownership point out that the case for a single entity relies heavily on (a) the ability of the government to regulate its activities and provide, through the enabling legislation and subsequent regulatory determinations, a framework of adequate incentives for the single entity to make progressive, efficient and socially optimal decisions; and (b) a substantially improved governmental capability, both in the regulatory agency and Executive Branch, as discussed earlier.

It is argued that a substantially increased governmental capability may not be forthcoming. It is also argued that problems of incentives associated with public ownership would not be greater than in the case of a regulated private entity, and that concerns associated with direct government involvement in industrial operations have been faced and disposed elsewhere, e.g., in the cases of the Tennessee Valley Authority and the Port of New York Authority. Still another view is that private enterprise would be more efficient and would ensure against untoward political interference.

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It is impossible to demonstrate conclusively whether a scheme of public ownership could be devised that would neutralize the danger of political interference and ensure efficient operations. But we are fairly entitled to conclude that, until a more convincing case for public ownership of our international communications facilities has been made, private enterprise should continue to serve the nation in this sector.

The critical role of the international communications industry in the achievement of our national goals justifies prompt remedial action with respect to the deficiencies in its structure that our study has revealed. The pace of technological advance is rapid in the international communications industry. The time for further reform of its structure is now, when the problems and opportunities are clear. That such reforms will undoubtedly require several years to implement lends added urgency to the case of prompt action.

APPENDIX

REPORT OF THE PANEL ON SATELLITES
AND OTHER LONG-HAUL TRANSMISSION MODES

Committee on Telecommunications

NATIONAL ACADEMY OF ENGINEERING

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REPORT OF THE PANEL ON SATELLITES AND OTHER LONG-HAUL TRANSMISSION MODES

For the last 75 years there has been a continuous competition between various modes of transmission of electrical signals for communications systems. Shortly after World War II microwave relay systems offered important cost savings over land cables at the level of demand then projected, and extensive installation of these systems was begun in 1948. They now interlace all parts of the United States and carry a large fraction of the TV and telephone traffic. Over this 20-year period improvements have been made in land cables, and the cost advantage of microwave relay for large cross-section routes is now disappearing. The result is that many of the systems now being installed in the Bell System use land cables rather than microwave relay links, and the longer-term prospect is that more of the traffic will be carried by land cables than by relay links. As we look ahead to even larger cross-section routes for land use, the leading candidates are millimeter-wave waveguide systems and laser guided-beam systems. Both of these can be regarded as extensions of the land cable concept, since both are fully enclosed systems.

Much the same situation that existed at the end of World War II for microwave relay links on land now exists for satellites used in overseas transmission. Satellite systems have a distinct cost advantage over undersea cables for long-haul systems, such as San Francisco to Tokyo, for the cross sections that are projected for the next decade. A satellite system also is able to provide flexible low-cost service on low cross-section routes through its multiple-access capabilities, that is, its ability to interconnect a multiplicity of earth stations in different locations. On the other hand, cable technology has been steadily improving and presently is the lower-cost solution at moderate levels of traffic density on shorter point-to-point routes, such as Florida to Puerto Rico. Satellite system costs are independent of the distance between terminals, whereas cable costs increase in proportion to the distance. There is normally a break-even distance for which both systems have the same costs for a given

traffic density. The break-even distance is a function of traffic density and of the number of points to be interconnected. The effect of improvements in the technology of either system is to change this break-even distance, and over the years it can be expected to change up and down.

When we make cost comparisons between alternative systems, it is important to realize that we are doing so at a particular instant of time for the particular demand and technology predicted at this time. Taking a longer-range view requires that we call attention at the outset to the uncertainty that exists with respect to the future development of both cable and satellite technologies. It may well be that 10 years from now, when we look at the larger cross-section needs of that era, cables will have advanced to the point where they are the minimum-cost technology for those needs. For this possibility to be realistic, it is essential that continued research on cable-related technology take place. In our view, it is in the national interest to continue research in the areas of both cable-based systems and satellite systems with a particular emphasis on the development of large-capacity systems appropriate to the projected demand for overseas communication.

In the following sections, after examining the costs of satellites and cables in the Atlantic basin, we will look at the potential applications of domestic satellites, both in the United States and in other countries, and finally at some of the problems of frequency management for long-haul modes and the related topic of orbital parking space. Our specific findings are provided in a summary at the end of the report.

The focus of this report is on technical problem areas known to be under consideration by the President's Task Force staff, rather than on specific reports by the Task Force staff or reports submitted to the Task Force by outside contractors.

We are not concerned here with organization or jurisdictional considerations. Rate-policy considerations as they affect the revenue to be expected from a given set of communications facilities have also been excluded.

Comparison of Satellite and Cable Costs for the Atlantic Basin

We have considered two specific comparisons of satellites and cables in the Atlantic basin. In the first instance, a

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single point-to-point link across the North Atlantic is considered and the costs of cable- and satellite-based systems are compared. In the second, the entire Atlantic basin is considered and the costs of meeting the predicted demand are compared using both satellites and cables in various combinations. Detailed calculations of the costs and other necessary data are given in Appendixes 1 and 2. These comparisons are not a prediction of what will or ought to happen. They are engineering cost studies and do not attempt to be representative of the political aspects of reality. Comparable studies of other regions can be expected to yield different numerical results, although the analytical approach is believed to be generally applicable.

Single Point-to-Point Link

In the first comparison, we picture a 20-year time period starting in 1970 and compare the cost of a satellite system designed especially for point-to-point service with the cost of the fifth transatlantic telephone cable (TAT-5), a system expected to be operative in 1970. We find that the costs of the two systems are essentially the same. The satellite system, however, is capable of providing much greater channel capacity than is the cable system. If there is insufficient demand to make use of this additional capacity, it is improper to compare the two systems on a cost-per-channel basis. However, the example illustrates the first important feature of this technology: the basically lower cost of satellite systems on a cost-per-channel basis for very large cross-section point-to-point routes where the demand exists for thousands of voice channels.

Entire Basin Using Mixed Modes*

Demand Projections

In order to make a more realistic comparison, we need to postulate a particular demand. We have done this for the period from 1968 to 1985, starting with the demand projections of the Joint World Plan Committee of the International Telecommunication Union (ITU) at the 1967 Mexico City Conference for the period 1968 to 1975.[2] For the period from 1975 to

*For a discussion of the high-frequency radio mode as a possible choice for low-density routes, see the section below, "Improved Utilization of the High-Frequency Radio Bands," in the report of the Panel on Electromagnetic Compatibility.

1985 we have considered further expansion of demand at rates of 10 percent and 20 percent per year. The degree of uncertainty of the demand projection for the 1975 to 1985 period is, of course, much greater than that for the 1968 to 1975 period. We have then matched this demand against the capacity of firmly committed systems for the Atlantic basin, including TAT-5 and INTELSAT-IV, the fourth-generation satellite of the International Telecommunications Satellite Consortium. We find that there is no need for additional capacity until 1976. So, starting in 1976 we match the two projected demand curves (10 percent and 20 percent growth rates) for the years following this, using strategies that meet various fractions of the demand by cables and by satellites. A satellite system provides multiple access, that is, an ability to interconnect a multiplicity of earth stations in different countries. This ability is essential for providing service in low- and medium-traffic portions of the basin. On the high cross-section routes to Europe and the Caribbean, either cables or satellites could be used. We could meet all the new demand with satellites, and such a system would be a minimum-cost system. Our comparison shows how much of a premium we must pay in order to use cables in various ways in this basin.

We may be quite willing to pay a premium for a composite system. The questions are how much of a premium is involved and what do we buy with it. Our cost comparison will give us an idea of the cost. We now examine some of the potential benefits.

Potential Benefits

First, there is quality of service. Because they are about 22,000 miles from earth, synchronous satellites in either one- or two-hop connections introduce a significantly greater time delay than do cables. A one-hop connection is one that connects two parties through a single satellite; it has a one-way time delay of about 300 milliseconds. In two-way communication, then, the time lapse between signal and response must be at least 600 milliseconds. A two-hop connection is one that connects two parties through two satellites, as in a connection between parties in the United States and India involving one hop to Europe and a second hop from Europe to India; the one-way delay and the two-way time lapse are, respectively, just twice as large for two hops as for one hop. Investigations give every reason to believe that, in the absence of echo and without echo suppression action (explained

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below) and with every other condition of communication being satisfactory, delays even as long as two satellite hops result in little or no adverse reaction by users. Time delay is only one consideration, however. Nearly all communications connections that include a satellite link will also include two-wire links, which will produce echo, that is, the delayed return of signals that have travelled to the far end of the circuit and back again. A difficulty then arises in telephone conversations in which one party interrupts the other or attempts to do so. During speech in one direction, the line is automatically blocked in the other direction because of the need of suppressing such echoes. Automatic blocking prevents echoes, but it can also clip part of the conversation. Quantitative measures of the effects of present-day echo suppressors on a one-hop circuit vary widely depending on which of several testing methods is used. The International Telegraph and Telephone Consultative Committee (CCITT) of the ITU in October 1968 recommended that circuits with one-way delays up to 400 milliseconds (covering one-hop) be considered acceptable with echo suppression. Those with one-way delays greater than 400 milliseconds (for example, two-hop) are to be considered unacceptable, except under exceptional circumstances. Work is under way on a concept of echo suppression that in the limit would hopefully approach the performance of a four-wire echo-free system. Additional development is needed before the actual performance and cost of such a system are known. For many conversations the time delay-echo suppression effect has no significance, but obviously a premium of some sort should be attached to a cable system with a time delay so small that the effect is negligible. Time delay can also have an effect on data transmission, and users might be willing to pay a premium for small delay in some situations.

Second, the fact that cables are fully enclosed and hence do not make use of the frequency spectrum constitutes a benefit of a cable system. In a mixed-mode system, where there must be satellites, the benefit associated with putting only a small part of the traffic into an enclosed system may, however, be rather small.

Third, the competitive environment of a mixed-mode system increases the likelihood that continued technical progress will take place in the improvement of economy and quality of service of both satellites and cables.

Fourth, perhaps the most important reason for paying a premium for a two-mode system is the reliability benefit obtained. Mode diversity introduces a higher probability that some part of the system will always be functioning than is present in a single-mode system, when the two modes do not have a common manner of failure. Similarly, message security and "hardening" of terminals for military reasons are obtained in different ways in the two types of systems. How much these benefits are worth and how much of the system should be put into a second mode for these reasons are important questions that we do not attempt to answer here. It is at least qualitatively clear that there are benefits associated with a two-mode system.

Demand Allocation Between Modes

We turn now to the cost comparison for the Atlantic basin, detailed in Appendix 2. As noted above, our estimate of demand to 1975 is that of the ITU at the Mexico City Conference. Figure 1 shows this demand along with two other growth curves of 10 percent per year and 20 percent per year from 1975 to 1985 that we think realistically bound the actual demand in that time period. The World Plan Committee projections for 1968 to 1975 reflect approximately 18 percent growth per year. The 20 percent per year growth curve yields approximately 50,000 two-way voice circuits in 1985. We consider this total to be a combination of TV, data, and voice traffic. We believe that a typical mix may include four one-way TV channels in full-time use by that date, and this number is used in Appendix 2. However, 20 TV channels at 300 two-way voice circuits per channel requires only 6,000 out of 50,000 total circuits, or 12 percent of the total, and the mix could develop in this direction by that date. The 20 percent per year growth curve in Figure 1 can be considered to cover both of these cases.

To meet these two postulated demand curves, we have considered a number of alternative strategies of resource allocation. Our strategy for the period 1968 to 1975 is determined by presently committed systems. Figures 2 and 3 show the number of circuits supplied by two typical strategies for the 1975 to 1985 period compared to the demand curves that they are designed to meet. Each strategy consists of a series of discrete additions to the total system that leads to the stepped supply curve. In practice, pricing of certain services might be adjusted to increase demand when large excess capacity exists, but that possibility is not considered here.

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Figure 2. Number of circuits versus year, showing both capacity and demand curves and illustrating how Strategy 3 (1985 traffic, 48 percent satellite) meets 10 percent per year demand curve.

Figure 3. Number of circuits versus year, showing both capacity and demand curves and illustrating how Strategy 5 (1985 traffic, 85 percent satellite) meets 20 percent per year demand curve.

Figure 1. Number of circuits versus year, showing the assumed demand for all services in the Atlantic basin in equivalent voice circuits. The curve for the period 1968 to 1975 was taken from the World Plan Committee Meeting in 1967. Curves for 1975 to 1985 illustrate assumed growth rates of 10 percent and 20 percent per year.

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Bases of Comparisons

The comparison of costs of alternative strategies may be done on several bases. The simplest method is a comparison of cumulated annual costs as a function of time. This basis for comparison is used in Figures 4 and 5, which show the cumulated annual costs for each strategy that we have considered from 1968 to 1985. The curve marked A in each figure is the cumulated annual cost of the subsystems installed between 1968 and 1975. This portion of the total system is seen to account for a considerable fraction of the total cumulated cost even in 1985. This result is probably typical of any system based on a rapidly changing technology. Subsystems with long lives provide only a small fraction of total system capacity toward the end of their lives, but they can account for a large fraction of the cost of the total system in later years. More rapid nonlinear depreciation schedules would yield more realistic cost allocations, but we have used straight-line depreciation throughout these comparisons.

We have also given the cumulated present worth of annual costs for each strategy in Appendix 2, using a six percent interest rate. This way of presenting the data gives the present worth of all resource allocations as of 1968 and has been used to plot Figures 6 and 7. The present-worth curves emphasize costs incurred in earlier years over costs incurred in later years. A decision maker with the time preference expressed by a six percent interest rate in 1968 might prefer to base his selection of a strategy on present worth rather than on cumulated annual cost.

The end points of either set of curves in 1985 tell us the difference in cost between the strategies. Table 1 combines the data of Tables 4 and 6 in Appendix 2 and provides this summary.

Conclusions

Several simple conclusions can be drawn from Table 1. The first is that in all cases, it does cost us something to provide part of the capacity with cables. If the percentage of traffic carried by satellite is reduced, the cumulated annual cost is increased. Cables can be used to postpone an investment in satellites by a year or two in certain cases. The result is a closer matching of supply and demand, in the sense of the curves in Figures 2 and 3. However, for this basin where the only large cross-section routes are the

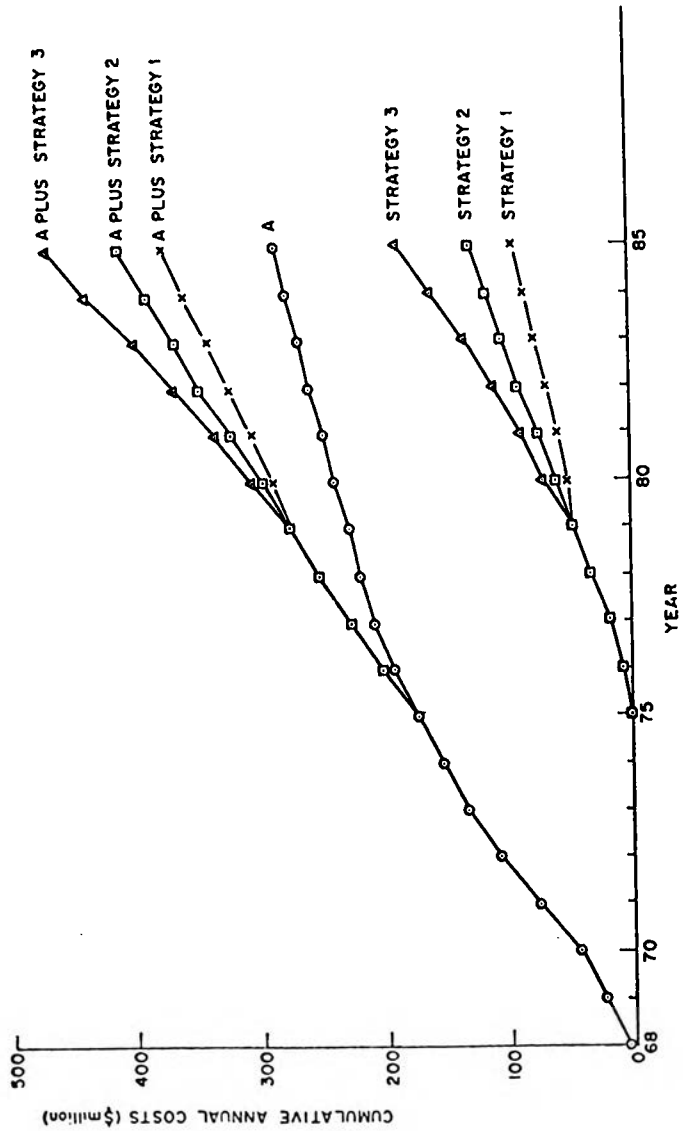


Figure 4. Cumulative annual costs versus year, for 10 percent per year demand curve for several strategies. Curve A shows cumulative annual costs for facilities installed in the period 1968 to 1975. Strategy 1 shows 1985 traffic, 85 percent satellite; Strategy 2 shows 1985 traffic, 70 percent satellite; and Strategy 3 shows 1985 traffic, 48 percent satellite.

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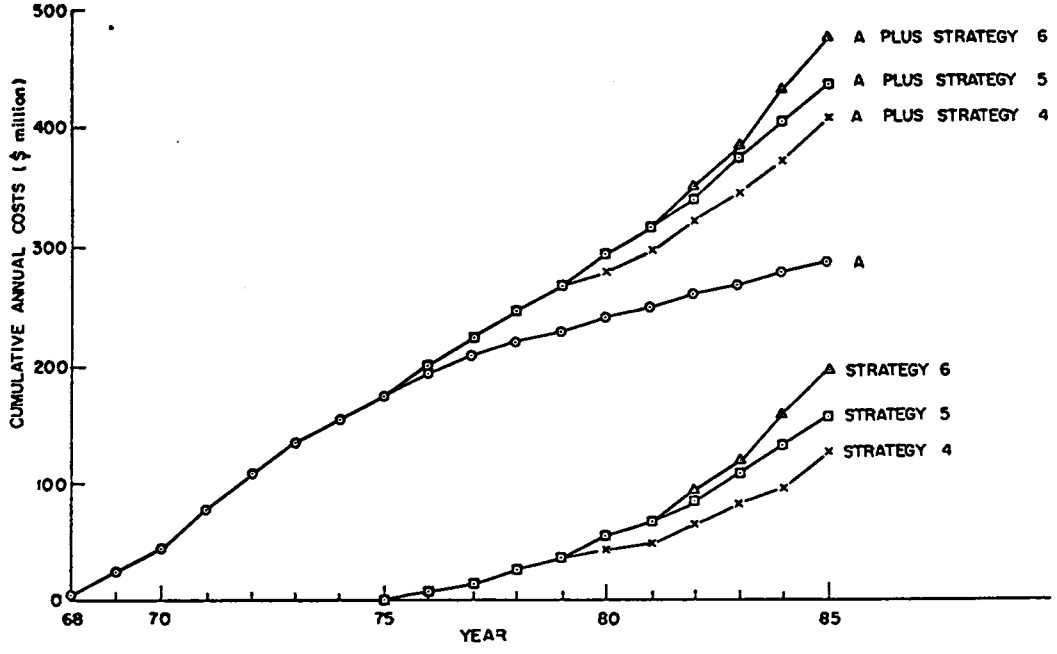


Figure 5. Cumulative annual costs versus year, for 20 percent per year demand curve for several strategies. Curve A shows cumulative annual costs for facilities installed in the period 1968 to 1975. Strategy 4 shows 1985 traffic, 93 percent satellite; Strategy 5 shows 1985 traffic, 85 percent satellite; and Strategy 6 shows 1985 traffic, 74 percent satellite.

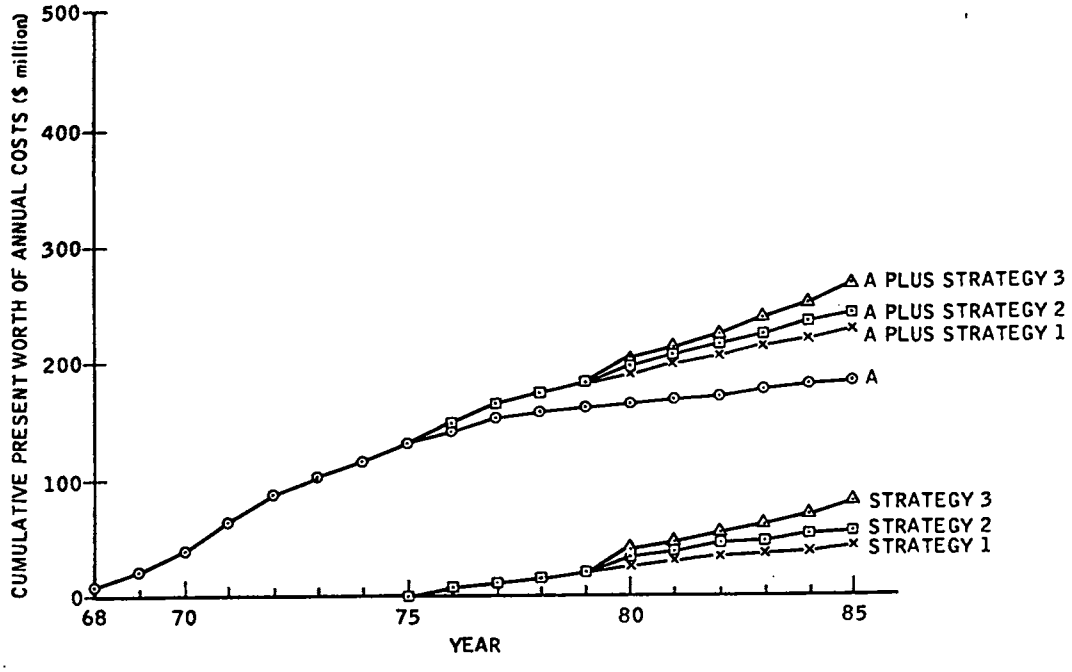


Figure 6. Cumulative 1968 present worth of annual costs versus year, for 10 percent per year demand curve for several strategies. Curve A shows cumulative present worth of annual costs for facilities installed in the period 1968 to 1975. Strategy 1 shows 1985 traffic, 85 percent satellite; Strategy 2 shows 1985 traffic, 70 percent satellite; and Strategy 3 shows 1985 traffic, 48 percent satellite.

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transatlantic route and the Caribbean route, the addition of a cable raises rather than lowers the total cost of the basin system. It is always a lower-cost solution in this basin to use satellites, even though the demand curve is not as well matched with satellites.

TABLE 1

Costs for Various Strategies for Growths in Demand of 10 Percent and 20 Percent per Year

Percent Growth in Demand per Year	Strategy	Percent of 1985 Traffic via Satellite	Cumulated Annual Costs, 1976-1985 (million)	Cumulated 1968 Present Worth of Annual Costs, 1976-1985 (million)
10%	1	85%	$90	$42
	2	70%	$127	$57
	3	48%	$184	$80
20%	4	93%	$124	$54
	5	85%	$153	$66
	6	74%	$194	$81

Figure 7. Cumulative 1968 present worth of annual costs versus year, for 20 percent per year demand curve for several strategies. Curve A shows cumulative present worth of annual costs for facilities installed in the period 1968 to 1975. Strategy 4 shows 1985 traffic, 93 percent satellite; Strategy 5 shows 1985 traffic, 85 percent satellite; and Strategy 6 shows 1985 traffic, 74 percent satellite.

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The second conclusion to be drawn from this study is that even a 3,000-circuit cable is too small to allow postponement of a satellite system by even a year in the case of the 20 percent per year growth. For such rapid growth it will be important to develop much larger cross-section systems. Even the satellite considered here, which supplies 20,000 two-way circuits, is not as large a unit as could be used effectively. A 50,000- to 100,000-circuit satellite or cable may be of interest by 1985 if growth continues at 20 percent per year.

The third conclusion to be drawn is that there is a very simple relation between the cumulated annual cost (or cumulated 1968 present worth) and the percentage of basin requirements met by satellite. If the data in Table 1 are plotted, a straight-line relationship is found between the percentage of 1985 basin traffic carried by satellite (or cable) and the cumulated annual cost (or cumulated 1968 present worth) of the system in 1985. The cumulated annual cost curves for 10 percent and 20 percent demand growth have slopes of $2.2 million per percent of 1985 basin requirements met by cable installed in the period 1976 to 1985 and $3.3 million per percent, respectively. If we average over the 10-year period, the average annual costs per percent are $0.22 million and $0.33 million, respectively. As an example, consider the 20 percent demand growth case. In order to have a certain degree of reliability through mode diversity, we might decide that 10 percent of the circuits installed in the period 1976 to 1985 should be cable circuits. The extra cost for this degree of diversity would be $3.3 million per year, which is 14 percent of the average annual cost ($23.4 million) for all facilities in that time period. If we do install 10 percent of the circuits in cable in this period, the 1985 traffic turns out to be approximately 85 percent satellite, including cable circuits installed prior to 1976. Whether this price is reasonable depends on the quantitative assessment of the benefits discussed previously.

The technology that has been considered in this comparison is not very far from present technology. The 3,000-circuit SG cable used here is already under exploratory development, and its cost and performance are fairly predictable. The satellites are only minor modifications of INTELSAT-III and -IV. Some minor improvements in power supplies and antenna systems have been predicted to make these satellites possible. One result of these rather conservative technology forecasts, however, has been that the costs,

particularly for research and development, that we have been able to use are quite low. So the cost per channel of the systems used in this comparison may well be reasonably correct for 1980, even though the actual technology used in that time period may be different from what we have projected.

Domestic and Regional Satellite Communications Systems

The initial interest in the application of communications satellite technology centered naturally on its employment in service between continents, over oceans, and over other long distances. The very broad area coverage provided especially by synchronous satellites suggested the reasonable possibility of economical service over long distances as compared with conventional means and, more particularly, the provisions of communication service between points that were otherwise very difficult to serve at all.

As satellite technology has advanced rapidly, even in the few years of its history, better appreciation has been reached of the possibilities for more local services, utilizing high-gain narrow-beam antennas, multiple antennas, and the provision of access to a very large number of earth terminal points from a single satellite. Thus a topic of increasing current interest is the application of communications satellites to domestic or regional service.

By domestic service we mean the use of the satellite in communications of various types more or less within the boundaries of a particular nation. By regional service we mean its use in communications within a limited area comprising perhaps several nations in geographic proximity that presumably have some rationale through economic or cultural interests for a shared communications system that is somewhat distinct from a peculiarly national system.

General Considerations

The arguments for and against providing any such domestic or regional communication service by satellite, as well as the factors involved in the selection of the technological approach,

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are complex indeed. Perhaps the most important observation is that it is impossible to generalize these considerations; the factors will be quite different in almost any particular situation that is examined. The range of potential zones of application may vary from the United States at one extreme, with its very extensive and highly developed existing network of terrestrial communication coupled with high present traffic density and rapid growth, to the situation of Brazil, with an equally large geographical area but minimal existing terrestrial facilities, a correspondingly low level of present traffic, and a future communication requirement both in telephony and television that is very difficult to forecast or define. To be specific and to illustrate the variety in the factors that may affect the choice of approach, other areas that have been considered for regional or domestic systems include Australia, Indonesia, Japan, India, Pakistan, Europe or Western Europe, Canada, some collection of South and Central American nations, and Mexico.

Economic Considerations

The economic consideration of a domestic satellite system tends to focus on the calculation of a break-even distance - the distance above which the satellite service will be cheaper than equivalent terrestrial links. As a broad generality, it is obvious that long distances favor the use of satellites and that very short distances favor the use of cables or microwave relay, so that somewhere in between there is a break-even distance. This calculation, of course, has the same significance for international or domestic service, but the parameters may have quite different values.

The break-even distance is also a complex function of total traffic handled and the number of routes to be served, that is, the route traffic density. It is difficult to present definitive numerical answers of general significance, although illustrative calculations have been made for some highly idealized models.[3]

The space segment cost of a satellite system is approximately independent of whether the total traffic capacity of the satellite is used in connecting two points (a high traffic-density route) or in interconnecting many points with lower traffic density. For example, a satellite with a 2,000-circuit capacity can equally well provide 2,000 circuits between two points or almost 200 circuits over each of ten

routes representing all possible interconnections among five different points. In such a system with many low traffic-density routes, the break-even distance can be lower than is the case for point-to-point systems. However, the cost of earth stations is a critical factor, and there is a point at which a further increase in the number of terminals in a given network reverses the cost trend. The important concept is simply the intuitively plausible idea that the special advantage of the satellite system typically lies in providing many routes between many points through a single relay point in space.

The break-even distance is influenced strongly by the extent of terrestrial facilities already in existence at the time the new satellite service is contemplated. Studies by the Bell Laboratories suggest that in the United States the break-even distance in 1968 may be in the neighborhood of 1,300 miles for INTELSAT-IV types of satellites. These studies also show that the break-even distance will tend to remain in this neighborhood since newer systems of both types are expected to have reduced per-circuit costs to about the same extent. In a less developed country, with minimal present facilities, the break-even distance could be much less, depending on traffic density.

The problem would be simplified if the factors to be considered were simply careful forecasts of the service required and economic optimization of the technical approach. As a practical matter, it is clear that many other factors may be involved. These could include the policy determination in a nation or region regarding the scope and purpose of service to be provided.

For example, it may be desired to provide special television services for educational or informational purposes. They could include the consideration of the impact of communication services on the economic growth of a nation or region, implying a return on investment quite different from the normal revenue flow through sale of service. Matters of national prestige and political influence will undoubtedly enter the picture.

Technological Considerations

From a technological point of view, a wide variety of choices is available in the mechanism for providing a domestic

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or regional service. The first and most basic choice is the question of whether to procure a service through a satellite otherwise employed in an international service, such as an INTELSAT satellite, or to provide a separate dedicated satellite. If the traffic demand is small, the alternative of sharing the international satellite with domestic traffic clearly offers the most economical solution. It offers the further advantage that the same earth terminals employed in the domestic service automatically have access to international connections, and any terminal point in the country's domestic system has available a one-hop connection to any foreign terminal also served by the international satellite.

On the other hand, if traffic demand is large (thousands of channels) and particularly if substantial TV traffic is contemplated, a separate satellite may be more practical. Other considerations beyond the purely economic may also point in this direction; it may be important in a national interest to have completely independent control over the type, volume, and routing of traffic to be carried, with no second-party negotiations required. Optimum location of the satellite may be a consideration. Plans for satellite replacement and growth in capacity might be better keyed to the peculiar demands of a nation's own requirements rather than to remain subsidiary to an international program. Furthermore, the satellite design itself may be optimized more effectively for a domestic service if that is the only service it is to provide.

If a separate satellite is used to provide domestic service, a disadvantage may arise in the connection with an international service - if two cities being served have no means of connection other than by satellite. For example, if City A provides the gateway for international traffic, in order to place an intercontinental call, City B would transmit first through the domestic satellite to City A and then through an international satellite to the foreign terminal. This type of two-hop transmission may result in objectionable time delay in transmission and may make it desirable to devise another means of connecting City B with its international correspondent. The other means could, for example, be direct access also from City B to the international satellite. Although this mixture of domestic and international traffic does pose problems with a purely domestic satellite, arguments given above for the dedicated system may still prevail.

Organizational Considerations

At this point it may be worthwhile to outline a strategy that might be applicable to one or more of the countries mentioned in "General Considerations." First, let us assume that because of long routes and low traffic density, a certain country has minimal existing terrestrial facilities among its large cities. On the other hand, this country has sufficient demand for international communication to justify one or more earth stations for the INTELSAT system. The timing may be such that the Atlantic basin capacity may be well in excess of the current demand (see Figure 3) because of the entry into service of a large-capacity satellite. Thus INTELSAT circuits could be used temporarily for domestic service.

Technologically speaking, it should be feasible to continue to use the INTELSAT system for communication services among this country's cities that have earth stations, provided the additional satellite capacity is available.

Meanwhile domestic demand would continue to grow, and excess INTELSAT capacity continue to diminish, whereby a decision to launch a domestic satellite might become justified. The major cities would already have international satellite earth stations. Additional equipment such as transmitters and antennas would be needed for use with the domestic satellite, but some savings could be realized by locating such equipment on the same sites as the international satellite earth stations. The two-hop problem (time delay) for international traffic from the major cities is avoided because of the INTELSAT facility.

The provision of new though perhaps limited domestic services at low incremental costs is an attractive feature of this strategy. It would provide data with which to forecast more accurately the future demand for a more fully developed domestic system. As mentioned above, domestic systems are often difficult to plan because of the lack of reliable demand forecasts.

Potential Applications

The technological and economic factors may not necessarily play the major role in the decisions regarding provision of service. It may be helpful nevertheless to illustrate several examples of the types of service that could be provided with

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the technology now reasonably well in hand or generally accepted as a near-future possibility. In the category of dedicated satellites, we should consider two primary size classes, one corresponding to the payload that may be orbited by the improved Thor-Delta class of booster, which might place in orbit a useful satellite weight of from 300 to 500 lb, and the second corresponding to a Titan booster, which can place in orbit a payload of 1,000 to 1,200 lb. This natural breakpoint in booster technology provides a natural breakpoint in satellite size that is likely to be typical, with some variation, for perhaps the next five to ten years. As a simple example, consider the smaller satellite, equipped with a narrow-beam antenna having a beam width of approximately 5 degrees, which illuminates a spot approximately 2,500 miles in diameter on the earth's surface. Very roughly, this would cover the whole of Brazil, essentially all of the United States, or more than all of Western Europe. A nearly equivalent but slightly altered beam shape, say 4 by 8 degrees, would cover all of Canada. With a prime power generated in this satellite of over 200 watts, it would be possible to provide six relayed television channels at a power level suitable for reception by earth stations with a 30-ft antenna. Each of these television channels could be used alternatively for the relay of approximately 300 voice circuits.

In a more ambitious approach, consider a satellite of the large size provided with the same antenna beam width. In this satellite, with a prime power of 400 to 500 watts, the total communication capacity could be 12 to 14 television channels operating into the same 30-ft antenna with the option of using each of these channels for approximately 300 voice circuits. If a larger earth antenna is employed, the efficiency of spectrum utilization is considerably increased. For example, with an 80-ft-diameter earth antenna, all of the above communication capacities would be approximately doubled. Larger earth antennas also permit greater use of the synchronous orbit and a larger number of satellites operating in the same frequency range. This topic is discussed further in the next section where orbital parking space considerations are described.

Thus the technology available today appears to offer attractive prospects for domestic communication services, either on a modest scale or on a large scale. The opportunities for massive increase in present traffic levels in some

cases, or for the provision of quite new types of services, which would otherwise be impractical, will no doubt lead to very serious consideration of this type of facility.

Frequency-Management and Orbital Parking Space Considerations for Long-Haul Transmission Modes

Communications Satellite and Terrestrial Microwave Systems

At the present time in the United States, commercial communications satellites and microwave relay links share the same frequency ranges in the 4-GHz and 6-GHz bands. Satellite systems use the 6-GHz band for their up-links and the 4-GHz band for their down-links. Bands in the 7-GHz and 8-GHz range are also available for satellites internationally, although there has been no formal United States allocation of these bands for commercial use.

There are many types of satellites other than communications satellites either in existence or projected for future use.[4] All of these systems require the use of the frequency spectrum for command, housekeeping, and launch, as well as for performing a basic function such as communications. There are more than 200 United States satellites now in orbit, and many more are projected for launch every year through 1980. All of these projected systems will make use of bands allocated to space services, partly on an exclusive basis and partly on a shared basis. Presently allocated bands are between 10 MHz and 8.5 GHz. The total portion of this part of the spectrum now available on some basis to space services is approximately 3 GHz.

The use of frequencies below a few hundred megahertz is limited by various difficulties with the ionosphere, and these frequencies are less promising than higher frequencies for satellite use. Similarly, propagation at frequencies above 10 GHz is much more strongly affected by liquid water than is the case at lower frequencies, and hence satellite communications using frequency bands above 10 GHz encounter difficulties due to rainstorms. It is important for us to understand the precise nature and extent of these difficulties in order to plan for future systems that will undoubtedly make use of these higher frequencies. At the same time, it is important for us to do everything we can to make the best possible use of the frequencies below 10 GHz where natural difficulties are minimized.

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The same part of the frequency spectrum can be used by more than one service when the two services are separated in some dimension other than frequency. For example, time is a dimension that obviously permits sharing by two services, if one service operates only in the day and the other only at night. Similarly, location is a dimension that allows sharing by two services operating at the same frequency, if they are sufficiently far apart that each of their signals is very small at the locations of the sharing user. The critical dimension that allows satellites to share the same frequencies with terrestrial services is that of pointing direction, since both services employ narrow beams. Synchronous satellites appear at large angles to the horizon and the beams of their earth stations thus point toward the sky at an angle of at least 3 to 5 degrees according to United States and international standards. On the other hand, terrestrial systems such as microwave relay links point toward the horizon, typically within 1 degree of it, thus allowing sharing with satellites. The opportunity potentially exists for satellite systems to share other bands between 1 and 10 GHz with other users, and a careful study of all the possibilities in this range should be made.

Sharing is not without its difficulties, however. Satellite systems and terrestrial systems can interfere with each other in nine distinct ways, as given in Table 2. There are three types of transmitters and three types of receivers, and each type of transmitter can cause a signal in each type of receiver. At the present time however, four modes of interference are the most troublesome, as indicated in Table 2.

TABLE 2

Satellite and Terrestrial System Modes of Interference

	Satellite Receiver	Terrestrial Receiver	Earth Station Receiver
Satellite Transmitter			
Terrestrial Transmitter	X	X	X
Earth Station Transmitter		X	

A present limitation on the expansion of the microwave relay system in the United States is interference between relay systems of all types in the approaches to the larger cities. This accounts for the cross in the box indicating interference between terrestrial transmitters and terrestrial receivers. As the number of satellite systems increases, the other modes can be expected to become more troublesome in similar ways.

The earth station transmitter of a satellite system usually employs a microwave tube with a power output of the order of kilowatts. This power is very narrowly confined by the large-diameter antenna used at the satellite earth station. However, the power radiated through the sidelobes of such beams into terrestrial receivers can approach the power levels normally radiated into terrestrial receivers by terrestrial transmitters. This source of interference is marked in Table 2. Standards have been established for the maximum allowable interference to terrestrial receivers from this source. Trouble can also be caused during rainstorms by scattering of the main beam of a satellite transmitter into terrestrial systems.

Similar problems exist between terrestrial system transmitters pointed along the horizon and the very sensitive receivers of satellite earth stations. Terrestrial microwave relay systems operate at power levels of only a few watts, but some systems with levels up to 10 watts are now going into operation. A standard in the form of an upper limit of 20 watts into a 43-dB antenna has been established. This does not put an undue burden on the terrestrial system and helps the satellite planner by putting a ceiling on what could happen in the future, in terms of power.

Just as energy can be radiated through the sidelobes of earth station antennas, energy can be received from terrestrial transmitters through these sidelobes. Thus, if a terrestrial system has its main beam aimed at an earth station, the interference may be excessive, even if the earth station antenna is aimed in another direction and elevated well above the horizon. The location of earth stations near major cities also depends on the extent of common-volume scattering between main beams of both systems during rainstorms. Proper standards for this source of interference have not yet been implemented because more information is needed.

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One way of increasing the signal-to-noise ratio in an earth station receiver is to increase the signal by increasing the power density transmitted to the earth by the satellite, for example, by using a narrower-beam antenna. This approach is now limited by an international and national standard that establishes an upper limit of radiated power density from satellites. If the power level is increased too much, interference with terrestrial receivers from satellite transmitters can result. Interference with an earth station receiver by transmitters in satellites other than the satellite associated with the given earth station results in the requirement to space satellites far enough apart in the stationary orbit (for a given earth station antenna size) to limit the amount of received signal from these other satellites. Since stationary orbit space may eventually become at least as precious as the frequency spectrum, we must be careful not to optimize the use of one at the expense of the other.

Interference with satellite receivers by terrestrial transmitters is indicated as a significant problem area. However, it is likely to be controlled in the future by preventing terrestrial systems from pointing their beams directly at the synchronous orbit.

Aeronautical and Navigational Satellites

Although our primary emphasis in this report has been on communications satellites, the use of frequencies and orbit space for satellites providing air traffic control, navigation or position determination, and communications is a closely related matter. The navigation function envisioned is in itself a special form of communication, probably using range information determined from signals transmitted by several satellites to establish position. In some proposed versions of such a system, the position information is available not only in the aircraft, but also at central control or information stations on the ground.

It appears quite probable that ultimately all three of these services - communication, navigation, and traffic control - will be provided through a single system of satellites and airborne receivers and transponders. The data rates required are relatively low, and the service will probably be provided by utilizing a modest part of the UHF spectrum.

For reasons of efficient system design, such satellites, although probably synchronous, may be designed and built separately from broad-band general-purpose communications satellites, whether international or domestic. Although nominal coordination would be required in the selection of orbital locations, there does not appear to be any compelling technical requirement for tight integration of an aeronautical system and the public communication system. In principle, such aeronautical and marine satellites could interfere with commercial general-purpose communications satellites and could introduce additional orbit-crowding problems. But as noted above, it appears to us that aeronautical satellites will be designed to operate at frequencies other than those used by general-purpose communications satellites and therefore will not present a significant problem of frequency interference.

As to orbital crowding, if they operate in different bands, there is no limitation on angular closeness between satellites of the two types that is set by electrical beamwidth considerations. Therefore, we must examine the question of physical crowding and avoidance of direct collision. If we picture the long-term use of orbit space by general-purpose communications satellites in the 4-GHz and 6-GHz frequency ranges, it is likely that a maximum of one satellite of this type per degree of orbit space will be used. To achieve this close a spacing, all earth station antennas must have diameters of at least 80 ft to provide sufficient directivity to avoid interference from adjacent satellites. Actual tests with INTELSAT-II have indicated that positioning within a 0.5-deg segment of arc is readily obtained. Thus, 35 to 40 general-purpose communications satellites may ultimately be in place in the Atlantic basin. If we now picture an aeronautical satellite occupying the same 1-deg region of the synchronous orbit as a particular general-purpose satellite, we can estimate the probability of collision from the volume of space shared by the two satellites and the volumes of the satellites themselves. One degree of orbit space is about 400 miles at synchronous altitude, and the region of operation about the synchronous orbit that is useful for satellite operation is about 60 miles in altitude and 400 miles in width, so the volume of interest is 400 x 400 x 60, which is approximately 10 million cu miles. A satellite has a volume of about 100 cu ft. The likelihood of two satellites colliding in this region is thus so small that this mode of failure has negligible probability in comparison with most other modes of failure. We thus conclude that orbital crowding between aeronautical and general-purpose

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communications satellites is not going to be an important problem, if the two types of satellites operate in different frequency ranges, as is expected to be the case.

The technology required to provide the three-service system mentioned above is available today. The complicating factor is that there are at least several ways of doing the job, involving various trade-offs between equipment in the satellite, in the aircraft, and on the ground. The real pacing elements in achievement of this service will be the difficulty in the decision-making process, the development of the various administrative arrangements and agreements necessary to implement it, and the natural inertia of the various parties and agencies involved. As a practical matter, it is therefore likely that the first step in this direction will be the provision of a small and simple part of the total service, namely, operational communication.

It should be noted that the navigation service would have value to the maritime shipping industry also. Other studies have shown, in fact, that the interest of this community in the navigation function may be even larger at the outset than that of the aeronautical community.

Frequencies Above 10 GHz

It is our basic view that a greatly increased level of effort should be put into the study of the possible compatible uses of the spectrum by satellite and terrestrial systems, both below and above 10 GHz. Certainly in the 4-GHz and 6-GHz bands, and probably in the 7-GHz and 8-GHz bands, carefully engineered systems for terrestrial and satellite applications can be built to coexist at some additional cost to both systems.

As we look toward the use of frequency bands about 10 GHz, there will be important advantages to the satellite service in the early designation of particular bands for communications satellite use, in order to allow component development to be started with confidence. It is recognized that bands above 10 GHz are presently allocated to other services. We do not wish to express an opinion on the relative benefits of these services in comparison with communications, but we do believe that a comparative study leading to a firm recommendation would be of value to all classes of users. If these higher

bands are made available for communications, it is likely that both regions of the spectrum will ultimately be put to use both for satellite and terrestrial communications systems, even though the costs will be greater than has been the case in lower-frequency systems. Further study is needed on the environment and the extent to which clear-channel designations should be made. Therefore, it is important to proceed immediately to gather the data that we know will be needed to make estimates of the cost of future systems and to set standards for compatible operation of terrestrial and satellite systems.

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Findings and Recommendations of the Panel

The major findings and recommendations of the Panel on Satellites and Other Long-Haul Transmission Modes, which result from the foregoing analysis, may be stated as follows:

1. On the basis of a simplified model of long-haul transmission in the Atlantic basin, it is found that the estimated demand in the 1975 to 1985 time period can be met at a minium cost using only satellites in new installations. However, the premium associated with the installation of cables in some routes is estimated to be fairly modest and can be compared with the benefits of composite systems with various degrees of mode diversity.

   Recommendation: Research on both satellites and undersea-cable technology should be supported with a view to the development of competitive high-capacity systems for which a demand is expected to exist during the coming decade.

2. From a technological and economic viewpoint, domestic and regional service, either by means of a dedicated satellite or by means of an international satellite, can be an attractive approach to the system needs of many countries.

3. Sharing of the frequency spectrum between satellite and terrestrial services on a broad basis, both below and above 10 GHz, appears to be feasible at reasonable cost. There are existing standards for sharing in the 4-GHz and 6-GHz bands.

   Recommendation: The studies necessary to implement sharing need to be carried out and the required additional standards need to be developed. Systems studies of the frequency-management and orbital parking space problems of long-haul transmission modes should be carried out with a view to the development of efficient low-cost systems.

4. Satellites for aeronautical, navigational, and other related services will probably be provided at frequencies different from those used for communications satellites, and therefore they will not add to the frequency-management and orbital parking space problems of communications satellite planning.

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SATELLITE COMMUNICATIONS AND EDUCATIONAL TELEVISION IN LESS DEVELOPED COUNTRIES

Eugene V. Rostow

President's Task Force on Communications Policy
Washington, D. C.

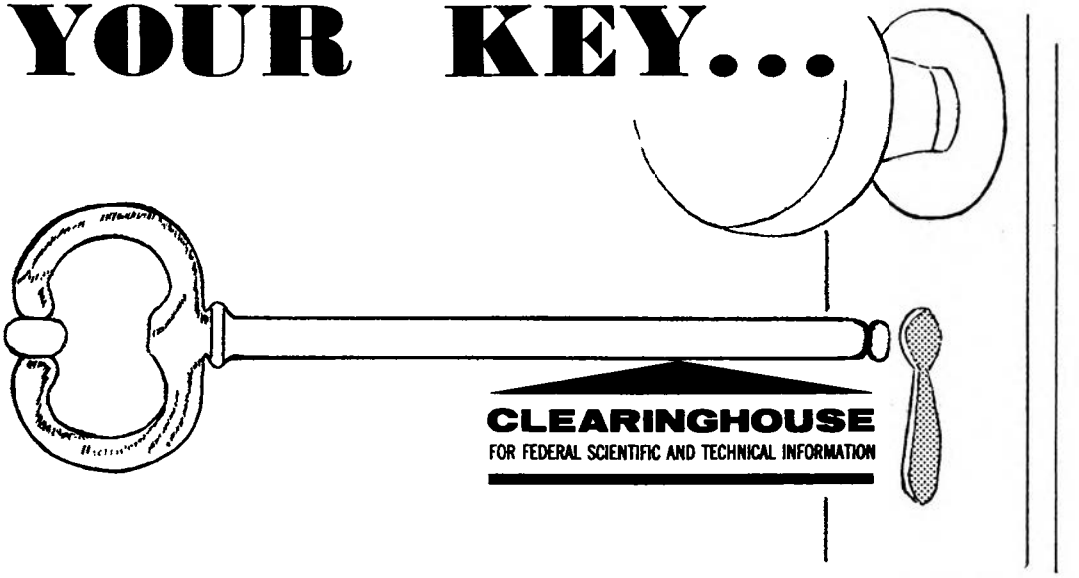
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PRESIDENT'S TASK FORCE ON COMMUNICATIONS POLICY

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SATELLITE COMMUNICATIONS AND EDUCATIONAL TELEVISION IN LESS DEVELOPED COUNTRIES

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STAFF PAPER THREE

SATELLITE COMMUNICATIONS AND EDUCATIONAL TELEVISION IN LESS DEVELOPED COUNTRIES

I. INTRODUCTION

As the President emphasized in his message of August 14, 1967, a global satellite system is particularly important for less developed nations which today do not receive the benefits of speedy, direct international communications. The present-day system often entails indirect routing through the advanced nations to the less developed countries, and renders international communications service to the latter relatively expensive and of low quality. The President noted, for example, that a telephone call from Rangoon to Djakarta must still go through Tokyo, while a call from Dakar, Senegal to Lagos, Nigeria is routed through Paris and London.

// Moreover, domestic communications links within less developed countries are generally rudimentary and unreliable, where they exist at all; high-frequency radio,

subject to atmospheric vagaries and of severely restricted capacity, is still relied upon to connect many major cities. Nationwide electronic distribution of television programming, common in the U.S. and Europe, is virtually unknown in the less developed countries.

It is clear that economic development will require vastly expanded communications capability. The growth of regional common markets will call for reliable links among closely working buyers and sellers who today are artificially separated by national boundaries. Domestically, the growth of a modern industrial sector, pushing beyond today's urban concentrations, will demand dependable long-distance voice, data, and record services, already so familiar in the advanced countries. And the growth of television for public affairs and classroom programming, covering the far reaches of each country, offers exciting opportunities for cultural enrichment and education.

The importance of modern communications for economic development, and its implications for foreign assistance, are by now widely recognized. In view of the inadequacy of today's system, the President stated in his message that technical and financial assistance should be considered

to assist the less developed countries in planning and procuring ground stations. With respect to domestic communications networks, it is notable that a Congressional Subcommittee has recently recommended that "the United States endeavor to assist the developing countries in organizing and developing their internal communications systems in order to advance their development objectives." */

With respect to a global network including the less developed countries, we are making striking progress through INTELSAT. At this writing 55 countries, including 40 less developed, have ground stations scheduled for completion by 1972 to work with INTELSAT satellites. Just recently, the first station in Latin America, near Santiago, Chile, was put in operation. With the broad-beam global coverage afforded by INTELSAT satellites, and the completion of the other earth stations, we will see by 1972 a high-capacity, reliable network within which each participant, rich and poor alike, will have direct access to each of the other participants in INTELSAT.

Of course, continued advancement in satellite technology will not simply come to a halt with the attainment of a basic

*/ Subcommittee on International Organizations and Movements, House Committee on Foreign Affairs, Report No. 5, 1967, p. 13R.

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global satellite network (as important as that goal is). In particular, use of narrower satellite beams to concentrate radiated energy from the satellite may permit much smaller and less costly earth terminals, making attractive domestic and regional uses of satellites in many parts of the world. [A leading example of such an application is the use of satellites to meet domestic U.S. needs, as treated at length in our domestic satellite paper.]

Given the rudimentary character of domestic and regional communications networks within less developed countries, it is not difficult to imagine the use of narrow-beam satellites to provide economic, high-grade telephone data and record service between and among major cities and outlying towns, and to relay educational and instructional television programming to many of today's widespread inaccessible locations. To explore these possibilities, the Central Staff has completed a substantial amount of work supported by outside research with Page

Communications Engineers, Inc.,*/ and the Stanford Research Institute.**/

One study, conducted primarily by the Staff with inputs from Page and other sources concentrated on promising applications of satellites for a wide range of communications services in South America. Among the several illustrative configurations we have considered, one interesting case is a satellite with four antenna beams covering the South American continent which could (1) tie together all cities in excess of 50,000 population (125 in all) with voice, data, and record service while also supplying television distribution between capital cities and outlying areas; and (2) in connection with the presently planned INTELSAT global system, tie this whole complex of cities into the global system. Moreover, the system would involve perhaps less than one-half the total cost of tying these cities together through conventional terrestrial microwave.

A second project, undertaken primarily by the

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*/ New Telecommunications Technologies for Less Developed Countries, July 1968 (2 Vols.).

**/ Vol. I: Satellite-Distributed Educational Television for Developing Countries ---Summary. Vol. II: Communication Satellites for Education and Development -- The Case of India. Vol. III: Satellite Distributed Educational Television -- the Case of Latin America. Vol. IV: Satellite-Distributed Educational Television for Developing Countries -- Working Papers. Vol. V is

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Stanford Research Institute, has concentrated on the prospects of educational and instructional television operating in two quite distinct environments: a regional multinational application involving Latin America, and a single large country application in India. In both cases the use of television is promising; but as the SRI work emphasizes, the most serious problems in exploiting this opportunity have little to do with satellites, but rather involve a host of other problems -- coping with language difficulties, integrating television instructional curricula into existing school systems, getting strong financial and moral support from political leaders, and many others. While satellites may permit widespread distribution of a television signal, the ability of a country to fruitfully employ that signal will crucially depend on its being able to solve a multitude of problems on the ground.

All in all, our general view is that prospects are bright for widespread use of satellite communications by less developed countries. However, many of these applications will require careful coordination and sharing arrangements among participating countries if unit cost are to be reduced to attractive levels; and, in the case of educational and instructional television, much prior spadework, discussed in detail in Part IV, is a vital

prerequisite. The thrust of our basic recommendations, contained in the last section of this paper, is to describe the kinds of planning functions and institutional mechanisms that should be introduced in the near term to facilitate later the full exploitation of the new technology by less developed countries.

II. ILLUSTRATIVE MULTI-PURPOSE FACILITIES FOR LATIN AMERICA

In this section we shall discuss illustrative satellite applications to provide telephone, record, and television service within the South American continent. First, we will discuas the level and composition of future traffic requirements as derived from the Page study; then we shall (a) describe two system designs developed by the Central Staff, (b) discuss the compatibility of these designs with the global INTELSAT system, (c) appraise in very rough terms the costs of terrestrial alternatives providing the same kinds of services, (d) consider the crucial elements of international cooperation and cost sharing, and (e) treat the problem of efficient use of spectrum with regional and domestic systems employing small earth terminals.

A. Future Traffic Requirements

Telephone and record. It is immediately clear that

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estimating communications requirements over the next decade or so is difficult, especially where facilities are rudimentary or nonexistent. Generally, when low-quality links such as high-frequency radio are replaced by high-quality facilities such as submarine cable, an immediate increase in demand for service arises -- an "impulse jump"-- even if rates to the user and the remainder of the physical telephone plant continue unchanged. The basis for the impulse jump is easily understandable: The higher quality telephone service offered by the new facilities encourages more people to make more and longer calls. Moreover, the new facilities generally have greater capacity than the old, thereby reducing queues and waiting times and encouraging that much more use of the service. For example, in Caracas, average delays in overseas service was cut from 15 to 5 minutes with completion of a submarine cable to Caracas from the Virgin Islands in 1966. However, the impulse jump complicates long-run projections because this factor is highly variable in strength from one case to another. For example, when the Virgin Islands-Caracas cable was completed, Venezuela's overseas service immediately tripled in volume. But when a Pacific cable was

completed to the Philippines in 1964, the impulse jump was much lower -- roughly 50%.

Once superior facilities are installed, an additional complication in making demand projections is that the rate of continued increase in traffic in later years is typically higher than before. In the Philippines, the annual traffic growth rate since the Pacific cable was completed was two or three times greater than it was before that time.

In addition, future growth of long-distance traffic obviously depends on development of local telephone plant. In extending long-distance service from capital cities to outlying areas, the level of traffic will grow only as the number of telephones and local exchange facilities are modernized and expanded. Typical of less developed regions, Latin America's local telephone plant consists largely of outmoded equipment, with the expansion rate severely limited relative to the burgeoning demand for service. In many smaller towns telephone service remains nonexistent. The rate of new investment in telephone facilities over the next decade will depend on many factors: for example, the priority accorded by governments to

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communications development relative to other investments, the overall rate of economic growth, the severity of balance-of-payments problems, and the degree of political stability.

Finally, changes in rates charged for domestic and international telephone service will affect the level of future demand for service. The degree to which demand is responsive to price change cannot be determined with precision. However, the statistical analysis discussed in our demand and technology paper does suggest that responsiveness of demand is reasonably high. That is, a reduction in price brings about a more that proportionate increase in volume. In Latin America one could reasonably conjecture that low prices coupled with dependable high-quality satellite circuits could tap markets that today are entirely closed -- situations in which both business firms and families would use telephones in a way they would not dream of doing today.

The upshot is that historical traffic flows provide a grossly inadequate basis on which to project future requirements. The gaps in quality, dependability, and capacity between exising facilities and those offered by satellite, the critical role of local telephone plant development

Table 1. Equivalent Voice Circuit Requirements
1978

	Inter-Latin America	Mainland USA and Canada	Europe	Other Countries	Total International	Total Intra-national
Argentina [1]	634/229	68/66	77/77	3/3	802/377	4,330
Bolivia	16/16	5/5			21/21	2,500
Brazil	125/69	81/61	61/61	4/4	271/215	32,730
Chile	217/89	64/64	37/37	3/3	321/233	9,830
Colombia	114/50	45/45	42/42	1/1	204/178	20,400
Ecuador	26/26	38/38			64/54	1,210
Paraguay	48/44	7/7	9/9	1/1	65/65	
Peru	59/52	72/72	32/32	1/1	164/157	2,550
Uruguay [1]	390/24	23/23	34/34	2/2	449/334	5,500
Venezuela [2]	119/[illegible]	126/69	87/87	2/2	334/213	9,980
Costa Rica	103/0	44/44			44/44	
El Salvador	122/0	34/17			156/17	
Guatemala	104/0	54/25	2/2	1/1	157/28	
Honduras	84/0	35/18			119/18	
Nicaragua	102/0	46/23			148/23	
Panama	127/39	93/44	9/9		229/96	
Mexico	119/10	1,686/0	96/96	7/7	1,908/194	31,350
Total	1,865/395	2,558/688	486/486	25/25	4,334/1,594	161,490

[1] Includes 3hl circuits between Montevideo and Buenos Aires.
[2] Includes a 96 channel submarine cable between Venezuela and the United States.
Source: Appendix B, p. 2-8

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and possibilities of major changes in rates, complicate greatly our task of forecasting future needs.

Nevertheless, in talking sensibly about using satellites one must have some rough notion of future requirements. For this reason the Page study has considered in substantial detail the character and levels of traffic demand over the next decade. Drawing on estimates made by CITEL, "the Santiago World Plan," and other sources, and employing correlation analysis, Page derives the voice circuit demand estimates shown in Table 1. For 17 countries, Table 1 indicates the equivalent voice requirements for inter-Latin American, international, and intranational or domestic needs in 1978. For international (but not intranational) service these requirements are broken down by total circuit requirements that Page estimates could be served by satellite to the right of the slashed lines. For example, in the upper left hand corner we see that Argentina would have an equivalent voice circuit requirement for inter-Latin American traffic of 654 channels, of which 229 might be satisfied by satellite.

Of course, estimating the total proportion of international traffic that might be suitable for satellite is

fraught with difficulty since so much depends on the nature of terrestrial long-distance facilities in place at the time the satellite goes into service, the distance, distribution of demand, relative costs, and many other factors. In its estimates Page assumes (a) that existing HF radio circuits would be replaced by satellite circuits, (b) where broadband microwave links exist or are firmly planned, satellite circuits would not be used, and (c) where areas of doubt exist regarding the certainty of proposed microwave systems, one-half the projected gross requirements would be satisfied by satellite.

The most striking aspect of Table 1 is that total domestic traffic, shown on the extreme right, is expected to maintain far higher levels than international, whether or not satellites are used. The figure of 161,490 circuits for domestic is nearly 40 times the total estimated international traffic of 4,334 (of which less than one-half, or 1,594 circuits, Page judges suitable for satellite). This suggests that a satellite system tailored for Latin American needs would depend very much on the degree to which it could be applied to the domestic service -- all the more so since most or all the estimated 1,594 international

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satellite circuits would be supplied through the currently planned INTELSAT program.

While detailed data are not available, undoubtedly the bulk of the 161,490 circuits would serve relatively short-distance traffic unsuitable for satellite. (Even within the geographical expanse of the U.S., about 50% of all toll calls involve distances of 450 miles or less.) Nevertheless, even a modest proportion of the total domestic traffic would provide a large economic base for a satellite system, especially if combined with television distribution as discussed below.

Television Distribution. In addition to voice service, the Page study notes that, "the key to cost effectiveness of this regional satellite system is that it provides an extensive, flexible, expandable, television capability to South America." The most straightforward television application would involve distribution from each capital city via satellite to earth terminals in outlying areas. From these terminals signals would be fed to broadcasting stations and translators from which they would be rebroadcast in the conventional manner. This mode of operation would be much the same as that of a U.S. domestic system as discussed in our domestic satellite paper.

As an alternative, a larger satellite might be employed to transmit signals directly into small rooftop antennas, thereby dispensing with the cost of rebroadcast facilities. At first glance, such a system might appear especially attractive for reaching large numbers of widely scattered, remote locations. However, because of the difficulty of maintaining television receivers in remote locations, and because a surprisingly large number of television stations already exist in Latin America,*/ a direct broadcast satellite does not appear a likely prospect for the region -- at least not in the early 1970's.

Whether or not direct broadcasting turns out to be economically feasible, the use of satellites for television has several interesting features. First, it would permit each capital city to distribute timely public affairs and news programs instantaneously to many points within its national boundaries.**/ Secondly, programming from

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*/ At recent count, Brazil had 47 television broadcasting stations, Mexico 32, Colombia 14, and Peru 20. There are over 2 million television receiving sets in Brazil, over 1 million in Mexico, and 200 thousand in Colombia.

**/ We emphasize the phrase "national boundaries" because special political and legal considerations would affect the extent to which countries would accept television programming beamed from other countries for consumption by their national audiences.

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international sources (such as important United Nations debates) could be transmitted by INTELSAT satellites to the several large earth terminals already planned or under construction in the region. From these terminals the regional satellite would relay the program to outlying areas. Third, the television distribution system would be useful for classroom instructional purposes. Thus, one could visualize a single channel being used during the day for instructional purposes in the classroom, and during prime-time evenings hours for public affairs and news programs. As the occasion arises, especially important international public affairs programs could be brought in to pre-empt regularly scheduled national programs.

However one question which immediately arises with respect to instructional television is: "Why use a satellite?" Since good instructional television is in any event "canned," what benefit is connected with instantaneous transmission to individual receiving points? If local television stations are needed anyway, would it not be less costly to distribute videotape thru the mail for local playback by these stations?

We offer four answers to such questions:

1. While video distribution for local rebroadcast would surely be much less expensive than the satellite system dedicated solely to instructional television, the additional cost of using the satellite for instruction may be low if the satellite is also used for other purposes such as telephone and public affairs television. That is, if the satellite is employed for supplying telephone services to widely scattered points, the additional cost of modifying ground stations and enlarging the satellite for television may be small. Or, if it is desirable to beam timely public affairs programming to the home and to the village square, for which instantaneous electronic distribution is essential, then the additional cost of classroom use of the same channel during the day would be small. As emphasized throughout this paper, the economic reliability of the satellite, in Latin America or other less developed areas, rests squarely on the system's doing a number of jobs simultaneously, and meshing the peaks and troughs

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in demand for various services in order to lower further the cost of doing each job.

2. While videotape distribution may appear inexpensive on paper (when one merely adds up the cost of tapes, tape playback machines, and distribution costs) many serious difficulties emerge in day-in, day-out operation.* The low cost embodied in tape distribution is very much dependent on local stations using particular tapes in accordance with pre-arranged schedules and then mailing them in sequence to other local stations. However, unless mail and transportation systems are good, and the competence of local personnel high, the snow-balling of delays and missing tapes can lead to a crashing fiasco.** Unfortunately, mail systems and transportation are typically unreliable in less developed countries -- especially in the

*The SRI report on Latin America, Vol. III, Table 20 estimates an investment cost including broadcasting stations of about $70 million for a satellite, but only $42 million for a videotape system serving Argentina, Bolivia, Chile, Peru and Uruguay.

**We know of not a single instance in less developed countries where instructional television systems depend on widespread distribution of videotape.

isolated areas one would be particularly interested in reaching by satellite.

3. Instantaneous transmission for instructional use is attractive even if much of what is distributed is canned. In the classroom it would sometimes be desirable to bring in programs of particularly timely interest (such as a crucial UN debate in New York), to revise televised lecture material on an ad hoc basis to reflect recent events and experience, and more generally to retain the option of changing programming on short notice -- things which can be done satisfactorily only with instantaneous distribution.

4. A widely voiced complaint about instructional television is that it is totally passive -- that it does not permit members of a large learning audience to interact with the teacher on the screen. But here, since the satellite would provide telephone channels along with television, exciting possibilities emerge for designing an interactive feedback system to employ voice channels during off-peak periods of telephone use. For example,

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> we could visualize a television channel, combined with telephone links to the originating studio in the capital city, employed on Saturdays for teacher training sessions; small groups of teachers scattered throughout the country could indeed ask questions, get immediate answers, and more generally interact directly with participants in the studio.*

Against these considerations, it must be recognized that nationwide distribution via satellite may suffer handicaps in special situations. A major educational constraint is that the less locally tailored the programming, the less likely it is to be effective. Thus, a tradeoff exists between the scope of satellite coverage and its institutional effectiveness, depending on the heterogeneity of the population, the nature of the school curriculum, and other factors.

With all these dimensions taken into account, it is impossible to foresee the level of television demand by satellite in Latin American during the 1970's. We assume, as an initial application, one TV channel to each of four

*/ It is important to bear in mind that interactive systems can be effective only with small audiences -- a situation that does not prevail in general classroom use, but may well exist for teacher training and other highly specialized vocational training programs.

subregions of South America. This would require, initially, several countries sharing a TV channel during the day and evening. (For example, a channel might be used by one country during prime evening time for public affairs and then used by another country during the day for classroom programming.) In its report on Latin America, SRI discusses the use of television for adult education, teacher training, primary education, secondary education, and technical training. SRI estimates a demand in South America of perhaps 11 channels by 1972 and 17 channels by 1980. But it is not clear how many of these channels would be suitable for transmission by satellite rather than by microwave which might or might not be in place at that time.

B. System Designs

Within the constraints of launch vehicles likely to be available during the 1970's, Page analyzed a number of alternative satellite configurations covering the 10 countries of South America (excluding Surinam and the Guianas). These systems include those with both TV and two-way voice service, those with voice only, some that would link all cities and towns in excess of 1,000 population (1,594 points in all), and others that would initially include only the larger towns and cities. For purposes of this paper we will

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concentrate on two designs developed by the Central Staff, utilizing the Page study as well as other sources of information on satellite communications.* One would involve a 1,240-pound satellite with four beams -- two covering Brazil, a third Colombia, Ecuador, Peru and Venezuela, and the fourth covering the remaining countries in the southern horn of the continent. With narrow beams the satellite capacity would total about 10,000 voice channels, plus one TV channel in each beam, working with small earth terminals (15-foot antennas). For each of the 16 cities on the continent in excess of 500,000 population, the satellite system would provide 250 voice channels, plus one TV-receive channel. Each of these cities (at least one is in each of the 10 countries) would also have one-channel TV transmit capability to distribute programming to its own national audience. In addition, the 109 cities with populations between 50,000 and 500,000 would have 50 voice channels and one television-receive channel. Altogether, the system would cover the

*Electronic Industries Association, Satellite Telecommunications Subdivision, Future Communications Systems Via Satellites Utilizing Low Cost Earth Stations, July 1968; plus private correspondence from the National Aeronautics and Space Administration, Hughes Aircraft Co., and General Electric. Our cost estimates are based on the model described in Appendix C of Staff Paper One.

largest 125 cities and towns on the continent and include directly about 35% of the population. The television signals rebroadcast from these cities and towns would cover a large additional percentage of the population. The estimated cost for this system, assuming a 10-year operational life, is given in Table 2.

Thus, at a total estimated investment cost of roughly $80 million it may be possible to bring a variety of telephone,

Table 2

INVESTMENT COST-SYSTEM SERVING 125 CITIES
(Millions of Dollars)

No. Ground Stations	Unit Cost (Including spares and test)	Total Cost
16	$4.60	$ 7.36
109	2.60	28.34
		35.70
Plus 12% spares & test		
Plus 3 satellites	6.50	19.50
2 boosters	12.60	25.20
Total cost		$80.40

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record data, and television services to a large number of urban centers. In an initial system, coverage restricted to cities in excess of 50,000 population would make sense insofar as these cities already have reasonably well-developed local telephone exchanges. Many already have television transmitting stations or will have by the time a satellite could be placed in orbit, and most have a fairly well-developed business community to provide a market for additional long-distance telephone service. What most of these cities lack -- and what the satellite would give them -- is reliable telephone service to the outside world, and timely television coverage to home, village square, and school.

To be sure, the selection of cities in excess of 50,000 is arbitrary. One could go on to consider an expanded system to include a larger percentage of population; for example, additional earth stations established in the 403 cities having populations between 10,000 and 50,000. The total cost of this addition would run about $210,000 per terminal or about $85 million, in addition to the $80 million shown in Table 2. The additional earth terminals, supplying 5 to 10 voice channels and one television-receive channel, would increase population coverage from 35% to 47% -- but at

the penalty of more than doubling total systems cost. Or we could consider a larger satellite or set of satellites that would provide one or more full-time television channels to each of the 10 countries. Of course, at this time we cannot say what the optimal level of coverage and capacity would be for either an initial or an advanced system. The basic point here is that the system could be tailored to meet the needs of the countries served, depending on a host of factors that will come to light only through time and much additional study.*

Finally, it cannot be overemphasized that our cost estimates and system designs are for illustrative purposes only. Major decisions would require much more detailed analysis of comparative costs, benefits and feasibility of both satellite facilities, and other alternatives.

C. Compatibility With the Global INTELSAT Facilities

It is notable that a regionally shared satellite system would complement and strengthen a global satellite system; for by "collecting" domestic traffic it would expand the demand for intercontinental service supplied by currently

*The cost figures in Table 2 and in the text vary somewhat from those of Page given in Appendix B, because we are assuming for illustrative purposes a satellite of different design with a substantially greater capacity.

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programmed INTELSAT satellites. We have already mentioned that television programming originating on other continents could be transmitted by INTELSAT and re-transmitted via regional satellites to reach additional cities, numbering a hundred or more, depending on the factors noted above. In addition, the regional satellite would provide the "tail-end" extensions in the participating countries for telephone, data, and record service involving overseas points. That is, traffic could be routed between outlying towns and cities to major cities where the large INTELSAT ground stations are located. From there the traffic would go by INTELSAT to Europe, the U.S., Africa, or anywhere else in the global system. To be sure, this would require two hops, which would result in somewhat degraded telephone quality because of the time delay. Nevertheless, given the reliability and general quality of international service that would be provided to outlying points, in contrast to the exceedingly poor service existing today, a two-hop delay might well be tolerated by most users.

D. Comparative Costs of Terrestrial Alternatives

Of course, a well-developed terrestrial microwave network could provide anything that a regional satellite

system can. Microwave can be used to distribute television programming, it can serve data and record markets, and it can provide high-quality telephone links (and without the time delay associated with satellite). No less than satellite, microwave would also complement an INTELSAT global system by collecting and distributing international traffic to outlying points in participating countries. So the question arises as to how the satellite system of the sort postulated above stacks up against alternative terrestrial means of performing the same functions.

The planning of future international communications facilities for Latin America has been carefully coordinated and a detailed plan has been developed for the ITN. The system consists of a combination of long-haul facilities throughout Latin America, interconnecting principal cities and interfacing with international systems. A proposed configuration of ITN has been completed by the Inter-American Development Bank and 1973 has been set as the target date for complete integration of the network. To accomplish this, an order of priorities has been established, involving the construction of domestic links by the various countries, and the closing of gaps between the countries, under the United

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Nations Development Program. Nearly all these projects are expected to use microwave radio relay. The ITN also plans to use INTELSAT satellite circuits for international communications. Five of the planned earth stations, Argentina, Brazil, Chile, Mexico, and Panama, are expected to be in operation by the end of 1968. Three others, Colombia, Peru, and Venezuela are scheduled for operation by the end of 1969. (However, the cost of present INTELSAT satellite circuits is high and they will be used in ITN only for distances beyond 2500 kilometers.)

Taking into account costs in addition to ITN that would be required to provide additional service to towns and cities covered by our illustrative satellite application, we derive the rough estimates shown in Table 3. If we assume that ITN is a "sunk" cost, the additional cost of including a one-channel TV capability in the planned ITN system, and the cost of spur-routes to include additional cities not covered by ITN (but covered by the satellite system), can be considered a fair approximation to a terrestrial system comparable to the satellite systems described above. At the right in Table 3, an additional cost of over $100 million or $200 million would be involved,

depending on whether 125 or 528 cities and towns are covered. Our cost estimates of microwave extensions are gross extrapolations of cost estimates given by Page in Appendix B for a system of lower capacity. These figures compare respectively to $80 million and $165 million for the satellite. Thus, if we presume that in any event ITN will be constructed, adding the satellite would show some advantage, according to our estimates, since expansion of ITN would involve a somewhat higher additional cost than if the satellite were to do essentially the same job.

At the other extreme, if we assume that no portion of ITN must be taken as given, then a satellite cost of $80 million to cover all cities in excess of 50,000 population would amount to far less than half the cost of an equivalent terrestrial system, since the latter would run to several hundred million dollars.

However, it is safe neither to assume that all of ITN is sunk cost nor that a satellite could be substituted for all of ITN. As it now exists, ITN represents a mixture of on-going construction, firm plans, attractive prospects, and hopes. We do not mean to imply that plans for ITN should be scrapped and a satellite substituted. What we do suggest

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is that the prospect for satellites merits careful appraisal as part of a mixed satellite-terrestrial network in Latin America.

Table 3

INVESTMENT COST OF SATELLITE VS TERRESTRIAL MICROWAVE
(Millions of Dollars)

Capability	Satellite	Terrestrial System in Addition to ITN
All cities above 50,000 (125 points)	$80	over $100
All cities above 10,000 (528 points)	$165	over $200

It is important to bear in mind that both satellites and terrestrial microwave have advantages and disadvantages not adequately reflected in the rough cost estimates of Table 3. On the one hand, the microwave has an advantage in that once a right-of-way is established between two given points, circuit capacity may be added to system at small additional cost. In other words, once major cities are linked together by microwave, smaller cities and towns along the microwave route can rather easily be tied in. For this reason the comparative terrestrial cost in Table 3 depends

heavily on whether or not we assume the existence of ITN. In contrast, the total satellite system capacity is fixed by the initial design and spectrum allocation, thus inclusion of additional intermediate points in the satellite system might require either a new, larger satellite or the use of two or more satellites with added interconnection problems. Another advantage of microwave is that the time delay for telephone conversations is significantly less -- a particularly important consideration in carrying international satellite traffic into the hinterlands.

On the other hand, a satellite has several advantages over microwave. First the reliability of service would be higher. If a ground stations goes out of commission, only traffic to and from that station is affected. Furthermore, since each station is in a well-populated area, probably with good transportation and other supporting facilities, it could be repaired and maintained rather easily. But if a microwave relay station goes out the story may be quite different. Not only are all stations up the line knocked out of the network during the outage, but long repair delays are involved if the relay is located in one of the many

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isolated areas of South America (say, in the Amazon jungle, several hundred miles from the nearest major town).*

Secondly, the satellite is more flexible to use than microwave. The capacity of a microwave system is fixed between any two points. Moreover, that capacity in the chain of relays between these two points. In contrast, the capacity of a satellite system can be shifted around under rather broad constraints to meet peak load demands. This flexibility would be very attractive in a South American regional environment. For example, since the school year in the northern tier of countries is reversed from that of the southern countries (though there is some overlap), a TV channel could be shifted from the southern horn of the continent to, say, Colombia and Venezuela to give them two rather than one TV channel for daytime classroom use during a large part of the school year. And then both channels could be shifted to the southern horn during the rest of the year for instructional use there. Or a channel used on Saturday morning for interactive teacher training, say in

*Of course reliability of the system crucially depends on reliability of the satellite itself. However, in view of the spare satellite backup included in the cost estimates of Table 2, and in view of the high operational reliability already demonstrated by existing satellites, we would hardly expect a problem on this score.

Argentina, could be shifted up to Venezuela for a similar application on Saturday afternoon. With three time zones on the continent, we would also expect that peak loads for telephone service would vary from one country to another, affording attractive opportunities to mesh peaks and troughs in traffic flows. All in all, the nominal capacity of a satellite would permit a higher total volume of traffic (perhaps by a factor of two or three), than would a microwave link of equivalent nominal capacity.

The satellite system would also have greater flexibility in another sense: because small ground stations are easily transportable they could be moved from city to city as needs evolve in the course of economic development. During the first stage, stations could be put in the widely scattered major cities described above. But as population grows and many intermediate points between these cities become important as industrial and commercial centers, microwave nets might expand outward to include these points. As the microwave system grows to include cities that were provided satellite service in the first stage, the ground stations could be moved to a second group of towns smaller and more remote than the first. Thus, the satellite system

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could be used through time to provide a highly reliable early capability, moving further and further into the hinterland.

E. The Crucial Factor of Regional Coordination and Cost Sharing

Over the next 5 to 10 years at least, the large economies of scale inherent in satellite technology can be exploited best if the system is shared among a number of the smaller, less developed countries. With the possible exception of Mexico and Brazil, it may be grossly uneconomic for Latin American countries to orbit satellites separately to serve their own telephone and television needs. In addition to earth terminals, a minimum orbiting system (perhaps 4.5 million for a launch vehicle, 3 million for a satellite, plus backup and replacements) is a large initial investment. As technology progresses and traffic demands grow in the more distant future, it may become economical for separate small countries to have their own systems. In the foreseeable future, however, the economic appeal of satellites rests largely on the condition that the system be spread over a number of countries.

But sharing a satellite system among a number of countries would obviously require a high level of cooperation

among them. The kinds of examples noted above -- using a TV channel for training during a morning in one country and then shifting it to another country for the afternoon or shifting satellite capacity around the region to mesh peaks and troughs in telephone service -- would require clear and workable agreements among the participants. Even before that, in the design of the satellite itself, agreement would have to be reached on its size, design characteristics, and other parameters. No less important, agreement about ground station characteristics to ensure compatibility among themselves and with the satellite would also have to be negotiated. In the illustrations above we have merely assumed a satellite with perhaps 2,000 voice channels plus one TV channel in each beam. But quite possibly more or less would be desired by the cooperating countries. Perhaps a much larger satellite or several satellites would be required in the near future to serve the many attractive uses to which satellites can be put. But what precisely the capacity of the system should be, how that capacity should be shared among users, and especially how costs should be shared among countries and among services would have to be carefully defined. A host of other agreements would

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have to be thrashed out on such matters as launching arrangements, satellite backup and spares, and procurement guidelines.

Of basic importance to satellite use is the need for a special degree of international cooperation differing substantially from the more traditional form of cooperative arrangements that govern terrestrial alternatives such as cable and microwave relay. Participating in a satellite system that provides domestic service, a country would become dependent for its domestic communications needs on facilities over which it does not have total control. The reliability and capacity of communications links, the cost burden borne by the country, the time phasing of the services, and other matters would depend partly on the actions of other countries -- what kinds of services other countries desire; whether agreement is reached about common procurement of ground stations, etc. In contrast, a microwave system built for domestic use would be entirely under the control of the national government. Though, as suggested earlier, microwave might involve a total cost considerably greater than that of satellite, the country would be free to choose its own hardware, build microwave links whenever

and wherever it pleases, and provide whatever services it desires.

The best solution might well involve INTELSAT establishing and maintaining the satellite portion of the system. In this case INTELSAT would procure and place in orbit the satellites (tailored to the needs of its users), provide backup satellites and other facilities, undertake the telemetry and control functions and, in general, perform all other tasks associated with implementing and maintaining the space segment. Each user would reimburse INTELSAT for its share of the space segment in proportion to use, while it would own and operate its own earth terminals. Thus, the presently planned INTELSAT Atlantic system would provide direct links between major Latin American cities (having the large INTELSAT ground stations) and points on the North American continent, Europe, and Africa. The regional satellite would (1) link the many cities with the larger INTELSAT stations in order to funnel traffic to and from these more remote points into the intercontinental network, and (2) provide direct links for both interregional and national traffic among the whole set of cities and towns in the regional system.

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Using INTELSAT has several advantages, not the least of which is that it is an organization with many members. While each participating country would necessarily face the prospect of not being in complete control of its telecommunications facilities, as noted above, it would at least have the assurance that responsibility for the space segment would be shared by many members with little risk that the organization would become dominated by one or a few potentially unfriendly neighbors. One might imagine a small country being reluctant to join, say, a four-nation group to put up a satellite, on grounds that such a group is bound to be dominated by the largest one or two members. If, on the other hand, membership were much larger, including even countries not directly involved in using the satellite system, the attraction of participating might be markedly enhanced.

Another advantage of an INTELSAT arrangement is that it would promote full exploitation of economies of scale as technology continues to advance. In our studies, we have presumed a separate satellite would be required to adequately serve a continent the size of South America. With the kinds of technology available in the 1970's and in the light of

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anticipated domestic and international demand, this is probably a safe assumption. However, as technology advances in the more distant future it may become technically feasible and economically attractive to serve a variety of domestic, regional, and intercontinental needs throughout the Atlantic basin from a single satellite. Thus, a satellite over the Atlantic, with many separate, narrowly focused beams, might simultaneously provide domestic and regional service both to Latin America and Africa while providing intercontinental links among all major points, including the dense routes over the North Atlantic. If this approach eventually proves attractive, as a way to reduce unit costs to all users, working through INTELSAT from the outset would facilitate its adoption.

The prospects for regional cooperation in the use of satellite will be enhanced if, as discussed more fully in another chapter of this report, the 1969 INTELSAT definitive arrangements establish a flexible framework within which the specialized satellite needs of groups of members -- as well as individual members -- can attractively be met. Such a framework would facilitate regional cooperation in the use of satellites by all countries, regardless of their stage of development.

F. Multi-purpose Versus Single-purpose Facilities

As a consequence of large economies of scale, the appeal of a satellite system of the sort described above depends very much on its simultaneous use for a number of services -- telephone, record, and television -- rather than being dedicated to only one. In this way large costs of the system could be shared to reduce unit costs.

In contrast to the multi-purpose approach, it has often been suggested that satellites be used for educational and instructional television in the less developed countries. For the near term at least, we think a system dedicated to such a single purpose makes little sense. If a country or group of countries goes to the trouble of designing and orbiting a satellite (with suitable backup) for this purpose, it would be unwise not to use the system for other services as well. Conversely, if a satellite system were emplaced for telephone use, it would provide a capability for distributing television programming at small additional cost. We must emphasize again that any application of satellites to educational and instructional

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television faces severe software problems, discussed at length in Part IV.

To be sure, as markets expand in the future it might become economical to have special dedicated systems that would exploit most or all the economies of scale in satellite technology. In the United States, for example, the market for television distribution is already large enough for a satellite system dedicated solely to television to be economical. But the less developed countries are far from that situation.

G. The Question of Efficient Spectrum Use

A potential problem in using small-antenna earth terminals, on which Tables 2 and 3 are based, is that satellites sharing the same frequency bands would have to be separated by greater distances in the orbital plane. The smaller the diameter of the ground antenna, the less the ability of the antenna to discriminate between adjacent satellites sharing the same frequencies, and the greater the distance that must be maintained between satellites to avoid interference. Since synchronous satellites are limited to the equatorial plane, considerable concern has been expressed about the potential "shortage" of

orbital parking slots that would result through use of small antennas on the ground.

For several reasons, we doubt that this problem will become serious in the foreseeable future; and that it would be unwise -- if not downright silly -- to discourage use of small, earth-terminal antennas (and hence deny the benefits of the new technology to millions of people) because of a fear that orbital space will someday be in short supply.

First, the orbital space that would be most useful for the South American continent would fall conveniently between the longitudes most useful for U.S. and Canadian systems on one side and latitudes most useful for an INTELSAT transatlantic system on the other. The best positions for U.S. and Canadian satellites would be over the Pacific Ocean to the west of Ecuador. The best position for transatlantic satellites with good coverage of Western Europe is near the bulge of Africa. The 45 degrees of longitude directly above the South American continent would not overlap these areas.

Secondly, even with small ground stations, this 45 degrees of orbital space would provide enormous capacity -- far greater than anything we can envision being needed by 1980. With the 15 to 20-foot diameter antennas in our previous illustrative cases, less than 4 degrees of space would be required between satellites. In addition, since satellites cannot be held in orbit precisely, some safety margin would have to be included to account for drift. Let us include another 3 degrees, for a total of 7 degrees as sufficient for each satellite. In this case, there would be room for at least 6 satellites over the South American continent.

Of course, as traffic grows in the more distant future, and as many countries find it economical to use their own satellites, orbital space might become increasingly crowded. But we must remember that during the same time technology will also advance to afford more efficient use of spectrum. As larger antennas are put into orbit and station keeping is made more precise, narrower beams can cover selected portions of the earth and permit re-use many times of the same spectrum space around the world. For example, a satellite covering only the southern horn

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TABLE 4

RADIO FREQUENCY ALLOCATIONS

Item	Freq. (MHz)	Link	BW (MHz)	Flux Density Limit Applies	Shared with:	In the U.S: Amateur, Commercial or Government
1	3400-3500	Down	100	No	Amateur & Government	G/A
2	3500-3700	Down	200	Yes	Fixed & Mobile Radio Location	G.
3	3700-4200	Down	500	Yes	Fixed & Mobile	C.
4	4400-4700	Up	300	Not Applicable	Fixed & Mobile	G.
5	5925-6425	Up	500	Not Applicable	Fixed & Mobile	C.
6	7250-7300	Down	50	No	Exclusive	G.
7	7300-7750	Down	450	Yes	Fixed & Mobile	G.
8	7900-7975	Up	75	Not Applicable	Fixed & Mobile	G.
9	7975-8025	Up	50	No	Exclusive	G.
10	8025-8400	Up	375	Not Applicable	Fixed & Mobile	G.

Source: Appendix B, p. 3-6

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of South America could use the same spectrum space in the same orbital slot as a satellite covering portions of the United States or Canada without mutual interference. Likewise, a narrow-beam satellite covering southern Africa would not interfere with a similar beam covering Europe.

Moreover, the illustrative examples so far have been predicated on the assumption that frequency space is confined to the 500 MHz in the 4 GHz and 6 GHz bands (Item 3 and 5 in Table 4) that today are used by INTELSAT. However, by existing international agreement several thousand additional MHz shown in Table 4 are available for satellite applications. Were this additional space employed for commercial purposes, potential satellite communications capacity could be multiplied severalfold.

Finally, in the yet more distant future frequencies about 10 GHz may become usable for satellites, and this would increase by many times over the spectrum availabilities shown in Table 4.

All in all, while the growth of regional and domestic satellite systems will require careful coordination among countries in terms of spectrum usage and orbital slots, we see no serious inherent difficulty in the emergence of

satellite systems operating with relatively small ground stations.

III. ILLUSTRATIVE APPLICATIONS IN INDIA

Of course, it is dangerous to generalize the results of our illustrative South American case to all less developed regions. The Latin American countries as a group are rather well off in comparison to the countries of Africa and Asia; their transportation and telecommunications systems are far better developed, personal incomes are higher, and the population is much more urbanized. Therefore, in addition to the regional approach we pursued in Part II, we have also examined briefly the possibilities of applying satellite systems to a single, large, less developed country -- India. This work represents the combined efforts of the Central Staff and one of the two studies of SRI, "Communication Satellites for Education and Development -- the Case of India" (Vol. II).

A. Contrasts to the South American Case

Designing a communications network is much more challenging in India than in the earlier regional case. We saw previously that by connecting all cities in excess of 10,000 population the system would include directly

about 47% of the population of the 10 South American countries. In India, only about 20% of the population live in urban areas. The remaining 80% live in the approximately 568,000 villages scattered about the country. Only 10% of these villages now have electricity and only 20% are expected to have electricity by 1974. No more than half are connected by roads to the outside world.*/

In contrast to the many television broadcasting stations and the numerous TV sets already in the hands of the public in Latin America, only one television station exists in India. Located in Delhi, the station has operated experimentally since 1959. It programs 21 hours a week to schools, teleclubs, and 79 nearby villages recently equipped with receivers. The total number of receivers is estimated at 6,000 to 7,000, all within the broadcasting radius of this one station. Radio, although substantially more

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*/ The staggering problem of India's population growth is, of course, well known. With a population of about 500 million (which will grow by 11 million in 1968) India has a population density of over 400 per square mile -- seven times that of the U.S. and 16 times that of Brazil.

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developed, reaches only about 52% of the land area of India, and only about 70% of the country's population, with about 8 million receivers.

The telephone and telegraph industry is also in its infancy. About 1,400 miles of microwave and 3,000 miles of coaxial cable are included in the long distance links. The ratio of telephones to people is roughly 2 to 1,000. An experimental satellite communication earth station operates near Ahmedabad. India is building a ground station near Poona as part of the INTELSAT global system.*/

Finally, and especially important: being a single country, India would not pose the difficulties of international cooperation discussed earlier; but it is severely fragmented in terms of language and culture. Fifteen official languages exist, 13 of them spoken by more than 10 million people. Sixteen unofficial Indian languages

*/ The one medium where the characteristic underdevelopment is not apparent is in films. India has one of the largest film industries in the world, producing an average of 320 films a year for an annual audience of a billion.

Table 5

MAJOR LANGUAGES OF INDIA

Language	Regions where spoken	Thousands of speakers
Assamese	Assam	6,804
Bengali	West Bengal	33,754
Gujarati	Gujarat	20,106
Hindi	Northern States	123,025
Kannada	Mysore	17,306
Kashmiri	Kashmir	1,904
Malayalam	Kerala	16,995
Marathi	Maharashtra	32,767
Oriya	Orissa	15,610
Punjabi	Punjab	9,867
Sindhi	Enclaves of persons relocated from West Pakistan	1,472
Tamil	Madras	30,465
Telegu	Andra Pradesh	37,643
Urdu	Northern States	23,323

Source: SRI Report, Volume II, page A-8

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are spoken by more than half a million people each. Altogether, there are over 800 recognized languages in India. Table 5 lists the major languages and regions where spoken. It discloses that the most important single language, Hindi, reaches only about one-third of the people. With Urdu, to which it is closely allied, it reaches about 40%.

Diversity in basic cultural patterns is greatest between the Dravidian peoples in the south and the Aryan cultures in the north; in addition, there are many Sino-Tibetan cultures in the north and pockets of Austrec culture. With respect to religion, 84% are Hindu, 11% Moslem, 2% Sikhs, 2% Christians, smaller numbers Buddhist and Jain (even these groups number in the millions). The 17 separate states and 13 Union Territories contribute additional heterogeneity and fragmentation.

B. The Special Promise of Television

In one sense India's needs for telecommunications development are similar to those of Latin America. Development of a reliable telephone and telegraph network would undoubtedly contribute strongly to economic growth by facilitating expanded and more efficient business trade relationships among firms and individual productive

activities scattered about the country. But beyond that, the growth of television in India may be especially important in reaching the masses of illiterate people presently remote and cut off from the mainstream of modern life.

For this reason the SRI report focuses largely on the potential benefits and the problems of developing a national television service by satellite and other means. It identifies several major areas of promising applications of television:

National Integration. The extraordinary heterogeneity of India makes understandable the virtual consensus among Indian leaders that national integration is first and foremost in the process of modernization. Of course, no one believes that from this rich mix of apparently independent cultures can come or should come a homogenous mixture; rather the hope is for the creation, within diversity, of an underlying sense of national unity powerful enough to take precedence over purely individual or regional interests.

When one searches for a mechanism to attain this "first and foremost" essential to Indian development,

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it is difficult to find any except a nationwide mass communications system that has any real chance of stimulating integration within the foreseeable future. Television's great contribution, as emphasized in the SRI report, is its ability to give Indians an opportunity to share common experiences. No Indian leader has ever been able to communicate to all of India; with television he could do so, frequently. Mass participation in the major events of national life would be possible. An understanding of the other cultures of India could for the first time be realistically attempted. The knowledge needed to arrive at great national decisions could be made common to all, and in the context of the national good rather than purely on regional grounds. And the "bridge" language of India could begin to be taught by television, both through entertainment and news programs and in formal instructional programs.

While other media might be considered to serve this goal, printed media is handicapped by the pervasive illiteracy, films by the necessary time lag (and their infrequency), radio by its inability to show as well as to

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tell. Only television could serve the eyes as well as the ears, surmount the literacy barrier, and be timely as well.

Upgrading and Extending Education. There has been great quantitative progress in education in India since independence in 1948. Primary school enrollment has increased from 19 to 52 million; middle school enrollment from 3 to 11 million; secondary school enrollment from 1 to 5 million. The number of teachers in India has doubled, there are many more schools, and educational expenditures have quadrupled. There are now 70 million students in India's school system.

However, India shares with other developing countries very serious concerns about the quality of education. The Indian Education Commission Report of 1966 noted that nearly two-thirds of all children who entered the first grade in 1960 had by 1966 still not progressed as far as the sixth grade, and that two-thirds of those who drop out do so in the first grade -- leaving them functionally illiterate. The ratio of teachers to primary school students is now 1 to 49, having deteriorated from a 1 to 35 ratio in 1951. Twenty-nine percent of India's primary school teachers are classified "untrained," which means they have

not had teacher training at the secondary school level. And the proportion of untrained teachers is expected to rise, since a need is forecast for 779,000 additional elementary school teachers and 209,000 secondary school teachers for the period of 1966-1971, while only 70,000 are now in teacher-training colleges.

There is other evidence that those going through the system are receiving education that is inadequate. Fifty-five percent of the students who took the university matriculation examination in recent years failed, as did 40% of those who took a higher secondary examination. There is also widespread concern about relevance of the curriculum and career goals. The child is groomed and advanced along the path whose natural destiny is a degree granted by a university. Hence the system is relatively indifferent to career needs of the vast majority of young people who will acquire some education without a degree. As in every situation where teachers are poorly trained and where opportunities for expert supervision or assistance are few, teaching is characterized by the deadening technique of rote memorization. Accordingly, the 1966 Education Commission report placed major

emphasis on upgrading the content of instruction. The Commission stated three related goals:

(1) All levels of education must do more to relate education to productivity, through programs of science education, vocationalization, and work experience.

(2) The educational system must contribute to national and social integration through purposeful programs.

(3) Teacher training school curricula and use of available facilities must be improved.

To accomplish this, and to accommodate expansion, the Commission recommended a 7-fold increase in educational expenditures by 1965.

Whether use of television is feasible on a national scale to upgrade education will be discussed later. Here, we note that potentially television can be used to achieve the "radical alteration in the methods of teaching and in the training of teachers" that the Indian Education Commission believes necessary. It could introduce new curricula, reduce the isolation of the teacher, increase the effectiveness of the teaching-learning process, and provide an experience of learning-through-seeing now lacking. A

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combination of television and partly trained teachers can potentially provide a high quality of education, compared to that now delivered. Perhaps most fundamentally, as the SRI Report notes, television could serve, as it has elsewhere, as the basis for a review of educational goals, content, and technique.

Of necessity, television brings with it a new kind of administration -- requiring more centralization, using a larger proportion of standardized and commonly shared learning experiences, greater flow of feedback from individual schools and students to the curriculum-makers, and in general a broad-based cooperative team approach to the teaching process. There is reason to hope that these characteristics can invigorate the educational system as nothing else on the horizon can.

Moreover, in other countries television has demonstrated its ability to motivate students, to reduce dropouts, and to reduce the dependence of expansion on the supply of trained teachers. The combination of a less well-trained teacher and television instruction can, if well done, at least equal the teaching effectiveness of an average well-trained teacher. Television can also

provide opportunities for adult education. While formal instruction may still require a teacher, many countries have found that effective adult education can take place in situations where the classroom leader is not a trained teacher, but rather a monitor who organizes classroom activities -- either with instructions through other communications (such as telephone feedback as mentioned on p. 19), or by combining television with correspondence instruction to provide feedback and direct contact with the skilled teacher. The cost of such extensions of education is not trivial; many of them, such as providing a classroom and some sort of teacher, are independent of whether or not television is used.

Again, the SRI study does not detail the costs of administrative structures for such an expansion. It is apparent that a thorough analysis would be required for any sizable program. Multiple channels would be needed for widespread extension of formal classroom education. However, even with the modest one channel it could be possible to expand educational opportunity at certain levels, such as for the first two grades or for middle secondary school. And even with one channel, basic

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adult education would be possible for millions now without such opportunity.

About three-quarters of India's population is illiterate. Currently, about 500,000 adults are becoming literate each year through special programs. This is three-tenths of 1% of the adult group. Unless vastly more resources are put into the effort, or new techniques such as television used, no significant progress will be made in the near future. Certainly as the percentage of students with enough formal schooling to provide literacy increases, as it is doing, the problem will slowly become less acute. As we have seen, however, large percentages of students now drop out in the first grade, before achieving any semblance of literacy.

A nationwide television system could help in at least four ways: First, it could serve as it has in Italy, Niger, and other places as part of a monitor-plus television instructional team in a formal program teaching adult illiterates. Second, it could be a powerful motivator to the people to do the things necessary to gain literacy -- join a formal group, organize to get a literacy teacher, study themselves, etc. Third, it could have an informal

role in teaching rudimentary literacy to the population as a whole. We have no experience to gauge how effective this could be in the absence of formal programs, nor do we yet know how to do it to maximize effectiveness. There is little question that it is less effective than formal literacy campaigns. But with limited goals and with recognition that the percentage of the population effectively taught will be limited, it might prove a fundamental first step toward full literacy and modern attitudes for many millions of people.

Fourth, television could assist in the most difficult problem surrounding adult literacy -- the maintenance of literacy once attained. Many studies have demonstrated that most participants in literacy campaigns become functionally illiterate within a year or two after the campaign ends, apparently because of little opportunity to use their skills -- not much to read and little reason to write. It would not be difficult to develop programs to serve as an electronic book or newspaper by giving illiterates constant reading practice. In India, of course, the language diversity would require

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such programs in many different languages, unless one of the bridge languages, Hindi or English, were used.

Strengthening the Vocational and Technical Component of Education. Clearly, Indian education must be made more relevant to employment needs and opportunity. India has one of the lowest percentages of secondary students enrolled in vocational courses of any country in the world -- 12% as opposed to 60% in Japan and 70% in West Germany. Like most developing countries, India is in critical need of middle-level personnel, the supply of which paces the rate of industrialization.

A severe shortage of technical teachers exists, and the cost of vocational education is, according to SRI, at least 50% more than for general education. And as the report points out, technical education to be effective should have a much improved base in general education at the lower grades, and must be accompanied by drastic change in attitudes toward vocational work. So the problem is partly one of reviewing the direction of the curricula and partly one of providing special services for vocational classrooms.

Television could markedly improve mathematics, science, and technical teaching throughout school years. It could share the best vocational teachers with schools having poorly prepared teachers or none at all. It could distribute training films and films on science and employment opportunities. The SRI report also suggests the interesting possibility of showing students what employment is like in areas of national need that they would otherwise never consider. Of vital interest is what such efforts might do to bring schools as a whole more into touch with employment realities.

Modernizing Agriculture. The urgent need for increased agricultural productivity in India is well known. The availability of new cereal varieties and improved fertilization and cultivation techniques makes possible far greater crop yields. These are beginning to be realized in India, and there is new hope that within 3 years India will never again have to depend on food imports to ward off famine.

Introduction of these new materials and techniques has been due largely to the effective use of 40,000 village-level workers, one for every 5 to 10 villages

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with about half the Indian villages being reached. While the current agricultural information service has been demonstrably effective, there seems little doubt that the future role of the development worker could be strongly supported by television.

The utility of television goes beyond its ability to communicate information on planting techniques, diseases, marketing methods, etc., to the farmer and to the field agent. It has the additional virtue of being able to demonstrate what has been done with such crops and techniques in other places. And it does so in a continuing way, beyond the capacity of films or direct contact with agricultural workers.

As mentioned earlier, a small pilot television project operates in 79 villages near New Delhi. Each village now receives two 20-minute programs a week. "Teleclubs" of about 20 farmers have been organized in each village to provide a continuing organized force for implementing the changes and procedures discussed on the television programs. As the SRI Report describes it,

> The first item in each program is a series of answers sent in by the teleclubs, and reports of actions initiated in the villages. Then comes the main part of the program: a farmer and an agricultural expert discuss the topic of the day. There is little or no lecturing. Most of the footage is filmed in the field, showing actual problems and their solutions, which are discussed by the two spokesmen. Finally, if the time is available, there is a brief segment of rural dancing and singing of folklore. /p.62/

Other contributions to rural life. In a personal interview, the Prime Minister of India emphasized to the authors of the SRI Report that one of the most important tasks of television would be to make the village a better place to live, and thereby enable it to retain the more ambitious and better educated young people who now live there. This implies that television, if available widely in Indian villages, would be used both for information and development programs and for the kind of entertainment that could make the village a more rewarding place to live.

Clearly it would lessen the isolation of the village. However, there is no systematic evidence on the effect of television on mobility or satisfaction. Experts disagree on whether mobility in most developing cultures is a stimulant to development or, on balance, a deterrent. But aside from these unresolved questions, undoubtedly television could have an extraordinary stimulating effect on the

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social and intellectual ambience of hundreds of thousands of isolated Indian villages, which together constitute the backbone of the country.

To introduce so drastic a change in the pattern of life of most people would of course, impose an obligation to provide the most imaginative programming and to integrate it with other attempts to improve the quality of life. Unfortunately, the spectre of hundreds of millions of people paralyzed each evening in front of the "idiot box" cannot be dismissed. While we cannot judge the benefits and the deficits of such phenomena, we emphasize that the concern is real and that India or any other country is well advised to control evening television programming carefully until its effects on social and work patterns are determined. Beyond this, we can only conclude that some regular television programming several evenings a week in the local language has the potential to substantially improve life in the Indian village.

Family planning. Family planning is of course one of the chief Indian priorities, aimed at lowering the annual population increase from 2.5% to somewhat over 1%. The goals of the family planning program are: first, to

persuade couples of reproductive age to limit family size to three children; second, to provide local family planning services. The campaign has not gone well. Only 1% have accepted the promulgated methods.

The basic problem seems to be that no way exists to satisfactorily reach with a persuasive campaign the nearly 100,000,000 couples of reproductive age. According to the SRI report, family planning experts in India are not hopeful that television could arrive in time to do any good. Yet, is there any faster and feasible way to do it? A persuasive argument, in our view, for rapidly establishing a nationwide television system is to ask where India would be today in its family planning efforts if it had access to such a system 10 years ago. Will this same question be asked 10 years from now?

C. Alternative System Designs

Satellite vs. terrestrial. Unlike South America, we do not have demand requirements or costs of terrestrial systems against which to compare a multi-purpose satellite system. However, SRI does consider a network model for television only, operating within a 20-year time frame, and eventually covering about 84% of the population. In

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this context, SRI considers four alternative systems: a ground-based microwave network, a direct-broadcast satellite, a satellite system with rebroadcast of the signal from the ground, and a combined ground-based/direct-broadcast satellite system.

A notable aspect of the SRI analysis is that the total investment and operating cost over the 20-year period for each system does not vary greatly, despite the large technical differences in the four systems. The most expensive (ground-based) at $756 million is less than 20% more costly than the least expensive (direct-broadcast satellite) at $636 million. In view of the great uncertainties inherent in all these systems over such a long period, this cost difference is more or less lost in the static. A major reason for the small differences between systems is simply that in an expanded system with large numbers of TV receivers, the cost of receivers themselves is a large part of the total, and receiver cost is largely independent of the manner in which programming is distributed.*/

*/ Of course, for the direct-broadcast satellite an additional cost is involved in the augmented antenna required for direct reception; this is more or less offset in the SRI figures by the saving in land rebroadcast stations.

Thus, SRI estimates that for the rebroadcast satellite 985 thousand receivers would be needed at an estimated $240 each. This would take an investment of nearly $240 million -- well over half the 20-year investment cost of $433 million for the direct broadcast satellite system.

Another notable aspect of the SRI analysis is that the total annual cost of any of these systems would be a small percentage -- less than 2% -- of India's projected expenditure on education. For the system combining satellite and ground-based television, Table 6 shows the projected growth in national income, expenditures on education, and annual cost of the system at four future periods. Cost of the television system as a percentage of education expenditure, shown on the last line, rises from .35% to a maximum of 1.4%. If the television system were combined with telephone and other telecommunications in a multipurpose network as discussed earlier in the South American case, the percentage would be even lower.

In illustrating such figures, however, bear in mind that major problems are associated with developing and successfully operating a widespread television system in India -- problems whose magnitude cannot be neatly

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Table 6

COMPARISONS OF NATIONAL INCOME, NATIONAL EXPENDITURE ON EDUCATION, AND ESTIMATED ANNUAL COST OF EXPANDING TELEVISION OVER INDIA BY A COMBINATION OF SATELLITE AND GROUND-BASED BROADCASTING, PROJECTED OVER 20 YEARS

(in $ billions)

	1970-71	1975-76	1980-81	1985-86
National income	37.5	50.1	67.1	89.7
National expenditure on education	1.3	2.1	3.3	5.3
Annual cost of establishing and operating national television	.0046	.0193	.046	.0656
Education expenditure/ national income	3.4%	4.1%	5.0%	6.0%
Cost of national television/national income	.012%	.039%	.069%	.073%
Cost of national television/education expenditure	.35%	.91%	1.4%	1.2%

Source: SRI Report, Volume II, p. 199.

quantified within the framework of a conventional cost analysis. They include both hardware and software aspects which we shall treat in turn.

Hardward Problems and the NASA Pilot Program. One of the most obvious obstacles in carrying television to a large percentage of the population is, of course, the operation and maintenance of receiver sets in far-flung villages and schools.*/ As mentioned earlier, 90% of the 568,000 villages lack electricity and one-half are without roads to the outside. Even in the 79 villages now equipped with television receivers, all within a 25-mile radius of Delhi, 10% of the sets are reported out of order normally, and up to 25% do not function during the monsoon season. Therefore, we cannot realistically expect any near-term system to cover more than a small percentage of the population. In the first instance, many isolated and distant villages will remain isolated and distant. This is no less true of television than of other telecommunications. The problem of receiver set operation and maintenance especially

*/ SRI estimates that each television set would require servicing on the average of six times a year.

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handicaps the direct-broadcast satellite whose main attraction is its ability to operate into small "rooftop" antennas for schools and villages in remote regions without electricity, roads, or other infrastructure.*/ The places where sets can be tolerably well-maintained, in and near urban centers, are precisely the areas where conventional television broadcast, tied either to a satellite or microwave system for program distribution, is a strong candidate.

For these reasons, an initial satellite system for India might strongly resemble the system described earlier for South America -- a satellite with several video channels and several thousand voice channels covering all cities over, say, 100,000 population. Today, 73 cities are in this category, all with electricity and tolerably good transportation. Television could be relayed from several programming sources about the country via satellite to ground

*/ Electricity can, of course, be supplied by portable generator. But the additional cost (perhaps $100 multiplied by the thousands of locations), and the additional maintenance requirement that the generator itself would impose, do not make this an attractive near-term prospect.

stations in separate subregions from which signals would be rebroadcast to these cities and surrounding agricultural areas, in the conventional manner. On a time-shared basis, a satellite with 3 video channels can provide 35 hours of broadcast time a week to each of 12 language groups. With such a multi-channel capability, SRI concludes that heterogeneity of language is not an insoluble problem for use of satellites in support of education and development. Of course, as in the South American case, the system could be expanded through time with much larger satellites and more ground stations as the ability to use and maintain the system grows.

A promising step in moving forward is the planned experimental use of a NASA satellite for television in India (a description of which is appended). The project was conceived about 3 years ago when NASA recognized that the ATS satellite series would, early in the 1970's, permit experimentation with television broadcasting over a controlled area into augmented home TV receivers. Studies have shown that such modification can be accomplished at costs ranging from $150 to $500 or $600, depending on the numbers produced, location for use, and similar factors.

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The experiment will offer India an important and useful domestic tool for national cohesion. It will provide a first and major test of educational television for the practical instruction of illiterate adults. (The evaluation plan is to emphasize quantitative tests of practical effectiveness in reducing birth rates and increasing agricultural productivity.) The experiment has already stimulated a domestic TV manufacturing enterprise in India with important managerial, economic, and technological implications. Above all, it should provide valuable information and experience for future application of educational programs elsewhere in the world.

Problems of Software. The most serious problems in using TV for education and development are not intimately connected with either satellites or alternative ways of transmitting signals over long distances, with television receivers, or with the rest of the hardware. Rather, they involve a host of software factors: developing good and effective programming, getting support and cooperation from schools and teachers, organizing and training people to use television effectively, and many others. As observed in

the SRI report:

> it will be evident, on reflection, that most of these are television, rather than satellite, questions. No matter how television is delivered, any major expansion of it will require a large capital investment and considerable operating costs; hiring or training of a large number of skilled personnel, both on the program and technical sides of the operation; an increase in the present technological capability to manufacture and maintain receivers; attention to problems of control and organization that are not bothersome so long as television exists in miniature in one city only; and new challenges to the programmers, educators, and national development agencies that plan to make use of television. /p. 74/

For one thing, an essential element of the required social infrastructure would be to develop thousands of trained broadcasters, engineers, and technicians. The experience of other countries suggests confidence that these kinds of people could be trained, but the build-up would have to be gradual.

More difficult is the task of training "utilization experts," who serve in the field as village-level organizers, advisers, and feedback/coordination links. For action-oriented applications like agricultural development, these people are crucial because of the need to maintain an organized group at the reception point. They are also essential to formal instructional use of the medium, since

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teachers require supervision and assistance, and since the complexity of the logistic and feedback system requires troubleshooters. At this time, the largest such group -- the 40,000 village-level workers -- functions mainly in agricultural development. That group alone would have to be substantially increased if, say, 80% of the villages were ultimately being reached with major agricultural education programs. In addition, the numbers involved for successful educational use would probably exceed 50,000.

The area of greatest difficulty, however, involves overall organization and administration. Television systems not only require coordination of large numbers of people in various specialties, many of whom will be dispersed over large and remote areas, they also require a degree of efficiency and precision in operation rarely found in a less developed country: programs must appear on time, schedules must be known in advance throughout the country, supporting materials must be supplied on

time, and technical interruptions of services must be minimized.*/

This is not to say that the task is hopeless. Rather, it says that television development will have to proceed slowly. Starting with urban centers, the system would expand into remote areas as transportation, electrical networks, communications links, the pool of trained people, and other elements expand in parallel. The potential contribution of the satellite is to provide one of the ingredients.

Within the South American and Indian context, the prospects for using television for educational and instructional purposes are very good. On the other hand, prerequisites for its effective use are numerous and not easily attained. Moving outside the illustrative examples, the next section of this paper, Part IV, is devoted to a more general analysis of these prospects, and to an examination of past experience with educational television in specific cases.

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*/ The very problem of coordination and organization in television makes imperative a parallel development of telephone and other telecommunications to provide support; hence, the importance of multi-purpose facilities as discussed previously.

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IV. THE PROSPECTS FOR EDUCATIONAL TELEVISION: A GENERAL VIEW */

A. The Context of Education in Less Developed Countries

The problems of education in less developed countries, and the potential of communications technology to accelerate their solution are worth special and detailed consideration for several reasons. First, the formal educational system is the one solid national institution in most developing countries. It is often also the most pervasive institution, reaching more people directly and indirectly, with its constant flow of communication, than any other source. By being both the primary channeler of trained manpower and the primary determinant of social values -- traditional and modern -- a country's educational system continuously shapes the character of the country, both immediate and in the long-term. Because the centrality of this communication system is universally recognized, less developed nations are committing great and ever-increasing resources to formal education, often ranging between 20% and 30% of their national budgets and encompassing

*/ Throughout this paper "educational" television is defined broadly to include the wide range of cultural, public affairs, and institutional services beamed to home, school, and other receiving points.

vast amounts of their skilled manpower; in this context the sizeable investments required to install a telecommunications technology represent fairly modest increments. In sum, education is the one communication system whose importance is obvious to everyone in a developing country. But most significantly, we should examine formal education in detail because it presents staggering problems for which communications technology may offer hope.

Quantitative needs. First, of course, are the problems of quantity, all exacerbated by rapid population growth. At least 750 million adults in the world are illiterate -- most in the less developed countries. Moreover, the proportion of children in school remains low; for example, in the 5-14 age group 31% are in school in Nigeria, 25% in Pakistan, 9% in Afghanistan. Dropout rates are enormous. Typically only 15% to 40% of those entering first grade complete the fifth grade, obtaining at least the rudiments of a useful education. Repetition of the early grades is so frequent in Brazil, for example, 40% of all school children are in the first grade, and five

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grades of education typically take 7 or 8 years.

However depressing these figures may seem, they are the most recent points on a rapidly rising curve of expansion that reflects within the last decade an increase in enrollments and graduates by a factor of 2 to 5 in most developing countries. Enormous quantitative progress has been made. There is serious question, however, whether present enrollment rates can be maintained, let alone increased further, during the next decade. The percentage of national income invested in education has rapidly increased, and, in many countries is now near maximum. Population increases will continue to increase student-age population. And in spite of these difficulties, the social demand for educational opportunity, which has risen even more rapidly than enrollments in the last decade, will continue to present acute political pressures for increased enrollments throughout the developing world.

The problem of numbers is also severe when applied to teachers. Recent expansion has caused a commensurately vast increase in the numbers of teachers, and most developing countries are finding it more difficult to maintain this

growth rate. They thus have been compelled to use large numbers of teachers with little or no higher education or teacher training. In India, for example, 27% of the teaching force is now classified "untrained," having had no teacher training at the secondary school level or above. Most other countries also reflect, some more acutely, that the recent quantitative increases in teachers and students has been accompanied by a widespread decline in teacher qualifications.

Problems of quality. Of greater seriousness than the quantitative problems are those of the quality and usefulness of the education being obtained by students in the system. The quality problems encompass many aspects which determine the effectiveness of the human output of educational systems; notably:

a. Rote memorization is still both the end and the dominant instructional method, rather than teaching for understanding or for development of problem-solving skills. With the teachers themselves poorly educated and working without significant assistance or teaching aids, no other method may be possible.

b. The relevance of the curriculum to the life of the student and to the processes of modernizing the country

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is often nil. Curricula are old -- often carryovers or variants of those used in the colonial periods and thus relevant largely to the life of a gentleman-scholar. Major efforts to update and make the curriculum more relevant are underway everywhere, but their implementation depends on the effective retraining of vast numbers of teachers and the mass availability of new books.

c. Similarly, vocational utility is severely limited by the lack of basic science education and courses in technical and vocational subjects. The difficulty of training and retraining many teachers in subjects so new to the traditional curriculum and so intellectually demanding for the poorly trained teacher has slowed the rate of progress in this area.

d. The effectiveness and efficiency of the instruction process has suffered, regardless of content, as these countries have tried to transform their educational systems from elitist to mass-educational systems. The interaction of many factors has led to unconscionably high rates of failure.

e. The inability to make school sufficiently communicative, interesting, and motivating to keep students in the

system and moving through it has undoubtedly contributed to the enormous wastage caused by early dropouts, failures, and repeaters in these systems.

Both students and teachers find themselves in a system rigid and painfully slow to change, despite what may be the best intentions and efforts to make it an effective instrument of national development. This inflexibility results, in large part, from the high costs of teacher training and retraining, an acute lack of skilled supervisory personnel, the great difficulty a poorly educated teacher has in further educating himself, the isolation of teachers in these predominantly rural countries, and the scarcity of modern books and other teacher aids. As these countries modernize from ancient peasant cultures to modern societies, the educational needs of their young will probably require even more rapid and constant changes than in Western societies, and the inflexibility problem will become all the more acute.

B. <u>The Potential of Television</u>

What, potentially, can television in classrooms contribute to accelerating educational progress? The commonplace view is that its chief service is to share an outstanding teacher with many classrooms, thereby replacing the poorer

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classroom teacher. This it can do (though the classroom teacher continues to play an important and well-structured complementary role). However, television's potential goes far beyond the substitution of one teacher for another. The kinds of changes it might be expected to accomplish in a well-planned and well-executed application result less from its effectiveness as an instruction medium and more from the changes it can bring in the structure of the educational system. Basically, it changes the educational system from a vaguely coordinated complex of individual craftsmen (teachers) to a centralized system using individual teachers in much more structured roles. It is thus in some real sense analogous to the transformations in manufacturing produced by the industrial revolution. Further, the use of such technology permits the realistic application of a modern systems approach to the educational process.

The potential advantages of a reorganization of an educational system around the use of television include:

a. Rapid and continuing change in course content and teaching methods is made possible. No longer need curricula be developed with a view that they must stand for 10 or 20

or more years; instead, they can be constantly modified, not only to update them, but to make them responsive to the reactions of students. It thereby encourages putting the instructional process on an empirical basis, with constant feedback and adjustment to that feedback.

b. New subjects, even those so intellectually new to teachers as "discovery science" and "new mathematics," can be rapidly and effectively introduced.

c. It can provide an opportunity to learn through seeing, making it possible to effectively study many subjects only remotely and abstractly available otherwise.

d. Extraordinary effort can be put into the preparation of lessons for television, bringing together subject-matter experts, great teacher-communicators, professional writers, experts in visual instruction, and skilled producers and directors. The same team can develop maximally effective and integrated guides for the classroom teacher and work materials for the students, which at their best can make possible a powerful team approach to learning. This kind of effort compares with that of the best classroom teacher burdened with teaching five or more courses every day.

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e. A constant and effective communications link can be provided with classroom teachers. In-service teacher training thus can be given with an effectiveness and intensity that even the wealthiest Western systems rarely approximate.

f. The teacher can, and will, learn from classroom programming itself. He will not only learn new techniques through using the television teacher as a model, but often for the first time will also learn to understand the subject matter fully himself.

g. The remote or isolated teacher and student can both be brought into continuous contact with a series of well-educated people, via television.

h. It provides experiences never before available to the isolated peasant child. The cumulative effects of this drastic broadening of perspective may be incalcuable. Probably most important, introduction of a radically new organizing and teaching instrument like television may serve as a stimulus to a basic review of educational goals.

As a result, instructional television holds promise of permitting rapid improvement of educational quality in

all quality problem areas listed earlier. It would seem to have the potential for making the educational system a more responsive instrument for national development.

In addition, it can help meet the requirements for further qualitative expansion in several ways. First, it can very significantly meet training needs for large numbers of additional teachers, reducing the amount of time they must spend in formal teacher training courses through the addition of in-service training in the classroom. Second, it can meet acute needs for expansion by providing effective teaching through combining television instruction with a poorly trained or poorly educated teacher or monitor. Third, by radically improving the quality of instruction, it can hopefully increase the efficiency of the system through reducing the numbers of repeaters. Finally, it can in many cases provide a large expansion of educational opportunity through reaching those not in the formal educational system, by programming for recent dropouts and adults outside of school hours.

Expansion of formal schooling will, of course, still be limited by costs of school building, provision of books, etc. However, teachers' salaries constitute from 60% to 90%

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of the cost of education in developing countries. Therefore, expansion through temporary use of low-cost untrained monitors with television may be very attractive to some countries.

C. Previous experience

In contrast to the remarkable theoretical potential of television, its use to date in developing countries has been on a very small scale. In most cases it has been directed toward achieving relatively trivial, fragmentary improvement in teaching one or two subjects, rather than toward basic educational change. Television is of course a new and not widely understood instrument of educational development. Educators are typically cautious (often properly so) and conservative; as yet no fully relevant operating systems exist for developing-country planners to observe and model their own systems after, and planning advice has been fragmentary.

To be sure, there is no lack of evidence that television can be used effectively for teaching. Hundreds of experiments have been done, at every level, with all kinds of children, and with almost every subject matter. The conclusion is clearly that viewers learn a great deal from television, typically at least as much as they can learn

from the same teacher, demonstration, and live setting.

There is a question, however, of what we know from actual operational experience in the developing countries, about the practical feasibility of using such systems, and about their real educational effects. As noted, the cases are scarce. Although efforts throughout the world and in the U.S. have increased our understanding of some of the problems, only three currently operating systems are of real interest: American Samoa, Colombia, and Jamaica. The only television use aimed at the kind of basic restructuring and rapid change in education that we have described is American Samoa, with a school population of only 8,000. The largest of the three, Colombia, has only limited educational goals. Clearly, inferences for India's 70 million students from these experiences must be cautiously drawn.

Samoa. The Samoan experience is nevertheless a provocative clue as to what might be accomplished, even though its small size, its assured funding by the U.S. Department of Interior, and its firm control by an American Governor made it far easier to develop a system according to plan than would be the case elsewhere. Here an effort began in 1961 to rapidly upgrade the entire primary and secondary school system from one where teachers with the equivalent

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of a fifth-grade education taught an outmoded and totally irrelevant curriculum, in broken English, using rote memorization as the sole technique, to a system designed to equal the best U.S. school systems in quality. With a remarkable display of systems planning the old curriculum was scrapped and a new, constantly evolving curriculum was initiated aimed at new objectives; irrelevant stateside textbooks were discarded and replaced with material for students and teachers keyed to each lesson; the traditional system of primary school grades was abandoned in favor of a more flexible system of several levels; the contents of the various courses were made to reinforce each other. And to teach and reinforce the student's ability to understand and communicate in the modern language (English), the world's leading expert on teaching English to Polynesians was called in to structure the teaching of the language throughout the curriculum to be most useful in the local culture, and to work with the entire staff in helping them understand the cultural problems of communications. Teaching of every subject was designed to be illustrated by examples familiar to the Samoan child. The core of teacher training was transferred from an academic setting to in-service

training in the classroom.

In addition, schools were consolidated, electricity was provided, new schools were built, and television equipment was installed. At the core of the system is a 6-channel broadcast television system with one receiver in every classroom to provide television lessons in every class, so that each student is instructed by television two or more hours a day.

Development of the instructional program became a daily team effort of curriculum experts, television teacher, a professional writer who worked with the teacher in preparing the television script and the associated teachers' guides and student exercise material, a producer-director, and of course technical experts. Another key team member was the classroom teacher, who was guided through printed material to prepare each class for its television lesson with a 10 to 15-minute discussion and to follow each with additional discussion and exercises designed to reinforce the lesson's points. The acquisition of these skills was guided by a skilled American principal in each school.

Initially, Americans played a dominant role in the system because very few well-educated Samoans could be

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utilized. But technical jobs were turned over to a large degree to Samoans within a few months of operation and instructional jobs are being phased over to Samoans.

The system has now completed its fourth year in operation. The first broad quantitative evaluations of student performance show rapid improvement in all objectively measured subjects after only 1 and 2 years in the new system. A number of less formal analyses by educational experts support the view that dramatic upgradings in student performance are occurring, including immediately noticeable efforts on the capacity to communicate in English. Further, school attendance has remained close to perfect since television was installed. The enthusiasm of the children, freed of the authoritarian regimen of dull memorization, has reportedly continued unflagged. While more objective evaluations over a long period will be required, at this point there is no reason to question the tentative conclusion that extraordinary change for the better has occurred in the very short period.

Colombia. Colombia has been attempting an impressively large program, now reaching 475,000 students and teachers in over 1,000 schools. The goals of this effort have been:

1. To enrich the educational environment and to engage students in useful educational experiences.

2. To introduce otherwise unavailable materials and teaching aids.

3. To raise the standard of teaching, by exposing teachers to new concepts and techniques and by offering them guidance.

This effort began being planned in 1960, went into small-scale operation in 1962, and expanded in 1963. It has had major assistance from 110 Peace Corps Volunteers and from AID, which provided 1,500 television sets. The program operates on a single channel at the five primary grades in most schools in Bogota, and in many in the surrounding countryside and in other cities.

Each student sees an average of two television lessons a week in each of three courses. Emphasis is on mathematics, foreign language, and science, but music, social studies, religion, and recreation are also included. The only course taught in all grades is the "new mathematics." At the adult level, a weekly voluntary teacher orientation program, health education, and infant care for mothers are included. The television teacher is primarily

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responsible for writing each lesson, but is aided by a specialist who writes the guide for classroom teachers, and by Peace Corps Volunteers. Observers have reported that the apparent educational quality of the lessons is variable. Much effort has been directed toward assuring effective utilization, through teams headed by Colombians and made up mainly of Peace Corps Volunteers. These utilization experts play a basic role as field agents for the system. They select participating schools, supervise set installation, coordinate maintenance, visit schools to observe student and teacher behavior and, most important, provide a personal link between the classroom teacher and the central staff. Total capital investment is now about $2,500,000 and operating costs are about $900,000 yearly.*/

A 2-year evaluation effort was designed into the program from the beginning. Its objective testing of student performance after the first year showed, in three of eight

*/ These figures include a prorated share of the transmission system which is used during the evening hours for commercial television.

courses evaluated, a significant superiority for students in television schools as opposed to regular schools teaching the same curriculum. In the others there were no significant differences. The evaluation also seemed to show that in schools with television, difficult-to-measure sparks of change were causing alterations in many aspects of the educational process outside teaching in the courses involved. Rote instruction was being questioned, a general spirit of innovation was about, and teachers and students seemed more excited.

However, there is little evidence that basic educational change and improvement is occurring in any dramatic fashion. Certainly problems of execution, such as a very tight production budget and difficulties in administrative coordination, have reduced the efficacy of the programs. And the general conservatism of Colombia's educational system has been reflected in television programming and in some passive resistance throughout the system. But these things seem to indicate that introduction of television was not conceived in a desire or expectation of producing fundamental change. It was instead regarded as a medium for periodically bringing

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better teachers into many classrooms, particularly for technical subjects. Without aspirations for major change, the effort was destined to be limited in support, funds, and content.

In achieving its goals, Colombia seems on the way to marked success -- something which can be said of few efforts in educational change. Although television is a long way from helping Colombia solve its fundamental educational problems, it does seem to provide a sound base for beginning.

Jamaica. This island provides the only other experience from a developing country of classroom instructional use reaching large numbers of students. Here some half-million student-lessons are taught each week (a student-lesson being defined as one student receiving one lesson). All managerial personnel, studio teachers, and production personnel are Jamaican. AID provided capital assistance and the services of two U.S. experts. The program also received field support from 16 Peace Corps Volunteers.

Today, eight courses are offered to students in the 12-15 age group, plus two courses designed specifically for the classroon teacher. Typically, a student watches one television lesson a week in each of two or three courses. Telecasts are not designed as supplemental, but to offer the core subject material.

The Jamaican Educational Broadcasting Service operates its own educational materials reproduction unit which, during the 1968 school year, produced some 29,300 Teachers' Guides, 25,000 Pupil Workbooks (for a pilot study to determine their effectiveness with a small group), and 800 Informational Booklets on ETV, plus other education-related projects.

Though no formal study of television's impact has been conducted, Jamaican educators and qualified observers believe the telecasts have significantly upgraded Jamaican education. In fact, the Jamaican Government has strong interest in a more comprehensive expansion of educational television and the reforms in educational methodology it has introduced.

In passing, we observe that to date few of the "measurements" of achievement appear to have dealt with what may be the most significant of television's contributions. The test is not necessarily whether television teaches what

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has been taught, but rather whether something quite different and useful is taking place. In many classrooms in developing countries, the advent of television has been accompanied by quite novel activities by the children -- bringing in fossils, making scrapbooks, creating weather stations and the like; where before, no such activities took place. Yet frequently, this sort of stimulation does not appear on the formal evaluation.

El Salvador. This triumvirate of on-going projects is being joined by another of major significance just starting at junior high level in El Salvador. This arose from a commitment by President Johnson at the Punta del Este Summit Conference in April 1967 to provide U.S. aid for a major demonstration application of instructional television in a Central American country. With an expected contribution of $4 million by AID, an effort is being made to thoroughly reform, upgrade, and expand junior secondary education through heavy reliance on television. For the entire junior high school population (now about 40,000 and expected to rapidly grow to 60,000) a fundamentally new curriculum will be taught. Beginning with broadcasts to 50 pilot schools in 1969, operations will expand on a grade-

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per-year basis until all three junior secondary grades are covered by 1972. An integrated plan has been devised to coordinate extensive classroom teacher training with the program -- in the teacher-training college, through a year of special training for present teachers, and through broadcasts to the teachers while in service.

The project has been thoroughly planned, is well-funded, and has the strong support of key local officials. For the two-channel system being introduced, the equipment and its replacement and repair will cost about $40 per student. Operating costs are estimated at between $10 and $20 per student a year, exclusive of classroom teachers' salaries. Should the program expand to primary school, the per student cost would drop to $10 to $15 for capital costs and to $4 a year for operating costs.

In addition to these major developing country applications, television has been used in Italy to teach adult literacy; in Brazil and Ivory Coast to upgrade educational skills of factory workers (who were given time off by their employers to "attend class" in a room set

aside at the factory); in Japan for the high school education of 100,000 students (combined with correspondence); in the United States to teach an entire junior college curriculum, to radically upgrade the education of a rural community, and to provide post-graduate education for physicians; and in a number of countries to provide a higher level of culture. Most recently, Cuba has announced a comprehensive educational development plan using television as the core of instruction for the entire junior and senior high school system. Ten thousand sets have reportedly been purchased, which would mean in effect one for each classroom in a system reaching 200,000 students.*/

*/ Special report to the Washington Evening Star, September 10, 1968.

D. Summary

There have been many abortive attempts to use television for instruction. In some ways these examples have been more helpful in understanding requirements for success than have successes themselves. In general, we find the following:

1. Success requires a serious commitment to educational change from those in top political and educational positions.

2. To achieve a major commitment, and to maintain it by demonstrating its success, television must be used -- or at least must be planned ultimately to be used -- for achieving fundamental solutions to priority educational problems. It must be thoroughly integrated to the educational system.

3. Planning must proceed from an analysis of problems in local conditions, not from a blueprint for introducing a technology.

4. Programming must be as relevant as possible to the individual student. Substantial parts must therefore be locally produced. The reach of any central system is determined by the homogeneity of the population.

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5. Systems characteristics of the educational process, with all their interrelatedness, must be fully recognized in planning the use of television. Many technical, organizational, and human elements must be given equal attention, for significant failure in any one of them will disrupt the entire system.

6. Systems requiring complicated interaction between technical and human or organizational systems -- e.g., training repairmen and providing efficient repair service -- are more difficult to master than the merely technical elements in the operating environments most likely to be encountered.

7. Organizational and human elements are by far the most demanding of energy, imagination, and resources. Organizational efficiency, teacher and student attitudes, coordinated teamwork, training, and like problems require complex planning, enlightened administration, and, most important a very strong will to succeed.

V. CONCLUSIONS AND RECOMMENDATIONS

Taking together all the studies of the Central Staff and the contractor efforts, we conclude that satellites, in combination with terrestrial facilities, have great promise

in providing a variety of long-distance telecommunications links for domestic and regional use as a strong complement to the INTELSAT global system. Our Latin American study shows that regional systems appear to afford substantial cost-savings and elements of flexibility over terrestrial alternatives. Reliable high-quality telephone and telegraph service to cities and town now essentially cut off from the outside would provide a valuable stimulus to economic development and individual well-being.

We do not foresee that even a rapid growth of regional satellite systems, operating with small ground terminals, would encounter serious problems of spectrum use or orbital slot scarcity. However, in the near term, satellite systems must be shared in most cases on a multinational basis, if economies of scale are to be satisfactorily exploited and unit costs minimized. This will, in turn, require extensive international agreement and cooperation in system design, operation, and cost-sharing. In this paper and in previous literature much attention has been given to the possibility of using these links for educational television. This application appears attractive. Satellites could provide not only instantaneous

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program distribution to widely scattered points, but especially notable, the two-way communications afforded by a multi-purpose satellite system would contribute to the critically important requirements of coordination and feedback for an effective television system.

To be sure, the satellite by itself is only one of many ingredients in a nationwide television system. On the hardware side, we have seen that television set operation and maintenance in remote locations is a special problem -- quite apart from the technique used to transmit television signals. On the software side, even more serious problems arise; an effective system requires the successful planning and management of complex technical, organizational, and human elements -- a complexity and precision which exceeds the experience of most developing countries to date. Limited experience with such systems suggests many preconditions for success, the most essential being a powerful commitment at the highest political and professional levels, a clear definition of social goals, imaginative and detailed planning, and well-coordinated administration, with substantial technical advice from the outside.

Unfortunately, in the face of this complexity, little relevant experience is available to help plan new systems. Western experience cannot be directly transferred, because our uses of the medium have been very different and our supporting social structures are radically different. Experiences from the developing countries are fragmentary and on a rather modest scale. No single project exists that other countries can use as a model for their own development.

However, the needs of the developing world are so urgent that they cannot afford to wait for chance developments to bring greater understanding. Indeed, only by going ahead with relevant new projects will needed information be generated. We believe that enough is known now to reduce the risk of most countries to a tolerable level in relation to the potential benefits. For this reason, we offer the following recommendations.

A. Multinational Educational Training Centers

We favor creation of organizational entities to promote the ability of individual countries to determine their own needs and objectives, determine what resources can best be applied to meeting these needs and objectives, and initiate action toward their achievement. The absence of sufficient knowledge in any one country and the absence of sufficient trained manpower in virtually all countries suggests that these entities

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cannot easily be created in each country. Establishment of regional multinational centers, along lines proposed by an OAS group of experts on educational technology, appears a very attractive approach for coping with these problems.*/

*/ Organization of American States, Final Report, Fifth Meeting, Inter-American Cultural Council, February 1968.

Speaking within the context of Latin America, this group concludes:

> Latin American countries face serious difficulties in carrying out of educational programs that will include educational television. Among these difficulties are: the lack of information or of understanding on the part of the educational authorities and other public servants directly or indirectly involved with educational problems, as to the real value of the application of technology to the solution of the major educational problems of Latin America; the lack of a team of specialists in various disciplines trained in the techniques of educational television in its many aspects such as program production, classroom supervision, and evaluation of results; the insufficient number of teachers trained in the use of the new techniques; the lack of specialists in administration; the lack of electronic specialists; inadequate textbooks; and difficulties arising from the incomplete electrification of rural areas. . .

The novelty of educational technology forces us to admit that we really know very little about its utility. National and regional efforts to utilize technology are guided more by an act of faith than by factual evidence. We need to know more in this regard, but no agency exists that is capable of producing this knowledge.

With the general goal of aiding member states of the Organization of American States to incorporate technology, especially educational television, into the Latin American educational systems, the Center would have the following functions:

a. To provide information to educational authorities and other public servants directly or indirectly involved in problems of educational development on the advantages of using technology to solve these problems, and on the need to reorganize educational systems to incorporate in them educational television and other audio-visual aids.

b. To offer training in the techniques of educational television, as requested by member states, for personnel in charge of applying technology to education.

c. To provide needed technical assistance to countries interested in utilizing technology to extend, accelerate, and improve the educational process. This assistance may cover anything from cooperation in formulating a new system using educational television, to solution of a narrowly specific technical problem.

d. To provide and coordinate technical facilities to enable member states to produce the audiovisual materials they consider necessary; for the necessary dubbing of educational television programs produced in other countries for use in Latin America; and for reproduction or copying of existing programs for more extensive use.

e. To establish an audiovisual materials exchange service so that member states can acquaint themselves with, examine, utilize, evaluate, and copy the audiovisual materials they may require, including slides, films, videotapes, audiotapes, charts, and others.

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f. To offer high-level courses and seminars for high-ranking educational authorities to promote, study the feasibility of, and evaluate projects aimed at incorporating the latest innovations in educational technology, including educational television. The purpose of these activities is to bring about, through an effective exchange of experience, increased reciprocal advances derived from national efforts and achievements, toward a new integrationist concept of education in Latin America.

g. To collaborate in specific projects of countries interested in utilizing technology to expand, accelerate, and improve the educational process, and to encourage the cooperation of other public and private organizations for the financing and operation of such projects.

Accordingly, the multinational training center recommended by the OAS group of experts should be given encouragement and support to implement a program for development of applied technology in education with special emphasis on the use of educational technology including television as an effective instrument in helping to meet Latin America's educational needs.

Moreover, appropriate agencies should be alerted to the possibility of encouraging the development of additional regional multinational centers in areas where the environment is favorable for success.

B. Assistance to Individual Country Programs

As an essential immediate step, the United States should take the lead in encouraging and supporting development of ETV educational systems, on a scale large enough to demonstrate the technology's capacity to deal with problems of substantial scope and consequence. It is important to include a major experiment in its use for village development, in addition to formal education. These should be frankly recognized as research and development efforts, with their world-wide significance placing them in a category meriting long-term and large-scale support.

C. A U.S. Institute for Educational Planning and Technology

In support of both the regional centers, and the individual country efforts described above, the United States should further develop its own competence in the application of educational technology. To achieve this, a U.S. supported institute or center should be established capable of performing the following functions:

a. Performing multi-disciplinary applied research in the applications of educational technology to meet the needs of less developed countries under the prevailing social and environmental conditions.

b. Performing basic research in the most effective ways to increase the educational efficiency of the

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c. Offering educational training for qualified persons who wish to develop competence in telecommunications as related to educational, cultural, and socio-economic development.

d. Offering training for individuals planning to work in a foreign country where a knowledge of the resources of telecommunications would enhance their effectiveness -- for example, in agriculture, public health, job training, or other areas where dissemination of information to large numbers is involved.

e. Offering training to foreign nationals in the techniques of planning and using educational technology, especially those lacking the resources of national or regional training centers.

f. Coordinating with professional experts of other countries and international agencies.

D. Development of Low-Cost, Low-Maintenance Television Receivers

As mentioned earlier, one of the greatest problems of extending television into remote areas is the difficulty of

maintaining and operating television receivers. Unfortunately, present receivers were designed for ordinary household use by viewers accustomed to electronic gadgetry. Large scale exploitation of the new technology in less developed countries will require that technical support requirements for television receivers be drastically reduced. Accordingly, we recommend that the U.S. Government, in cooperation with private industry, explore the feasibility of developing a low-cost, low-maintenance receiver, perhaps with only 1 or 2 channel tuning capability, suitable for use with batteries or other sources in regions lacking electricity. Ideally, the receivers would be mass-produced by the using countries themselves.

We also noted previously that the total cost of any large system is likely to be dominated by the investment and operating cost of the receivers themselves. Therefore, any effort that substantially reduces the cost of the receivers will have a major impact on economic feasibility.

E. Cooperative Planning in Expanded Use of Satellites

Clearly, much of the planning and organization of educational television can precede the use of satellites or other long-distance electronics telecommunications media.

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The earliest pilot programs will, in any event, probably operate with existing television stations in large urban areas, operating from videotape libraries. However, as systems expand, long-distance electronic transmission either by satellite or other means will become increasingly vital in providing instantaneous, (real-time) distribution and two-way communications links. Instantaneous distribution will be important because: (a) as systems expand into the hinterlands, alternative videotape distribution systems will become increasingly costly and unwieldly; (b) program schedules and content can be changed on short notice to take into account the myriad problems that will undoubtedly arise in day-in, day-out operation of the ETV system; and (c) major news and timely public affairs programming can be brought into the classroom on an ad hoc basis. The two-way communications links are important in (a) permitting use of feedback systems for television programs beamed to small scattered audiences, as for teacher training, and (b) permitting schools to call in immediately when sets break down or other major problems arise.

Quite apart from educational television, satellites are attractive for providing domestic and international telecommunications links as a major contribution to the infrastructure

required for economic development. While we have discussed this role largely in the specific context of South America, it is no less important in other areas of the world.

Of course the particular countries must determine their own needs and requirements for both educational television and two-way communications links. The major thrust of this paper has been largely to delineate, in general terms, some potentially attractive applications. We recommend that these countries be encouraged to explore further and much more concretely the potential use of satellites on a regional basis. Given INTELSAT's expertise and experience in the field, we recommend that nations look to it for appropriate assistance in developing and maintaining satellite programs to meet their regional needs. Finally, we applaud the pilot program to be undertaken by NASA and the Government of India to explore through actual experiments the use of satellites for educational television.

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APPENDIX A

December 12, 1968

THE INDIA-UNITED STATES TELEVISION SATELLITE EXPERIMENT

Steps are in progress toward a benchmark experiment in the direct broadcast of educational television via a U.S. satellite to Indian villages. The project was conceived nearly three years ago when NASA recognized that the ATS satellite series would, early in the 1970's, reach a stage which would permit experimentation with television broadcasting over a controlled area into augmented home TV receivers. Studies have shown that such modification can be accomplised at costs ranging from $150 to $500 or $600, depending on the numbers produced, location for use, and similar factors.

Basis for experiment. The proposed experiment involves the use of a NASA satellite which has been independently planned and programmed for other purposes and which would proceed without regard to the Indian application. The ATS-F satellite will be placed in synchronous orbit principally to explore the technical feasibility of large (30-foot) erectable antenna structures and accurate (plus or minus 0.1°) earth pointing. Subsidiary experiments will likely include meteorological, nagivational, and communications applications and scientific experiments in the space environment.

NASA early recognized that such satellites could be moved along the equator and positioned to be available to a suitable area for educational TV experimentation. India is peculiarly appropriate for a satellite experiment of this type since the subcontinent is of a convenient size for reasonable antenna patterns, there is no TV distribution network existing in India which could be utilized by conventional means, the population is distributed relatively homogeneously throughout the subcontinent rather than concentrated in a few large cities easily reached by conventional TV methods (as in Latin America), and there is strong high-level Indian government support.

In early interagency discussions, reference was made to adverse experience by the Voice of America (which attempted to establish radio broadcast facilities in India) and by the Ford Foundation (which tried to assist in the development of an educational television system in India). In these cases, there was political opposition in India to the prospect of U.S. control of program content within the country. This issue has not arisen in the India/NASA ITV project and is not expected to arise. It has repeatedly been made clear that the preparation of TV programs in the project is to be left entirely to India. (Continued use of the satellite is, however, under U.S. technical control.)

Description of experiment. The proposed experiment, which follows naturally from the ATS F/C satellite missions and the case with which they can be made available to India, is structured as follows:

India will undertake to manufacture augmented TV receivers for installation in as many villages as possible, with a minimum number of several thousand villages to be equipped. India has the means and the technology to manufacture these receivers though it may be economical to import glass bottles for TV tubes. Thus, the non-satellite aspects of the program can be handled entirely on the basis of rupee funding by India.

India will beresponsible also for programming which is to be directed primarily toward increasing agricultural productivity and supporting family planning campaigns. Secondary objectives may include language cohesion, community hygiene, handicraft instruction, teacher and student training, etc. The programs will be transmitted to the satellite from an experimental ground station at Ahmedabad which has been completed and in operation. (It was funded in part by the UN Special Fund and is already in use to train technicians in developing countires.) The satellite will then relay the programs directly into village receivers throughout India. The geographical limit to the broadcasts will coincide closely with those of the Indian subcontinent. India is responsible for maintaining the receiver network and, finally, for extensive professional evaluation of the program.

Project support and preparation in India. High officials in the Government of India are personally interested in the satellite experiment and endorse long-range plans to expand television on an operational scale within the country. Agricultural research and family planning authorities, as well as All-India Radio and prospective televion manufacturers, are also deeply interested and involved in preparations for the experiment. Of particular relevance in this connection is the fact that an educational TV test has been conducted over the past year in the Delhi area as a direct precursor of the NASA satellite project. (The sole television transmitter in India is located in Delhi.) Eighty conventional receivers have been placed in as many villages surrounding Delhi; they receive two special (and all regular) programs per week, consisting of news, entertainment, and farm productivity instruction. U.S. officials have visited a participating village and were enormously impressed with the practical impact of the program. Farmers cited specific examples of instruction which they had converted to actual use and which had significant increase in their income. They are eager for more such instruction. Quite remarkably, the audience before a simple "portable" home TV receiver screen in such a village is three to four hundred persons. U.S. personnel stood behind such an audience and could see and hear perfectly. The long-range impact on the education and expectations of the men, women, and children attending can only be judged as very high.

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Current status. As a first step toward realization of the experiment, NASA proposed a joint study by U.S. and Indian technicians, with appropriate consultants, to make certain that the cost implications of various alternatives to the same purpose were fully explored and understood by India. A Memorandum of Understanding was arrived at between NASA and the Department of Atomic Energy of India (with the concurrence of the Department of State) and was signed on October 2, 1967. A meeting of the Joint Study Group was held in late January 1968 and its draft report is now in process. On the basis of cost data supplied by Indian and U.S. experts, the Joint Study Group agreed that the proposed experiment is sufficiently cost-effective, relative to other means of conducting such an experiment, to warrant proceeding.

It is anticipated that the Joint Study Group will complete its formal report shortly and will recommend to principals that the project proceed. If the recommendation is accepted, a Memorandum of Understanding will then be drafted to state the objectives and the nature of the program to be conducted by India, indicate the U.S. contribution (which limited to the satellite that is projected in the U.S. program for other purposes), and indicate the Indian contributions (ground transmitter, programming, receivers, maintenance, evaluation, etc.).

Relationship to future operational services. The experimental character of the project has been emphasized at every point, formally and informally, so that India fully understands that the experiment is only that. Its planned duration is one year. India must therefore consider other means for extending the service if, as is generally expected, the experiment persuades her to continue such programming. On this point, India has been advised repeatedly that the question of continuing service would best be discussed with Intelsat.

Values and benefits. The India/NASA ITV experiment will provide dramatic proof of the President's interest in applying advanced technology to the problems of less-developed countries.

The experiment will offer India an important and useful domestic tool in the interests of national cohesion. It will provide a first and major test of educational television for the practical instruction of illiterate adults. (The evaluation plan is to emphasize quantitative tests of practical effectiveness in reducing birth rates and increasing agricultural productivity.) The experiment has already stimulated a domestic TV manufacturing enterprise in India with important managerial, economic, and technological implications. Above all, it should provide information and experience of value for future application of educational programs elsewhere in the world.

FINAL REPORT

NEW COMMUNICATIONS TECHNOLOGIES

FOR

LESS DEVELOPED COUNTRIES

Volume I

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THE PRESIDENT'S TASK FORCE ON
COMMUNICATIONS POLICY

By

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PAGE COMMUNICATIONS ENGINEERS, INC. [illegible]

July 31, 1968

Errata

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New Communications Technologies for Less Developed Countries

Vol. 1

Page

Conclusions and Recommendations, 10th. line:
change "geographic" to "geography".

2-15 2nd. line from bottom:
change "spare" to "space".

5-64 Reference 3,
change author's name to "Hesselbacher".

5-64 These references are actually the references for Annex 3C.

Vol. 2, (Annexes)

Page

3C-18 add note: "References to this annex are in Volume I, page 5-64".

3A-42 Caption of Table 3A-11:
delete entire 2nd. line of caption beginning "SPADE".....

FINAL REPORT
NEW COMMUNICATIONS TECHNOLOGIES
FOR
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Prepared by [signature] Approved by [signature] Date 7/31/68

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CONCLUSIONS AND RECOMMENDATIONS

A comprehensive analysis of the potential long-distance communications needs within and among the countries of Latin America has been conducted. Various system alternatives for meeting these needs have been developed and compared.

This study has considered the general question of applying new communication technologies such as regional satellite systems, using Latin America as a specific example. The methodology used here is suitable for the study of other regions, and the results, as they apply to Latin America, can be used in guiding or aiding the implementation of such systems.

International and intercontinental traffic requirements for Latin America were derived from authoritative sources. Intranational traffic was estimated on the basis of the demand that would be generated if the use of telecommunications in South America were the same as a more developed region having similar characteristics.

Satellite, earth station, and launch vehicle capabilities have been projected through the 1970's. Only launch vehicles that are highly likely to be operational during that time frame have been considered as potential boosters for the system. The characteristics of earth station, satellites, and multiple access and modulation techniques in that period have been estimated based on surveys of the literature and by direct inquiry to manufacturers.

Several AMERISAT (AMERIcan Hemisphere SATellite) system configurations have been generated. One assumes that the system would carry all the international and intercontinental traffic terminating in Latin America which is

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suitable for satellites. This is essentially the traffic that would be carried via the INTELSAT Atlantic satellite according to present plans. A regional system to provide the same service would have characteristics similar to those planned by INTELSAT. That is, a 1000 channel satellite, standard earth stations (G/T = 40.7 db), and a Thor-Delta launch.

Different AMERISAT system configurations are proposed to provide intranational telephone and television service with the option of adding international South American telephone service. For reasons of cost effectiveness and geographic coverage is not provided initially to Central America for intranational service.

In the version without international South America traffic, the satellite is provided with three spot transmit and receive beams covering three regions. These are:

- Brazil
- Argentina, Chile, Paraguay and Uruguay
- Bolivia, Colombia, Ecuador, Peru and Venezuela

In the option with South American international service, one 10° satellite receive beam is provided to cover the continent and three spot transmitting beams are provided to cover the three regions.

CCIR quality and grade of service will be supplied for telephone, while the two alternative calculations for television are based on lower, but still acceptable signal-to-noise ratios.

On the basis of existing and projected communication requirements in Latin America and national and regional development objectives, we conclude that there is a large, unfilled need for modern telecommunications services, at current rates. With tariff reductions resulting from system economies, traffic can be expected to increase even more. There are some 500 South American communities having populations over 10,000, which are not adequately interconnected to one another, and to the outside world via modern telecommunications facilities. These towns, representing about 43% of the population of South America, lack adequate facilities for long-haul telephone and record services.

A number of alternative long-haul systems capable of meeting these needs have been analyzed and compared. Based on a tradeoff analysis among alternative satellite configurations, the most cost-effective Amerisat satellite system models for providing television-only services or television plus basic voice/record services, have been selected based on technology now available or capable of being developed within a 2-3 year period (see Section 6). These models consist of a 315 pound satellite providing three television channels and about 2000 voice circuits throughout South America (in three beams centered on Argentina, Brazil and the northwest part of the continent) working with 32' - 600°K earth stations; or a 315 pound satellite providing 2500 telephone circuits to 25' - 600°K earth stations*. As shown in Section 6, both of these satellite models have been fully-costed and compared with an extension of the present terrestrial network that would be necessary to provide equivalent service. From these comparisons, we conclude that satellite communication systems for serving many new intranational South American communications needs are cost competitive with expansion of the existing terrestrial plant at this time.

In light of these findings, which are elaborated fully in the Report, we recommend that further development of detailed plans and cost analysis for Amerisat satellite systems serving primarily intra-South America communications needs be pursued by those agencies and organizations concerned with development programs in these countries.

*55% antenna efficiency is assumed throughout. Should higher efficiency antennas become available, the resulting increased G/T can be utilized to increase system capacity slightly through a reduction in channel spacing.

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SECTION 1

INTRODUCTION

1.1 CONTRACT REFERENCE

This report is in partial fulfillment of the requirements of Contract F18600-68-C-0036, dated 5 April 1968. The contract was issued by HQ AFSC (SCKAC), Andrews Air Force Base, Washington, D.C. 20331. The technical direction of the contract has been performed by the Office of the Director of Research, President's Task Force on Communications Policy, Department of State, Washington, D.C. 20520.

1.2 OBJECTIVE OF THE STUDY

The objective of this study is to provide an improved basis for assessing the promise of satellite communications technologies over the next decade or so in supplying a wide range of services, including telephone, record and educational television, to less developed countries. While focusing on applications in Latin America, the analysis is sufficiently general to carry meaningful implications for other less developed areas. This report is intended to provide a basis to the Central Staff of the Task Force for (a) evaluating problems of sharing costs and benefits among the countries involved, (b) suggesting policies of financial and technical assistance to facilitate employment of these technologies consistent with the development objectives of the Alliance for Progress, and (c) appraising the effect of INTELSAT operating policies on the application of satellite technology in Latin America and in other less developed areas.

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Specifically, this study addresses the following principal tasks:

a. Projection of demands for various domestic and international telecommunications services.

b. Analysis of tradeoffs of system characteristics.

c. Analysis of multiple access techniques in respect to penalties compared to dedicated systems.

d. Cost analysis of a range of multiple purpose and single purpose systems employing satellites as well as terrestrial facilities.

e. Evaluation of providing educational TV channels through a shared, multiple purpose satellite system.

f. Examination of various system configurations in terms of types of service provided.

g. Examination of interference problems.

h. Examination of tariff/cost considerations.

i. Consideration of organizational interface questions arising from multi-nation participation in a single regional system.

1.3 ACKNOWLEDGEMENT

Page Communications Engineers, Inc., would like to express its appreciation to the four major American manufacturers of communications satellites who responded to our requests for information. We are grateful to the Lockheed Aircraft Company, General Electric, Philco-Ford (Space and Re-Entry Systems Division, Palo Alto, California) and the TRW Systems Group, for furnishing detailed answers to our inquiries about future spacecraft capabilities.

Page Communications Engineers, Inc., assumes responsibility for the interpretation of these data. It should be emphasized that the satellite configurations described, proposed and recommended herein do not result from a detailed design study, but represent the capabilities of spacecraft that most probably will be within the state-of-the-art of the 1970 s. The significant problems of detailed design, weight tradeoffs, development of critical and complicated antenna structures, feeds, power supplies, and other subsystems must await careful study by a spacecraft manufacturer skilled in the art who might eventually have to design, build, and guarantee performance of these satellites.

1.4 ASSUMPTIONS USED IN THE STUDY

Assumptions used in this study can be divided into five categories:

a. Operating Frequencies
b. Launch Vehicles
c. Spacecraft
d. Earth Stations
e. Configuration Options

The assumptions made can be categorized as a realistic and representative state-of-the-art of about 1972, a target date for the implementation of this system. Assumptions have also been made of improvements in performance to be expected during the lifetime of the system through 1978.

1.4.1 Operating Frequencies

This study assumes the use of frequencies presently allocated to the earth-space (communication satellite) service by international agreement. The use of frequencies that might be allocated at some future Administrative Conference are also discussed and considered.

It is further assumed that the flux density limit of $-(152 + \phi/15)$dbw/m^2/4 KHz will apply to satellite transmissions (down-link) in the shared bands between 1 GHz and 10 GHz. It is considered unlikely that a subsequent Administrative Conference would ease this limit.

1.4.2 Launch Vehicles

Only those launch vehicles that will be operational at the Eastern Test Range (Cape Kennedy), during the time frame 1970-1978 will be considered as suitable for emplacing satellites of the regional system.

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1.4.3 Spacecraft

Spacecraft assumed are those having the maximum weight that can be placed in stationary orbit by each of the launch vehicles considered. It is assumed that the skilled spacecraft designer will use those payloads optimally and be able to generate a certain maximum RF power.

1.4.4 Earth Stations

Earth stations of four different figures of merit have been assumed. They range from a 10-foot diameter antenna and a 150°K system noise temperature (giving a G/T of 17.7 db) to a 32-foot diameter antenna with the same system temperature (G/T - 27.8 db); a low cost 600°K tunnel diode amplifier receiver has also been studied. All are assumed to have only manual positioning capability and rely on commercial power (with local power conditioning equipment) and uncooled receivers. 55% antenna efficiency has been assumed.

1.4.5 Configuration Options

Many factors influence the configuration of a Latin American regional system, including economic, political and social considerations, existing and planned facilities, INTELSAT, and future technical developments.

The Page study has concluded that two major classes of configurations should be considered, based on the types of traffic they would handle (traffic includes telephone, data, and television for distribution to conventional broadcast stations and educational television, to community receivers).

a. All traffic, including intra-national, international within Latin America, and all other international traffic.

b. Traffic given above, except intercontinental traffic likely to be carried by INTELSAT, if present INTELSAT plans are implemented.

Consideration of the first set of requirements is useful to determine the design, economics, etc., of a regional system if there were to be a change in present plans to carry international and intercontinental circuits on INTELSAT III and its successors.

Consideration of the second set is useful to answer the same questions if it is assumed that a Latin American and other regional systems are to be developed as separate systems to meet special needs either within or outside the basic INTELSAT system.

1.5 ORGANIZATION OF THIS REPORT

This report is in two volumes: this volume, the "Final Report," and a second volume, "Annexes to the Final Report." This volume presents all major findings, conclusions and recommendations of the study, organized in separate sections as follows:

Section 2	Forecast of Circuit Requirements, 1968-1978
Section 3	System Constraints
Section 4	Characteristics and Costs of System Elements Available in the 1970's
Section 5	Formulation of System Configurations
Section 6	Costs of Alternative Configurations
Section 7	Organizational Considerations
Section 8	Summary

The "Annexes" provide additional supporting data, information and calculations relevant to several of the above sections, and are numbered accordingly (i.e., Annex 2 supports Final Report, Section 2, etc.).

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SECTION 2

FORECAST OF CIRCUIT REQUIREMENTS, 1968 - 1978

2.1 GENERAL

An important step in assessing the promise of new communications technologies for less developed countries in the determination of the proposed system's telecommunications requirements.

This section describes the traffic forecasting methodology used in the study and presents the projections of circuit requirements for the years 1973 and 1978 in the following classifications.

a. Inter-Latin American circuits
b. Intercontinental circuits
    1. Mainland US and Canada
    2. All other countries
c. Intranational (within each country)

The traffic considered in this study consists of the following telecommunications services: telephone, telex, telegraph and television including educational television (ETV).

Inter-Latin American circuits are those between countries which are members of CITEL.

Intercontinental circuits are circuits between CITEL countries and other countries of the world, primarily the US Mainland, Canada and Western Europe.

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Intranational circuits are those within each CITEL country. These requirements are not developed for Paraguay or Central American countries because their existing and planned terrestrial systems appear better suited than satellites to accommodate these requirements.

A Glossary of Terms used in this section is included as Annex 2-A.

2.2 SOURCES OF TRAFFIC INFORMATION AND OTHER DATA

In developing telecommunications requirements for the developing nations of Latin America, two basic approaches were selected:

a. For Inter-Latin American and Intercontinental requirements, traditional telephone traffic engineering methods based on historical data.

b. For Intranational requirements, more recent socio-economic methodologies which correlate telephone demand with telephone density and economic indicators.

2.2.1 Inter-Latin American and Intercontinental

The major sources of traffic information (historical data) used in the study were:

a. CITEL Questionnaire
b. Santiago World Plan
c. FCC Statistics of Communications Carriers
d. COMTELCA Feasibility Study
e. Page Study for IDB
f. IDB Feasibility Study - Vol. IV

The details of these information sources appear in Annex 2-B.

2.2.2 Intranational

Projections were made for the number of telephones in each South American country and Mexico. Using United Nations estimates, population projections were obtained.[1] Projections for number of telephones were taken from an earlier Page survey[2] prepared for the Inter-American Development Bank. Telephone density and growth patterns were taken from a Stanford Research Institute paper.[3]

2.3 TRAFFIC FORECASTS

2.3.1 Inter-Latin American and Intercontinental

Inter-Latin American and intercontinental telephone traffic forecasts are made by assuming a specified annual rate of increase in telephone traffic over a period of years and applying the resulting factors to the actual volume of traffic during a specific reference year. The reference year should be the latest year for which accurate traffic figures are available and which was not affected by unusual conditions such as economic depression, political upheaval or special events which might have a severe impact on the daily volume of international calls. The annual rate of increase must be supplemented at various intervals by abrupt changes in trend, either higher or lower due to substantial changes in the number of telephones, predictable factors such as improvements in the quality of service, establishment of large new business enterprises, and changes in the economic or social conditions. These abrupt changes are referred to in this report as impulse jumps, particularly when they reflect the stimulation of international calling due to better service. This better service is, in turn, the result of improved switching equipment, better transmission and more adequate provision of circuits.

---

1. "Transport and the Economic Integration of South America," Robert T. Brown, the Brooking Institute, Washington, D.C., May, 1966. Brown used U.N. projections for 1980 from "U.N. Provisional Report on World Population Prospects, as Assessed in 1963," but with adjustments for certain countries. See Appendix B, p. 238 for his methodology.

2. "Feasibility Study of Space and Terrestrial Telecommunications in South America," Page Communications Engineers, Washington, D.C., December, 1966.

3. "Relative Rates of Growth of Telephone Density in Different Administrations and their Implication for the Future," A.J. Lipinski, and M.P. Marchal, Stanford Research Institute, Menlo Park, California.

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The same principles as are used in forecasting international telephone traffic also apply to the forecasting of telex and telegraph traffic.

All traffic forecasts in this study are for both-way traffic between individual countries, being the sum of the traffic in both directions. Wherever possible, the traffic in each direction was calculated separately, using its own reference year and annual rate of increase. However, if data were available in only one direction the traffic figures were calculated for that direction and multiplied by two to get both-way traffic.

The details of developing traffic forecasts, forecast periods, projected rates of increase, telephone increase rates, telex increase rates, telegraph increase rates, and traffic forecast summaries are presented in Annex 2-C.

2.3.2 Intranational

Forecasting intranational telephone traffic using the same techniques as for Inter-Latin American and Intercontinental (paragraph 2.3.1) was not possible because only fragmentary data was available. Therefore, a new forecasting technique was employed. This methodology, the details of which appear in Annex 2-D, applies the high correlation between telephone density and long distance calls per capita to develop traffic forecasts.

2.4 CIRCUIT REQUIREMENTS

2.4.1 Inter-Latin American and Intercontinental

2.4.1.1 General. Circuit requirements for the years 1973 and 1978 were calculated from the forecasts of country-to-country average business day traffic. For telegraph traffic, the circuit requirements were determined directly from the circuits charged per average business day. For telephone and telex traffic the minutes charged per average business day were first converted to minutes of busy-hour circuit usage by use of a factor which was developed individually for each country. The number of circuits required to carry the resulting minutes of circuit usage was read directly from circuit capacity tables based on CCITT recommendations.

Having determined the countries between which direct circuits were warranted, a routing pattern for the remaining traffic was established. The minutes of busy-hour circuit usage required for the switched traffic were then added to the minutes required for direct circuit traffic on the affected groups. Revised circuit requirements were then determined by reference again to the circuit capacity tables.

Details of the development of telephone, telex and telegraph circuit requirements and summaries of these requirements are presented in Annex 2-E. Details of traffic routing appear in Annex 2-F.

2.4.1.2 Total Equivalent Voice Circuits. Total circuit requirements are best expressed in terms of equivalent voice circuits. The total equivalent voice circuits are determined by adding the telex and telegraph requirements, determining how many voice frequency carrier telegraph systems are required to accommodate them, and adding the total to the number of telephone circuits required for for each circuit group.

Telex and telegraph requirements impose a relatively small additional load on the total voice equivalent circuit requirements, due to voice frequency carrier telegraph multiplexing which translates up to 24 telex or telegraph circuits on one voice circuit. Total equivalent voice circuit requirements are shown in Tables 2-1 through 2-3.

2.4.1.3 Total Satellite Circuit Requirements. It is likely that only a portion of the total circuit requirements would be candidates for transmission by satellite, for several reasons; technical, economic, etc.

The requirements for a Latin American Regional Satellite System were estimated using the following assumptions.

- Existing HF radio circuits would be replaced by satellite circuits;
- Where high density broadband radio exist or are firmly planned, satellite circuits would not be used;

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Table 2-1. Equivalent Voice Circuit Requirements

1968

	Inter Latin America	Mainland USA &Canada	Europe	Other Countries	Total Inter national
Argentina	166/0	11/0	19/0	1/0	197/0
Bolivia	1/0	1/0			2/0
Brazil	14/0	13/0	16/0	1/0	44/0
Chile	43/0	10/0	4/0	1/0	58/0
Colombia	16/0	13/0	2/0	1/0	32/0
Ecuador	4/0	7/0			11/0
Paraguay	9/0				9/0
Peru	7/0	13/0	1/0		21/0
Uruguay	126/0	6/0	11/0		143/0
Venezuela	21/0	34/0	18/0		73/0
Costa Rica	16/0	6/0			22/0
El Salvador	18/0	5/0			23/0
Guatemala	16/0	7/0			23/0
Honduras	12/0	7/0			19/0
Nicaragua	13/0	7/0			20/0
Panama	11/0	27/0	2/0		40/0
Mexico	38/0	557/0	18/0	3/0	616/0
Total	266/0	724/0	91/0	7/0	1088/0

NOTE: 166/0 means there is a requirement for 166 circuits, of which none (0) are suitable for a regional satellite. International figures for individual countries are half-circuits, whereas the total is full-circuits.

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Table 2-2. Equivalent Voice Circuit Requirements

1973

	Inter Latin America	Mainland USA &Canada	Europe	Other Countries	Total Inter-national	Total Intra-national
Argentina	356/172	39/39	52/52	2/2	449/265	33,440
Bolivia	11/11	4/4			15/15	2,100
Brazil	78/63	45/48	41/41	3/3	170/155	22,100
Chile	109/109	33/33	28/28	3/3	173/173	6,170
Colombia	64/31	45/45	30/30	1/1	140/107	10,310
Ecuador	17/17	24/24			41/41	590
Paraguay	27/27	5/5	7/7	1/1	40/40	
Peru	37/37	39/39	24/24	1/1	101/101	1,490
Uruguay	214/15	15/15	24/24	2/2	255/56	3,700
Venezuela	66/33	64/5	47/47	2/2	179/87	6,260
Costa Rica	64/0	26/26			90/26	
El Salvador	76/0	19/10			95/10	
Guatemala	65/0	30/15	1/1	1/1	97/17	
Honduras	54/0	20/10			74/10	
Nicaragua	63/0	27/14			90/14	
Panama	80/24	52/26	5/5		137/55	
Mexico	87/64	907/0	61/61	4/4	1059/129	19,350
Total	734/304	1397/358	320/320	20/20	2471/1002	105,510

NOTE: See Note, Table 2-1

- Where areas of doubt exist regarding the certainty of proposed broadband surface systems, one-half of the projected gross requirements are planned via satellite.

The final determination of the circuit groups or portions of groups that would be handled by satellite was made by employing the above assemptions and the judgements of Page personnel most knowledgeable in the factors that would affect this selection. The most unimportant of these factors are as follows:

a. Existing and planned facilities
b. System design details
c. Socio-economic environments
d. Political climates
e. Geographical and topographical limitations

The projected satellite circuit requirements, in terms of equivalent voice circuits for 1973 and 1978, are shown in Tables 2-1 to 2-3. The data for 1973 and 1978 are illustrated graphically in Figures 2-1 to 2-3.

2.4.2 Intranational

Intranational circuit requirements were developed by projecting the telephone density for each country and employing a least-squares regression relationship to obtain the number of long distance calls per capita and thence the number of required circuits. The details of this methodology are presented in Annex 2-D; the statistical relationships are discussed in Annex 2-H.

The number of intranational telephone circuits calculated for 1973 and 1978 are shown in the last colomun of Tables 2-2 and 2-3.

2.5 TELEVISION REQUIREMENTS

The key to the cost effectiveness of this Regional Satellite System is that it provides an extensive, flexible, expandable, television capability to South America. As is shown in Section 6, the provision of this TV capability by conventional terrestrial means is considerably more expensive than by a satellite system.

NOTE: See Note, Table 2-1.

		Inter Latin America	Mainland USA &Canada	Europe	Other Countries	Total Inter-national	Total Intra-national
1. Includes 141 circuit between Montivideo and Buenos Aires 2. 96 channel-submarine cable between Venezuela and the United States.	Argentina	654/229	68/68	77/77	3/3	802/377	45,130
	Bolivia	16/16	5/5			21/21	2,500
	Brazil	125/69	81/81	61/61	4/4	271/215	12,730
	Chile	217/89	64/64	37/37	3/3	321/193	9,810
	Colombia	114/50	85/85	42/42	1/1	242/178	20,480
	Ecuador	26/26	38/38			64/64	1,210
	Paraguay	48/48	7/7	9/0	1/1	65/65	
	Peru	59/52	72/72	32/32	1/1	164/157	2,580
	Uruguay	190/25	23/23	34/34	2/2	440/94	5,600
	Venezuela	119/55	126/69	87/87	2/2	334/213	9,980
	Costa Rica	103/0	45/45			148/45	
	El Salvador	122/0	34/17			156/17	
	Guatemala	104/0	50/25	2/2	1/1	157/28	
	Honduras	84/0	35/35			119/18	
	Nicaragua	102/0	46/23			148/23	
	Panama	127/39	93/48	0/0		229/96	
	Mexico	119/01	1686/0	96/96	7/7	1908/194	31,350
	Total	1265/305	2538/688	486/454	25/25	4334/1594	161,490

Table 2-3. Equivalent Voice Circuit Requirements

1978

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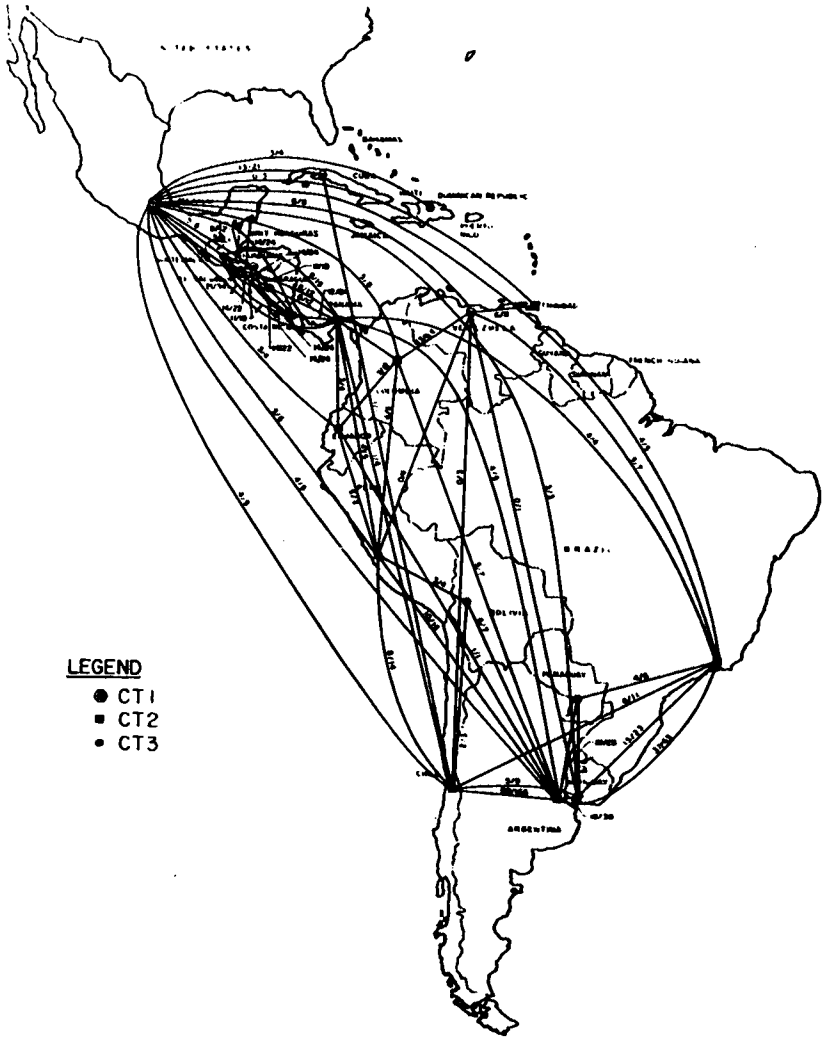
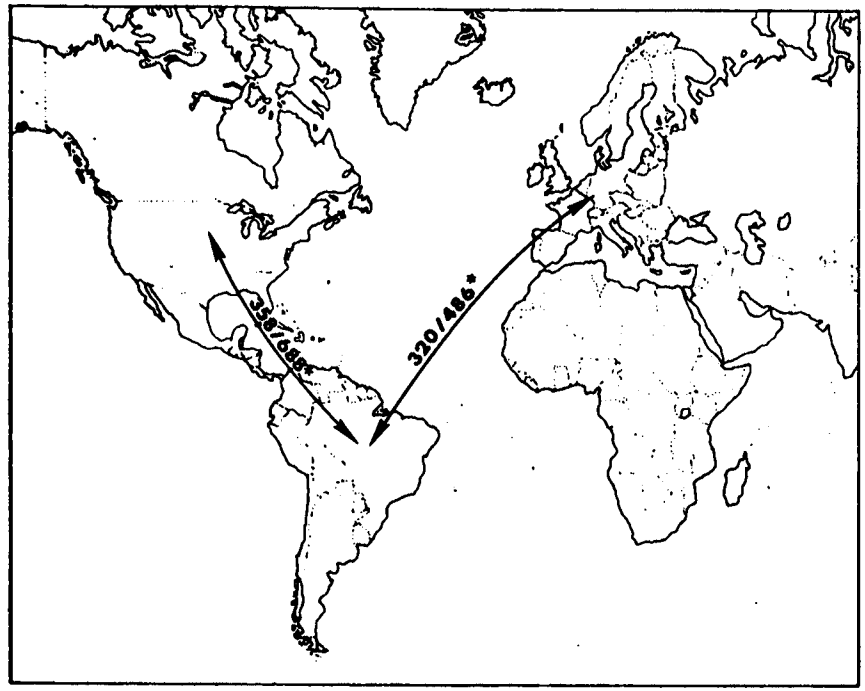


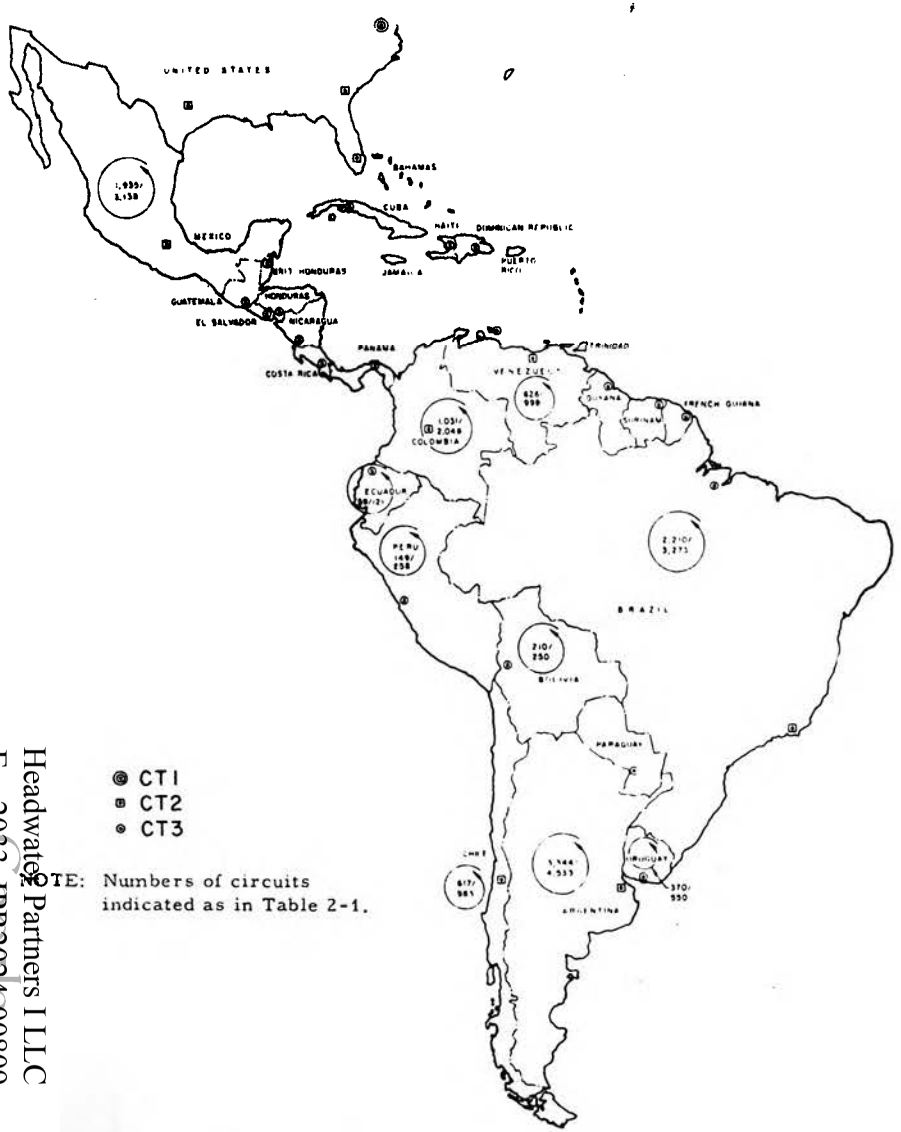
Figure 2-1. Latin American International Equivalent Voice Circuits 1973/78



*Nomenclature is the same as in Table 2-1.

Figure 2-2. Latin American Intercontinental Equivalent Voice Circuits via Satellite 1973/1978

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NOTE: Numbers of circuits indicated as in Table 2-1.

Figure 2-3. Latin American Intranational Equivalent Voice Circuits 1973/78 (assuming 10 % of long distance circuits to be carried via Satellite)

Once a large number of towns and cities are equipped with an earth station for only reception of TV, the transmitter and channel equipment for telephone service can be added, as needed, at moderate additional cost.

2.5.1 General

The need for television services and the problem of how best to utilize a television capability by a developing nation have been studied. The conclusion of these studies is that television can be employed to advantage for educational, instructional, cultural, and entertainment purposes by these nations. In addition television can provide national and international news services and programs to make the populace more aware of domestic and world-wide political and current events.[1-9]

The number of television channels recommended, or thought necessary, by various investigators varies widely, ranging from a portion of a channel to approximately 12 channels per country. The Presidential Task Force advises that they expect to have a maximum requirement for 24 channels during this study period and a minimum of three channels.

This study considers a satellite that initially supplies one television channel to each of three Latin American regions. While the choice of three channels is arbitrary, it is in accord both with the capabilities of satellites that could be launched at reasonable cost during the 1970's and the number of hours of programming that the developing nation would be able to generate initially.

According to Dr. F. S. Cespedes,[10] Director of Educational Technology of the Pan American Union (The Secretariat of the Organization of American States), the provision of one television channel initially to each of three areas in Latin America is adequate. Even if these channels had to be shared throughout the day by several countries, and used for different purposes (grade and high school instruction, adult education, entertainment, etc.) it would be quite demanding of the program production capabilities of the countries, at least initially.

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The time-sharing of television channels would also provide a cultural-sharing effect on the countries using a common beam. While much of the programming would be produced by one country for reception in that country, there would be some subjects and topics that could be useful to all, for example, instruction in reading and writing, mathematics and the sciences.

On the other hand stations could be controlled either by terrestrial means or by a satellite control circuit which would black out a given program in areas in which its reception is not desired.

At this time the number of television channels required or desired for educational and other purposes has neither been studied in detail nor agreed to, by Latin American educators and governments.

2.5.2 Types of Television Services

The various types of television services under consideration in this study are as follows:

a. Educational Television
b. Instructional Television
c. Computer-Aided Instruction
d. Commercial Television
e. Government Television
f. Network Television

Each of these services is discussed in Annex 2-G.

2.5.3 Methods of Television Distribution

2.5.3.1 Re-Broadcast. Re-broadcast refers to television programs that are received at earth stations would be carried (by cable or microwave) to a nearby television transmitting station for live or taped broadcast to conventional television receivers.

This is similar to the method proposed by COMSAT, and others, for a television distribution satellite. With an extensive terrestrial microwave and cable network substituted for the satellite, it is the method used today for network programming in the USA.

2.5.3.2 Limited Direct Broadcast. Limited direct broadcast is the reception of television at a relatively small, simple, and less expensive earth station for viewing on monitors distributed throughout a town or community. Alternatively, the programs may be re-broadcast by a co-located, low-power television transmitter to conventional television receivers. This method differs from re-broadcast in degree but not in principle; in this system there could be more earth stations and, hence, the re-broadcast stations would each have to cover considerably smaller areas.

2.5.3.3 Direct Broadcast. For the pruposes of this study direct broadcast is defined as reception on conventional television receivers using existing transmission standards (525 lines, 4.2 MHz bandwidth, etc.). Direct broadcasting is further discussed in Annex 3-C.

2.6 OTHER STUDIES

A discussion of the impact of spare communications on Latin American Telecommunications is presented in Annex 2-H.

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9. "Educational Television Satellite Distribution System for India," Hughes Aircraft Company, SSD 70547B, December 1967.

10. Private Communication.

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SECTION 3

SYSTEM CONSTRAINTS

3.1 CONSTRAINTS IMPOSED BY LAUNCH VEHICLES AVAILABLE IN THE 1970's

As stated in the Assumptions, only those launch vehicles that are likely to be operational at the Eastern Test Range during the 1970's will be considered as potential boosters for regional satellites.

While other combinations of launch vehicle stages and new vehicles have been suggested, the uncertainty of their being operational, coupled with nonrecurring high development costs, that would have to be borne by the regional system should these vehicles be developed specifically for it, rules them out. For example, a new combination, the Titan 3C, Centaur, has been hypothesized. Such a launch vehicle would be capable of placing about 16,000 pounds in transfer orbit, and thus, about 7,300 pounds of useful payload in the stationary orbit. Recurring cost is estimated as 30 million dollars. No figures are available for nonrecurring costs, but they could easily be in excess of 40 million dollars.

The vehicles that have been considered are:

Vital	Payload (pounds)	
	Transfer Orbit	Useful Payload
Long Tank Delta w/TE 364-3 (DSV-3L) (INTELSAT III launch vehicle)	725	315

Vehicle	Payload (pounds) Transfer Orbit	Useful Payload
TITAN 3B-Agena*	2400	1240
ATLAS-Centaur	3400	1700
TITAN 3C	7600	3420

Costs of these vehicles are given in paragraph 4.1.7.

3.2 FUNDAMENTAL SYSTEM TECHNICAL CHARACTERISTICS THAT HAVE A MAJOR INFLUENCE ON SYSTEM CONFIGURATION

3.2.1 Signal Quality and Grade of Service

CCIR and CCITT standards have been assumed for telephone service. A discussion of the relevant CCIR and CCITT Recommendations is given in Annex 3-A.

For television, two signal-to-noise ratios have been assumed: 51 db Spp/Nrms (54 db Vpp/Nrms), and 44 db Spp/Nrms (47 db Vpp/Nrms).†

Consideration has been given to values below CCIR standards for two reasons: Significant savings in satellite EIRP, or earth station G/T, would result, with a consequent reduction in system costs; and the quality expected of educational TV does not have to meet the strict standards for commercial TV. Moreover, the signal would almost always be viewed on monitors close to the earth station, or distributed over a limited area by cable systems or rebroad cast by local transmitters and thus suffer little additional degradation as does commercial TV sent over many links and subsequently rebroadcast.

The first quality (54 db Vpp/Nrms) is the TASO/FCC subjective quality 1.5 (between grades 1.0, "Excellent" and 2.0, "Fine"). The second (47 db Vpp/Nrms) is TASO/FCC grade 2.5, (between "Fine" and "Passable"). The latter is equivalent to the Bell System 1958 Commercial Performance standard "Worst Picture to Customer."

*It is not definite, but likely, that this vehicle will be available, since a booster of about this payload capability will be required for INTELSAT IV. In the cost calculations, the estimated $11 million development cost is conservatively spread over an assumed schedule of six launches for INTELSAT IV, a U.S. domestic system, and the Latin American regional system.

†Vpp includes synch, Spp is black to white picture.

3.2.2 Rain Margin

A rain margin of 3 db has been used for all analyses for the following reasons:

a. Antenna radomes are not recommended for earth stations in this system. Therefore, the 6 db rain margin for INTELSAT stations with randomes is not required.

b. Experience at Goonhilly Downs, England, indicates that a 3 db margin is adequate for earth stations without randome.

c. The 3 db margin takes into account an increase in effective system noise temperature which is not exceeded more than 0.01 percent of the year for an average yearly rainfall of 100 cm and 200°K system temperature. Buenos Aires and Santiago, for example, have less rainfall than this, and Rio de Janiero only slightly more (118 cm). Essentially, the same conclusion can be drawn for stations having a clear sky overall system noise temperature of 150°K.

3.2.3 Continuity of Service

The semiannual eclipse periods reach a maximum of about 70 minutes, and are centered around local midnight at the subsatellite point, depriving the solar cells of illumination during that time. If operation is desired during eclipse, batteries must be carried. Depending on their capacity, batteries can supply all, or only a portion of, the satellite's design power. Batteries impose a weight and reliability penalty. For example, a satellite with a prime dc power of 1000 watts would need about 155 pounds of batteries for full eclipse operation. It has been assumed for the purpose of this study, that one possible subsatellite longitude would be the West Coast of South American. Hence, the local time at eclipse will be between about 2400 on the West Coast and 0300 on the East. This is a period of low telephone traffic and minimal television viewing requirements. Therefore, it has been assumed that no television will be carried during eclipses and only 10% of the telephone circuits will be maintained

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Another possible location considered in this study for a satellite providing spot beams for several South American countries or regions, is at 100°W longitude. A satellite at that location would experience eclipse at local South American time between 0100 and 0400. These are times of even lower telephone demand, and practically nonexistent television demand.

3.2.4 Spare Philosophy

The provisions made for spares: whether emplaced in orbit, standing ready on the launch pad, or resting in a manufacturer's warehouse is a question of cost effectiveness versus required continuity of service.

Experience with the INTELSAT satellites (among others) has shown that lifetimes of three years in orbit have been demonstrated, and that lifetimes in excess of five years can be expected during the 1970's.

More important is the spacecraft and the transponders aboard can be designed for "graceful degradation" so that failures of individual components, for the most part, do not result in a completely inoperative satellite.

This can be and has been accomplished by several techniques. For example:

- Redundant subsystems
- Switchable TWTs
- Multiple, independent transponders
- Series-parallel solar cell operation

The emplacement of a spare can be scheduled as dictated by the actual performance of the operating satellite(s) as measured by telemetry, and by the knowledge of which redundant elements have failed.

Notwithstanding the desire or requirement of communicators who use these systems for guaranteed uninterrupted service, it will be assumed for this study that spare satellites will be constructed and held in the manufacturer's plant until needed.

Such a spare philosophy is likely to provide, but not guarantee, continuous service which may rarely and for brief periods be reduced to partial service.

3.2.5 Frequency Allocations

The radio regulations of the ITU, which have the force of treaty law, presently allocate certain bands, shown in Table 3-1, to the earth-space service in Region 2 (North and South America).

Of these, only Items 3 and 5* (500 MHz each) are assigned within the U.S. to commercial communication satellite systems. The remaining ones are used "on an interim basis by the government." (Footnote 91 of the FCC Regulations). At present, the U.S. IDCS system operates in bands 6 and 9. No satellite systems operate in the others (1, 2, 4, 7 and 8).

It is known that several European countries have plans to use the government frequencies in Items 6 and 9 for their own government (i.e., military) systems. It is reasonable to assume that such systems, both U.S. and European could eventually involve the use of ship-borne or mobile earth stations in many parts of the world, for example, in the international waters of the South Atlantic and South Pacific Oceans. Even so, U.S. or European government satellites would likely be positioned far over the Atlantic or Pacific to interconnect distant areas. A Latin American regional satellite (or satellites) would be positioned over the continent, or near it, and would thus offer little interference to the other system(s).

This interim U.S. domestic regulation restricting these frequencies to government systems should not prevent the use of these internationally allocated space service frequencies in a Latin American system.

If Items 7, 8 and 10 were to be used, the additional 450 MHz down and up could furnish an additional 4500 channels for Latin American regional use at 100 KHz per channel.

*As shown in Table 3-1.

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Table 3-1. Radio Frequency Allocations

Item	Freq. (MHz)	Link	BW (MHz)	Flux Density Limit Applies	Shared with:	In the US: Amateur. Commercial or Government
1	400-3500	Down	100	No	Amateur & Government	G/A
2	3500-3700	Down	200	Yes	Fixed & Mobile Radio Location	G.
3	3700-4200	Down	500	Yes	Fixed & Mobile	C.
4	4400-4700	Up	300	Not Applicable	Fixed & Mobile	G.
5	5925-6425	Up	500	Not Applicable	Fixed & Mobile	C.
6	7250-7300	Down	50	No	Exclusive	G.
7	7300-7750	Down	450	Yes	Fixed & Mobile	G.
8	7900-7975	Up	75	Not Applicable	Fixed & Mobile	G.
9	7975-8025	Up	50	No	Exclusive	G.
10	8025-8400	Up	375	Not Applicable	Fixed & Mobile	G.

Alternatively, these three bands and bands 3 and 5 could be employed using 200 KHz per channel to provide a total of 4750 channels, while reducing the required satellite EIRP through the doubling of the frequency deviation. This question is discussed in Annex 3A.

Other frequencies not presently allocated to the earth space service, but which might be allocated are contained in Annex 3C. This annex also contains a discussion of the frequencies that could be used by a direct broadcast satellite.

3.2.6 Harmful Interference

The following sources of potential interference between a communications satellite and a terrestrial line-of-sight radio relay systems exist due to the shared use of the 4 GHz to 6 GHz bands.

a. Illumination of a line-of-sight receiver operating in the 4 GHz band from the satellite transmitter.

b. Illumination of the satellite receiver and from the line-of-sight transmitter operating in the 6 GHz band.

c. Illumination of the earth station receiver from the line-of-sight transmitter operating in the 4 GHz band.

d. Illumination of the line-of-sight receiver from the earth station transmitter to the 6 GHz band.

Modes (a) and (b) will determine the maximum allowable EIRP from both the satellite and the line-of-sight system to prevent harmful interference.

Modes (c) and (d) can be avoided by site selection. Theoretically, they can be kept to an acceptable level by situating earth stations and terrestrial line-of-sight station, sufficiently far away from each other. In calculating the required separation, the possibility of interference via the tropospheric scatter mechanism, line-of-sight propagation must be considered. Careful field intensity measurements will be required to confirm these calculations prior to the final decision to use a given site. See Annex 3A, Paragraph 1 for relevant CCIR

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recommendations. All system configurations utilize the entire 500 MHz bandwidth now allocated for satellite to earth station transmission in the 4 GHz band.

The opportunities for harmful interference will be fewer in a regional system compared with the INTELSAT system. The regional satellite will be at a much higher elevation angle where the antenna gains of terrestrial stations are low and the possibility of main beam illumination almost non-existent.

In a system with high power earth stations having sensitive receivers, such as the present INTELSAT system, stations are generally sited far from population centers, to avoid microwave interference, since the costs of carrying these circuits to telephone facilities can be spread over the large numbers of circuits carried. For example, the remote locations of the Comsat stations in the U.S: Maine; the extreme western tip of Oahu, Hawaii; Jamesburg, California; Etam, West Virginia; and Comay, Puerto Rico.

In a South American regional system, however, there will be many more tations and, in many cases, they will be carrying a small number of channels. erforce, they will be installed near the towns and cities they serve. In a developed country, towns are the nodes and terminals of microwave systems that use the same frequencies as the earth-space service.

At present, the microwave network in South America is rudimentary and, in most cases, it will not be difficult to find earth stations sites near towns and cities that will not cause or receive interference. As the microwave network grows, interference possibilities[1] will increase. Care will have to be exercised to prevent harmful interference to the then existing earth station, and still permit the expansion of the terrestrial network.

1. "Expected Interference Levels Due to Interactions between Line-of-Sight Radio Relay Systems and Broadband Satellite Systems," by R.G. Medhurst and J.H. Roberts, Proc. IEEE, Vol. III, No. 3, March 1964.

3.3 MULTIPLE ACCESS TECHNIQUES

For the system traffic assumption that intra-national telephone service will be supplied to individual countries or a small group of countries, demand assignment of satellite capacity is indicated. The provision of many pre-assigned circuits to many small terminals, with a few circuits per terminal, would be inefficient, and hence costly in terms of satellite capacity.

Even for the international and intercontinental traffic assumption, demand assignment results in more efficient utilization of satellite power and hence in a more cost effective system. In this case, a portion of total satellite capacity might be preassigned, and the remaining capacity used on a demand assignment basis. While this would reduce the required satellite power and bandwidth slightly, if at all, it would ease the load on the demand assignment equipment.

Ideally, a spacecraft for regional use would: a) serve earth stations of differing figures of merit (G/T) so that earth stations having large circuit requirements could use the higher performance stations; b) require only one earth station at each location to be served; c) operate in either the demand assigned or preassigned mode as dictated by traffic volumes between given points; and d) provide an educational TV capability to smaller stations in contrast to the conventional international exchange of television (i.e., programs intended for distribution through existing facilities) such as would be carried over the INTELSAT satellites.

Several modulation methods have been analyzed for their suitability for use in this system.

Detailed calculations are given in Annex 3A.

Of the methods considered, only the Star and Spade systems were considered suitable. Since the Star system requires about 6 db more satellite EIRP when utilizing the same bandwidth, Spade system is the preferred type. Moreover, Spade would be simpler, more compact and thus less expensive to implement.

Several system configurations have been assumed and the required satellite rf power determined for each. They are summarized in Table 3-2.

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3.4 TRAFFIC CAPACITY OF A MULTIPLE ACCESS DEMAND ASSIGNED SYSTEM

A multiple-access, demand assigned satellite system with voice operated carrier switches, permits a larger number of telephone subscribers to be accommodated with less expenditure of satellite transmitter power, than might be apparent from a calculation of the channel capacities given in the previous paragraphs.

With either the Star or Spade method (Annex 3A) the individual voice modulated carriers are switched on only when speech is present. Thus, the maximum transmitter power that must be supplied by the satellite, can be less than dictated by the number of channels in use at a given time, by an activity factor that takes conventional sources into account. A value of 2.5 (4.0 db) is typical. This value has been used in the calculations of required satellite EIRPs.

Another factor which would permit the satellite to provide a higher grade of service between many more locations than would appear to be indicated by the maximum channel capacity of the sattellite, is the more efficient loading of a satellite that is possible when all channels are available to all stations.

If an earth station is to provide access to the satellite from many telephone subscribers connected to the telephone office served by that earth station, there must be a sufficient number of channels available so that the busy hour traffic can be accommodated with a low probability of blocking. This would be when a caller receives a busy signal because all the trunks to the sattellite are in use, not because the called party is busy. For example, if a maximum of 6 trunks can be established simultaneously to the satellite from each station, and a low probability of blocking of P=.03 (3%) is desired, average utilization of each of the trunks is 38.3%. As the number of trunks increases, the utilization efficiency of all trunks increases. For 16 trunks, the utilization is 58%.

If each station supplies 2.3 Erlangs, a satellite capable of carrying 2090 Erlangs can accommodate 910 stations. If 90 MHz is reserved for 3 TASO Grade 1.5 TV channels, 4100 telephone channels (2050 circuits) remain. In this case, 847 stations can be accommodated. This analysis is conservative in that it does not take into account the variation in the busy periods throughout the day due to the time difference that exists across South America. This three-hour spread has the effect of decreasing the busy hour peaks. In effect, 910 (or 847) active stations can be accommodated simultaneously.

Both of these numbers are greater than the number of towns in South America with a population greater than 10,000 people. Thus, a satellite with a capacity of 2200 circuits could supply telephone service at P = 0.03 to every town over 10,000 people if the average traffic offered per station was 2.3 Erlangs, with a considerable excess that could be made available to the larger cities, or to smaller towns to which telephone service is desired for some special reason. Alternatively, this excess can accommodate growing requirements.

Three satellite system configurations are described in paragraph 5.5.3, designed to serve intranational needs. Erlang loads for these systems (A, B, and C) have been calculated for a grade of service of P = .03.

Each can be accommodated on a satellite capable of providing about 2,000 circuits in addition to 3 TV channels.

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Table 3-2. Satellite RF Power Required (watts) for Various Service Requirements and Earth Station G/T s Assuming a 4.3db Back-off and Spade System for Telephone

Service Required	17.7	21.2	25.7	27.8
Case 1				
3 TV channels (TASO 2.5) and 4400 telephone channels 3 antenna beams	199.5	89.1	31.6	19.5
Case 2				
3 TV channels (TASO 1.5) and 4100 telephone channels 3 antenna beams	210.5	94.0	33.3	20.6
Case 3				
5000 telephone channels 3 antenna beams	168.5	75.2	26.7	16.5
Case 4				
1 TV channel (TASO 2.5) and 4800 telephone channels 5° antenna beam (Brazil)	284.5	127.0	45.1	27.8
Case 5				
1 TV channel (TASO 1.5) and 4700 telephone channels 5° antenna beam (Brazil)	288.9	129.0	45.8	28.2
Case 6				
5000 telephone channels 5° antenna beam (Brazil)	268.8	120.0	42.6	26.3
Case 7*				
25 TV channels (TASO 2.5) BW = 20.0 MHz 5° antenna beam (Brazil)	676.5	302.0	107.1	66.1
Case 8*				
16 TV channels (TASO 1.5) BW = 30.0 MHz 5° antenna beam (Brazil)	650	290	102.9	63.5
Case 9				
1 TV (TASO 1.5) +1650 telephone channels 5° antenna beam (Brazil)	127	58	20.6	12.7

*Cases 7 and 8 assume a 2 db back-off

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SECTION 4

CHARACTERISTICS AND COSTS OF SYSTEM ELEMENTS AVAILABLE IN THE 1970's

4.1 GENERAL

This section discusses the characteristics and costs of spacecraft and earth stations that are expected to be available in the 1970's.

4.2 SPACECRAFT

Spacecraft are not available in a continuum of sizes, and hence, in radiated powers. For each of the launch vehicles assumed in this study, the competent designer will be able to design a spacecraft having a certain maximum radiated power capability that will not differ appreciably from that of other manufacturers. This maximum is, of course, affected by the constraints imposed: lifetime, reliability, eclipse operation (battery capacity to be carried), required position-keeping tolerance in both longitude and inclination, etc. This radiated power can be converted to EIRP once the stability of the platform, and the coverage desired on the earth are specified.

For the purposes of this study, several manufacturers were consulted. Estimates of spacecraft performance based on their conclusions follow.

Present communications satellites, being used by the global INTELSAT network, have relatively low-power transmitters with omnidirectional antennas. These satellites, the INTELSAT II type, are used with large earth stations, having gain to temperature ratios (G/T) of 40.7 db or greater. Each provides 240 duplex voice channels with a satellite EIRP of 15.5 dbw in a bandwidth of 130 MHz.

Satellites for regional systems, however, would be operating with a larger quantity of smaller, less expensive earth stations with lower G/T's. Therefore, the satellite must make up an increase in EIRP for the decreased G/T of the earth stations economically desirable for use in a regional system.

This section considers larger, higher-powered satellites than are presently being used for the international satellite system. To provide estimates of the performance and costs of the space hardware, several spacecraft manufacturers were questioned concerning satellite capabilities. The data obtained from these questions as well as published data were used to derive the necessary functional relationships for predicting future satellite capability.

4.2.1 Present Satellites

Table 4-1 is a list of communications satellites in present use. Some of these satellites contain hard limiting repeaters, as in the case of INTELSAT I and the IDCSP satellites, while others, such as INTELSAT II, contain linear repeaters. Hard limiting repeaters where used with an FDM-FM system are intended for a single access only and, hence, are used for communications between only two earth stations, while the linear repeater allows multiple access and can be used for simultaneous communication between many earth stations.

4.2.2 Planned Satellites

Table 4-2 is a list of major future and planned communications satellites, both for international and regional use. All have multiple access capability and are capable of higher EIRP's than present satellites through the use of directional

Table 4-1. Communications Satellites Presently in Use
(VHF Transponders, if any, not included)

Satellite Name (Type)	Launch Vehicle	Useful Weight (lbs)	DC Power (watts)	Antenna Gain Transmit (db)	Trans/Receive Frequency (GHz)	Receiver Type	No. of Transponders	Bandwidth (MHz)	EIRP dbw (Saturated)
Syncom II	Delta/TAD	85	33	5.3	1.8/7.3	Frequency Translation (limiting)	2	0.5	[illegible]
							1	[illegible]	
Syncom III	Delta/TAD	85	33	8.0	1.8/7.3	Frequency Translation (limiting)	1	[illegible]	
							1	5.0	
INTELSAT I	TAT/Delta	85	33	9.0	4.0/6.0	Frequency Translation (limiting)	2	25.0	13.0
INTELSAT II	TAT/Delta	190	75	6.0	4.0/6.0	Frequency Translation (linear)	1	130.0	15.5
ADCSP	Titan III C (6 at a time)	100	40	5.0	7.275/8.0	Frequency Translation (limiting)	1	50.	4.0
ATS-F1, F-3	Atlas/Agena	675	175	17.0*	4.0/6.0	SSB/PM** FM/FM	1	25.0	22.2
ATS-F2***	Atlas/Agena	775	130	9.0	4.0/6.0	SSB/PM**	1	15.	14.4

*F3 only, mechanically despun
**May be operated in either mode on ground command
***Gravity gradient stabilization

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4.2.3 Satellite Technology and Capability

Given a certain satellite weight, the most fundamental problem is to maximize the satellite EIRP by trading off power versus weight among the satellite subsystems. In this way the satellite equipment configuration may be optimized for maximum efficiency in terms of the power to weight ratio. Since useful payload constraints, of 315, 1240, 1700 and 3420 pounds, due to launch vehicle availability in the 1970's, have been assumed, as discussed in paragraph 4.2, the EIRP's will be determined for these weights only.

The two primary subsystems which will be considered in the configuration trade off are:

a. The power subsystem, including the prime power; the secondary, or eclipse power; and the power conditioners.

b. The transponder subsystem, including the receiver, transmitter and antenna.

These subsystems require about 60% of the total useful satellite weight. Since the rest of the satellite weight, i.e., station keeping equipment structures, telemetry and command encoders, etc., is relatively unaffected by changes in satellite power and are more a function of total satellite weight and design life, they will be considered constants.

4.2.3.1 The Power Subsystem. The satellite power system must produce the required amounts of DC power in a minimum power subsystem weight. Thus, a figure of merit of a satellite prime power system may be measured in watts per pound. In a secondary power system used for eclipse operation, the figure of merit is energy per unit weight, or watt-hours per pound.

4.2.3.1.1 Prime Power Source. The silicon solar cell has been the primary power source used in communications satellites to date. Thin film solar cells, of which the most promising is cadmium sulfide, described by Morrow[1], have installed power to weight ratios of more than twice that of silicon solar cells. Silicon solar cells have an efficiency of 10%[2], as opposed to 4-7% efficiency[3]

Table 4-2. Planned or Proposed Communications Satellites

Satellite Name	Launch Vehicle	Useful Weight (lbs)	DC Power (watts)	Antenna Gain Transmit (db)	Trans/Receive Frequency (GHz)	Receiver Type (all translating)	No. of Trans-ponders	Trans-sponder Bandwidth (MHz)	EIRP (Steerable)
INTELSAT III	TAT/Delta	270	130	18.0	4/6	Linear	2	225.0	25
INTELSAT III #2	TAT Delta	290	130	29.0 or 20.0	4/6	Linear	2	225.0	31
INTELSAT IV	Titan IIIC/Agena	1200	500-600	18.0 or 30.0	4/6	Linear	12	35-5	
Hughes ETV-HS-303D	TAT/Delta	300	130	33.0	4/6	Quasi-Linear*	9	35-40	
Comsat Phase I Program	Titan IIIC/Agena	≈1900**	1000-1400	30.0	4/6	Linear	12	35-40	
Fixed Foundation	Titan IIIC/Agena	1910	900	34.0	4/6	Linear	24 *	35-40	

*Operation linearly but may be saturated for single carrier operation

**With frequency re-use

for cadmium sulfide cells. The cadmium sulfide cells, although lighter than silicon cells, because of their lower efficiencies require more array surface area to develope the same power levels. This can be seen from the comparison in Table 4-3 shown below.

Table 4-3. Comparison of Silicon Solar Cells and Cadmium Sulfide Solar Cells

Parameter	Cadmium Sulfide	Silicon
Efficiency	4-7%	10%
Power-weight ratio[4]	93 watts/lb	14.9 watts/lb
Power-surface area ratio	5.75 watts/ft^2	8.22 watts/ft^2

Therefore, because of this lower power to surface area ratio, to take advantage of the higher power to weight ratio, a deployable solar array must be utilized. This is due to the launching shroud limitation which restricts the fixed surface area of body mounted solar arrays. The use of large solar arrays is subject, however, to increased solar pressure, which tends to disturb the spacecraft stabilization. This effect can be overcome through the use of solar sails to balance the torques, and larger quantities of impulse fuel to compensate lateral forces.

At present, cadmium sulfide solar cells are overcoming problems in construction which, in earlier versions, caused power degradation due to temperature cycling and moisture absorption. They can, with further development, begin to approach silicon solar cells in efficiency(3). Data based on conventional silicon solar cell technology and thin film technology relating satellite dc power capability to total useful weight is plotted in Figure 4-1. From this data the end of life power capability of the chosen satellite payloads can be determined and are listed in Table 4-4.

Table 4-4. End of Life Power for Selected Payloads

Satellite Payload (lbs)	DC Power (Watts) Silicon-Body Mounted	Silicon Deployable	Thin Film Deployable*
315	140	290	1050
1240	600	1250	4700
1700	750	1750	6750
3420	1750	3600	15000

*This technology is estimated at about five years from being state of the art.

4.2.3.1.2 Secondary Power Source. Since a reduced traffic requirement during eclipses of 10% of normal telephony and no TV has been assumed the storage battery capacity required is less than the primary power capacity. The prime power levels presented in Table 4-4 are based on a sufficient amount of storage batteries for this reduced eclipse operation.

The number of charge-discharge cycles which a storage battery must sustain is approximately 90 per year. The longest discharge period is 1.3 hours[5]. A five to ten year mission would require about 450 to 900 cycles. The nickel-cadmium battery is the best and most proven choice under the above conditions of use. The cycle life of a nickel-cadmium battery, however, is dependent on battery temperature and the depth of discharge of each cycle. These parameters must therefore be considered when determining battery capacity. It is desirable, of course, to minimize the amount of batteries to be carried because their weight tends to lower the overall dc power output and to reduce the reliability of the entire spacecraft.

Figure 4-2 shows the cycle life of a nickel-cadmium battery as a function of discharge depth for different ambient temperatures. The maximum permissible number of cycles occurs at about 77°F and the battery life under the same discharge depth degenerates at temperatures above and below this value. Because the temperature within the spacecraft will vary from 20°F to 100°F[6], a conservative discharge depth limit would be 50%, since a battery cycle life in excess of 1000 cycles is necessary to ensure eclipse operation for the entire spacecraft design life.

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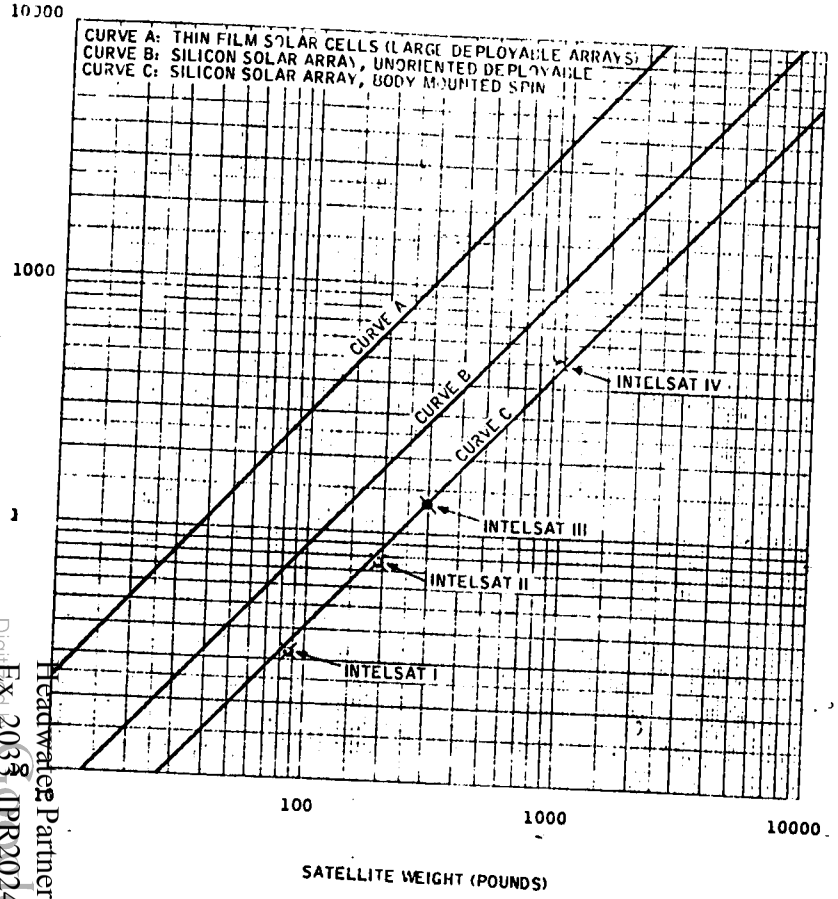


Figure 4-1. Prime Power as a Function of Useful Satellite Weight

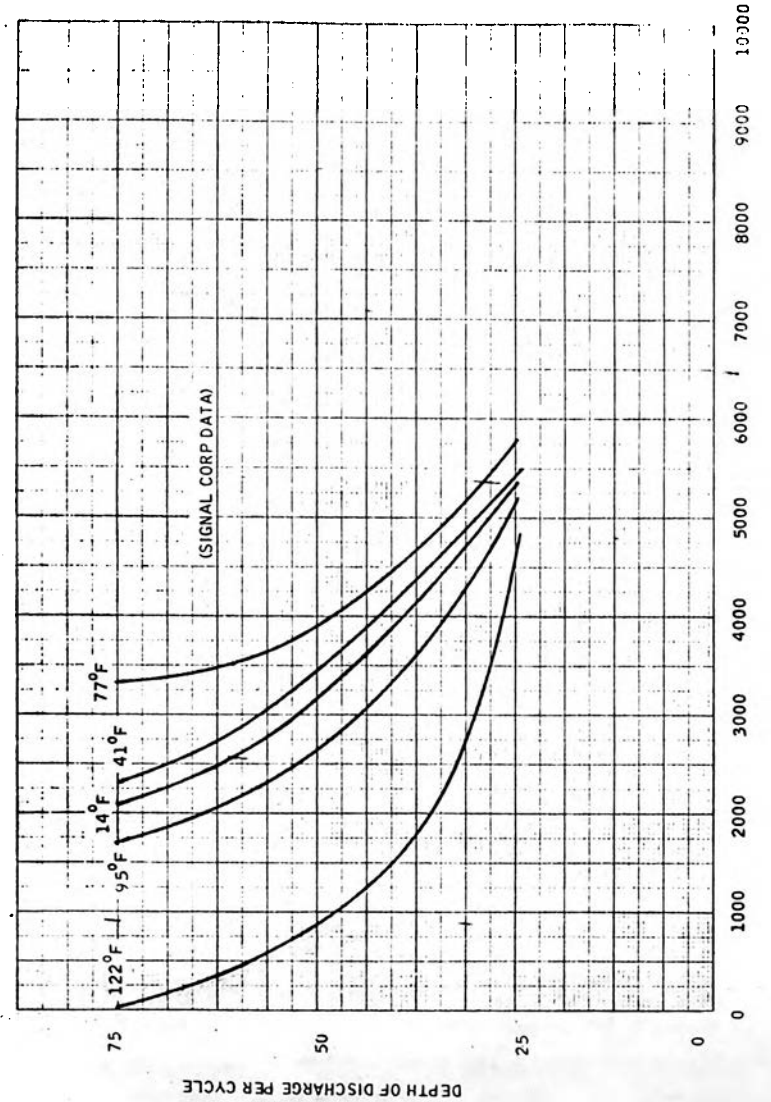


Figure 4-2. Nickel Cadmium Battery Cycle as a Function of Discharge Depth for Different Temperatures

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The energy to weight ratio for a nickel-cadmium battery is 15 watt-hours/pound[2]. At the design discharge depth limit of 50% it becomes 7.5 watt-hours/pound. The storage battery weights for each satellite payload and assumed eclipse requirement given in Table 4-5.

Table 4-5. Secondary Battery Characteristics

Payload (lbs)	Energy Required (watt-hours)	Battery Weight (lbs)
315	40	5.4
1240	105	14.0
1700	130	17.4
3420	330	44.0

4.2.3.2 RF Power Conversion Efficiency. The figure of merit of a satellite transmitter is the power conversion efficiency or the rf power output for a given dc power input. The amount of rf power is, of course, limited by the number of redundant transponders used which increases the weight of the total electronics package. This total transponder weight must be traded off with the dc power system weight to achieve an optimum configuration which will produce the highest EIRP in the given satellite weight.

At present, traveling wave tubes are used as the transmitter in all communications satellites which operate in the 6 GHz commercial frequency band. The reasons that a TWT is chosen for this purpose above a solid state amplifier are: (1) As the frequency increases, the efficiency of a solid state amplifier decreases while the TWT efficiency remains constant. This is illustrated in Figure 4-3 where efficiency as a function of frequency for a TWT and a solid state amplifier is shown; (2) Solid state amplifiers in this frequency band are still experimental in nature and have not been space proved.

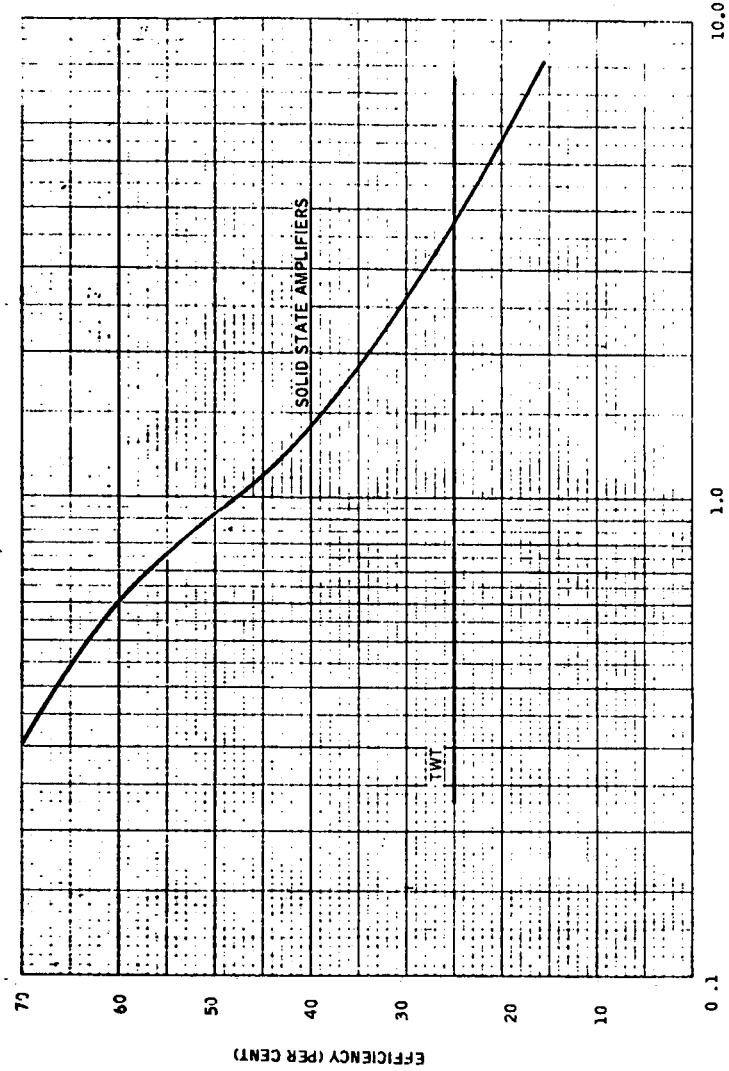


Figure 4-3. Efficiency as a Function of Frequency for TWT's and Solid State Amplifiers

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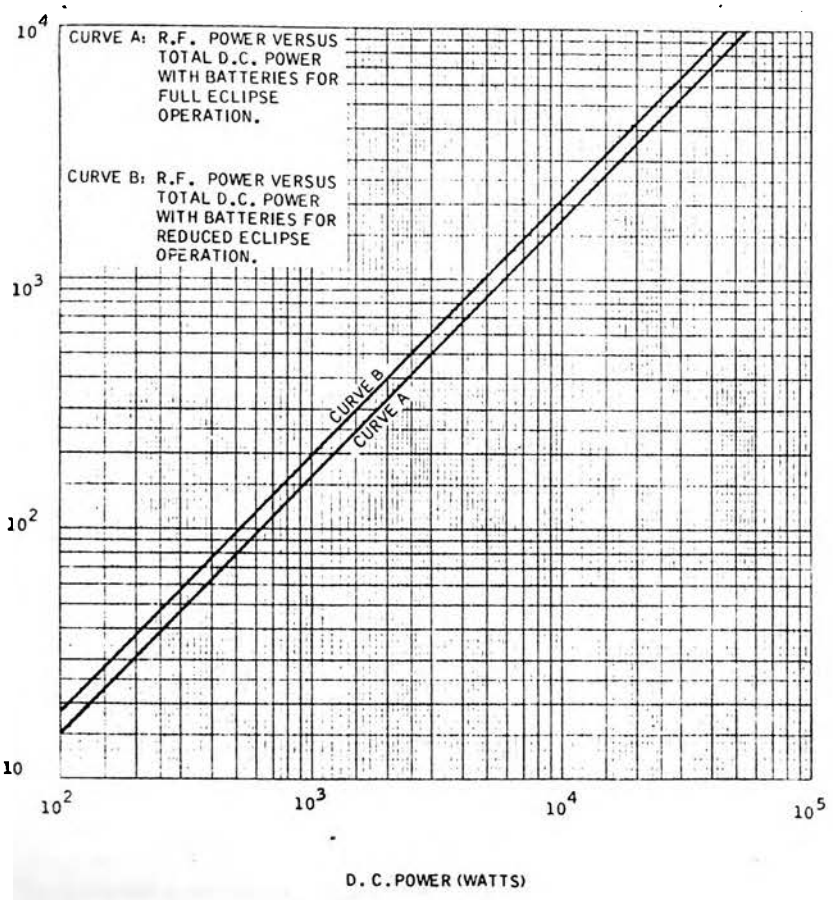


Figure 4-4. RF Power as a Function of Total D.C. Power

RF power as a function of total satellite dc power, assuming a TWT efficiency of 25%, is plotted as Curve A in Figure 4-4. The data used to plot Curve A is based on a satellite with full eclipse capability; hence, includes a full load of batteries. The penalty paid for batteries is twofold. First, as previously mentioned, the battery weight subtracts from the weight of the power system and, thus, lowers the total dc power capability. Secondly, the batteries must be recharged during non-eclipse periods, using power which could have been used by the rf subsystem. The results of battery capacity reduction is illustrated by Curve B of Figure 4-4. The increase is due to the more efficient use of the total dc power.

The total rf power output can now be obtained for each satellite payload class, assuming existing technology. The results are listed in Table 4-6.

Table 4-6. RF Power Available from Each Satellite (existing technology)

Payload (lbs)	Full Eclipse Operation (watts)	Reduced Eclipse Operation (watts)
315	21.5	26
1240	95	112
1700	138	168
3420	290	350

4.2.3.3 Antenna System. Communications satellite antennas, to date, have been of the omnidirectional type to eliminate the necessity of providing a control system to point the antenna beam precisely at some area on the earth.

The technology necessary for producing such a system is presently existing and has been demonstrated. The systems presently designed are for use with a spin stabilized satellite and consist of a control system with earth sensors which "despins" the antenna at the satellite spin rate to keep it pointed toward the earth at all times.

ATS III, launched in November of 1967 into a synchronous orbit, has the capability of pointing a "despun" high gain antenna at the earth to an accuracy of $\pm 1^{\circ}.7$ INTELSAT III will be launched in 1968 with a similar pointing

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accuracy of ±1.0° RMS[8], with a global coverage (17° beamwidth) antenna of 13 db minimum gain. INTELSAT IV presently in the proposal stage will have a pointing accuracy of ±0.35°. Therefore our study concludes that, within the time frame of the 1970's a satellite can be launched which will provide illumination of regions and individual countries with antenna beams of 2.5° minimum, with a 0.1 beamwidth pointing accuracy.

From experience gained with present satellites, it is also reasonable to assume that the station keeping ability of satellites will be within 0.1° latitude and longitude[9], eliminating the need for tracking with ground station antennas of less than 30 foot diameters.

4.2.4 Overall Satellite Characteristics

The RF power characteristics of each class of satellites are summarized in Table 4-6 based on the following assumptions:

a. Conventional silicon solar cells will be used for the power supply. (no deployable arrays)

b. A minimum quantity of batteries will be carried for eclipse operation.

c. The antenna pointing accuracy is 0.1 beamwidth which, for the assumed beamwidths will give at the worst, 0.25°.

d. TWT's are used for the transponder electronics.

e. The dc power subsystem and the rf subsystem comprise 60% of the satellite weight.

4.2.5 Effect of Technological Improvements Anticipated in the 1970's

The total available rf power will probability be most affected by certain subsystem parameters. These are:

4.2.5.1 The Weight Allotment of the RF and Power System. The weight allotment of 60% can be increased by using more efficient impulse positioning systems, such as ion propulsion.

4.2.5.2 The Power to Weight Ratio of the DC and RF Power Systems. The increase of the dc power to weight ratio through the use of deployable silicon and especially deployable thin film solar arrays will occur within the 1970's time frame. These will give increases in power to weight ratios of from 2 to 5 times the present body mounted cylindrical solar arrays. They will, however, cause increases in torques and lateral forces due to increased solar pressure on the large deployed solar array surfaces.

4.2.5.3 The DC to RF Conversion Efficiency. The conversion efficiency of TWT's will not make significant improvements except possibly in the dc to dc conversion equipment. Since this equipment efficiency represents a small portion of the overall efficiency, any improvement will not have a large influence on the rf subsystem performance. Although advances are being made in other areas, such as transistors, crossed field amplifiers, etc., it does not appear likely that these equipments will be developed and operational in the time frame of the 1970's.

Based on data available on the use of thin film solar cells for dc power and ion impulse systems for station keeping, the rf power for the satellites can conservatively be expected to improve, as shown in Table 4-7.

Table 4-7. Expected EIRP Improvements in the 1970's

Satellite Weight (pounds)	RF Power Increase (db)
315	6.6
1240	7.6
1700	8.6
3420	8.0

4.2.6 Other Possible Technological Developments

It was anticipated that the technology in various subsystem areas discussed in previous paragraphs would be available in the 1970's. There are, however, other alternatives in critical areas which could have profound influence on satellite design, but would have to be a subject more intensive study than is possible here. These are discussed in the following paragraphs.

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4.2.6.1 Power Systems. The solar cell has been the primary source of power for long term, unmanned missions to date; but, there are other power systems which could be considered in the future (e.g., radio isotope sources and nuclear fission reactors).

4.2.6.1.1 Radio Isotope Supplies. The radio isotope supplies presently under development have several major disadvantages:

a. They are quite expensive and have a cost of approximately $70/watt for the heat source ($C^{o}60$), plus the cost of the converter. Since the efficiency of the converters is only about 10%, the cost per electrical watt becomes $700, as compared with about $220 per watt for silicon solar cells[4].

b. They require considerable radiation shielding in order to protect personnel at the launch facility prior to launch and to protect the electronics after launch.

c. The power output per pound is not competitive with solar cells producing only about 6.5 watts per pound, as compared with 15 watts/pound and 93 watts/pound for silicon and cadmium sulfide solar cells respectively.

4.2.6.1.2 Nuclear Fission Reactors. Nuclear fission reactors produce relatively high power levels on the order of 25 KW. However they are heavy and cannot be considered, at the present time, in the satellite weight classes under consideration in this study. As with the radio-isotope sources, the shielding requirement is large. For instance, the SNAP II reactor which provides about 3 kw of well-regulated power and weights about 750 lbs requires an additional 300 to 600 lbs of shielding depending on whether radiation resistant or conventional electronic circuitry is used[10].

4.2.6.2 Transponders. Traveling wave tubes have been used exclusively for the transmitters in communications satellites in the 6 GHz frequency band. However, the tubes, in general, have been of low output power (<10 watts). Because of increased demand for higher power, larger tubes are being manufactured and will be space qualified during the 1970's. Estimates are, that by 1976, tubes with saturated power outputs in excess of 200 watts will be available[11], and this was taken into consideration in the satellite configurations developed in the section on overall satellite characteristics.

4.2.6.3 Station Keeping Systems. Hydrazine, hydrogen peroxide and dry nitrogen mono-propellant have been used to date for station keeping purposes. These systems, however, require a considerable amount of fuel for a typical five to ten year mission. Ion propulsion systems are being developed which can produce a longer specific impulse in much less weight, although the thrust level is less than 10^{-3} lbs, as compared with 0.1 lb for hydrazine and hydrogen peroxide. The weight of an ion system is about 2% of the total spacecraft weight, as compared to 10.5% for the hydrazine system to produce the same velocity.

4.2.7 Satellite Costs

The satellite unit costs were obtained by a linear extrapolation of cost versus weight, based on the INTELSAT satellite costs and some costs supplied by spacecraft manufacturers. A plot of satellite unit and development cost versus useful satellite weight is shown in Figure 4-5. From this data on satellite costs, together with launch system costs, the summary in Table 4-8 was derived.

It should be noted that the data that were used to derive these curves were obtained from programs that relied heavily on new satellite development. Some reduction in costs could be expected by purchasing satellite designs already developed.

Table 4-8. Space System Costs (Millions of Dollars)

Satellite Weight (lbs)	R&D Costs	Unit Cost	Launch Vehicle	Estimated Launch Vehicle Cost* R&D	Unit
315	11.0	4.0	Thor Delta	-	4.5
1240	25.0	6.5	Titan 3B/Agena	11.0	12.6
1700	30.0	7.2	Atlas/Centaur	-	16.0
3420	44.0	9.4	Titan 3C	-	20.0

*Includes Range Costs, Insurance, and Launch Assistance.

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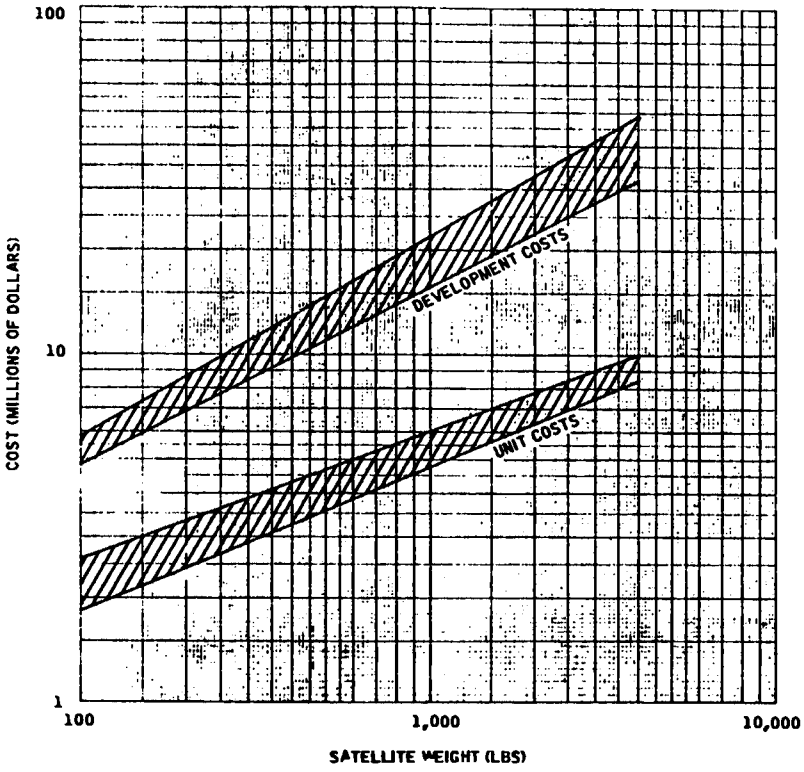


Figure 4-5. Estimated Satellite Costs as a Function of Useful Weight

4.3 EARTH STATIONS

4.3.1 Existing Stations

The design of a satellite communications earth station is already an established technology. A total of 21 commercial stations located across the world which are now operational in the INTELSAT II global system are shown in Table 4-9. These earth stations are generally large and expensive installations utilizing antenna sizes from 60 feet to 90 feet in diameter for fixed stations, and 42 feet for transportable stations.

Table 4-9. Existing Intelsat Earth Stations

Country	Name/Location	Satellite
U.K	Ascension Island	Atlantic Ocean
Spain	Canary Island	Atlantic Ocean
France	Pleumeur-Bodou	Atlantic Ocean
Germany	Raisting	Atlantic Ocean
Italy	Fucino	Atlantic Ocean
Italy	Fucino	Atlantic Ocean
Spain	Buitrago	Atlantic Ocean
U.K.	Goonhilly	Atlantic Ocean
Australia	Carnarvon	Pacific Ocean
Australia	Marce	Pacific Ocean
Japan	Ibaraki	Pacific Ocean
Philippines	Manila	Pacific Ocean
Philippines	Tanay	Pacific Ocean
Thailand	Bangkok	Pacific Ocean
Thailand	Srirachi	Pacific Ocean
Canada	Mill Village	Atlantic Ocean
U.S.	Andover	Atlantic Ocean
U.S.	Andover	Atlantic Ocean
U.S.	Brewster	Pacific Ocean
U.S.	Hawaii	Pacific Ocean
U.S.	Hawaii	Pacific Ocean

4.3.2 Planned Stations

The existing commercial global system is planning expansion to larger numbers of stations with larger channel capacities to operate with the expanded capability INTELSAT III satellite to be launched in the late 1968. There are presently being designed or under construction approximately 35 additional

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stations (shown in Table 4-10) planned for completion by 1970, all of which are expected to meet the ICSC mandatory requirements for a "standard" earth station which requires antenna sizes of approximately 90 feet in diameter and system noise temperatures of approximately 70°K with capability of receiving the entire satellite transmitted bandwidth of 500 MHz.

Table 4-10. Additional Intelsat Earth Stations Planned for Completion by 1970

Country	Name/Location	Satellite
Bahrain	Zellag	Indian Ocean
France	Pleumeur-Bodou	Atlantic Ocean
Germany	Raisting	Indian Ocean
Italy	Fucino	Indian Ocean
Ivory Coast	Abidjan	Atlantic Ocean
Kuwait	Basra	Indian Ocean
Morocco	Rabat	Atlantic Ocean
Nigeria	Lagos	Atlantic Ocean
Pakistan	East	Indian Ocean
Pakistan	West	Indian Ocean
Senegal	Dakar	Indian Ocean
U.K.	Goonhilly	Indian Ocean
Australia	Ceduna	Indian Ocean
Australia	West Coast	Pacific Ocean
U.K.	Hong Kong	Pacific Ocean
U.K.	Hong Kong	Indian Ocean
India	Poona	Indian Ocean
Indonesia	Djakarta	Indian Ocean
Japan	Ibaraki	Pacific Ocean
Japan	Yamaguchi	Indian Ocean
Malaysia	Kuantan	Indian Ocean
Taiwan	Shan Li	Pacific Ocean
Argentina	Buenos Aires	Atlantic Ocean
Brazil	Tanqua	Atlantic Ocean
Canada	Mill Village	Atlantic Ocean
Chile	Longovilo	Atlantic Ocean
Colombia	Bogota	Atlantic Ocean
Mexico	Mexico City	Atlantic Ocean
Panama	Utibe	Atlantic Ocean
Peru	Lurin	Atlantic Ocean
Venezuela	Maracay	Atlantic Ocean
U.S.	West Virginia	Atlantic Ocean
U.S.	Hawaii	Pacific Ocean
U.S.	California	Pacific Ocean
U.S.	Puerto Rico	Atlantic Ocean

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4.3.3 Earth Stations for the Regional System

4.3.3.1 Existing Station Technology and Anticipated Advancements in the 1970's. Earth station design depends largely upon the available satellite Effective Isotropically Radiated Power (EIRP) and required saturation flux density from the earth station transmitter.

An important parameter in the design, therefore, is the overall receiving figure of merit (G/T) where (G) is the antenna gain and (T) is the receiving system noise temperature both expressed in db. This figure of merit must be achieved over the required operating bandwidth.

Another important parameter in the design is the carrier to temperature ratio (C/T) existing at the demodulator. This relates the carrier intensity required to a given noise environment to achieve the desired degree of noise suppression.

Other considerations in the design of earth stations are the degree of steerability and method of pointing of the antenna to the satellite and the method of generation of the multidestination carriers for transmission to the satellite.

4.3.3.1.1 Antennas. The antenna performance is determined by the antenna size, efficiency, and sidelobe structure which is important to system noise temperature and mutual interference with other stations.

Simple antennas such as the Yagi, or log periodic antennas commonly used in home TV have a gain limit of about 13 db, a frequency limit of about 2 GHz and a notably poor sidelobe structure. Arrays of single element antennas are available which, through the array factor, can increase the gain limit to approximately 20 db. All other factors remain about the same.

Continuous surface antennas include the prime feed parabola, the Cassegrain, the Hoghorn and the Casshorn. These antennas are not gain or frequency limited but become more expensive as frequency is increased due to increased surface tolerance requirements. In our analysis, we have considered 10, 15, 25, and 32 foot diameter antennas. 55% antenna efficiency has been assumed through.

We do not expect major improvements or break-throughs in the antenna field for the next 5 to 10 years. Productions costs are known and can be easily related to the weight of the antenna.

4.3.3.1.2 Low Noise Amplifiers. Low noise maser amplifiers are available at very low noise temperatures (approximately 10°K) but are very expensive and complex and are available only with limited bandwidths (approximately 1% or 40 MHz at 4 GHz). Parametric amplifiers are available at noise temperatures down to 20°K with 500 MHz bandwidth. Both of these amplifiers are cryogenically cooled. Uncooled parametric amplifiers are presently available with 500 MHz bandwidth at 150°K. Performance gains are expected by 1972 which will result in 12°K for cryogenically cooled and 90°K for uncooled paramps.

4.3.3.2 Basic Design Assumptions. In the consideration of the costs of earth stations for the regional system, the following practical assumptions are made regarding the basic design configuration: Stations for the regional system should use:

a. Antenna diameters no larger than 32'.

b. Only manual positioning capability.

c. Uncooled receiver front ends.

d. A design that permits servicing by relatively untrained personnel (replaceable, throwaway subsystems).

e. The ability to operate from widely varying (voltage and frequency) commercial power sources that may also be interrupted for periods of time.

The earth station costs also assume implementation of the PCM-FDMA (Spade) demand assigned, multiple access system as described elsewhere in this report. The modem equipment will employ PSK, two phase modulation and coherent phase lock demodulation.

The lower limit on antenna diameter is assumed to be 10' (with a 3 db beamwidth of 1.2° at 6 GHz and a beamwidth to the first null of 2°). This is dictated by the concern that this system should minimize the possibility of interference to other stationary orbit satellite systems sharing the same frequencies, and should minimize the interference received from other systems and by the marginal decrease in cost achieved by using smaller antennas.

The system noise temperature is assumed to be 150°K utilizing a 90°K paramp. Such amplifiers are still under development, but it is expected that by 1972 that the production costs will be half that now being quoted and that the performance will be improved from the 150°K now available, to 90°K.

The availability of commercial power has been assumed. Comments on the commercial power available in South America, are given in Annex 3C.

In the non-critical and supporting subsystems we are dealing with stock equipment, the performance of which is not likely to be improved greatly. The auxiliary subsystems are unique to the proposed system design. One-time costs will be high but fortunately there are but a few of these subsystems required.

The basic technical characteristics of earth stations which are assumed for this study are listed in Table 4-11.

Table 4-11. Characteristics of Earth Stations Assumed

Diameter (ft)	Antenna Gain db (55% eff.) At 4 GHz	for T = 600°K (27.8 db) G/T	for T = 150°K (21.8 db) G/T (db)	Antenna Gain At 6 GHz
10	39.5	11.7	17.7	43.0
15	43	15.2	21.2	46.6
25	47.5	19.7	25.7	51.0
32	49.6	21.8	27.8	53.0

4.3.3.3 Earth Station Cost Elements. The major elements of cost of earth stations are shown schematically in Figure 4-6.

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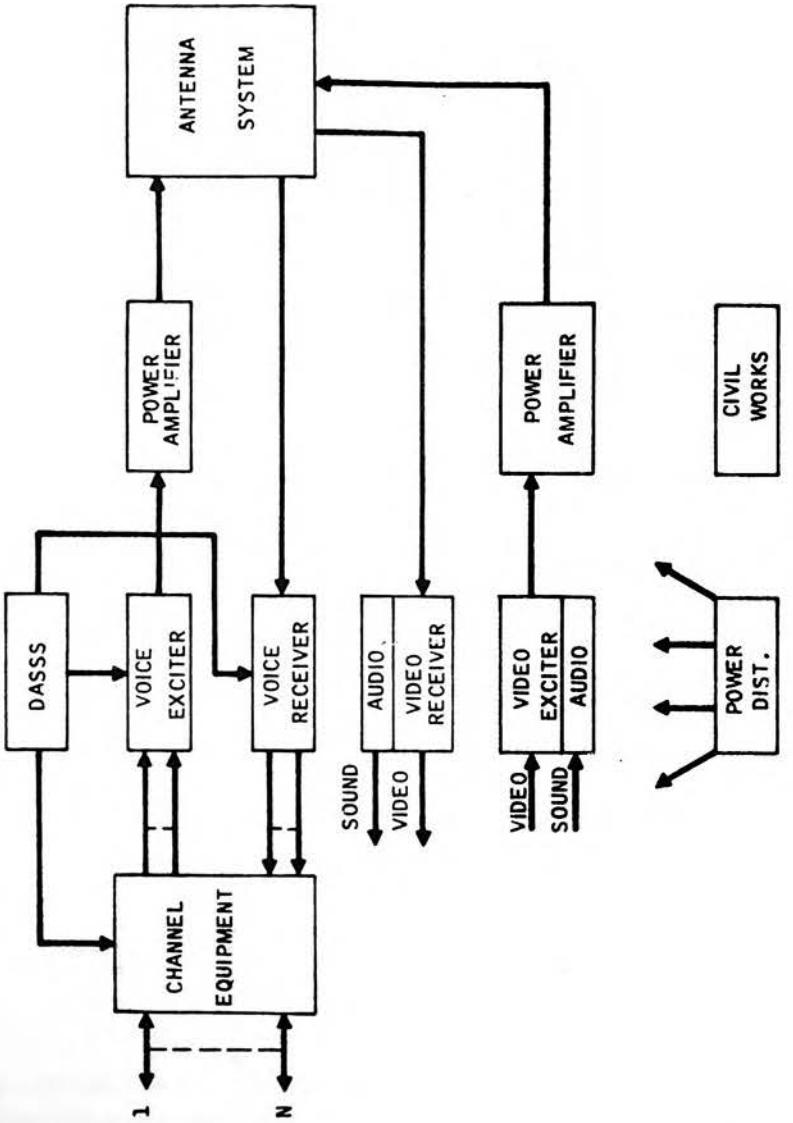


Figure 4-6. Earth Station Configuration

Earth station costs have been derived by summarizing the costs of the several subsystems and are based upon a production of 250 or more stations. The values presented represent the funding allocation to the using agency necessary to procure the particular subsystem: e.g., a high power amplifier, in an installed, integrated and operating condition at the desired operating location. These values, therefore, are not the factory FOB price; rather, they include all of the shipping, cabling, installation, test and administration necessary to secure as subsystems as part of an operating communications facility. They do include the one time cost of three quarters to one million dollars for initial system-design, tooling, etc.

4.3.3.3.1 Antennas. Conventional and shaped Cassegrain, Dielguide, Hoghorns and Casshorns were considered. Shaped Cassegrains were used as the most representative since their figure of merit (G/T) is close to, or equals, that of the other techniques and more units of this style have been constructed at all sizes so that cost information is relatively accurate.

The primary receiving system includes the main reflector, subreflector, orthogonally polarized transmit and receive feed (or receive only feed as the application may require), redundant parametric or tunnel diode amplifiers, antenna foundation and mount, and manually operated antenna drive. Table 4-12 A&B shows the comparative costs of primary receiving systems utilizing several types of antenna and preamplifiers.

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Table 4-12a. Antenna Cost Breakdown*

Antenna Diameter (ft)	10	15	25	32
Reflector	1,000	5,000	8,000	10,000
Pedestal (Foundation)	1,000	5,000	8,000	10,000
Dual Polarized Feed	500	500	1,000	2,000
Manually Operated Drive	500	2,500	5,000	10,000
**Installation	2,000	7,000	8,000	13,000
Total Cost ($)	5,000	20,000	30,000	45,000

*Based on catalog listings for 10 and 15 foot antennas and manufacturers quotations for 25 and 32 feet, factored for quantity production.

**Includes shipping, erection, alignment, testing, and administration.

Table 4-12b. Primary Receiving System Costs for Different Antennas and Preamplifiers

Antenna Diameter (ft)	10	15	25	32
Gain at 4 GHz (db)	39.5	43.0	47.5	49.6
Cost (x $1000)	5	20	30	45
With 20°K Paramp (50°K System)				
Cost (x $1000)	135	150	160	175
G/T	22.5	26.0	30.5	32.6
With 90°K Paramp (150°K System)				
Cost (x $1000)	30	45	55	70
G/T	17.7	21.2	25.7	27.8
With 600°K System (Using TDA)				
Cost (x $1000)	15	30	40	55
G/T	11.7	15.2	19.7	21.8

4.3.3.3.2 Power Amplifiers. The exciter rf output level is normally increased by a redundant high power amplifier system (HPA) so that the combination of the HPA and antenna gain yields sufficient EIRP to properly illuminate the satellite. These wideband units amplify single or multiple carriers by means of a traveling wave tube (TWT) having a 500 MHz bandwidth.

The development of higher power high frequency (6 GHz) transistors in the near future will tend to eliminate the TWT or klystron requirements for the lower EIRP designs (50-60 dbw). Table 4-13 shows the comparative costs of power amplifiers against the number of voice channels transmitted. Standardized increments of power are utilized; i.e., 5, 25, 50, 100, 250, 500, 1000, 1500, 2500, 5000, and 10,000 watts.

Table 4-13. Power Amplifier Costs*** vs Channel Capacity

Antenna Diameter (ft)	10	15	25	32
Antenna Gain at 6 GHz (db)	43.0	46.6	51.0	53.0
**Single Channel				
Total Power (watts)	25	5	5	5
Cost (x $1000)	10	3	3	3
**Five Channels				
*Total Power (watts)	250	100	50	25
Cost (x $1000)	50	35	30	20
**Ten Channels				
*Total Power	500	250	100	50
Cost (x $1000)	75	50	35	30
**Fifty Channels				
*Total Power (watts)	2500	1000	500	250
Cost (x $1000)	105	95	75	50
TV Transmit				
Total Power (watts)	10,000	5000	1500	1000
Cost (x $1000)	110	100	80	75

*Includes 6 db backoff
**Assumes "Spade" Voice Operated Carrier System
***Assumes 10° Satellite Beamwidth (21 db gain)

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4.3.3.3.3 Power Subsystem. The cost of stations using local power includes a half hour capacity battery for power interruptions and the necessary switchgear and power distribution equipment.

4.3.3.3.4 Civil Works. Civil works consists of the equipment building or shelter, site preparation and utilities installation. Costs are related to the traffic handling capacity of the station.

4.3.3.3.5 Receivers and Exciters (Voice). A redundant exciter capable of amplifying and converting individual carriers at IF to multiple frequencies in the 6 GHz band at the level sufficient to drive the PA is estimated to cost $3,000 per carrier. The same estimate applies for a receiver employing multiple carrier frequencies which must be converted to individual carriers at IF.

4.3.3.3.6 Terminal Equipment. The equipment capable of accepting the individual voice channels, modulating and/or demodulating, and interfacing with the Ground Control Equipment (GCE) is estimated for each station as:

Interface and IF Equipment	$25,000
Demand Assigned Switching and Signaling Equipment	10,000
Channel Equipment	2,000/channel

4.3.3.3.7 Control and Monitor Equipment. To maintain an operable station control and monitoring (remote and local) capability is required. A cost of $5,000 will supply this function as well as general rf cabling and waveguide, etc.

4.3.3.3.8 Logistics. Central repair depots and traveling repair teams with large amounts of test equipment and spare parts up to subsystem size are the most economical maintenance philosophies both in cost and in numbers of skilled personnel. Initial spares will cost 7% and test equipment will cost 5% of the cost of the operating station.

4.3.3.4 Total Earth Station Costs. Total system costs for various station configurations are presented in Table 4-14.

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Table 4-14. Earth Station Cost Summary

Antenna Diameter (ft)	10		15		25		32	
Temperature (°K)	600	150	600	150	600	150	600	150
Figure of Merit (G/T) (db)	11.7	17.7	15.2	21.2	19.7	25.7	21.8	27.8
TV Receive Only								
• Antenna and Low Noise Receiver	15	30	30	45	40	55	55	70
• Video Receiver	10	10	10	10	10	10	10	10
• Audio Receiver	10	10	10	10	10	10	10	10
• Control and Monitor	3	3	3	3	3	3	3	3
• Civil Works	9	9	9	9	9	9	9	9
• Power	3	3	3	3	4	4	4	4
• Total Cost	50	65	65	80	76	91	91	106
TV Receive Plus One Voice Channel								
• Civil Works	1	1	1	1	1	1	1	1
• Receiver	3	3	3	3	3	3	3	3
• Exciter	3	3	3	3	3	3	3	3
• Power Amplifier	10	10	3	3	3	3	3	3
• Terminal Equipment	37	37	37	37	37	37	37	37
• Power	1	1	1	1	1	1	1	1
• Cost TV Receive Only	50	65	65	80	76	91	91	106
• Total Cost	105	120	113	128	124	139	139	154
TV Receive Plus Five Voice Channels								
• Civil Works	3	3	3	3	3	3	3	3
• Power Amplifier	50	50	35	35	30	30	20	20
• Power	1	1	1	1	1	1	1	1
• Receiver	15	15	15	15	15	15	15	15
• Exciter	15	15	15	15	15	15	15	15
• Terminal Equipment	45	45	45	45	45	45	45	45
• Cost TV Receive Only	50	65	65	80	76	91	91	106
• Total Cost	179	194	179	194	185	200	190	205
TV Receive Plus Ten Voice Channels								
• Civil Works	5	5	5	5	5	5	5	5
• Power Amplifier	75	75	50	50	35	35	30	30
• Power	6	6	6	6	6	6	6	6
• Receiver	30	30	30	30	30	30	30	30
• Exciter	30	30	30	30	30	30	30	30
• Terminal Equipment	55	55	55	55	55	55	55	55
• Cost TV Receive Only	50	65	65	80	76	91	91	106
• Total Cost	251	266	241	256	237	252	247	262
TV Receive Plus Fifty Voice Channels								
• Civil Works	9	9	9	9	9	9	9	9
• Power Amplifier	105	105	95	95	75	75	50	50
• Power	10	10	8	8	6	6	5	5
• Receiver	150	150	150	150	150	150	150	150
• Exciter	150	150	150	150	150	150	150	150
• Terminal Equipment	135	135	135	135	135	135	135	135
• Cost TV Receive Only	50	65	65	80	76	91	91	106
• Total Cost	609	624	612	627	601	616	590	605
TV Receive Plus TV Transmit Plus Fifty Voice Channels								
• Power Amplifier	110	110	100	100	80	80	75	75
• Civil Works	2	2	2	2	2	2	2	2
• Video Exciter	10	10	10	10	10	10	10	10
• Audio Exciter	10	10	10	10	10	10	10	10
• Power	10	10	8	8	6	6	5	5
• Cost TV Receive Plus Fifty Voice Channels	609	624	612	627	601	616	590	605
• Total Cost	751	766	742	757	709	724	692	707

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Table 4-14. Earth Station Cost Summary (Continued)

Antenna Diameter (ft)	10		15		25		32	
Temperature (°K)	600	150	600	150	600	150	600	150
Figure of Merit (G/T) (db)	11.7	17.7	15.2	21.2	19.7	25.7	21.8	27.8
One Voice Channel Only								
• Antenna and Low Noise Receiver	15	30	30	45	40	55	55	70
• Control and Monitor	3	3	3	3	3	3	3	3
• Civil Works	8	8	8	8	8	8	8	8
• Power	3	3	3	3	3	3	3	3
• Receiver	3	3	3	3	3	3	3	3
• Exciter	3	3	3	3	3	3	3	3
• Power Amplifier	10	10	3	3	3	3	3	3
• Terminal Equipment	37	37	37	37	37	37	37	37
• Total Cost	82	97	90	105	100	115	115	130
Five Voice Channels Only								
• Civil Works	3	3	3	3	3	3	3	3
• Power	2	2	2	2	2	2	2	2
• Receiver	12	12	12	12	12	12	12	12
• Exciter	12	12	12	12	12	12	12	12
• Power Amplifie	40	40	32	32	27	27	17	17
• Terminal Equipment	8	8	8	8	8	8	8	8
• Cost One Voice Channel	82	97	90	105	100	115	115	130
• Total Cost	159	174	159	174	164	179	169	184
Ten Voice Channels Only								
• Civil Works	5	5	5	5	5	5	5	5
• Power	4	4	4	4	4	4	4	4
• Receiver	27	27	27	27	27	27	27	27
• Exciter	27	27	27	27	27	27	27	27
• Power Amplifier	65	65	47	47	32	32	27	27
• Terminal Equipment	18	18	18	18	18	18	18	18
• Cost One Voice Channel	82	97	90	105	100	115	115	130
• Total Cost	228	243	218	233	213	228	223	238
Fifty Voice Channels Only								
• Civil Works	9	9	9	9	9	9	9	9
• Power	10	10	10	10	10	10	10	10
• Receiver	147	147	147	147	147	147	147	147
• Exciter	147	147	147	147	147	147	147	147
• Power Amplifier	95	95	92	92	72	72	47	47
• Terminal Equipment	98	98	98	98	98	98	98	98
• Cost One Voice Channel Only	82	97	90	105	100	115	115	130
• Total Cost	588	603	593	608	603	598	573	588

Note: For grand total cost of each station configuration add 7% for initial spares and 5% for test equipment.

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SECTION 5

FORMULATION OF SYSTEM CONFIGURATIONS

5.1 GENERAL

This section describes the existing communication facilities in Latin America and planned facilities which are scheduled for implementation during the 1968-78 time frame. Based on these existing and planned facilities, a number of alternate system configurations using regional satellites are defined in paragraph 5.3; these are based upon the traffic requirements projected in Section 2 and the technology defined in Section 4.

5.2 INTERNATIONAL FACILITIES

5.2.1 Existing International Facilities

5.2.1.1 High Frequency (HF) Radio. HF radio for many years has been and still is the mainstay of long-haul, point-to-point communications in Latin America. Although some HF radio has been replaced by microwave for telephone, in general, the HF facilities have been retained for telegraph, telex and as a back-up for the telephone circuits. Figure 5-1, indicates existing HF Radio systems, and the capabilities of each link.

5.2.1.2 Open Wire. A substantial portion of the domestic trunk networks are of open wire construction, consisting of individual circuits and open wire carrier systems. There is an existing open wire installation between Argentina, and Santiago, Chile, via Mendoza, over which a 12-channel carrier system is operated. In general, the transmission performance of open wire circuits is not satisfactory except for relatively short links, and maintenance may be expensive

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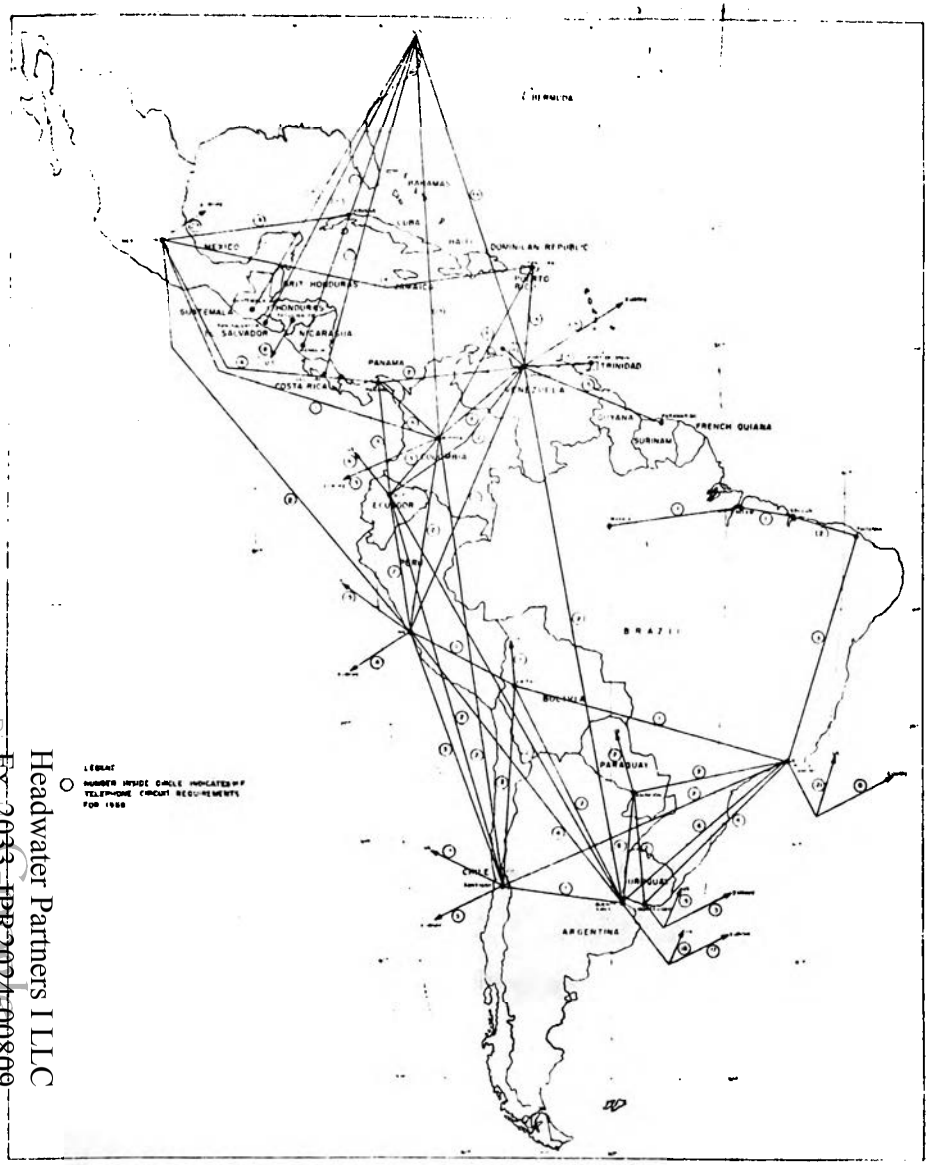


Figure 5-1. 1968 HF Radio Network, Interamerican Telecommunications Network

because of unfavorable terrain. No open wire circuits are assumed as part of the ITN in 1973 or later.

5.2.1.3 Very High Frequency (VHF) Radio. In most countries VHF radio actually has and is continuing to "bridge the gap" between open wire facilities and microwave radio. This is the situation in several countries at this time: VHF radio systems providing a limited number of circuits, with high density microwave systems in various stages of implementation. The existing VHF systems are shown on Figure 5-2.

Ultra High Frequency (UHF) Radio has played a role in Latin America similar to that of VHF, but to a lesser degree.

5.2.1.4 Microwave Radio. During the last several years the general trend in Latin America has been one of replacing previous exsiting systems with microwave radio. The two most typical cases have been the replacement of: (1) high density open wire routes; and, (2) long haul HF radio systems. This does not imply that HF radio has been largely replaced, nor that it will be completely eliminated. Such is not the case as explained in paragraph 5.2.1.1.

Some microwave radio systems exist in Latin American countries today as indicated in Figure 5-2, "Existing Coaxial Cable and Microwave Radio in Latin America". The number of microwave systems is quite limited and is confined to certain heavy usage routes.

5.2.1.5 Cables. Existing coaxial cable is limited to a few main routes. In general, the nature of the terrain and distances between major switching centers favor the use of radio-type facilities. Existing undersea cables connect Panama and Venezuela with the United States.

5.2.1.6 Communications Satellite. The International Telecommunications Satellite Consortium (INTELSAT) presently operates two Atlantic satellites, INTELSAT I (Early Bird), and INTELSAT II, both of which include Latin America in their coverage areas, as shown in Figure 5-3, "Satellite Coverage Area INTELSAT II, Atlantic."

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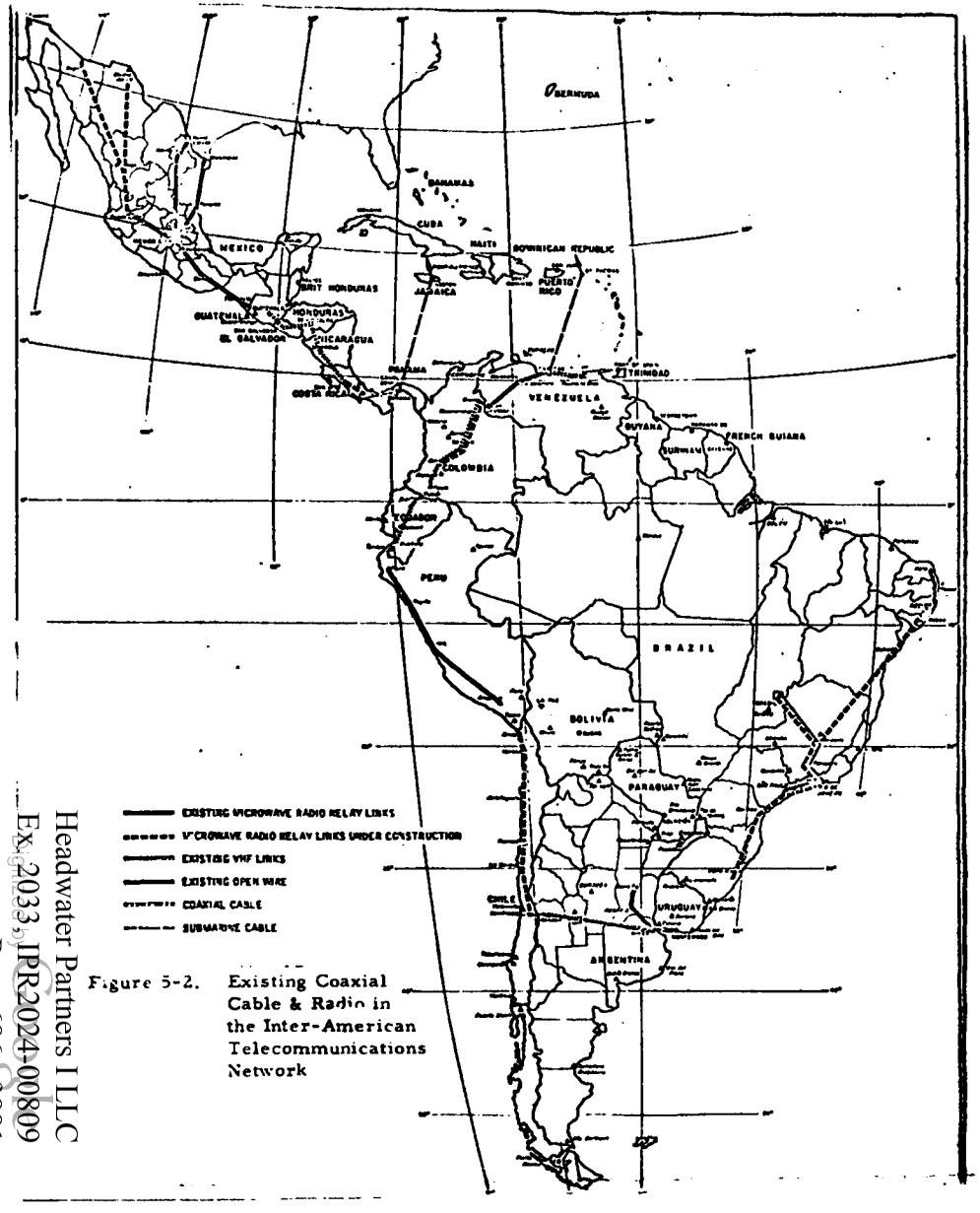
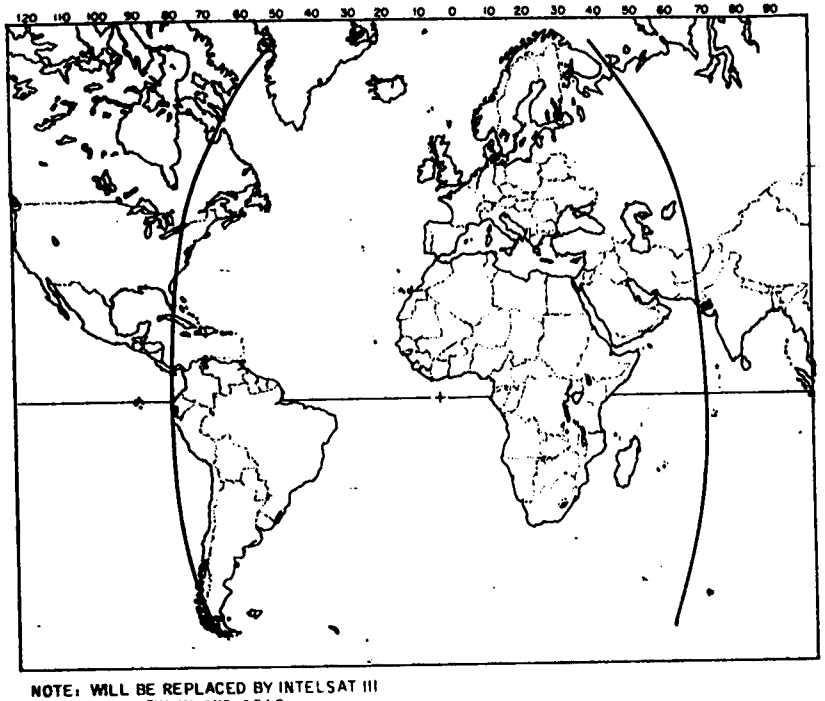


Figure 5-2. Existing Coaxial Cable & Radio in the Inter-American Telecommunications Network

AREA OF SATELLITE COVERAGE FOR 24-HOUR ORBIT



NOTE: WILL BE REPLACED BY INTELSAT III (F-1) 6°W IN MID-1968.

Figure 5-3. Atlantic Coverage Area (5° Look Angle) INTELSAT II (F-1) 6°W, Equatorial

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Early Bird, the first commercial communications satellite, was launched April 16, 1965 with a design lifetime of 18 months. However, still in full service after three (3) years it continues to operate with complete reliability. Because of its antenna patterns and its single access limitations, Early Bird cannot be used for circuits terminating in Latin America. Instead, it will continue to accommodate United States-Western European circuits, thus reducing the load on the INTELSAT II and III Atlantic satellites so that Latin American traffic can be accommodated by them.

The second satellite of the INTELSAT II series (Atlantic II) was launched on March 22, 1968 and is positioned near 9.5 degrees West Longitude, supplementing service in the Atlantic Ocean basin including Latin America. Larger and more powerful than Early Bird, the INTELSAT II Atlantic satellite provides 240 two-way voice circuits when used with standard earth stations, and a multiple access capability for operation with several earth stations at one time.

The INTELSAT III Atlantic satellite is described in Paragraph 5.2.2 Planned International Facilities."

Although there are no earth stations operational in Latin America at this time, eight stations are either under construction or firmly planned. Construction began in 1967 on earth stations in Chile, Mexico and Panama. Also, construction contracts have been awarded for earth stations in Argentina, Brazil, and Peru, and planning is in progress for earth stations in Colombia and Venezuela.

5.2.2 Planned International Facilities

The planning of future international communication facilities for Latin America has been carefully coordinated and a detailed plan has been developed for an Inter-American Telecommunication Network (ITN). The ITN is configured as a system of long-haul facilities throughout Latin America, inter-connecting principal cities and interfacing with international systems. The organization and planning of the ITN are further discussed in Section 7.

A proposed configuration of the ITN, shown in Figure 5-4, has been completed by the Inter-American Development Bank (IDB) and 1973 has been set as the objective date for complete integration of the network. To accomplish this, an order of priorities has been established, involving both the construction of domestic links by the various countries, and the closing of gaps between the countries, under the United Nations Development Programme (UNDP). The principal steps and the order of priority in the completion of the ITN are as follows.

a. Installation in Chile of the existing equipment to allow for the connection of Santiago with Arica. This should be completed by 1970, including the additional connection to Tacna.

b. Porto Alegre-Brazil, to Montevideo, Uruguay. This link should become operational by the latter part of 1970.

c. Rosario to Mendoza in Argentina, plus the interconnection from Mendoza to Santiago, Chile, to be completed by the end of 1971.

d. Upgrading to system from Arequipa to Piura in Peru, going through Lima. Expected date for completion should not be later than the middle of 1972.

e. Inter-connection of Panama and Colombia, including the installation of the new Colombian network, should be completed by the end of 1971.

f. Work on the Bolivian network and its inter-connection with Chile, Peru, Brazil and Argentina also should be completed by the end of 1971.

g. Inter-connection of Paraguay with Bolivia, Brazil and Argentina should be completed in 1972.

Completion of the COMTELCA network inter-connecting the Central American countries with each other, and with Mexico and Panama, is expected before 1975 which is the target date specified by Comision Tecnica Regional de Telecommunicaciones.

All of the above projects are expected to utilize microwave radio relay, with the exception of Buenos Aires-Mendoze (open wire). There also will be

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several installations of tropo scatter radio on individual network links, some of which are not included in the above. A complete tabulation of all links in the ITN network is shown in Table 5-1.

The ITN plans also provide for extensive use of satellite circuits for international intercontinental communications, as shown in Figure 5-4. Five of the planned earth stations: Argentina, Brazil, Chile, Mexico and Panama are expected to be in operation by the end of 1968, while the three others, Colombia Peru and Venezuela, are scheduled for operation by the end of 1969. For those countries which do not have definite plans for installing an earth station, transit routes to a neighboring earth station will be provided. An Atlantic INTELSAT III is to be implaced during 1968.

Transmission over satellite circuits is comparable to the better grades of cable and radio systems, and large numbers of high grade channels can be provided. The satellite channels are suitable for a full range of services, telephone, telegraph, data, television and program transmission, and have the same potential for handling future new services as terrestrial systems. However, the cost of present INTELSAT satellite circuits is generally higher than for microwave circuits. It is planned to utilize such circuits only for distances in excess of 2500 kilometers. However, the provision of satellite circuits for domestic communications, using a regional satellite and low cost earth stations, may prove less expensive for much shorter distances. This is discussed in paragraph 5.3.

5.3 NATIONAL FACILITIES

5.3.1 Existing National Facilities

In general, the existing communication facilities of Latin America are antiquated and have not kept up with the latest developments. This has resulted in intercity and long distance service being very inadequate.

The following paragraphs summarize the existing national facilities by country, highlighting the outstanding characteristics of each.

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Table 5-1. Existing and Proposed Inter-American Telecommunications Network

Key to Figure 5-4.

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits 1973 Telegraph	1973 Leased Telegraph	1973 Telex	1973 Total Telegraph and Telex	1973 Total 4 KHz VFCT Channels	1973 Telephone	1973 Leased Telephone	1973 Total 4 KHz Channels	1978 Telegraph	1978 Leased Telegraph	1978 Telex	1978 Total Telegraph and Telex	1978 Total 4 KHz VFCT Channels	1978 Telephone	1978 Leased Telephone	1978 Total 4 KHz Channels
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
1	Rio de Janeiro - Sao Paolo	423	RR	UC	1800	5	15	28	48	4	53	5	62	5	15	51	71	6	91	5	102
2	Sao Paolo - Curitiba	350	RR	UC	960	5	15	28	48	4	53	4	61	5	15	49	69	5	91	4	100
3 *	Curituba - Montevideo	1340	RR	P	960	5	12	25	42	3	50	3	56	5	12	45	62	4	86	3	93
4	Montevideo - Buenos Aires	230	RR	E	960	14	16	99	129	12	259	5	276	15	16	184	215	19	469	5	493
5	Buenos Aires - Rosario	280	CX	E	960	5	18	54	77	12	114	8	134	5	16	90	111	15	221	8	244
6	Rosario - Mendoza	820	RR	P	960	3	9	12	21	1	84	4	90	3	7	21	29	3	173	4	180
7 *	Mendoza - Santiago	240	RR	P	960	3	9	12	21	1	84	4	90	3	7	21	29	3	173	4	180
8	Santiago - Arica	1760	RR	P	960	4	7	7	18	2	9	5	16	2	5	17	24	3	16	5	24
9 *	Arica - Arequipa	340	RR	P	960	2	7	7	16	1	7	3	11	2	3	17	22	2	13	3	18
10	Arequipa - Lima	860	RR	P	960	6	10	12	28	3	12	4	19	5	7	25	37	4	20	4	28
11	Asuncion - Curitiba	840	RR	P	960	0	3	3	6	1	3	1	5	0	3	4	7	1	5	1	7
12 *	Asuncion - Rosario	1070	RR	P	960	2	8	38	48	9	25	2	37	2	8	64	74	11	42	2	55
13	La Paz - St. Cruz	600	RR	P	960	1	3	4	8	1	5	2	9	1	3	7	11	2	6	3	11
14 *	St. Cruz - Cpo. Grande	1100	OH	P	24	0	0	0	0	0	0	1	1	0	0	2	2	1	0	1	2

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits															
						1973								1978							
					Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 Kils Channels	Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 Kils VFCT Channels	Telephone	Leased Telephone	Total 4 Kils Channels	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
15	Cpo. Grande - Sao Paolo	920	RR	P	960	0	0	0	0	0	0	1	1	0	0	2	2	1	0	1	2
16 *	St. Cruz - Rosario	1970	RR	P	960	1	3	4	8	1	5	2	8	1	3	5	9	1	6	2	9
17 *	La Paz - Arequipa	420	RR	P	960	4	3	5	12	2	5	1	8	3	4	8	15	2	7	1	10
18 *	La Paz - Arica	340	RR	P	960	2	0	0	2	1	2	2	5	0	2	0	2	1	3	2	6
19 *	Lima - Quito	1560	RR	P	960	3	6	4	13	2	5	7	14	1	12	5	18	2	8	4	14
20 *	Quito - Bogota	880	RR	P	960	4	17	16	37	6	38	5	49	5	19	28	52	6	61	3	72
21	Bogota - Cucuta	519	RR	UC	1200	2	5	3	10	2	36	2	40	3	5	6	14	2	70	2	74
22 *	Cucuta - Caracas	800	RR	P	960	2	5	3	10	2	36	2	40	3	5	6	14	2	70	2	74
23	Caracas - Maturin	560	RR	P	960	7	2	15	24	6	53	0	59	12	2	25	39	9	96	0	105
24 *	Maturin - Port of Spain	220	OH	P	120	7	2	65	24	6	53	0	59	12	2	25	39	9	96	0	105
25	Barbados - Port of Spain	350	OH	E	60	2	1	6	9	3	23	0	26	3	1	9	13	5	21	0	26
26	Port of Spain - Georgetown	570	OH	UC	120	4	0	9	13	4	27	0	31	4	0	15	19	4	45	0	49
27																					
28																					

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits															
						1973								1978							
					Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 Khz VFCT Channels	Telephone	Leased Telephone	Total 4 Khz Channels	Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 Khz VFCT Channels	Telephone	Leased Telephone	Total 4 Khz Channels	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
29	Caracas - St. Thomas	920	SC	E	80	0	0	0	0	0	57	0	57	0	0	0	0	0	80	0	80
30	St. Thomas - Jacksonville	1840	SC	E	128																
31	St. Thomas - St. Domingo	560	SC	UC	144	4	0	11	15	2	53	0	55	4	0	18	22	2	76	0	78
32 *	St. Domingo - Port of Prince	300	RR	P	960	1	0	3	4	1	14	0	15	1	0	4	5	1	18	0	19
33 *	Bogota - Panama	860	RR	P	960	1	15	3	19	3	14	4	21	1	15	7	23	3	24	2	29
34	Panama - Kingston	1120	SC	E	128					0	45	29	74					0	51	29	80
35	Kingston - Miami	1320	SC	E		6	6	21	33	4	156	29	189					6	240	29	275
36	Cuba - Miami	390	OH	E	180	23	0	2	25	2	28	0	30	23	5	3	31	4	42	4	50
37	Panama - San Jose	640	RR	E	960					10	97	38	145					10	164	38	212
38	San Jose - Managua	375	RR	P	960					14	122	60	196					14	203	67	284
39	Managua - Tegucigalpa	350	RR	P	960					16	135	62	213					16	226	69	311
40																					
41	Tegucigalpa - San Salvador	285	RR	P	960					16	133	64	213					16	223	71	310

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits															
						1973								1978							
					Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 KHz Channels	Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 KHz Channels	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
42	San Salvador - Guatemala	225	RR	P	960					14	108	52	174					14	175	59	248
43	Guatemala - Mexico	1320	RR	P	1800					10	66	32	108					11	135	41	187
	Mexico - USA	1020	RR	E						17	1046	32	1095					16	1753	17	1786
	Brazil - Mexico		S	UC		1	0	3	4	1	3	0	4	1	0	5	6	1	4	0	5
	Brazil - Panama		S	UC		0	0	2	2	1	3	0	4	0	0	3	3	1	3	0	4
	Brazil - Colombia		S	P		1	1	0	2	1	0	0	1	1	1	2	4	1	0	1	2
	Brazil - Venezuela		S	P		0	4	3	7	1	4	2	7	0	4	3	7	1	6	2	9
	Brazil - Peru		S	UC		0	1	3	4	1	0	0	1	0	1	4	5	1	0	0	1
	Brazil - Chile		S	UC		1	1	4	6	1	5	1	7	1	1	6	8	1	10	1	12
	Brazil - Canada		S	UC		0	0	4	4	1	0	0	1	0	0	8	8	1	3	0	4
	Brazil - USA		S	UC		5	16	71	92	5	45	4	54	6	16	147	169	8	75	4	87
	Brazil - England		S	UC		2	2	30	34	3	4	0	7	3	2	50	55	3	6	0	9
	Brazil - France		S	UC		2	1	16	19	1	7	0	8	2	1	29	32	2	12	0	14

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits														
						1973							1978							
						Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 KHz Channels	Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 KHz Channels
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
	Brazil - Spain		S	UC		1	1	4	6	1	5	0	6	1	1	7	9	1	8	0	9
	Brazil - Germany		S	UC		3	0	26	29	2	[illegible]	0	11	3	0	33	36	2	14	0	16
	Brazil - Italy		S	UC		1	0	15	16	1	5	0	6	1	0	25	26	2	8	0	10
	Argentina - Mexico		S	UC		1	0	4	5	1	3	0	4	1	0	6	7	1	4	0	5
	Uruguay - Mexico †		S	UC		0	0	0	0	0	3	0	3	0	0	0	0	-	3	0	3
	Argentina - Panama		S	UC		0	0	0	0	0	3	0	3	0	0	2	2	1	4	0	5
	Argentina - Colombia		S	P		1	0	4	5	1	4	0	5	1	0	6	7	1	6	0	7
	Uruguay - Colombia †		S	P		0	0	2	2	-	0	0	0	0	0	3	3	-	0	0	0
	Argentina - Venezuela		S	P		1	1	3	5	1	6	1	8	1	1	4	6	1	8	1	10
	Uruguay - Venezuela †		S	P		0	0	0	0	-	0	0	0	0	0	2	2	-	0	0	0
	Argentina - Peru		S	UC		1	3	4	8	1	9	1	11	1	3	6	10	1	15	1	17
	Uruguay - Peru †		S	UC		0	0	0	0	-	0	0	0	0	0	2	2	-	0	0	0
	Paraguay - Peru †		S	UC		0	0	0	0	0	0	2	2	0	0	2	2	-	0	2	2
	Argentina - Canada		S	UC		0	0	5	5	1	3	0	4	1	0	8	9	1	4	0	5
	Uruguay - Canada †		S	UC		0	0	3	3	-	0	0	0	0	0	4	4	-	0	0	0

† denotes via Argentina

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits 1973 Telegraph	1973 Leased Telegraph	1973 Telex	1973 Total Telegraph and Telex	1973 Total 4 KHz VFCT Channels	1973 Telephone	1973 Leased Telephone	1973 Total 4 KHz Channels	1978 Telegraph	1978 Leased Telegraph	1978 Telex	1978 Total Telegraph and Telex	1978 Total 4 KHz VFCT Channels	1978 Telephone	1978 Leased Telephone	1978 Total 4 KHz Channels
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
	Argentina - USA		S	UC		9	12	81	102	5	32	1	38	11	12	170	193	10	57	1	68
	Uruguay - USA †		S	UC		2	3	17	22	1	13	0	14	2	3	29	34	2	21	0	23
	Paraguay - USA †		S	UC		0	0	8	8	1	4	0	5	0	0	12	12	1	6	0	7
	Argentina - England		S	UC		2	0	27	29	2	7	0	9	2	0	55	57	3	13	0	16
	Uruguay - England †		S	UC		0	1	14	15	1	0	0	1	0	1	26	27	2	4	0	6
	Paraguay - England †		S	UC		0	0	3	3	1	0	0	1	0	0	5	5	1	0	0	1
	Argentina - France		S	UC		1	2	33	36	2	7	0	9	1	2	63	66	3	9	0	12
	Uruguay - France †		S	UC		0	0	10	10	1	6	0	7	0	0	17	17	1	6	0	7
	Paraguay - France †		S	UC		0	0	4	4	1	0	0	1	0	0	5	5	1	0	0	1
	Argentina - Spain		S	UC		1	0	10	11	1	5	0	6	1	0	18	19	1	8	0	9
	Uruguay - Spain †		S	UC		0	0	2	2	1	0	0	1	0	0	3	3	1	0	0	1
	Paraguay - Spain †		S	UC		0	0	2	2	1	0	0	1	0	0	3	3	1	0	0	1
	Argentina - Germany		S	UC		1	0	38	39	2	11	0	13	1	0	74	75	4	17	0	21
	Uruguay - Germany †		S	UC		0	0	11	11	1	5	0	6	0	0	18	18	1	9	0	10
	Paraguay - Germany †		S	UC		0	0	5	5	1	0	0	1	0	0	6	6	1	0	0	1
	Argentina - Italy		S	UC		1	0	27	28	2	9	0	11	2	0	51	53	3	15	0	18

† denotes via Argentina

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits 1973 Telegraph	1973 Leased Telegraph	1973 Telex	1973 Total Telegraph and Telex	1973 Total 4 KHz VFCT Channels	1973 Telephone	1973 Leased Telephone	1973 Total 4 KHz Channels	1978 Telegraph	1978 Leased Telegraph	1978 Telex	1978 Total Telegraph and Telex	1978 Total 4 KHz VFCT Channels	1978 Telephone	1978 Leased Telephone	1978 Total 4 KHz Channels
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
	Uruguay - Italy †		S	UC		0	0	6	6	1	4	0	5	0	0	9	9	1	5	0	6
	Paraguay - Italy †		S	UC		0	0	3	3	1	0	0	1	0	0	5	5	1	0	0	1
	Chile - Mexico		S	UC		0	0	3	3	1	3	0	4	1	0	4	5	1	4	0	5
	Chile - Panama		S	UC		0	0	2	2	1	0	0	1	0	0	3	3	1	3	0	4
	Chile - Colombia		S	PP		1	0	2	3	1	0	0	1	1	0	3	4	1	0	0	1
	Chile - Venezuela		S	PP		0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
	Chile - Canada		S	UC		0	0	4	4	1	0	0	1	0	0	5	5	1	4	0	5
	Chile - USA		S	UC		4	5	45	54	3	30	1	34	5	5	88	98	5	56	1	62
	Chile - England		S	UC		1	0	17	18	1	4	0	5	2	0	28	30	2	6	0	8
	Chile - France		S	UC		0	0	8	8	1	5	0	6	0	0	13	13	1	8	0	9
	Chile - Spain		S	UC		0	0	2	2	1	4	0	5	0	0	3	3	1	6	0	7
	Chile - Germany		S	UC		1	0	15	16	1	4	0	5	1	0	25	26	2	16	0	12
	Chile - Italy		S	UC		0	0	6	6	1	4	0	5	0	0	9	9	1	6	0	7
	Peru - Mexico		S	UC		0	1	3	4	1	4	0	5	0	1	7	8	1	5	0	6
	Peru - Panama		S	UC		0	1	2	3	1	3	0	4	0	1	2	3	1	4	0	5
	Peru - Venezuela		S	PP		0	1	0	1	1	0	0	1	0	1	2	3	1	3	0	4

† denotes via Argentina

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits 1973								Required International Circuits 1978							
						Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 KHz Channels	Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 KHz Channels
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
	Peru - Canada		S	UC		0	0	0	0	0	0	0	0	0	0	2	2	1	3	0	4
	Peru - USA		S	UC		4	12	45	61	3	37	1	41	5	12	89	106	5	67	1	73
	Bolivia - USA via Peru		S	PP		2	0	2	4	1	3	0	4	2	0	4	6	1	4	0	5
	Peru - France		S	UC		0	0	6	6	1	4	0	5	0	0	9	9	1	6	0	7
	Peru - England		S	UC		1	0	4	5	1	4	0	5	1	0	6	7	1	6	0	7
	Bolivia - England via Peru		S	PP		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Peru - Spain		S	UC		0	0	2	2	1	0	0	1	0	0	3	3	1	5	0	6
	Peru - Germany		S	UC		1	0	9	10	1	4	0	5	1	0	15	16	1	4	0	5
	Peru - Italy		S	UC		0	0	3	3	1	4	0	5	0	0	4	4	1	6	0	7
	Colombia - Mexico		S	P		2	0	3	5	1	4	0	5	2	0	4	6	1	7	0	8
	Ecuador - Mexico		S	P		0	0	0	0	0	3	0	3	0	0	0	0	0	4	0	4
	Colombia - USA		S	P		5	6	39	50	3	43	1	47	6	6	76	88	4	81	1	86
	Ecuador - USA		S	P		2	2	7	11	1	23	0	24	2	2	12	16	1	37	0	38
	Colombia - Canada		S	P		0	0	0	0	0	0	0	0	0	0	2	2	1	0	0	1
	Colombia - England		S	P		1	1	11	13	1	5	0	6	1	1	19	21	1	8	0	9
	Colombia - France		S	P		1	0	7	8	1	0	0	1	1	0	10	11	1	0	0	1

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits 1973 Telegraph	1973 Leased Telegraph	1973 Telex	1973 Total Telegraph and Telex	1973 Total 4 KHz VFCT Channels	1973 Telephone	1973 Leased Telephone	1973 Total 4 KHz Channels	1978 Telegraph	1978 Leased Telegraph	1978 Telex	1978 Total Telegraph and Telex	1978 Total 4 KHz VFCT Channels	1978 Telephone	1978 Leased Telephone	1978 Total 4 KHz Channels
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
	Colombia - Spain		S	P		0	0	2	2	1	5	0	6	0	0	3	3	1	8	0	9
	Colombia - Germany		S	P		1	0	13	14	1	4	0	5	1	0	23	24	2	6	0	8
	Colombia - Italy		S	P		0	0	3	3	1	4	0	5	0	0	4	4	1	6	0	7
	Mexico - Canada		S	UC		0	0	3	3	1	0	0	1	0	0	4	4	1	0	0	1
	Mexico - England		S	UC		1	0	12	13	1	12	0	13	1	0	19	20	1	22	0	23
	Mexico - France		S	UC		2	0	10	12	1	11	0	12	2	0	17	19	1	19	0	20
	Mexico - Spain		S	UC		0	0	0	0	0	11	0	11	0	0	0	0	0	19	0	19
	Mexico - Germany		S	UC		2	0	15	17	1	12	0	13	2	0	26	28	2	20	0	22
	Mexico - Italy		S	UC		1	0	3	4	1	7	0	8	1	0	5	6	1	16	0	17
	Panama - Canada		S	UC		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Panama - England		S	UC		0	0	0	0	0	5	0	5	0	0	0	0	0	5	0	5
	Panama - France		S	UC		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Panama - Spain		S	UC		0	0	0	0	0	4	0	4	0	0	0	0	0	4	0	4
	Panama - Germany		S	UC		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Panama - Italy		S	UC		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Table 5-1. (Continued)

Link No.	Route	Distance in Km	Type of Facility	Present Status	Facility Channel Capacity	Required International Circuits 1973								Required International Circuits 1978							
						Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 KHz Channels	Telegraph	Leased Telegraph	Telex	Total Telegraph and Telex	Total 4 KHz VFCT Channels	Telephone	Leased Telephone	Total 4 KHz Channels
1	2	3	4	5	6	7	8	9	10	11	12	13	14	7	8	9	10	11	12	13	14
	Venezuela - England		S	P		2	0	6	8	1	8	0	9	2	0	11	13	1	21	0	22
	Venezuela - France		S	P		1	0	5	6	1	5	0	6	1	0	7	8	1	8	0	9
	Venezuela - Spain		S	P		1	0	0	1	1	8	0	9	1	0	2	3	1	15	0	16
	Venezuela - Germany		S	P		1	0	2	3	1	6	0	7	1	0	9	10	1	11	0	12
	Venezuela - Italy		S	P		0	0	4	4	1	13	0	14	0	0	5	5	1	25	0	26
	Venezuela - Canada		S	P		0	0	0	0	0	5	0	5	0	0	7	7	1	9	0	10
	Trinidad - Canada via Venezuela		S	P		0	0	0	0	0	5	0	5	1	0	0	1	1	9	0	10
	Trinidad - England via Venezuela		S	P		2	0	0	2	1	8	0	9	2	0	0	2	1	12	0	13
	Venezuela - USA		S	P		6	25	43	74	8	48	1	57	7	15	65	87	6	75	1	82
	Panama - USA		S	UC						7	63	0	70					7	134	0	141

NOTES: 1. Routes marked with an asterisk (*) are under study by the IDB in behalf of the UNDP.

2. Abbreviations: E Existing; UC = Under Construction; P = Planned
CX = Coaxial Cable; OW = Open Wire; OH = Troposcatter Radio
RR = Radio Relay; S = Satellite Route; SC = Submarine Cable

3. Column 3 is the approximate distance between the terminal stations on the route. Colomn 6 is the total number or channels available, national and international. Columns 7 to 10 are the projected number of communication channels for each type of service. Column 11 is the number of 4 KHz channels, each of which can accommodate up to 24 data channels. Column 14 the sum of Columns 11 to 13 and is the total number of 4 KHz international channels.

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PANAMA	73	78
BRA	4	4
ARG	3	5
CHI	1	4
PER	4	5
EUR	5	9
USA	76	116
CAN	-	3
	93	146

VENEZUELA	73	78	TRINIDAD & T TRANSIT	73	78	BARBADOS TRANSIT	73	78	GUYANA TRANSIT	73	78
ARG	8	10	CAN	5	10	EUR	1	1	CAN	4	[illegible]
BRA	7	9	EUR	9	13				EUR	1	5
MEX	7	9		14	23					5	10
CAN	5	10									
EUR	45	85									
CHI	-	4									
PER	-	4									
URU	-	1									
USA	57	82									
	129	214									

MEXICO	73	78
BRA	4	5
ARG	4	5
URU	3	3
CHI	4	5
PER	5	6
COL	5	8
CAN	1	1
EUR	57	101
ECU	3	4
	86	134

COLOMBIA	73	78	ECUADOR TRANSIT	73	78
BRA	1	2	MEX	3	4
ARG	5	7	ARG	1	1
CHI	1	1	USA	24	38
MEX	5	8	CHI	-	1
USA	47	86		28	44
EUR	23	33			
URU	-	1			
CAN	-	1			
	82	139			

2198

A

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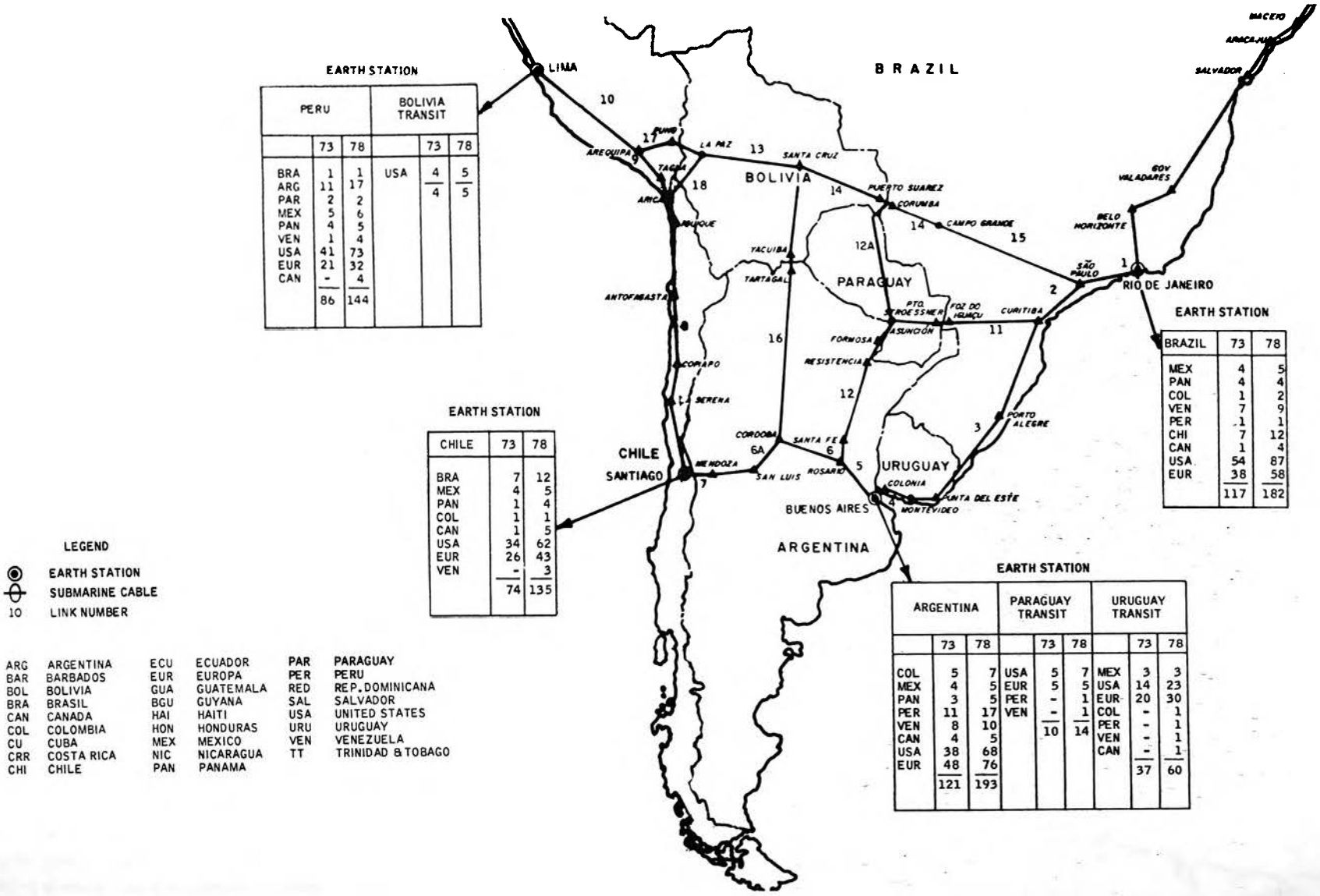
5.3.1.1 Argentina. The long distance circuit facilities in Argentina are provided by coaxial cable, radio relay, open wire, and HF radio. Carrier systems are operated over many of the open wire lines. There is coaxial cable from Buenos Aires to Mar del Plata, Chivilcoy, Rosario, and Sante Fe and a short section out of Rosario with a projection to Cordoba. Radio relay, likewise, fans out of Buenos Aires. Other cities are served by open wire. These principal facilities are shown in Figures 5-5 and 5-6. Circuit's to outlying points where requirements are small are provided by HF radio.

5.3.1.2 Bolivia. The intercity telephone plant in Bolivia consists of open wire between La Paz, Viacha, Oruro, and Cochabamba. This line owned by ENTEL furnishes three circuits, in whole or in part, of copper wire. There is also a HF channel between La Paz and Cochabamba owned by ENTEL. The Government (DGT) has a network of radio circuits from La Paz to six cities, as shown in Figure 5-7. One telephone and one telegraph circuit are operated over each radio channel. From each of the six cities there are single channel telegraph radio circuits to distant points. Another company, SERVAL also has a network of radio circuits.

5.3.1.3 Brazil. The backbone of the toll plant in Brazil still consists of interstate HF links. Except for the four states serviced by Companhia Telefonica Brasileira and its associates and for connection of those three states with the Federal District of Brasilia, all interstate telephone service is carried through the HF links belonging to Radional (Companhia Radio Internacional de Brasil) and DCT, connecting Rio de Janeiro with most of the other state capitals. Rio de Janeiro is the switching center for most of the HF circuits. The quality of the circuits is very poor. With few exceptions, calls are relayed in Rio and most of the traffic is handled through CTB. Within the states, intercity toll facilities where existing are by open wire with or without carrier and by microwave of low capacity.

The main intercity toll circuit facilities are shown in Figure 5-8. Toll circuit facilities of CTB and associated companies interconnect with most of the main localities in the States of Guanabara, Rio de Janeiro, Sao Paulo,

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EARTH STATION

PERU			BOLIVIA TRANSIT		
	73	78		73	78
BRA	1	1	USA	4	5
ARG	11	17		4	5
PAR	2	2			
MEX	5	6			
PAN	4	5			
VEN	1	4			
USA	41	73			
EUR	21	32			
CAN	-	4			
	86	144			

EARTH STATION

CHILE	73	78
BRA	7	12
MEX	4	5
PAN	1	4
COL	1	1
CAN	1	5
USA	34	62
EUR	26	43
VEN	-	3
	74	135

EARTH STATION

BRAZIL	73	78
MEX	4	5
PAN	4	4
COL	1	2
VEN	7	9
PER	1	1
CHI	7	12
CAN	1	4
USA	54	87
EUR	38	58
	117	182

EARTH STATION

ARGENTINA			PARAGUAY TRANSIT			URUGUAY TRANSIT		
	73	78		73	78		73	78
COL	5	7	USA	5	7	MEX	3	3
MEX	4	5	EUR	5	5	USA	14	23
PAN	3	5	PER	-	1	EUR	20	30
PER	11	17	VEN	-	1	COL	-	1
VEN	8	10		10	14	PER	-	1
CAN	4	5				VEN	-	1
USA	38	68				CAN	-	1
EUR	48	76					37	60
	121	193						

LEGEND

EARTH STATION
SUBMARINE CABLE
10 LINK NUMBER

ARG	ARGENTINA	ECU	ECUADOR	PAR	PARAGUAY
BAR	BARBADOS	EUR	EUROPA	PER	PERU
BOL	BOLIVIA	GUA	GUATEMALA	RED	REP. DOMINICANA
BRA	BRASIL	BGU	GUYANA	SAL	SALVADOR
CAN	CANADA	HAI	HAITI	USA	UNITED STATES
COL	COLOMBIA	HON	HONDURAS	URU	URUGUAY
CU	CUBA	MEX	MEXICO	VEN	VENEZUELA
CRR	COSTA RICA	NIC	NICARAGUA	TT	TRINIDAD & TOBAGO
CHI	CHILE	PAN	PANAMA		

Figure 5-4. Proposed Interamerican Telecommunications Network 1973-1978

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Figure 5-5. Wire Line Connections between Principal Points in Argentina

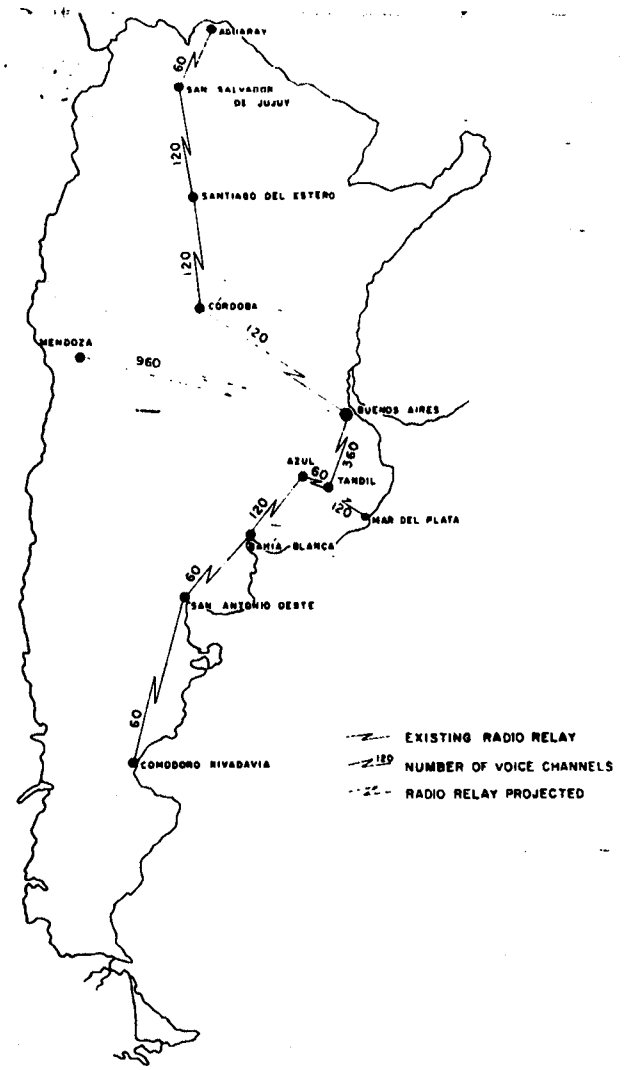


Figure 5-6. Existing and Proposed Radio Relay in Argentina

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Figure 5-7. Intercity Telephone Network in Bolivia

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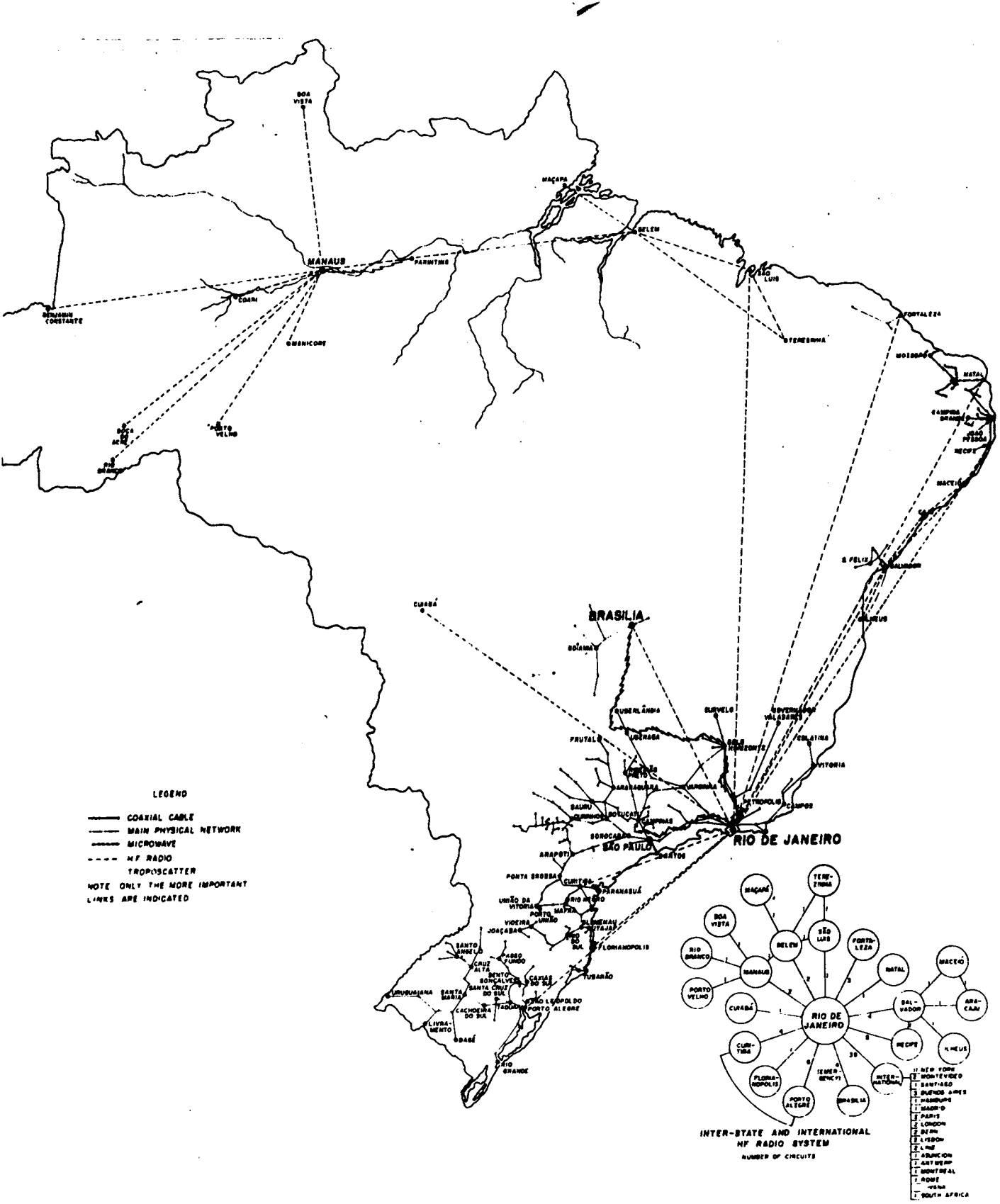


Figure 5-8. Interurban Telephone Network in Brazil

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Espirito Santo, and Minas Gerais. These facilities are interconnected with other toll circuits belonging to other concessionaires in those States.

Toll circuit facilities are mainly open wire lines with carrier. In addition to open wire facilities there are the following wideband systems: microwave radio-relay from Petropolis to Belo Horizonte, carrying 120 channels (ultimate capacity 600 channels), microwave radio-relay Rio - Sao Paulo - Campinas, carrying 420 channesl at full capacity between Rio - Sao Paulo and 150 channels between Sao Paulo - Campinas; a coaxial cable connects Rio to Petropolis, carrying 131 channels (ultimate capacity 480); another coaxial cable system connects Sao Paulo to Santos, carrying 280 circuits (ultimate capacity 600).

In Parana, Santa Catarina and Rio Grando de Sul intercity toll facilities are mostly by open wire lines with carrier. However, interstate circuits are inadequate and limited to localities near the border of the states. Intrastate toll facilities in the northern and northeastern States are practically nonexistent. Only a few cities are interconnected. Toll facilities are mainly by VHF and microwave radio-relay systems, with a capacity of 24 channels or less.

There is an interstate microwave system between Joao Pesso (Paraiba) and Recife (Pernambuco), Maceio (Alagoas), Natal (Rio Grande do Norte). This system is carrying 24 channels to Recife, 12 to Maceio and 8 to Natal.

In the State of Bahia, a 12-channel tropo system connects Salvador to Ilheus.

5.3.1 4 Chile. There is a microwave system operating in the 4000 MHz band between Santiago and Valparaiso with one working channel and a "cold" standby channel. The Santiago terminal is at Cerro Blanco with a 4-tube coaxial cable to the toll office. The Valparaiso terminal is at Vino Alto with a 4-tube coaxial cable to the Recreo office. There is one intermediate station operated from commercial power with a diesel engine standby and no-break flywheel. There are 144 circuits now equipped. There is a 120-channel G.E.C. system without standby between Santiago and Valparaiso. This system has orderwire and fault reporting over an open-wire line.

Of the two high-frequency systems, one is owned by Compania de Telefonos de Chile (CTC) with the transmitting station at La Granja and the receiving station at Pudahuel near the new airport; and the other is owned by ENTEL with the transmitting station at Batuco and the receiving station at Golondrinas.

There are also VHF circuits to several points including Portillo, Concepcion and Coihaique. Otherwise, the great majority of circuits are now provided by open wire facilities. Existing national communications facilities in Chile are shown in Figure 5-9.

5 3.1.5 Colombia. The intercity plant in Colombia consists principally of manual toll switchboards and Ericsson ARM-20 and AFA-10 crossbar switching systems with cities interconnected by circuits operated over radio relay systems or open wire lines on some of which carrier systems are operated.

The Ericsson ARM-20 system is located at seven points: Bogota, Barranquilla, Bucaramanga, Cali, Medellin, Tunja and Pereira. This system permits routing calls over the direct route or over several alternate routes. Ericsson crossbar systems, without alternate routing, are located at other points.

The backbone of the toll circuit network consists principally of VHF radio relay systems. These are RCA-250H and 250L types which have capacities of 96 and 32 three KHz circuits, respectively. Other types of systems, such as the General Electric Company of England types 51 and 56, Siemens of England, and REDIFON are used on branch or spur routes. A map of the radio relay systems, with pertinent circuit data, is shown in Figure 5-10.

Other cities in Colombia are served by open wire lines (mostly 104 copper) over some of which carrier systems are operated. Cables are used only for short distances.

5.3.1.6 Ecuador. The intercity plant in Ecuador consists principally of the domestic toll and international manual switchboards and Ericsson crossbar ARM systems at Quito and Guayaquil, a Marconi VHF radio system between these cities with branches and other shorter HF and VHF systems having a small

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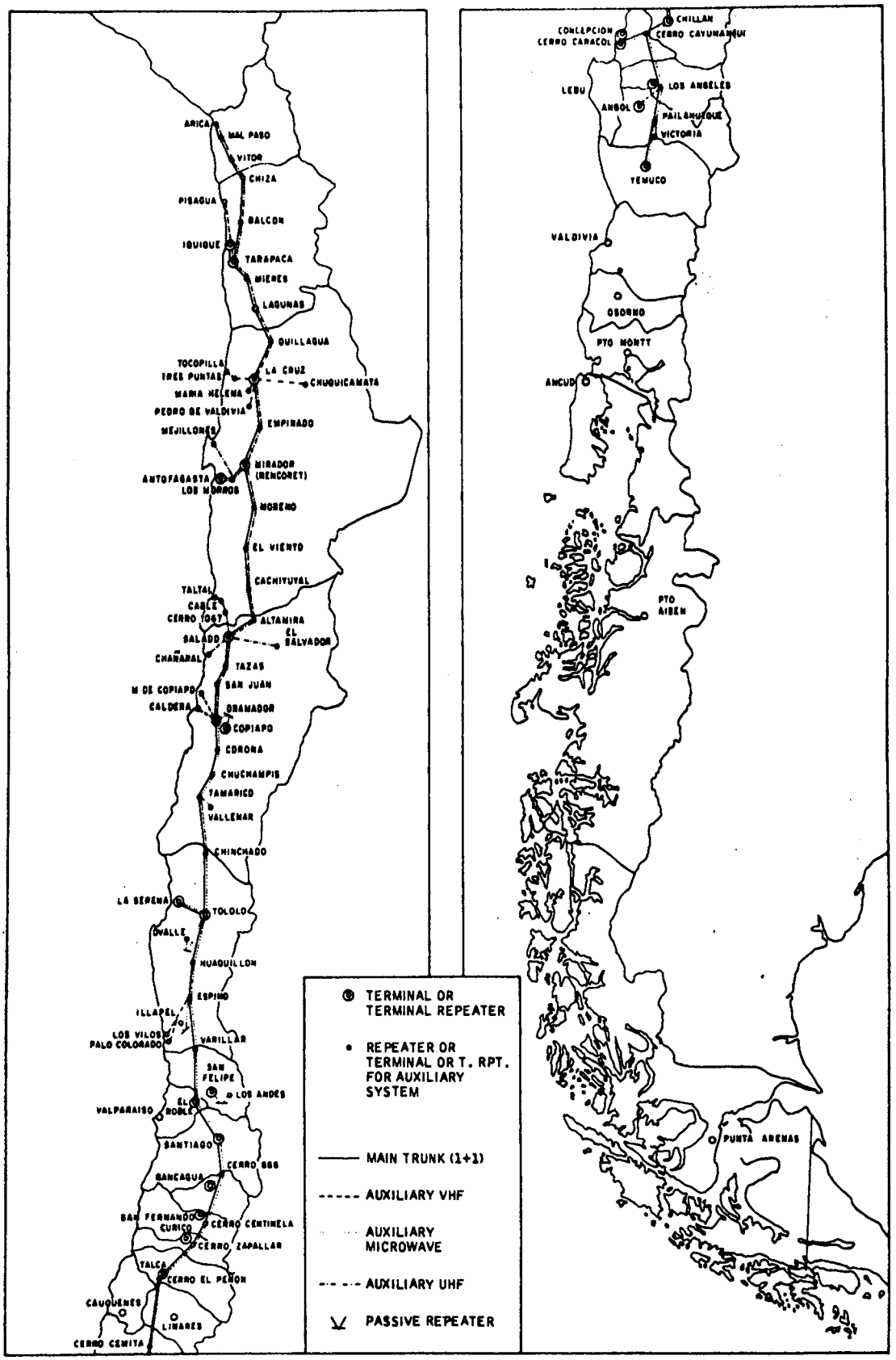


Figure 5-9. Chilean Wideband and Tributary Facilities (under Construction or Contracted) - ENTEL

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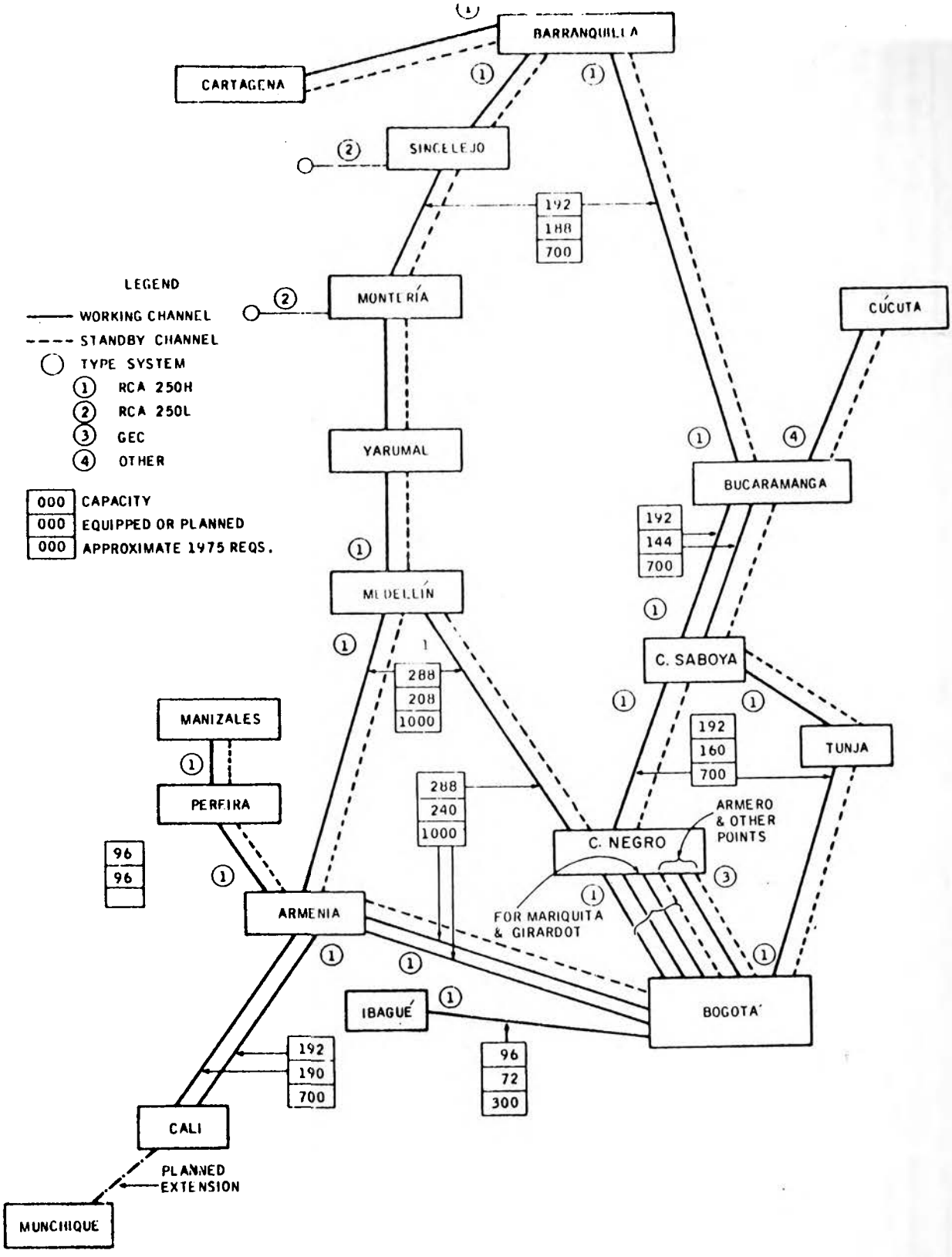


Figure 5-10. Microwave Radio Layout for Colombia

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number of channels. The Marconi system consists of two RF channels, one of which is nominally a standby. Each channel has a capacity of 48 telephone circuits and when both channels are operating, which is now the case, the capacity is 96 circuits. The routes of the radio systems are shown in Figure 5-11.

5.3.1.7 Paraguay. The intercity facilities in Paraguay consist mainly of open wire over which three (and later twelve) channel carrier systems are operated. There is a single channel radio system between Asuncion and Concepcion. There is a small-sized cable between Encarnacion and Posadas, Argentina. The routes of these intercity facilities are shown in Figure 5-12.

5.3.1.8 Peru. Intercity plant in Peru consists of the following: manual toll switchboard (except for a location in the north, discussed below); radio relay systems between Lima, Trujillo, Chiclayo, and Piura and between Lima and Arequipa; open wire lines over which 3, 4, 5, and 12-channel carrier systems are operated; and HF and VHF radio systems. The routes of these principal facilities are shown in Figure 5-13.

The microwave radio relay along the coast is a GEC system having a capacity of 240 telephone channels per RF carrier.

5.3.1.9 Uruguay. In general, the toll circuits in Uruguay are provided by overhead copper wire. Some secondary circuits use iron wire. Carrier systems of 1, 2, 3, or 4-channels are operated over some open wire lines. There are no twelve-channel carriers installed as yet. The following routes have transposition systems which permit operation of carrier up to 150 KHz:

- San Jose - Trinidad - Paysandu
- San Jose - Colonia - Mercedes
- Canelones - Florida - Durazno - Tacuarembo - Rivera
- Montevideo - Pando - Maldonado

There are a total of about 700 circuits. A microwave system extends from Montevideo to Buenos Aires via Colonia. The intercity toll circuit routes are shown in Figure 5-15.

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Figure 5-11. Routes of Radio Systems in Ecuador

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Figure 5-12. Existing Communication Routes in Paraguay

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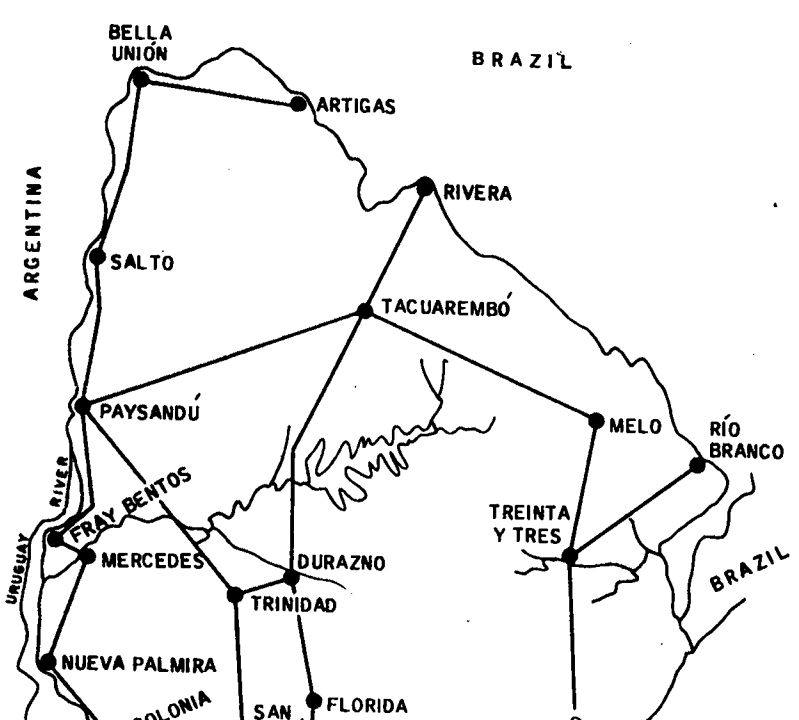


Figure 5-15. Principal Toll Telephone Routes of Uruguay

5.3.1.10 Venezuela. Initially the intercity circuits in Venezuela were provided principally over open wire and some VHF radio and switching was manual. In recent years, a radio relay system operating in the 300-400 MHz band was installed to the east of Caracas. This is an Electrik Bureau system, the same type as is used between the HF stations and the toll central office. Details of this system are shown in Figure 5-16.

There is also a microwave radio-realy system (Marelli-Lenkurt) with 960 circuit capacity per radio channel between Caracas and Maracaibo and San Cristobal as shown in Figure 5-16.

Several companies, particularly oil companies, have their own radio relay or other types of radio systems to provide circuits for their own use.

5.3.1.11 Central America. The countries comprising Central America - Guatemala, Honduras, Nicaragua, San Salvador, Costa Rica, and Panama, feature mainly open wire for their inter-city facilities with a few VHF radio and microwave links or heavy routes. The major radio network interconnects the Central American countries as shown in Figure 5-16.

5.3.1.12 Mexico. Mexico's national telecommunications network is characterized by an extensive radio network as shown in Figure 5-17.

5.3.2 Planned National Facilities

A configuration has been proposed for each of the national trunk networks based on CCITT recommended principles, and the two highest categories of switching centers in each country have been identified. These configurations with an index are shown in Appendix 5A.[1] In most cases, existing circuits interconnecting these switching centers are inadequate even for conventional messages telephone traffic and there is little if any capacity for other services. Existing circuits between these and the other switching centers of lower rank are of even less capacity. It may be assumed, therefore, that nearly all routes in the national networks which are not on the route of the ITN are incapable of carrying television programs and would have to be replaced by radio relay systems.

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Figure 5-16. Existing and Proposed Facilities on Main Routes and between Major Switching Centers in Central America



Figure 5-17. Existing and Proposed Facilities on Main Routes and between Major Switching Centers in Mexico

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No plans are currently under way for use of INTELSAT satellite circuits for domestic communications within any Latin American country.

5.3.3 Interface Between National Networks and the ITN

The ITN is expected to be an organization which provides only the transmission facilities for the international service. The dividing line between the national and the international facilities may be any convenient point but would, in general, be at the distribution frame separating the switching equipment from the multiplex equipment at the CT switching locations in each country. This would allow the national administration full jurisdiction and responsibility for the international switching facilities, since in general the national and international traffic would be handled by the same, or closely related, switching facilities.

The Interamerican Telecommunications Network consists of international transit centers of two categories, designated at CT2s and CT3s and a fabric of international circuits. The CTs are interconnected by a backbone structure of final circuit groups engineered with a low probability of lost calls in a definite homing pattern. Each CT3 homes on a parent CT2; each CT2 homes on a parent CT1, and all CT1s are interconnected by final circuit groups. This hierarchy of transit centers and final groups determines a theoretical routing pattern for international telephone traffic throughout the world.

In addition to the final group structure, the various CTs of any category are interconnected by direct circuit groups which bypass the theoretical final route wherever warranted by the volume of traffic and other considerations. These bypass groups, when engineered with a low probability of lost calls, constitute the actual final route. Traffic does not overflow from low-loss bypass groups to the theoretical final route chain.

A selection of several CT1 centers has been made by the CCITT World Plan Committee. These include White Plains (New York), London, Paris, Moscow, Sydney, Tokyo, Singapore, Kuala Lumpur and Bombay. Each of the CTs throughout the world will home on one of these CT1s, as well as changes in the choice of CT2 and CT3 locations and homing arrangements. The CT1 for Latin America has been provisionally designated as White Plains (New York). The final choice of a CT1 for Latin America must be made by the Regional Group for Latin American Telecommunications.

A "General Plan for the Development of the International Latin American Network" was prepared by the CCITT/CCIR Joint Plan Committee meeting in Santiago de Chile in 1965, and revisions were made at the World Plan meeting that took place in Mexico City during November, 1967. In general, the selection made by the Mexico City 1967 meeting has been incorporated in ITN plans. However, at the CITEL meeting that took place in Mexico City in October, 1967, it was recommended that Lima be designated as a CT2 instead of CT3, and that La Paz home on Lima. In addition, it is recommended that San Jose home on Panama City. It is expected that a CT1 will be selected for Latin America, other than White Plains, New York.

5.3.4 Sources of Information

The proposed configuration of the ITN is based principally on information received directly from the countries concerned. Many of the traffic statistics upon which circuit requirements are based were supplied subsequent to the 1967 Mexico City meeting. Where these were not available, recourse was had to earlier information, outlined in detail in Section 2.

Information regarding existing international circuits and switching facilities, and additions proposed or in progress, were obtained where necessary by correspondence and personal discussion with the respective Administrations. Much useful information was obtained from publications of CCITT and of the CITEL countries, including the report of the first ITN conference in Mexico City in 1960; the General Plan for Development of the International Latin American Network - Santiago de Chile 1965; Proceedings of the Second Consultative Meeting of IDB and CITEL, July 1967; the IDB and COMTELCA Feasibility Studies

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and various other studies conducted by the individual Administrations. Other references included the following material:

a. Economic and Technical Feasibility Study - EMBRATEL: Page Communications Engineers, Inc., May, 1967.

b. Societa Generale Telefonica Electronica Spa. September 21, 1967.

c. Informes Nacionales sobre el Desarrollo de los Sistemas de Telecommunicaciones. OEA/SER. H/XIII CIES/COM X/98, September, 1967.

d. Feasibility Study for a Nationally Integrated Telecommunications System in the Republic of Chile. Page Communications Engineers, Inc., 1968.

e. The National Telecommunication Plan. A survey of telecommunications in Paraguay. Geneva, 1967.

f. "195 Management Report," March 20, 1968.

g. "The REL Communicator," Volume II. No. 9, March, 1968.

h. Comision Tecnica Regional de Telecomunicaciones. Estudio de Factibilidad. Mayo de 1967. Costa Rica.

i. Telecommunication Systems of EMBRATEL by Microwave and Utilizing Satellites. Jose Maria Couto de Oliveira.

j. La Red Interamericana de Telecomunicaciones y el Impacto del Segmento Espacial Sobre su Concepcion Original. Juan Arnaud.

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5.4 POTENTIAL REGIONAL SATELLITE SYSTEMS CONFIGURATIONS

A satellite telecommunications system for Latin America must be planned taking existing and firmly planned facilities into account.

A satellite system to be superimposed on the communications grid must obviously keep duplication of facilities to a minimum (except where desired, to provide alternate means of communication).

Hence an important goal for a Latin American system is to provide communication to areas not now served, and one that is flexible in that it would permit service to be added to towns and cities as their communications needs increase. At the same time, the system should permit the withdrawal of capacity from routes as they grow to cross sections that would make the installation of terrestrial facilities or the use of INTELSAT satellite circuits economically attractive.

Such a system can be thought of as not only providing communications services to remote regions and urban centers, but of providing the stimulus for the further development of internal domestic networks in the several countries served.

Ideally the system should be, in a sense, portable. (The satellite will be available to serve earth stations wherever they may be at a given time, subject to its overall circuit capacity.) As the need for trunks shifts, the small earth stations can be shifted to other growing towns and regions.

What is needed is:

a. A satellite having a total capability commensurate with the overall, unfulfilled, long-distance circuit requirements that can be expected during its design life.

b. Earth stations of sufficiently low-cost to make a system with many of them economically attractive in comparison with other means.

c. A multiple-access method that can accommodate a large number of earth stations with different and varying circuit requirements.

d. A modulation method that permits earth stations to be equipped with baseband channel equipment as dictated by the number of circuits to be provided.

Figures 5-18 and 5-19 illustrate the phases through which this AMERISAT regional satellite system might progress.

5.4.1 Antenna Coverage Patterns for a Regional System

The South American continent may be illuminated effectively in many different ways. Figures 5-20 and 5-21 show the -3 db radiation contours of several different antennas. As examples, subsatellite points of 100° W and 79°W were chosen. These points provide favorable ground station look angles (greater than 16°) from all of the major cities in South America and allow the comparison of direct overhead satellite illumination (79° W) with off-angle satellite illumination (100° W). Table 5-2 indicates the satellite antenna gain for the various illuminations shown, assuming a 55% antenna efficiency.

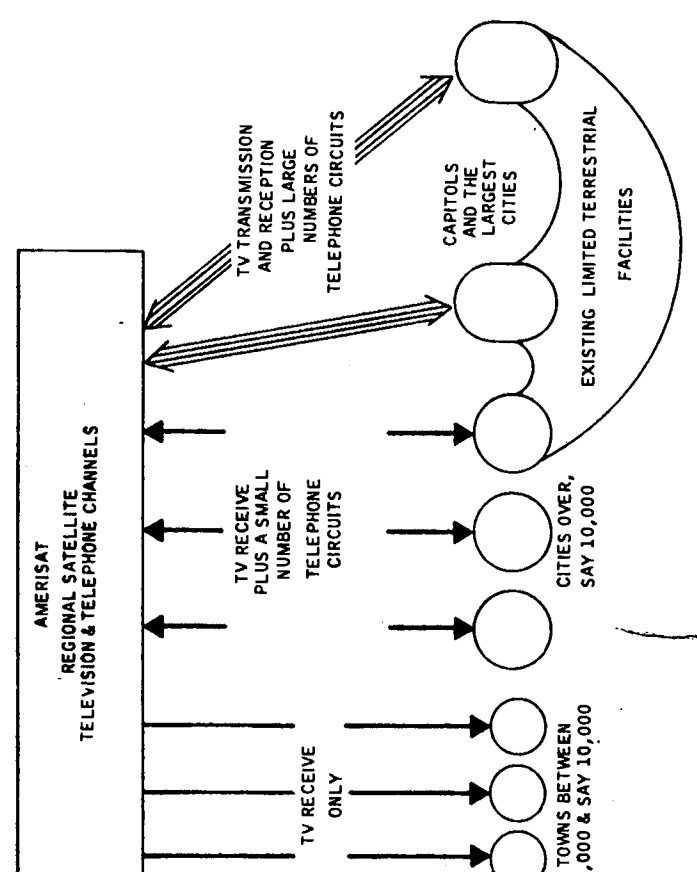


Figure 5-18. Amerisat Phase I

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Figure 5-20. Amerisat Satellite Antenna Patterns

Figure 5-19. Amerisat Phase II

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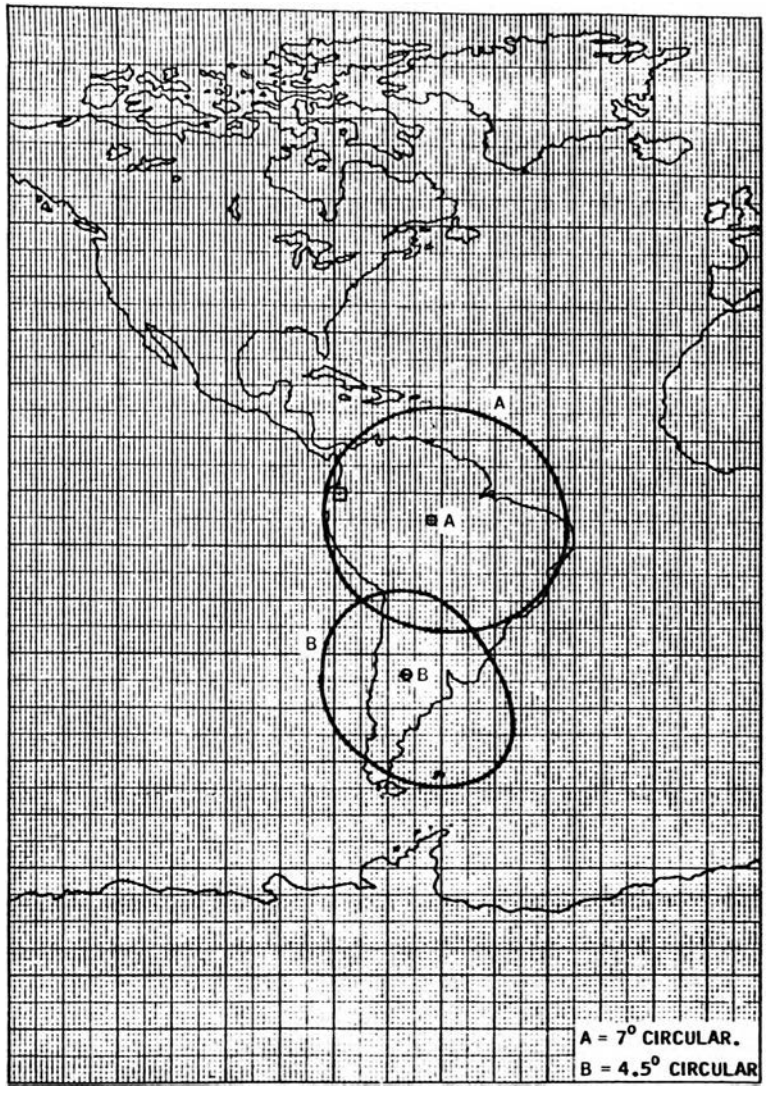


Figure 5-21. Amerisat Satellite Antenna Patterns

Table 5-2. Antenna Gains and Beamwidths

Contour	-3 db Beamwidth (degrees)	Gain (db)	Gain at Beam Edge (db)
A, Figure 5-20	10	24.2	21.2
B, Figure 5-20	5	30.2	27.2
C, Figure 5-20	2.5 x 4.0	34.2	31.2
A, Figure 5-21	7	27.3	24.3
B, Figure 5-21	4.5	31.1	28.1

5.4.1.1 Pointing Accuracy. The pointing accuracy of the satellite beam affects the antenna gain by requiring a larger beam to cover a given area with a poorly pointed antenna than is required from a perfectly pointed antenna. On this basis, a plot of antenna gain loss as a function of pointing accuracy is shown in Figure 5-22. From this plot it can be seen that the advantage gained by pointing accuracies greater than 0.1 beamwidth is quite small (1.5 db). Also, as pointing accuracy requirements increase, so does the antenna and stabilization subsystem weight.

5.4.1.2 Increasing Illumination Efficiency.* A gain advantage can be obtained by moving the satellite off in longitude and using a smaller antenna beam to cover approximately the same area. The concept may be demonstrated by comparing Figure 5-21, contour A and Figure 5-20, contour B, which cover approximately the same area. A comparison is presented in Table 5-3. Both antenna gain and path loss increase as a function of slant range from a satellite in synchronous orbit.

*Comment added during publication:

Although the principle of moving a satellite off in longitude to decrease the required beamwidth is valid, the example given here is not a particularly good one, since the areas covered on the ground are not exactly the same.

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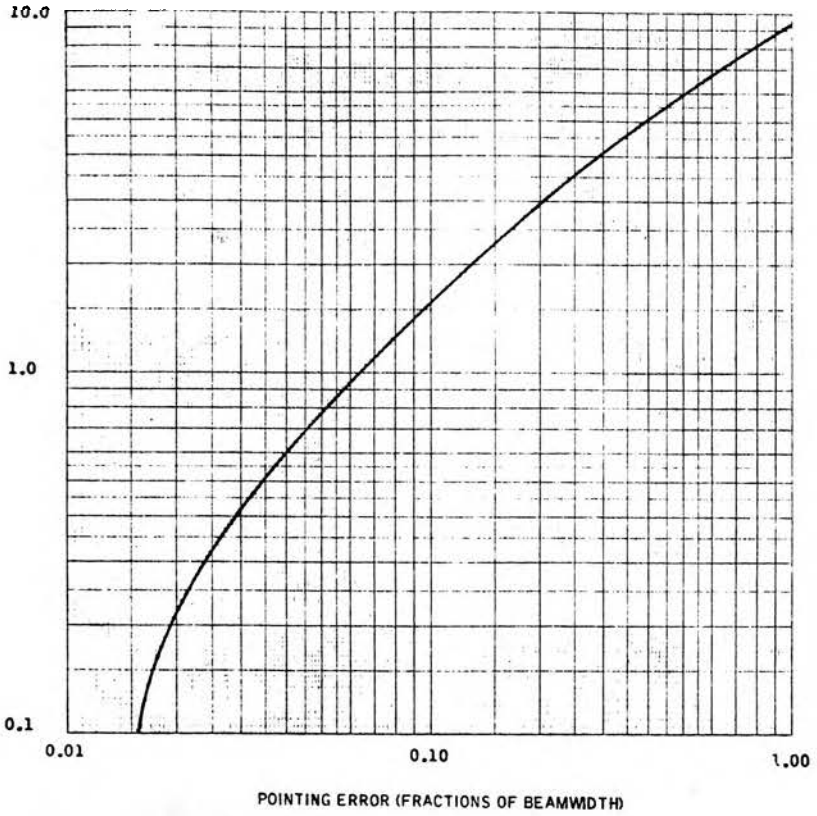


Figure 5-22. Reduction in Satellite Antenna Gain as a Function of Pointing Accuracy

Table 5-3. Comparison of EIRP's at Different Slant Ranges

	Contour A, Figure 5-21	Contour B, Figure 5-20	Comparison
Antenna gain	27.3 db	30.2 db	2.9 db
Coverage	6.91×10^6 mi^2	6.89×10^6 mi^2	
Space loss	195.9 db	196.2 db	-0.3 db
		Net increase in gain =	2.6 db

The satellite antenna pattern can be shaped to produce a more efficient illumination of the serviced area. For instance, Contour C in Figure 5-20, a $2.5^\circ \times 4^\circ$ elliptical beam with a gain of 34.2 db, is used instead of a 4° circular beam with a gain of 32.2. db. This produces a net increase of 2 db in EIRP for approximately the same coverage of land area.

From this discussion it would appear that the most efficient method of illumination would be to move satellite off in longitude and shape the beam to fit the shape of the desired area of illumination more closely. However, care should be taken not to move the satellite so far that it causes a degradation of ground terminal G/T which decreases rapidly as elevation angle decreases.

5.4.2 Intercontinental and International Latin American Telephone and Television Services

5.4.2.1 System Concept. This system is similar to the INTELSAT Atlantic Basin System in its traffic requirements and their geographical distribution. Consequently, its characteristics would be similar. The traffic requirements given in Section 2 indicate the need for a large, standard earth station. Regardless of what organization operates a regional system, the costs of the space segment must be distributed among the earth stations that use it. For a satellite of a given EIRP, the number of channels that can be derived are proportional to the figure of merit (G/T) of the earth stations. Up to the point where the system becomes bandwidth limited, earth stations with lower G/T must be charged more per channel, than one with higher G/Ts. To this cost must be added the cost of amortizing, operating and maintaining the earth station. For a given satellite

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EIRP, a break point can be calculated beyond which the per channel costs will be less if the earth station has a high G/T.

For an INTELSAT II type satellite, a 32 db G/T earth station will be less expensive than a 40.7 G/T standard station (85', 50°K) up to 12 channels. For an INTELSAT III type satellite, a standard station becomes less expensive when a total of 50 channels are received. From the Traffic Requirement section it will be seen that practically all Latin American earth stations will be carrying a total of at least 50 channels during the time period under study. Standard earth stations are expensive although 42' stations are not significantly less expensive. Neither permits a large number of stations to be used to achieve the goal of this study of a regional system to bring the advances of space technology to developing areas.

5.4.2.2 Earth Stations. As discussed above, earth stations tend to the higher G/Ts. Some cost reductions can be achieved by the elimination of the tracking requirement when used with satellites held to accurate position in both longitude and inclination, but this represents a small part of the overall station cost.

5.4.2.3 Satellites. Traffic requirements for 1978 dictate a satellite capable of carrying about 780 circuits. This requires a spacecraft having the capacity of INTELSAT III.

5.4.3 Intranational and International South America Traffic, AMERISAT

5.4.3.1 System Concept. When intranational traffic is to be carried, the system must serve a large number of earth stations; many carrying small numbers of channels. For this application, low-cost, low G/T earth stations are necessary and desirable.

It is expected that the growing national networks of Central America will accommodate their intra-national traffic. The relatively short distances of most population centers from the main, North-South backbone route makes terrestrial facilities more attractive than service by satellite. Central American coverage is not provided initially in these system configurations.

The proposed system configuration consists of a satellite having several spot transmitting beams to illuminate the desired coverage areas with the least satellite RF power. The receive antenna provides coverage of all of South America to permit channels to be established between countries covered by different transmit beams. Frequency re-use is not possible since the transmit beams overlap geographical regions (see Figure 5-23). The cost of providing interconnection between beams -- and thus between geographical regions -- is to lower the gain of the satellite receive antenna, and thus require greater earth station transmitter power at all stations.

5.4.3.2 Earth Stations. All earth stations should have, at least, a TV receive only capability. Such stations are intended for towns in which TV is desired, but no telephone circuits.

For towns and cities requiring telephone service, the transmitting, IF, and channel equipment is added to the basic station.

5.4.4 Intranational Traffic Only

5.4.4.1 System Concept. This configuration differs from the one outlined in paragraph 5.4.2 in that the South American coverage, satellite receive antenna, is replaced with beams identical to the transmit beams, and all earth station transmitter powers can be reduced accordingly. The deletion of the single receive antenna simplifies the construction of the spacecraft at the expense of providing transmit/receive diplexers in the three beams. (See Figure 5-24.) Central America is not assumed in this configuration either.

5.4.5 Satellite Earth Station Combinations

The modulation discussion in Annex 3A indicated that for a single channel per carrier multiple access system such as SPADE, a maximum of 5000 telephone channels could be accommodated in the 500 MHz satellite bandwidth if each carrier occupies 100 KHz. Therefore, this indicates the system is bandwidth limited rather than EIRP limited. Nine cases of traffic requirements were assumed for the 500 MHz bandwidth and the satellite power required was computed

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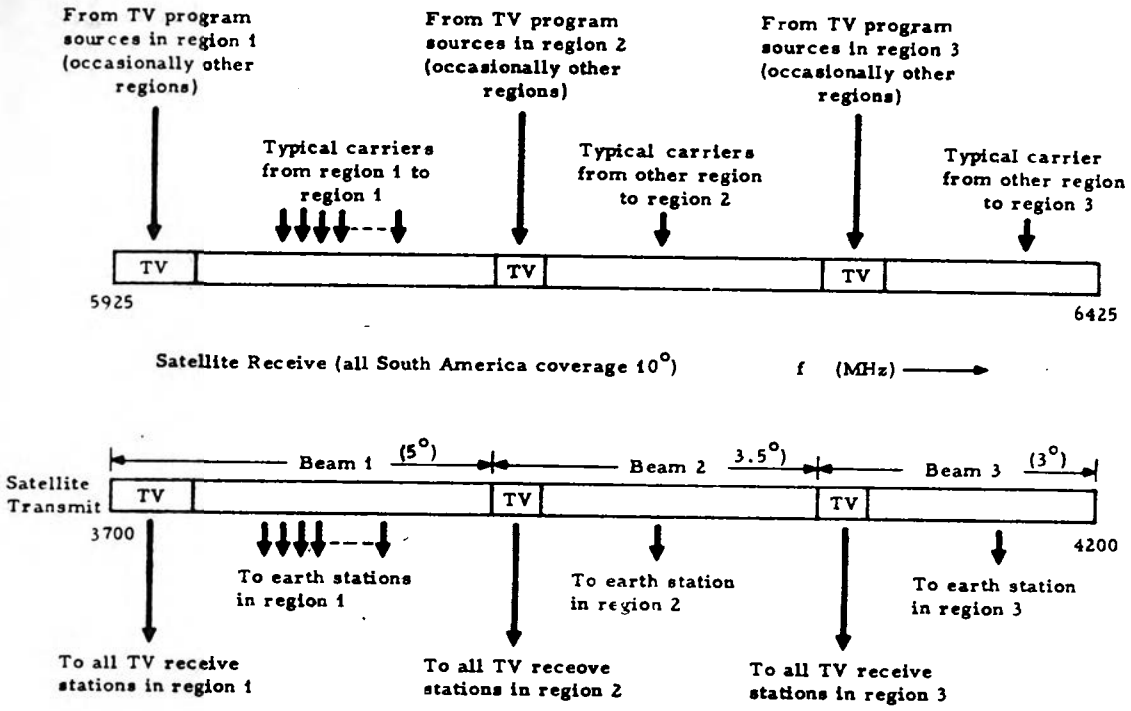


Figure 5-23. Amerisat Frequency Plan & Antenna Patterns for Intranational & International South America Traffic System

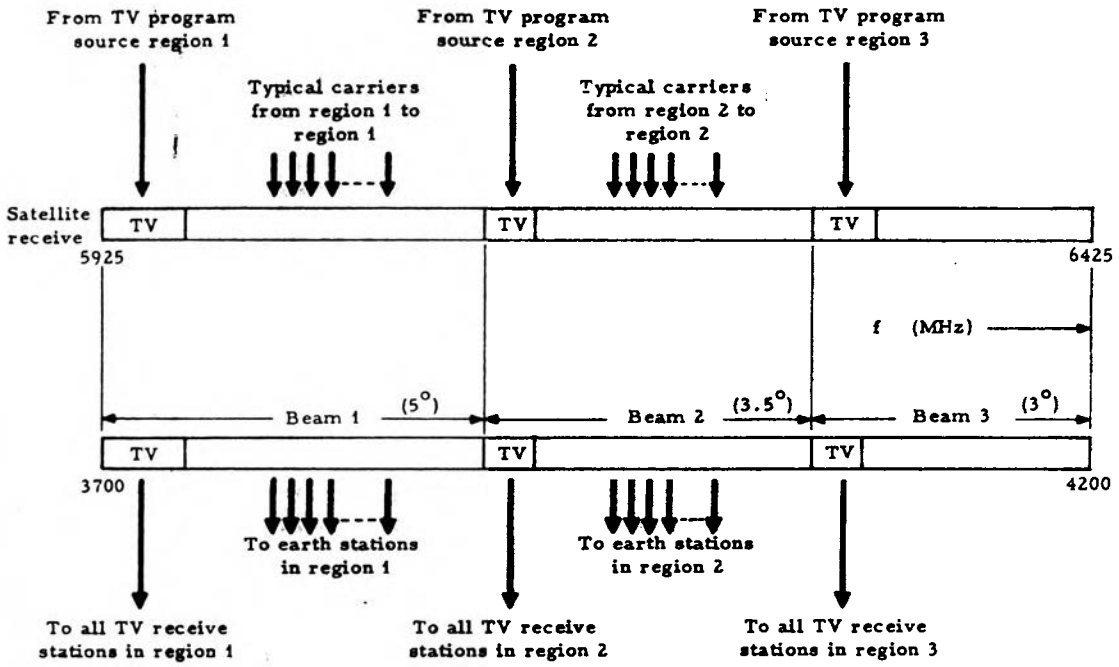


Figure 5-24. Amerisat Frequency Plan & Antenna Patterns for Intranational Traffic System

for each case for four different earth station G/T's. Results are shown in Table 3-2 assuming a 4.3 db or 2 db back off, depending on the case considered.

The satellite power available using a certain weight satellite was derived and presented in paragraph 4.2. Table 5-5 lists the present and projected RF power capabilities for each satellite weight class. Since the satellite size and power are fixed by launch vehicle constraints, the optimum system would utilize all the available satellite power and adjust the earth station G/T accordingly.

Figure 5-25 is a plot of earth station G/T as a function of satellite power for each of the assumed traffic requirements. The intersections of the requirements line and the satellite RF power line for each satellite class indicates the minimum earth G/T necessary for operation in the system. Since these parameters are minimum, a manufacturing margin on G/T of 0.5 db should be added in each case. The minimum earth station G/Ts for all traffic cases, including 0.5 db margin, is presented in Table 5-6 for each satellite class.

Table 5-5. Satellite RF Power Capability for Various Weights

Launch Vehicle	Useful Payload Pounds	Available Satellite Saturated RF Power (watts) Present	Projected*
Thor/Delta	315	26	119
Titan IIIB/Agena	1240	112	645
Atlas/Centaur	1700	168	1220
Titan IIIC	3420	350	2210

*Projected state-of-the-art of approximately 1975 from Section 4.2.

Table 5-6. Minimum Earth Station G/Ts for Each Satellite Class and for the Indicated Service Requirements

Service Required	Satellite Class							
	315 Pounds		1240 Pounds		1700 Pounds		3420 Pounds	
Case No.**	Present	Projected	Present	Projected	Present	Projected	Present	Projected
1	27.0	20.4	20.6	13.0	18.9	10.4	15.7	7.7
2	27.3	20.6	20.9	13.3	19.1	10.6	16.3	8.3
3	26.2	19.6	19.9	12.4	18.1	9.6	15.0	7.3
4	28.6*	22.0	22.2	14.6	20.5	12.0	17.3	9.3
5	28.7*	22.0	22.3	14.7	20.6	12.1	17.4	9.4
6	28.4*	21.7	21.8	14.2	20.2	11.7	17.0	9.0
7	30.1*	23.4	23.8	16.2	21.9	13.4	18.8	10.8
8	29.4*	22.8	23.0	15.4	21.3	12.8	18.1	10.1

*Higher than G/Ts considered in this study.
**As defined in Table 3-2.

Satellite and earth station combinations for these cases can be drawn from Table 5-7.

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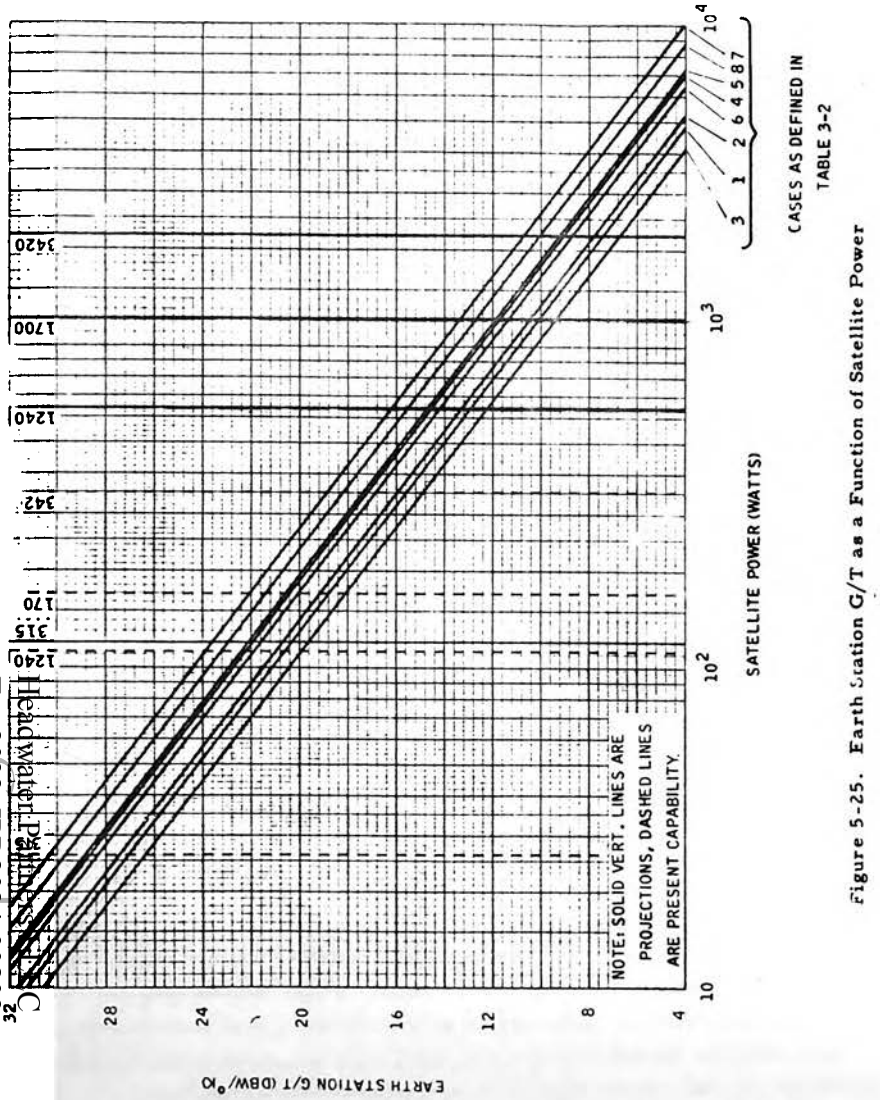


Figure 5-25. Earth Station G/T as a Function of Satellite Power

Table 5-7. Satellite/Earth Station Combinations

Satellite (pounds)	Cases*	Required Earth Station Assuming	
		Present Satellite Power Capability	Future Satellite Power Capability
315	Case 1 or 2 TV and Voice Case 3 Voice only	32'-150° 32'-150°	15'-150° or 32'-600° 15'-150° or 25'-600°
1240	Case 1 or 2 TV and Voice Case 3 Voice only	15'-150° or 32'-600° 15'-150° or 32'-600°	10'-150° or 15'-600° 10'-150° or 15'-600°
1700	Case 1 or 2 TV and Voice Case 3 Voice only	15'-150° or 25'-600° 15'-150° or 25'-600°	10'-600° 10'-600°
3420	Case 1 or 2 TV and Voice Case 3 Voice only	25'-600° or 10'-150° 10'-150° or 15'-600°	Smaller than 10'-600° Smaller than 10'-600°

*As described in Table 3-2.

5.5 SATELLITE CAPACITY VERSUS TRAFFIC REQUIREMENTS

5.5.1 General

The communications capability of the satellites described above can be exploited with two factors in mind:

a. The first consideration is the potential demand for long-distance voice communications which is applicable to satellite communications. This topic was dealt with in Section 2, which presents the intranational traffic potential. The extent to which this long-distance traffic should be handled through satellite depends primarily upon comparative economics of terrestrial versus space communications, the degree of diversification of population centers, and the existing plans of terrestrial development.

b. A further consideration is supply. Since the regional system is designed around a satellite that provides 3 TV channels, the bandwidth required for them must be deducted from the 500 MHz leaving a lesser amount available for voice communications. From the discussions outlined in Annex 3A a capacity in the order of 2,000 Erlangs is available for telephone use from a single satellite.

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This capacity can be apportioned to favor the earning of revenue or to stimulate national development. If the objective is to maximize revenue (the revenue goal), all available satellite circuits should be allocated to highly populated cities where nearly all of the telephones are installed. On the other hand, if the objective chosen is to provide communications facilities to remote and underdeveloped areas, (the development goal), then the provision of some minimum number of circuits to the least populated areas will provide communications link which hitherto have been nonexistent and are most unlikely to be implemented by terrestrial means, in the near future.

5.5.2 A Survey of Existing Population and Telephone Distribution

To allocate the circuits available initially from a single satellite a tally was made of number of towns with over 10,000 and those with over 1,000 population. These populations were summed to determine the proportion of the total population in those towns. As shown in Table 5-8, there are 528 towns with a population of over 10,000, which contain 42.1% of the total population; there are 1,594 towns with a population of over 1,000, containing 45.0% of the population of South America.

However, the telephone distribution is disproportionate to the population distribution. Table 5-9 shows that the 16 cities in South America with populations over 500,000 contain only 20% of the total population, but have 59.9% of the total telephone installed. Figure 5-26 shows a further breakdown of telephone distribution. Number of towns and the cumulative percentage of total telephones are illustrated.

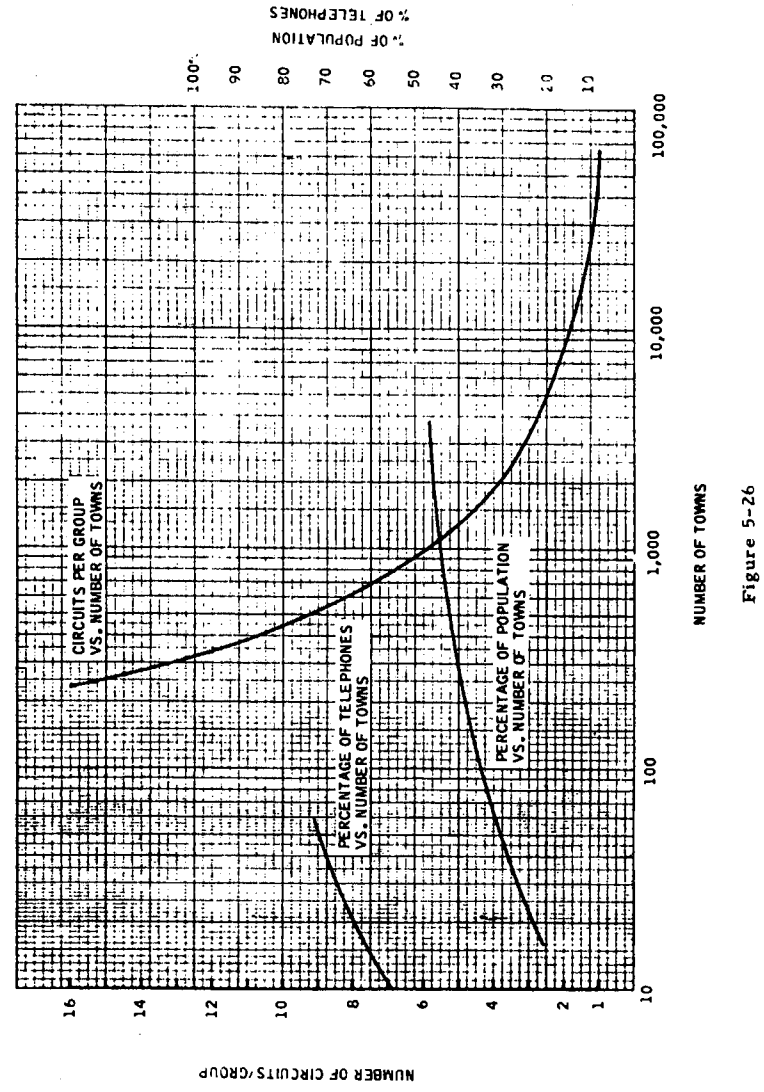


Figure 5-26

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5.5.3 Allocation

Following the discussion in Annex 3A on coverage based on supply limitations, and on the population concentration survey discussed above, we arrive at a point where a certain allocation of circuits in relation to population centers is possible. Figure 5-26 presents a summary view of the situation. Here the coverage expressed in number of towns is shown as a function of number of circuits per group, assuming an equal number of circuits per group is assigned to each town. For instance, if 16 circuits per group is chosen for each town, the coverage would be approximately 230 towns, which are inhabited by approximately 40% of the total population in South America. On the other hand, if 6 circuits per group is chosen, the coverage would be 950 towns with 1% of the total population.

One intermediate solution between the revenue and development goals presented here for illustration. The population centers are divided into four asses with one circuit assigned to every town of over 1,000 inhabitants, and ıcreasing numbers for higher populated centers. The satellite-earth station combinations listed in Table 5-7 can be utilized to provide this service. Thre system configurations are possible:

System A. A regional satellite system with one-way television broadcasting and two-way communications facilities for all towns of 10,000 population or over, covering 42.06% of the total population of South America. Coverage of this system is given in Table 5-10.

System B. This configuration differs from System A in that television is supplied to all towns of 1,000 population and over. Population coverage increases to 44.95%. However, the towns of between 1,000 and 10,000 population have no voice circuits. Coverage of this system is given in Table 5-11.

System C. Voice channels are added to System B in towns of between 1,000 and 10,000 population. Population coverage remains at 44.95%. Coverage of this system is given in Table 5-12.

A graphic portrayal of these systems is shown in Figure 5-27. Erlang loads are summarized in Table 5-13 which is based on data given in Annex 3B.

Table 5-8. Summary of Population Distribution in South America

Country	Total Population	Number of Towns with Population Over 10,000	Population of Towns Over 10,000	% of Total Population	Number of Towns with Population Over 1,000	Population of Towns Over 1,000	% of Total Population
Argentina	20,005,691	89	15,150,000	75.7%	278	15,862,500	79.3%
Brazil	70,967,185	251	25,375,878	35.8	642	26,973,378	38.0
Bolivia	3,311,000	6	575,000	17.3	67	729,500	22.0
Chile	7,339,546	39	4,320,000	58.9	117	4,569,000	62.3
Colombia	12,939,140	37	4,135,000	31.2	120	4,479,500	34.6
Ecuador	3,796,000	10	895,000	23.6	53	1,050,500	27.7
Paraguay	1,638,000	16	585,000	35.7	42	701,000	42.8
Peru	8,132,793	22	1,550,000	19.1	144	1,922,000	23.6
Uruguay	2,163,000	19	1,440,000	66.6	48	1,545,500	71.5
Venezuela	7,583,999	39	3,980,000	52.5	83	4,162,000	54.9
Totals	137,876,354	528	58,005,878	42.1%	1,594	61,994,878	45.0%

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Table 5-9. Summary of Telephone Distribution in South America

Sixteen Largest Cities in South America	Total Number of Telephones in Country	Number of Telephones in Largest Cities	% of Total Telephones in Sixteen Largest Cities
Argentina	1,526,767		
Buenos Aires		762,862	
Rosario		75,418	
Cordoba		51,088	
		889,368	58.3%
Brazil	1,431,653		
Sao Paulo		296,741	
Rio de Janeiro		407,521	
Belo Horizonte		33,811	
Recife		20,600	
Salvador		24,642	
Porto Alegre		34,237	
Fortaleza		17,986	
		835,538	58.4%
Chile	281,532		
Santiago		166,513	
		166,513	59.1%
Colombia	479,134		
Bogota		181,426	
Medellin		93,273	
		274,699	57.3%
Peru	142,589		
Lima		91,711	
		91,711	64.3%
Uruguay	190,000		
Montevideo		150,224	
		150,224	79.1%
Venezuela	308,898		
Caracas		205,057	
		205,057	66.4%
	4,360,573	2,613,110	59.9%

Table 5-10. System A

Population Class	Population (thousands)	Towns Stations	Assigned Voice Circuits per Station	Pop. %	Cumulative Pop. %
I	500 and over	16	50	20.91	20.91
II	50 - 500	109	10	14.59	35.48
III	10 - 50	403	5	6.58	42.06
IV	1 - 10	No coverage in this case			

Table 5-11. System B

Population Class	Population (thousands)	Stations	Assigned Voice Circuits per Station	Pop. %	Cumulative Pop. %
I	500 and over	16	50	20.91	20.91
II	50 - 500	109	10	14.59	35.48
III	10 - 50	403	5	6.58	42.06
IV	1 - 10	1066	None	2.89	44.95

Table 5-12. System C

Population Class	Population (thousands)	Stations	Assigned Voice Circuits per Station	Pop. %	Cumulative Pop. %
I	500 and over	16	50	20.91	20.91
II	50 - 500	109	10	14.59	35.48
III	10 - 50	403	5	6.58	42.06
IV	1 - 10	1066	1	2.89	44.95

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Figure 5-27. Alternative Amerisat Systems & Terrestrial Scheme

Table 5-13. Erlang Loads for Systems A, B, and C, Grade of Service = P = .03

Population Class	Population (thousands)	Number of Stations	Maximum No. Voice Circuits per Station	Erlangs per Station	Total Erlangs
I*	Over 500	16	50	37.6	602
II	50 - 500	109	10	4.94	538
III	10 - 50	403	5	1.713	690
				Subtotal	1830
IV	1 - 10	1066	1	.0389	41.5
				Grand total	1871.5**

*Class I represents the 16 largest cities in South America as shown in Table 5-8.
**For this number of Erlangs, trunk efficiency is about 95%, indicating a satellite trunk capacity of 1871.5/.95 = 1970 circuits (3940 channels). This is approximately the capacity of a 500 MHz satellite carrying 3 TV channels plus voice channels at 100 KHz spacing plus some excess capacity for growth.

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SECTION 6

COSTS OF ALTERNATIVE CONFIGURATIONS

6.1 INTRODUCTION

This section presents an analysis of the costs of various satellite and terrestrial systems based upon the circuit requirements for intra-Latin American, intercontinental, intranational and television requirements, as discussed in Section 2, and the system's technical constraints imposed by launch vehicle availability, satellite capacity and multiple access requirements, as expounded in Section 3. The proposed schemes are reasonable ones in the present context of comparative cost and coverage, and a realistic compromise between the revenue goal and the development goal as discussed in Section 5.

6.1.1 International and Intercontinential System

First, we shall analyze the cost implications of a substitute to INTELSAT III, a Latin American regional satellite system serving both the intra-Latin American traffic, as well as the intercontinental traffic.

6.1.2 Regional Satellite System: AMERISAT

Second, we shall examine a regional amerisat satellite system providing television with varying degree of voice communications capabilities related to certain population concentrations.

6.1.3 Terrestrial Network

Third, we shall consider a terrestrial network as an extension of the proposed inter-American telecommunications network now under consideration to offer, to the extent practicable, the same services as those under a regional South American satellite system.

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In so doing, we cover the basic alternatives in serving the whole spectrum of requirements by technical means reflecting the current state of the art, and the realistic financial resource towards its implementation.

In none of the calculations that follow is the cost of distribution television or telephone beyond the earth station of the satellites included, nor is the cost of distribution beyond the terrestrial facilities to telephone offices or to broadcasting stations considered or included. These costs must be added to both means of supplying the basic long distance communications.

6.2 COSTS OF A REGIONAL SATELLITE SYSTEM SERVING SOUTH AMERICAN INTERNATIONAL AND INTER-CONTINENTAL TRAFFIC

An attempt is made here to present a regional amerisat satellite system serving the South American International and intercontinental traffic requirements for the period 1973 - 1978. The traffic projections for 1973 and 1978 are taken from Tables 2-2 and 2-3. The purpose here is to demonstrate the comparative economics of using a regional satellite instead of INTELSAT III for serving the same traffic and routes.

6.2.1 Traffic Requirements

Table 6-1 lists the South American international telecommunications requirements for the 1973 and 1978 time frame. In order to serve these a- INTELSAT III satellite and standard earth station will be employed in the 10 South American countries. In addition, a standard earth station is assumed to have been constructed in each of the following three areas; USA, Europe and Mexico.

Table 6-1

	1973	1978
	Total Voice Circuits	
Argentina	265	378
Bolivia	15	21
Brazil	155	215
Chile	173	103
Colombia	107	178
Ecuador	41	64
Paraguay	40	65
Peru	101	157
Uruguay	56	84
Venezuela	87	213
Total Circuits	1040	1568
Total Satellite Circuits	520	784

*The sum of the individual circuit requirements will be twice the number of satellite circuits needed to link the countries because each circuit is counted twice in the table: once for each country where it terminates.

6.2.2 Cost Assumptions

System costs components are:

13 Earth Stations at 6 million dollars each	$78,000,000
1 INTELSAT III	5,600,000
Launch:	
Titan III B/Agena and R&D (shared)	13,700,000
Management (per year)	500,000

The assumptions below are used to calculate level annual costs:

* Earth stations to be 15% of First Cost,
* 10% cost of capital
* 20% launch failure probability
* 10 year depreciation perod for earth stations
* MTTF for satellite: 5 years

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Based on these assumptions the resulting annual costs are:

Earth Station Capital Recovery	$12,700,000
Earth Station Operation and Maintenance	11,700,000
Satellite Capital Recovery including Failure Insure and lanuch	6,400,000
Management	500,000

6.2.3 Observations

In order to calculate the average annual changes which will cover costs for the five year period, revenue requirements are based on 652 average annual number of circuits in use. This results in an average annual total circuit charge of $48,500. The space segment channel charge will be only $10,600 per full circuit, compared to a projected average INTELSAT charge during this period of $12,200 per full circuit. This $12,200 is based on the weighted average of (for this time frame) the following INTELSAT projections:

Year	INTELSAT Utilization Charge	Regional Satellite Utilization Charge
1968	$20,000	---
1969	15,000	---
1970	10,000	---
1971	9,000	---
1972	8,000	---
1973	7,000	6,600
1974	6,000	6,200
1975	5,000	5,800
1976	5,000	5,300
1977	5,000	4,800
1978	5,000	4,400

6.3 COSTS OF INTRANATIONAL AND INTERNATIONAL SOUTH AMERICAN AMERISAT SATELLITE SYSTEMS

Total investment costs have been calculated for each of the possible amerisat systems, A, B, & c, and each of the satellite earth station combinations.

The features and coverage of systems A, B, & C are described in Section 5 with telephone and television capacity divided among them:

a. Case 1 : 3 TV channels, (TASO Grade 2.5) plus 4400 telephone channels.
b. Case 2 : 3 TV channels, (TASO Grade 1.5) plus 4100 telephone channels.
c. Case 3 : 5000 telephone channels only.
d. Total system cost comprises:
    1. Unit cost of 3 satellites
    2. Satellite R&D cost
    3. Launch cost of two launches
    4. Earth station costs plus 12% for spares and test equipment.

This costing assumes a system life of 10 years and a satellite MTTF of 5 years. The third satellite is to the constructed, tested, and held as a spare on the ground. Launch costs include a 20% allowance for launch failure.

If more than one regional system is implemented, or if these satellites are useful for any other satellite system, R&D costs would be apportioned over more units, thus reducing the space segment cost.

The R&D cost for the Titan 3B Agena only, has been split over 6 launches on the reasonable assumption that this vehicle will be used by INTELSAT for its INTELSAT IV launches and by Comsat for a domestic system.

Earth station costs are given in Table 4-14 and the number of stations of each capacity used in each System are shown in Tables 5-10, 5-11, and 5-12.

The costs given in Tables 6-2 and 6-3 do not include yearly operations and maintenance for the earth stations, nor the cost of money. They do allow a comparison of total system investment costs to pick the least expensive earth station/satellite combination, and reveal the increased investment required to expand service to more towns.

Note that the least system cost combination always uses the 315 pound satellite, whether one assumes present or projected satellite rf power capabilities.

Other cases and systems are possible. Consider the launching of additional satellites in future years to accommodate traffic in excess of the capacity

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of the single initial satellite. The incremental investment cost can be determined from the satellite and launch vehicle cost table. No more earth stations would be necessary.

Likewise, the incremental cost of serving more cities or towns can be obtained by adding the cost of the appropriate number of earth stations from the table of their costs. In essence, this is a building block approach.

Table 6-2. Total System Costs Based on Present Satellite Capabilities (millions of dollars), Television and Telephone (Cases 1 or 2)

Satellite/E.S. Combinations	System A	System B	System C
315 lb/32' - 150°K	168.5	295.1	352.4
1240 lb/15' - 150°K	204.9	300.4	357.7
1240 lb/32' - 600°K	201.0	309.6	366.9
1700 lb/15' - 150°K	215.1	310.6	367.9
1700 lb/25' - 600°K	208.0	298.8	356.1
3420 lb/25' - 600°K	236.6	327.4	384.7
3420 lb/10' - 150°K	245.0	322.6	388.3

Table 6-3. Total System Costs Based on Future Satellite Capabilities (millions of dollars), Television and Telephone (Cases 1 or 2)

Satellite/E.S. Combinations	System A	System B	System C
315 lb/15' - 150°K	163.5	259.0	316.3
315 lb/32' - 600°K	159.6	268.3	325.6
1240 lb/10' - 150°K	206.2	283.8	349.4
1240 lb/15' - 600°K	196.0	273.6	330.9
1700 lb/10' - 600°K	207.5	267.2	332.9

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6.3.1 Telephone Service Only (Case 3)

If the entire capacity of the satellite is used for telephone channels at 100 KHz spacing, 5000 channels can be accommodated (2500 circuits).

Total system costs for present and future satellite capabilities are shown in Tables 6-4 and 6-5.

Table 6-4. Total System Costs Based on Present Satellite Capabilities, Telephone Service Only (millions of dollars)

Satellite/Earth Station Combinations	Voice Only to Towns Over 10,000 Population	Voice Only to Towns Over 1,000 Population
315 lb/32' - 150°K	154.6	309.9
1240 lb/15' - 150°K	191.2	316.6
1240 lb/32' - 600°K	187.1	316.6
1700 lb/15' - 150°K	201.5	326.8
1700 lb/25' - 600°K	194.4	313.8
3420 lb/10' - 150°K	231.2	347.0
3420 lb/15' - 600°K	221.2	328.5

Table 6-5. Total System Costs Based on Future Satellite Capabilities, Telephone Service Only (millions of dollars)

Satellite/Earth Station Combinations	Voice Only to Towns Over 10,000 Population	Voice Only to Towns Over 1,000 Population
315 lb/15' - 150°K	149.9	275.2
315 lb/25' - 600°K	142.8	262.2
1240 lb/10' - 150°K	192.4	308.2
1240 lb/15' - 600°K	182.4	289.8
1700 lb/10' - 600°K	193.2	291.6

These tables show system costs: that is, they include the full complement of earth stations. Should additional satellites be required to supply increasing traffic requirements, the system configuration can be altered to supply fewer countries on each satellite, reaching, in the limit, one country per satellite. Those satellites would have to be modified to provide only one spot transmitting and receiving beam to the country (or countries) for which coverage is desired. With separate satellites, spaced in orbit to re-use the same frequency allocation, connection between countries would not be possible. It is assumed that, in this later time period, terrestrial international facilities will have improved so that they could be utilized for any international portion of the total link, thus avoiding two satellite hops and reserving the regional satellites solely for intranational service. The change in antennas should not affect the cost of these future satellites appreciably. With smaller beamwidths, slightly more than 5000 channels can be accommodated with smaller channel spacing. The incremental cost of this new multiple-satellite system can be determined by adding only the cost of the appropriate number of satellites and launches from Table 4-8 to the cost of the already installed complex of earth stations.

6.4 THE COST OF THE EQUIVALENT TERRESTRIAL MEANS OF PROVIDING TV AND VARYING DEGREES OF INTRA-NATIONAL VOICE TRAFFIC

An attempt is made here to present an alternative by using terrestrial means offering a similar scope of coverage as that outlined in Section 5.

Naturally, the point of departure is the proposed Inter-American Telecommunications Network currently under active consideration. The comprehensive technical standards of transmission, switching, numbering and signaling for the proposed integrated long-distance network was laid out for both terrestrial and space segments. Estimates of the traffic potential arising from economic integration were completed and preliminary economic feasibility of the ITN was confirmed. The ITN under consideration provides an option for a third 2-way wide-band channel for TV network distribution. This constitutes the point of departure in laying out the additional terrestrial network required to provide television coverage comparable to those offered by the regional satellite system.

Some sample estimates of costs on local television distribution via terrestrial means is given in Annex 6-A. An estimate for providing light-route voice traffic only covering towns of over 10,000 population is given in Annex 6B.

The present interest is in the principal ten countries of South America, and in the towns therein with populations of 10,000 or more. The towns which are now considered to be of this class have been identified, and their locations have been plotted on a map of South America of suitable detail, as shown in Figure 6-1. Many of these are along the routes of "backbone" radio relay facilities assumed to be installed by 1973, but numerous others are not. The proposal here considered is to provide as many of these 528 towns as is feasible with television coverage, by radio relay extension from the backbone routes where necessary, together with facilities for light-route telephone service.

6.4.1 Approximate Area to be Covered, and Corresponding Upper Limits of Cost

The total area of 10-country South America is about 17,350,000 square kilometers, with an average population density of about 8.5 persons per square kilometer. The more populous half of this total area has an average of about 15 persons per square kilometer, and it is less than one-half of this or, say, one-fifth of the total area for which coverage is attempted herein. This one-fifth is about 3,500,000 square kilometers.

The radio relay links to be considered for this extended coverage are of two types. Each type provides two-way working and protection bands of video width, and each is assumed to have at least ancillary equipment for adding about 24 voice circuits. Repeaters of the backbone type are heterodyne repeaters, while those of the short-haul type are less-costly but noise-introducing back-to-back terminal repeaters. Estimated average repeater spacings, costs per repeater and costs per route-kilometer are given in Annex 6C.

It will be noted from these data that, through the use of average spacings and costs for normal construction, one could estimate the cost of blanketing

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an entire area of 3,500,000 square kilometers with radio relay links of the backbone type. This would require one repeater station for every 50 x 50 = 2,500 sq. km., or 1,400 stations at a total cost of about $400 million. It would not be feasible, as an alternative, to blanket this area with radio relay links of the short-haul type, with one repeater station for every 40 x 40 = 1,600 sq. km., requiring about 2,190 stations. A more practicable arrangement would involve a mix of backbone and short-haul type links which might have a total cost of $300 million.

An actual radio relay installation, to be made in South America to serve the present purpose, would take into account and stem from the then existing backbone routes used for general telecommunication, with the result that the total cost chargeable to television would be considerably less than $300 million. This is brought out in the following sections.

6.4.2 Costs of Network Television on Backbone Routes

Figure 6-1, which gives the locations of the towns of 10,000 or more persons, also shows the backbone radio relay routes expected to be used by the ITN and assumed to be in service by 1973. In addition, it shows certain intra-national extensions of this network, in Brazil and Chile.

All of these radio relay routes are treated herein as backbone routes, capable of being extended as required by means of radio-relay spur routes, to obtain the desired television and limited message-circuit coverage. The links of these spur routes can be of either the backbone type or the short-haul type, as may be suitable. In most cases the presence of all-weather roads may be assumed, but for a few spur routes of the backbone type the higher unit costs associated with the essential absence of roads will apply.

In the planning of the radio relay routes to be used by the ITN, allowance was made for provision at the time of construction of a third two-way wideband channel for network television. It will be understood that network television refers to the means for interconnecting television stations, exclusive of the stations themselves.

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Figure 6-1

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With regard to the 10-country South American portion of the ITN radio-relay routes, the parts of the installed first costs which are chargeable to network television are given in Table 6-6. Also shown are representations of corresponding costs for the radio-relay intra-national extensions in Brazil and Chile.

The radio relay routes referred to in Table 6-6 are a cross-sectional mix of backbone-type facilities, with cross-sections of 600, 960, 1200 and 1800 circuits. It will be seen from the totals given that the average first cost of the additional wideband channel, provided for network television as an adjunct to needed voice-circuit facilities, is only $800 to $850 per route-kilometer, depending upon the provisions made for video dropping and adding. The inclusion of an allowance for an accompanying program channel increases this to only $870 per route-kilometer.

These incremental unit costs are to be compared with $5,000 to $5,300 per route-kilometer, for the cost of a video channel of sufficient width unsupported by other telecommunications needs, or $5,800 per route-kilometer to include provision for video plus light-route telephone service. In particular, if the last named rate is applied to the 25,723-kilometer total length shown, the total installed cost becomes about $149,200,000. Although this would make auxiliary provision for slightly more than the one program channel of Table 6-6, the total cost in the absence of the ITN would be greater by about $127,000,000.

Table 6-6. Incremental First Costs for Countries Indicated Due to Provision on Radio Relay Routes of Third Channel for Network Television (thousands of dollars)

	ITN		National Facilities		Total	
	Rte. Km	Cost	Rte. Km	Cost	Rte. Km	Cost
Argentina	3,710	2,888			3,710	2,888
Bolivia	2,010	1,076			2,010	1,076
Brazil	3,733	2,824	6,064	5,152	9,797	7,976
Chile	2,120	1,816	976	858	3,096	2,674
Colombia	1,760	1,416			1,760	1,416
Ecuador	710	584			710	584
Peru	2,450	2,104			2,450	2,104
Paraguay	320	240			320	240
Uruguay	550	468			550	468
Venezuela	1,320	1,072			1,320	1,072
	18,683	14,488	7,040	6,010	25,723	20,498
Added Allowances						
Video dropping and adding at intermediate points (6%)		869		361		1,230
Accompanying program channel (3%)		435		180		615
Total		15,792		6,551		22,343

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6.4.3 Population Data

The data which have been obtained on South American towns of more than 10,000 population are summarized by country in Table 6-7. These are the 528 towns whose locations have been plotted on Figure 6-1.

Table 6-7. Numbers of South American Towns of Population Over 10,000

Argentina	89
Bolivia	6
Brazil	251
Chile	39
Colombia	37
Ecuador	10
Peru	22
Paraguay	16
Uruguay	19
Venezuela	39
	528

6.4.4 Country-by-Country Consideration of Extensions from Backbone Routes to Provide Television and Limited Message-Circuit Coverage

6.4.4.1 General. The determination herein of type of extension and proportionate use is in terms of the information shown on Figure 6-1. No extensions are considered necessary for towns on the backbone routes. Extensions of the backbone type are provided on at least part of the routes more than 240 km in length, as influenced to some extent by the importance of the towns served. Otherwise, extensions of the short-haul type are assumed on routes not longer than 240 km.

Transmission along the route of a radio relay system is effected through the use of highly-directive antennas which "beam" the microwave radiation from one relay station to another. Such a beam is subject to suitable allocation, by frequency subdivision, into several wide transmission bands.

The common arrangement of transmission bands in a South American radio relay system is the same as that of the initial installation on a prospective heavy route in the United States. This is an installation of four such bands, so directed as to form one two-way wideband working channel and one two-way wideband protection channel. Here the bandwidths are sufficient for video transmission or, alternatively, for at least 600 voice channels arranged in frequency-division multiplex.

6.4.4.2 Extensions of ITN Backbone Routes to Increase Television and Light-Route Telephone Coverage. In the planning of the ITN radio relay backbone routes for South America, in addition to the working and protection channels, cost provision was made for a third two-way wideband channel for television. The resulting arrangement of six transmission bands or paths along each ITN route is shown in the upper part of Figure 6-2.

The consideration given to increased television and light-route telephone coverage in South America involves the construction of spur-route extensions from ITN and other backbone routes provided with the third channel for television. The provision on these spur routes is for (1) wideband working and protection channels for television service, and (2) ancillary equipment (Farinon type SS4000 A/B/SS2000, for example) for light-route telephone coverage, as shown in the lower part of Figure 6-2.

6.4.4.3 Argentina. A fair proportion of the >10,000 towns of Argentina are located near the backbone radio relay routes of that country. An important exception is Comodoro Rivadavia, a seaport of about 26,000 population on Golfo San Jorge. Owing to its importance and the area which it serves, a spur route extension to this town is included in the list.

There are five spur routes or spur-route extensions of the backbone type. Their approximate lengths and installed costs, were derived in Annex 6B are repeated here as Table 6-9.

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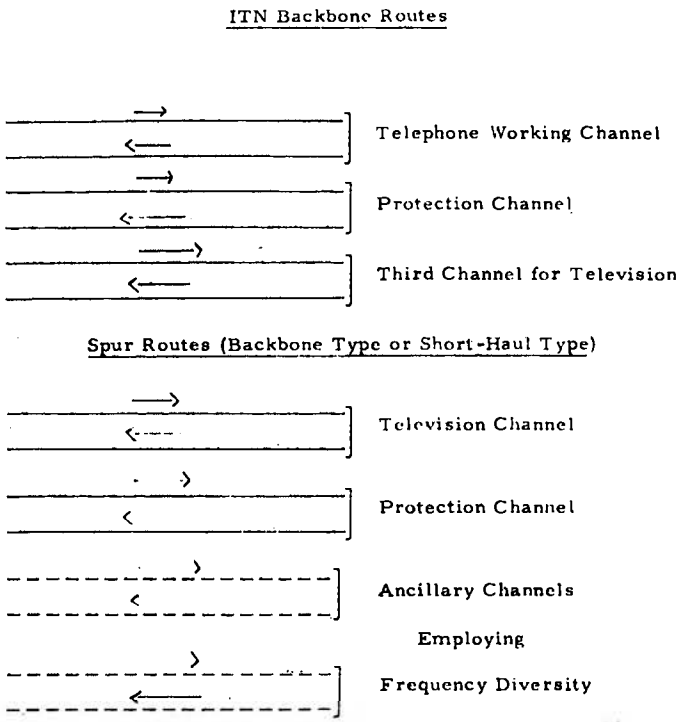


Figure 6-2. ITN Backbone Routes

Table 6-8. Argentine Spur Routes of Backbone Type

Route	Route Km	Installed Cost
Buenos Aires - Bahia Blanca	560	$ 3,248,000
Bahia Blanca - Com. Rivadavia	1,030	5,974,000
Buenos Aires - Santa Rosa	560	3,248,000
Santiago del Estero - La Rioja	310	1,798,000
Zarate - Posadas	810	4,698,000
	3,270	$18,966,000

In addition, there are about 25 spur routes of the short-haul type, each being not more than 240 km in length. These routes have a total length of about 3, ~~180~~ km... With the application of the unit costs of Annex 6B, the corresponding total installed cost becomes $7,950,000.

6.4.4.4 Bolivia. Of the six towns of appropriate size in Bolivia, three are on the backbone route and two of the others can be reached from Cochabamba by a backbone type spur route, 340 km in length and about $1,972,000 in installed cost. The remaining town can be served by a further spur route, of the short-haul type, 70 km in length and about $175,000 in cost.

6.4.4.5 Brazil. The 251 towns of Brazil are densely distributed to the south of Brasilia and Belo Horizonte, somewhat scattered along the northeast coast, and are few to non-existent in the Amazon-basin interior. In the matter of backbone-type construction costs for radio relay systems, the lower unit costs of Annex 6B are considered to be applicable for feasibility purposes in all areas except the region of the Tocantins and Amazon Rivers. In this region of no all-weather roads and heavy jungle growth construction costs would be higher. For this application one should use the higher unit costs of the no-roads case, in which the basic-repeater costs are increased at 24 percent.

Four towns, all in the remote upper Amazon region, are omitted from this coverage on the basis that their inclusion does not appear to be justified.

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Except for the region of the Tocantins and Amazon River, Brazil will require eleven normal backbone-type spur routes, totaling 5,620 km in length and about $32,596,000 in installed cost. In the excepted high-cost region, there should be three spur routes of the no-roads type, totaling 2,380 km in length and about $16,660,000 in cost.

The total length of spur routes of the short-haul type is estimated to be 6,880 km, with a total installed cost of about $17,200,000.

6.4.4.6 Chile. The towns of Chile are well served by the backbone routes of that country. Omitting the very distant town of Punta Arenas, it appears that only 440 km of short-haul radio relay is required, at a cost of $1,100,000.

6.4.4.7 Colombia. It appears that a single spur route of the backbone type, 840 km in length, would serve the group of important towns north and west of Cucuta, at a cost of $4,872,000. A total of 1,060 km of short-haul facilities would serve the remaining towns at a cost of $2,650,000.

6.4.4.8 Ecuador. There should be a single spur route of the backbone type, 100 km in length at a cost of $580,000. A total of 600 km of short-haul routes, at a cost of $1,500,000, would serve the remainder.

6.4.4.9 Paraguay. There should be two spur routes of the backbone type, totaling 580 km at a cost of $3,364,000. Also required is a total of 360 km of short-haul routes at a cost of $900,000.

6.4.4.10 Peru. Most of the towns of Peru which are off the backbone route can be served by a mixed spur route, which is roughly parallel to that principal route. The backbone-type links of this have a total length of 1,100 km at a cost of about $6,380,000. The links of the short-haul type are 510 km in length and about $1,275,000 in cost.

The towns of Iquitos and Pucaurco are more inaccessible owing to the absence of roads, and reaching them requires high-cost construction. It is estimated that they can be served by backbone-type links from Tarapoto, the length being 750 km and the cost being $5,250,000.

6.4.4.11 Uruguay. Uruguay can be served by (1) two spur routes of the backbone type 710 km in length at a cost of about $4,118,000 and (2) a total of 660 km of the short-haul type at a cost of about $1,650,000.

6.4.4.12 Venezuela. Here there are two spur routes of the backbone type, totaling 530 km in length at a cost of about $3,074,000. There are also 1,600 km of short-haul routes at a cost of about $4,000,000.

6.4.4.13 Summary of Route Lengths and Costs. The route lengths and estimated costs to provide the desired television coverage, as derived in the preceding paragraphs, are summarized by countries in Table 6-9. The table shows that this coverage is provided for all but five of the 528 towns of 10,000 or more population.

The first of the length and cost sections of Table 6-9 repeats the basic total data of Table 6-6. That is, it gives the total route lengths and installed costs, on backbone routes otherwise used for general telecommunication, of the third wideband channel provided for network television. It also shows the cost consequencies, by country, of allowing for video dropping and adding and for an accompanying program channel. The average cost per route-kilometer of this augmented facility is seen to he about $870.

The second of these sections of Table 6-9 is concerned with spur routes of the backbone type. It shows that only Chile has no need for this type. For normal costs of construction, the total length of spur routes of this type is shown to be 13,090 km. For high-cost construction, in certain parts of Brazil and Peru, the total route length shown is 3,130 km. The corresponding total cost for spur routes of the backbone type are about $76 million for routes of normal cost and $22 million for the high-cost routes.

The third such section of Table 6-9 is concerned with spur routes of the short-haul type. Nearly one-half of the total length of spur routes, 31,580 kilometers, is in routes of the short-haul type. The cost of the short-haul portion is a smaller fraction of the total, of course, being about 38,400/136,232 = 28 percent thereof.

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Table 6-9. Summary of Radio Relay Route Lengths and Costs

SOUTH AMERICA. THIRD CHANNEL FOR TELEVISION ON BACKBONE ROUTES WITH ACCOMPANYING PROGRAM CHANNEL, ALSO PROPOSED EXTENDED TELEVISION AND LIGHT-ROUTE TELEPHONE COVERAGE TO OVER 99 PERCENT OF TOWNS OF OVER 10,000 POPULATION. COSTS IN THOUSANDS OF DOLLARS.

		3rd CHANNEL FOR TV			SPUR ROUTES OF BACKBONE TYPE							
			FIRST COST		ALL-WEATHER ROADS		NO ROADS		SPUR ROUTES OF SHORT-HAUL TYPE		TOTAL	
	NO. OF TOWNS >10,000 OMITTED	KILOMETERS	BASIC	WITH 9% ADDED *	KILOMETERS	FIRST COST	KILOMETERS	FIRST COST	KILOMETERS	FIRST COST	KILOMETERS	FIRST COST
ARGENTINA	0	3,710	$2,888	$3,148	3,270	$18,966			3,180	$7,950	10,160	30,064
BOLIVIA	0	2,010	1,076	1,173	340	1,972			70	175	2,420	3,320
BRAZIL	4	9,797	7,976	8,694	5,620	32,596	2,380	$16,660	6,880	17,200	24,677	75,150
CHILE	1	3,096	2,674	2,915					440	1,100	3,536	4,015
COLOMBIA	0	1,760	1,416	1,543	840	4,872			1,060	2,650	3,660	9,065
ECUADOR	0	710	584	637	100	580			600	1,500	1,410	2,717
PARAGUAY	0	320	240	262	580	3,364			360	900	1,260	4,526
PERU	0	2,450	2,104	2,293	1,100	6,380	750	5,250	510	1,275	4,810	15,198
URUGUAY	0	550	468	510	710	4,118			660	1,650	1,920	6,278
VENEZUELA	0	1,320	1,072	1,168	530	3,074			1,600	4,000	3,450	8,242
	5	25,723	20,498	22,343	13,090	75,922	3,130	21,910	15,360	38,400	57,303	158,575

* CONSISTS OF 6% FOR VIDEO DROPPING AND ADDING AT INTERMEDIATE POINTS, PLUS 3% FOR PROGRAM CHANNEL.

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The last section of Table 6-9 shows for this television coverage a total route length of 57,303 km and a total installed cost of $158,575,000. This represents an average cost of about $2,770 per route-kilometer.

Finally, we note that if to this total installed cost of $158,575,000 we add the sum of $127,000,000 mentioned at the end of paragraph 6.4.2 above, we obtain a total of about $285,000,000. This is to be compared with the sum of $300,000,000, estimated in paragraph 6.4.1 above, as the total cost of blanketing 3,500,000 square kilometers with a suitable mix of radio relay links of the two types.

6.5 COST COMPARISONS BETWEEN SATELLITE AND TERRESTRIAL SYSTEMS

From cost data derived in previous sections, the following summary and comparison can be drawn:

Table 6-10. Cost of Regional Amerisat Satellite versus Terrestrial Means of Serving Intra-National and Inter-National South American Requirements Assuming Future Satellite Capabilities (millions of dollars)

	Capability	Least-Cost Amerisat Satellite System	Terrestrial System	
			In The Absence of ITN	Excluding ITN Cost
From Table 6-3 (System A)	3 TV plus voice to towns of 10,000	$159.6	$285	$158
From Table 6-5	Voice only to towns of 10,000	$142.8	$197	$ 70
From Table 6-3 (System B)	3 TV to towns of 5,000 plus voice to towns of 10,000	$259.0	no equivalent	no equivalent
From Table 6-3 (System C)	3 TV plus voice to towns of 1,000	$316.3	no equivalent	no equivalent

a. For television and voice communications for towns of over 10,000 population, (providing population coverage on the order of 42%) the cost for the regional satellite and terrestrial systems are comparable, even if we consider only the

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incremental ITN costs for new spur routes. If we are to compare the total system costs, the satellite system is 55% as expensive. Since only a fraction of this ITN system has yet been funded, this is the better comparison.

b. On the other hand, the incremental cost for providing voice only as an extension of a fully-sunk ITN cost is on the order of $70 million in comparison with $142.8 million for the new regional satellite system. However, the cost of providing voice via terrestrial means including ITN costs is $197 million.

c. There is no estimate for a terrestrial system providing the same coverage as those in Systems B & C. It would appear that the cost for an equivalent terrestrial network would be much higher than satellite systems B or C.

d. Using a regional satellite as a substitute to INTELSAT III in serving intra-Latin American and intercontinental needs, the cost advantage is reflected by 1/8 reduction in the annual space segment charges.

SECTION 7

ORGANIZATIONAL CONSIDERATIONS

7.1 GENERAL

The implementation of a regional satellite system and its integration into the Latin American Communications complex is a complex undertaking. Paragraph 5.3 considers possible system configurations that have been hypothesized with the following considerations in mind:

a. The expected growth in international telecommunications traffic from 1,350 circuits in 1968 to 5,700 in 1978; a growth of 320 per cent.

b. The expected growth in intranational circuits in the 1970's (limited only by local plant expansion) of 10 per cent per year.

c. The growth of investment in telecommunications facilities over ten years on the order of billions of dollars.

d. A substantial growth in television facilities.

e. An increase in cooperation in the planning, execution, and funding of regional projects by nations which have had a history of a relative isolation from each other.

7.2 BASIS FOR ORGANIZATION

Besides INTELSAT, there is no precedent in the field of multinational projects which would provide a parallel to a regional satellite system. However, there are and have been within Latin America, a number of programs and developments which provide a basis for projection of conceivable modes of implementation of a regional Latin American system.

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7.2.1 Existing Organizations

There are a number of organizations, currently active in the development of integrated communication systems in Latin America, which most probably would be concerned with the systems envisioned in this study. Some of these entities are:

7.2.2.1 International Telecommunications Union (ITU). The International Telecommunications Convention, established the International Telecommunications Union. Chapter 1, Art. 4, of the Convention both establishes broad goals, and outlines the basic principles by which the ITU will realize these goals. Particularly relevant to this study is the Union's goal:

> "...to promote the development of technical facilities and their most efficient operation with a view of improving the efficiency of telecommunication services, increasing their usefulness and making them, so far as possible, generally available to the public"

In conjunction, the ITU shall:

> "...foster the creation, development, and improvement of telecommunication equipment and networks in new or developing countries by every means at its disposal especially in participation with the appropriate programs of the United Nations."

The ITU is a specialized agency of the United Nations. To a limited extent, it has provided technical assistance and telecommunications training programs in underdeveloped nations. In addition, the Union formulates World and Regional Telecommunications Plans. The charter of the ITU clearly implies that it could extend its good offices in the areas of systems/traffic engineering for regional satellite systems, and could provide related technical services, including training. As a UN related organization, it would be the important implementating agency if the United Nations Development Programme (UNDP) described below, were to become active in promoting regional satellite systems.

7.2.1.2 Inter-American Development Bank (IADB). The IADB was established to accelerate the process of economic development of the member countries, individually and collectively. By charter, it is conceived as a development bank: to mobilize public, private, domestic and foreign capital for economic development and preparation, financing and implementation of development plans. Since its organization in 1959, the Bank has made roughly 450 loans totaling nearly $3 billion. It has mobilized an additional $3 billion in development capital from local and other sources. Current liquid assets exceed $430 million. Most loans are made on the provision that only 50% of the total project cost will be financed by the Bank.

It is noteworthy that the Telecommunication Program Management Group at the IADB has been particularly successful by working through CITEL (described below) in furthering the development of the ITN. The same IADB group has also been instrumental in establishing a program of cooperation between the UNDP and a number of countries in Latin America to further international communications. The IADB has been designated the executing agency in conjunction with the ITU to establish and guide eight separate projects for linking the communications of adjacent national networks. This activity will be important in the creation of the ITN, since international communications is now largely blocked as a result of the lack of these "across the border" facilities. The Bank personnel have an understanding of the specific communications problems of Latin America without which little can be accomplished in that region.

7.2.1.3 Organization of American States (OAS) and CITEL. The OAS was founded in 1948 by the American States meeting, in Bogota, Colombia. Its charter establishes the Inter-American Conference as the supreme organ of the OAS. It meets every five years, setting the general activities and policies of the Organization. The Pan American Union is the permanent Secretariat of the OAS. Between meetings, the Council of the Organization, a representative body, makes operational decisions, and exercises jurisdiction over the Organs of the Council, including the Inter-American Economic and Social Council. The IA-ECOSOC, realizing

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that "there remain a number of questions related to telecommunications development and operation which have to be dealt with at the regional level and which are beyond the responsibility of ITU," has established the Inter-American Telecommunications Commission (CITEL). This body promotes international cooperation and fosters regional telecommunications planning. CITEL has a broad charter to plan, coordinate and advise local and regional organizations in the development of modern systems. Its chief undertaking to date has been the IADB financed planning of the ITN which will, among other things, interconnect American capitals when the ITN is actually completed.

7.2.1.4 The United Nations Development Programme (UNDP). The UNDP is the economic development arm of the United Nations. Operating under the Economic and Social Council, it is a consolidation of the UN Special Fund and the Expanded Program for Technical Assistance. It is a decision making and financing organization which directs the concerned UN agencies to act in development programs which it deems desirable and appropriate. The organization is illustrated in Figure 7-1.

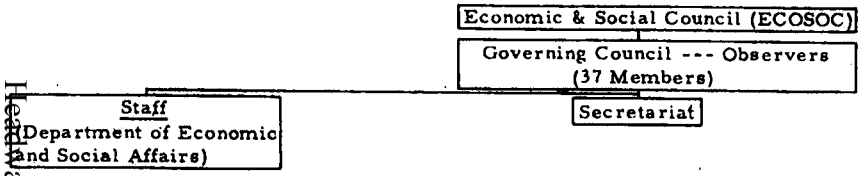


Figure 7-1. UN Development Program Organizational Chart

The decision-making, Governing Council has broad multi-national membership, with observers from UN member states as well as other specialized UN agencies and interested international development organizations (including the IADB, which is represented by a member of its telecommunications program staff). It meets twice annually, making appropriations and directing the relevant specialized agencies. At its 5th Session, in January 1968, $45 million was targeted as its expenditure goal allocated in the underdeveloped nations. Of this, roughly $8 million is earmarked for communication and transportation; about half of that amount for studies.

7.2.1.5 INTELSAT. INTELSAT owns commercial communications satellite systems. Outside the USSR, it is the only group providing commercial satellite service. INTELSAT operates under an "Agreement Establishing Interim Arrangement for a Global Commercial Communications Satellite System" (Definitive Arrangements are to be made in 1969). INTELSAT operates several satellites. Its present goal is the establishment of a global communications system, with primary emphasis on an international telecommunication. In the present context, INTELSAT is important because many Latin American nations (including all the large ones) are members. The table below indicates their current INTELSAT status.

Table 7-1. INTELSAT Membership Status

Country	Yes	No
Argentina	X	
Bolivia		X
Brazil	X	
Chile	X	
Columbia	X	
Costa Rica		X
Ecuador	Pending	
El Salvador		X
Guatemala		X
Honduras		X
Mexico	X	
Nicaragua		X
Panama	X	
Paraguay	X	
Peru	X	
Uruguay		X
Venezuela	X	

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The relationship of INTELSAT to a regional system is discussed later in this section.

7.2.2 Current Programs

Several current projects and programs pertinent to regional development as envisioned in this report are as follows:

7.2.2.1 Inter-American Telecommunications Network. The Inter-American Telecommunications Network (ITN) is the name applied to the configuration for an integrated system of long-haul communication facilities throughout Latin America which is designed to meet estimated traffic through the late 1970's.

In 1956 the Secretary for Communications and Transportation of Mexico presented to the ITU an original solution for the communication problems existing in Latin America. The aim of the project was the efficient interconnection of the telecommunications facilities within the American Continent as well as with the rest of the world. According to the Mexican proposal, it was felt that "good communications would bring countries closer together, make for easier relations among them, harmonize their interests and be conducive to their economic growth."

At a meeting convened by the ITU in Mexico City from April 19 to May 6, 1960, and attended by representatives of the OAS, serious consideration was given to the Mexican proposal and thus the ITN reached official status.

The IADB, aware of the importance of telecommunications and of the insufficiency of telecommunications in Latin America, early in 1966 began a program of preinvestment studies which would serve as the basis for the integrated development of Latin American telecommunications. This program was divided into a number of phases:

Task 1. To collect pertinent data and carry out a survey of South American countries to determine the status of telecommunications, the expressed needs as well as latent demand, and to develop a telecommunications system plan, technically and economically feasible, which would make use both of terrestrial and satellite facilities (planned and carried out by Page in 1966-67).[1]

Task 2. To develop comprehensive technical standards of transmission, automatic switching, numbering, and signaling for the integrated long-distance Inter-American Network (ITN), and lay out its terrestrial and space configuration (directed by the Telecommunication Program Management Group, PMG, of the IADB and executed by Page Communications Engineers from July, 1967 to November, 1967).

Task 3. To estimate the telecommunications traffic potential arising from economic integration and determine the economic feasibility of the ITN (performed by Page under the direction of the PMG, and completed in July 1968).

Task 4. To study in detail and prepare documentation for implementation of those portions of the ITN that do not exist at present, with a view toward closing the gap and permitting a continuous flow of communications throughout Latin America to be directed by the Telecommunication Program Management Group of the IADB and carried out, with the cooperation of ITU, by telecommunication consulting firms and counterpart personnel of Latin American Telecommunication Organizations. This phase is scheduled to begin in the second half of 1968, for completion in nine months.

While Tasks 1, 2, and 3 have been funded entirely by the IADB, Task 4 is funded jointly by the UNDP, the IADB and individual countries concerned. The IADB will also act as Executing Agency, administering the funds. CITEL has served to analyze the IADB's pre-investment studies and to prepare recommendations for acceptance or modification of technical plans.

The impact of the ITN on inter-Latin American political, social cultural goods and services exchange would undoubtedly be substantial. Furthermore, the procedures to be followed in the development of the ITN will suggest a general mode of operation for the initial phase of developing a regional satellite system.

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7.2.2.2 Latin American Free Trade Association and Central American Common Market. There are two major regional economic groups in Latin America. The first is the Central American Common Market (CACM) and the second is the Latin American Free Trade Association (LAFTA).

LAFTA consists of Argentina, Brazil, Chile, and Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay, and Venezuela, and the CACM of the five Central American Republics of Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua.

These groups of nations were formally organized in order to promote inter-regional cooperation for reciprocal trade. This has resulted in a shift of the total trade among the L. A. nations, as well as an increase in the magnitude of regional trade. The trade consideration is an important one, since 25 per cent o 50 per cent of these nations' national income is derived from exports.

Viewed in the context of this study, these organizations provide a successful example of regional cooperation for development. They mark the most fruitful cooperative effort on the part of the nations of this region, and establish a precedent for the formation of other integrating associations.

7.2.2.3 Multi-national Educational Programs of the OAS. The Second Special Meeting of the Inter-American Cultural Council entrusted the General Secretariat with making the studies and recommendations necessary for carrying out the decisions taken by the American Chief of State with regard to the multi-national efforts called for in Chapter V, Section A, of the Action Program of the Declaration of the Presidents of America.

The General Secretariat, on the basis of the general criteria and guidelines established by the Ad Hoc Committee on Education and by a group of consultants, prepared six multi-national projects each of which runs for five years. The amounts proposed for the first year of their operation are:

Name of Project	Amount Proposed
Development of Educational Research, Experimentation, and Innovation	$ 709,000
Training of Specialized Personnel in Education	2,681,130
Multinational Project on Educational Television	2,442,305
Harmonization of National Curricula with Latin American Integration Goals	156,886
Organization of Regional Volunteer Teacher Programs	99,700
Teacher Exchange Project	50,000
	$6,139,021

The Ad Hoc Committee resolved to submit these projects to the Fifth Meeting of the Inter-American Cultural Council so that they might be considered as activities of the Regional Educational Development Program. The authorization of these programs could have an important influence on the development of the video transmission aspects of the systems considered in this Report.

7.2.3 Development of Other "Regional" Systems

Several other non-INTELSAT satellite systems plans have arrived at various stages of development, ranging from active promotion to actual system design. The experience gained in these programs should be considered in the analysis of organizational alternatives. The current programs include:

a. Brazilian National System[2]
b. Canadian Domestic Satellite System[3]
c. Possible European Regional Satellite System[4]

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7.3 ORGANIZATIONAL REQUIREMENTS

The fundamental steps involved in the development of systems of the type described in Section 5, are:

a. Planning
b. System engineering and design
c. Approval and coordination
d. Management
e. Technical support
f. Financing

7.3.1 Planning

Implementation of modern telecommunications facilities in underdeveloped areas must commence with basic planning in three areas.

a. Traffic engineering--National requirements must be established, projected to configure an efficient system.

b. Interface with local plant expansion plans. Since the satellite system must interface with local telecommunication plant, the system must be planned with these considerations in mind. Earth stations locations must also be selected.

c. Basic Parameters--Such basic operational concepts as numbering, signaling, etc. must be agreed on by all participants.

7.3.2 System Engineering and Design

In conjunction with the established requirements and interface considerations, systems must be configures taking into account:

a. The selection of the optimum space and terrestrial investments.

b. The selection of the appropriate operational modes and access method.

c. The selection of hardware which will satisfy these needs.

In addition to the INTELSAT System Manager (Comsat), there are a number of qualified system engineering firms capable of implementing this phase.

7.3.3 Coordination and Approval

In order to have a homogeneous system, coordination must be undertaken at several levels. They are:

a. Local plant--as in 8.3.1 (b).

b. Governmental--Individual government, as a matter of national policy, establish telecommunication goals. The regional system should be configured with these in mind, as well as national goals being established with regard to the regional system.

c. International
   1. ITU - The ITU makes recommendations regarding frequency allocation and a great variety of other telecommunication matters. In addition, it also provides planning and related services, in conjunction with its function as a UN specialized agency. Participation as well as guideline establishment will be the probable scope of regional interface with the ITU.
   2. CITEL - Since CITEL is the organization of Latin American telecommunications authorities, who represent their governments as well as communication entities (in most cases the government owns the communications entity), approval of system configuration and design will have to be reached within this body.

7.3.4 Management and Ownership

This study has concerned itself primarily with the technical parameters of systems that could fulfill Latin American telecommunication requirements. By conceiving of a regional system that would be operational at a time when INTELSAT will have implemented its global system by no means, precludes the ownership or operation of these systems also by INTELSAT. Many of the Latin American nations are already members of INTELSAT and more eventually will be. Even those that are not, can have access to all INTELSAT satellites under the terms of the Agreements.

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Should INTELSAT decide that it was permitted to operate regional systems under the Interim or Definitive Agreements, and that it was desirous of operating one or more such systems, it could certainly do so.

Should it decide not to, of if the Latin American nations desire another arrangement, there are other possibilities.

Developing nations constructing a regional satellite system would require technical aid in the following areas:

a. Hardware Procurement - Both satellites and terrestrial facilities must be procured. Cost/effective purchasing can be best accomplished with the assistance of an organization qualified to evaluate the complex proposals which would result from an RFP for regional system components.

b. Technical Assistance - There are two areas where technical assistance of a continuing nature will be needed as well as a third planning group. These areas are:

   1. Earth Station Maintenance & Operations. With trained local personnel in short supply, a large scale training program to develop earth station maintenance staff must be undertaken. This may well be in the province of the ITU, since it has established several telecommunications training schools in underdeveloped areas.

   2. Satellite Maintenance & Operations. Station keeping and spacecraft control will be continuing function of the System Manager.

   3. Planning. With system growth to be expected, continuous planning must be built into the managerial process. This will require a group qualified to accurately forecast new demands and assess their impact on system configuration.

7.3.5 Financing

In light of the fact that most Latin American telecommunications entities are government owned, and that an investment of this magnitude will probably require assistance from the more developed nations, a means of providing multilaterial financing will be required. IADB is in a unique position to carry out the function of financial coordination. It accepts contributions from all nations into its Fund for Special Operation (the soft-loan window), which makes low-interest, long-term loans from government grants, moreover the IADB has the ability to mobilize resources. If, for example, the U.S. were to finance a system as envisioned in this study, this would be both an efficient and politically expedient mechanism.

In addition to IADB, the UNDP provides international financing for development projects. As far as telecommunications projects are concerned, it would operate through the appropriate UN agency, the ITU, in processing the requests for assistance as well as implementing them.

It is also possible that the World Bank may take a more active part in the development of telecommunications systems. The Bank is presently staffing itself with specialists in this field.

7.4 COMPETITION IN THE SPONSORSHIP OF REGIONAL SATELLITE SYSTEMS

Various estimates place the lead of the United States in construction and emplacing large communications satellites in the stationary orbit, between 5 and 10 years ahead of other members of INTELSAT.

Outside of INTELSAT, however, the Soviet Union has demonstrated the capability of launching large, high power (40 watt RF) communication satellites--their Molniya series.

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Although these satellites ope ate between 800 and 1000 MHz it is highly likely that they could construct high power satellites for use in other frequency bands.

The present launch sites of the USSR are not favorably located for launching spacecraft into equatorial orbits (Tyurtam at 45.6°N Lat. the Molniya launch site, and Kapustin Yar at 48.5°N Lat.). These sites entail a thrust loss of up to 60% to remove all initial inclination.

Even so, with their high-thrust launch vehicles, they still might be able to emplace stationary satellites of the necessary weight and power from their present sites.

Alternatively, they could launch from the near-equatorial site now under construction, French Guiana, or from a near equatorial site that could be developed in a country desiring regional satellite service and with which the USSR could reach an agreement for such an installation. Among the technically possible sites permitting a nearly over-water, Easterly launch are: Brazil, the Somali Republic, Kenya, Malaysia, and Indonesia. Not to be discounted is the barge launch of a USSR satellite from any place on the ocean near the equator.

These considerations lend some sense of urgency to the sponsorship of, or aid to, regional satellite systems by the United States. There have already been some Franco-Soviet experiments using the Molniya satellites and the French earth station at Pleumeur-Bodou. There have been reports of using the USSR satellites in a regional system with France being the gateway station to Western Europe.[5]

7.5 REFERENCES

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3. "Considerations for a Canadian Domestic Satellite System: J. A. Collins, AIAA 2nd CSS Conference, Paper No. 68-413.

4. "Regional and Global Implications of a European Satellite Communications System," G. K. Pardoe and L. W. Steines, AIAA Paper No. 68-468.

5. Aviation Week, August 28, 1967 page 76 and Sept. 4, 1967 page 51.

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SECTION 8

SUMMARY

8.1 INTRODUCTION

The purpose of this section is to unify the findings of the various elements of the study and to summarize the material presented in each study area.

The system design is influenced by many factors. These factors listed here were considered in various sections of this report.

a. The magnitude and distribution of the region's traffic.

b. Existing and planned conventional terrestrial and satellite facilities.

c. The required grade of service.

d. Frequency allocations and interference.

e. Modulation and multiple access techniques.

f. The state of the art of the launch vehicles, spacecraft and earth stations available during the period under consideration.

g. Relative costs of the system elements.

8.2 CIRCUIT REQUIREMENTS

Voice and record traffic is projected for 1973 and 1978 in the following categories:

a. Inter Latin American, by country

b. Intercontinental, by

   1. Mainland U.S. and Canada
   2. All other continents

c. Intranational, by country

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The forecasts of inter-Latin American and intercontinental traffic are based on actual and estimated data provided by the various national administrations and telecommunications organizations involved, and projected using growth rates developed from experience, from international conferences of traffic experts, and in certain cases, from correlation of traffic with economic indicators.

Intranational traffic is derived for each country by applying the correlation which exists between traffic and telephone density, based on projected telephone densities determined in earlier Page work.

Circuit requirements are developed from traffic projections using standard conversion procedures, and based on an analysis of routing and switching alternatives.

The total circuit requirements for 1968, 1973 and 1978 are summarized in Table 8-1, in terms of equivalent voice circuits. The number of circuits which might reasonably be carried by satellite are shown in parentheses. It may be seen from Table 8-1 that the requirement for international and intercontinental circuits is expected to quadruple in the next ten years, with the fastest growth assumed in the 1968 to 1973 period, based on an anticipated impulse jump due to the availability of major new facilities by 1973. The requirement for new long distance intranational circuits is expected to increase more than 50% from 1973 to 1978.

The potential use of satellite circuits shows a somewhat different pattern of growth than total circuits: a regional satellite system available in the early 1970's would carry a large portion of the impulse jump by 1973, but would increase its traffic only very slightly from 1973 to 1978 due to the draining away of traffic by the new terrestrial circuits which would be constructed during that period; intercontinental circuit requirements, however, would continue to increase from 1973 to 1978.

The potential use of satellites for intranational long distance circuits is much more complex, representing a small percentage of total requirements, and is discussed in Section 6.

Table 8-1. Summary of Requirements for Communication Circuits

	Number of Equivalent Voice Circuits		
	1968	1973	1978
Inter-Latin America			
South America	204 (0)	490 (320)	884 (330)
Mexico	19 (0)	43 (32)	60 (45)
Central America	43 (0)	201 (12)	321 (20)
Inter-Latin America Total	266 (0)	734 (364)	1265 (395)
Mainland U.S. and Canada			
South America	109 (0)	316 (257)	569 (512)
Mexico	557 (0)	907 (0)	1686 (0)
Central America	58 (0)	174 (101)	303 (176)
Mainland U.S. and Canada Total	724 (0)	1397 (358)	2558 (688)
Europe and Other			
South America	75 (0)	268 (268)	396 (396)
Mexico	21 (0)	65 (65)	103 (103)
Central America	2 (0)	7 (7)	12 (12)
Europe and Other Total	98 (0)	340 (340)	511 (511)
All International			
South America	388 (0)	1074 (845)	1849 (1238)
Mexico	597 (0)	1015 (97)	1849 (148)
Central America	103 (0)	382 (120)	636 (208)
Grand Total International	1088 (0)	2471 (1062)	4334 (1594)
Intranational (excludes Central America)			
South America		86,160	130,140
Mexico		19,350	31,350
Intranational Total		105,510	161,490

Note: 490(320) means there is a requirement for 490 circuits, of which 320 are suitable for a regional satellite.

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8.3 TELEVISION SERVICES

The need for television was investigated in different areas for different applications. The most important application considered was educational television (ETV). Several problems were discussed concerning ETV:

a. Agreement has not been reached among educators as to the amount of television required for educational purposes in Latin America.

b. More than three television channels directed toward and time shared by a region would probably provide more hours of coverage than the countries could individually generate.

c. Distribution of television transmissions beyond the earth stations would be under the control of the local Government. Thus, programs originating in one of the countries sharing a satellite beam would not necessarily be viewed in other countries.

.3.1 Types of Programs

The types of television programming discussed are:

a. Educational television: television programming designed for the education of adults on a wide variety of subjects.

b. Instructional television: a type of educational TV, but one used to assist teachers and which includes daily or regular classroom lectures.

A video bandwidth channel can be utilized entirely for television, or only a portion can be used for graphic displays. In the latter case the remainder of the bandwidth would be used for a multiplicity of two-way teletype-speed circuits for direct communication between classrooms and a computer that would provide programmed instruction or some form of feedback to the students.

c. Computer aided instruction: the system would consist of remotely located consoles for student use which are tied to a large central processor. This would not require the bandwidth necessary for real time video transmission, but could perhaps use a voice frequency circuit.

d. Commercial TV: a certain number of hours per day could be leased by commercial interested for programming purposes.

e. Political information and news: the system could be used to present government policies and news. Such programs would be viewed in other countries sharing a satellite beam at the option of the administration controlling each earth station.

f. Network television: distribution of network television in lieu of using terrestrial microwave links.

Several techniques of television distribution are possible by satellite. Those discussed are rebroadcast, limited direct broadcast and direct broadcast.

8.4 SYSTEM CONSTRAINTS

The system is constrained by the following conditions and requirements.

a. Spacecraft. The spacecraft payload classes will be determined by the launch vehicles available in the 1970's. The launch vehicles considered and their payload capabilities are presented in Table 8-2.

Table 8-2. Available Launch Vehicle Characteristics

Vehicle	Transfer Orbit Weight (lbs)	Stationary Orbit Payload (lbs)
Long-Tank Delta w/ TE 364-3 (DSV-3L)	725	315
TITAN 3B-Agena	2400	1240
ATLAS - Centaur	3400	1700
TITAN 3C	7600	3420

b. Operating Frequencies. The system operating frequencies considered should be those which are presently allocated to commercial satellite use (4 and 6 GHz band). Other frequencies which could be shared by regional satellites are also discussed.

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c. Service Quality. CCIR Recommendations have been used to design telephone service. A grade of service of P = .03 has been assumed, implying that not more than 3% of all attempted calls would be blocked because of trunk-busy conditions.

d. Television. The television distribution will be based on two subjective video signal qualities, both below the CCIR recommendation for signal-to-noise ratio for international television exchange via terrestrial means. These qualities were TASO grades 1.5 and 2.5.

e. Earth Station. Only earth stations smaller than the standard INTELSAT design were considered for intranational service. These stations have lower gain antennas with diameters of from 10 to 32 feet and uncooled preamplifiers resulting in either 150°K or 600°K system noise temperatures. The antenna beamwidth and the spacecraft station keeping ability were assumed sufficient to allow the use of non-tracking antennas. Commercial power was assumed, although its frequency and voltage are variable and interruptions may occur. 55% antenna efficiency is assumed.

8.5 MODULATION AND MULTIPLE ACCESS TECHNIQUES

Because of the large numbers of earth stations assumed in the regional systems, only a demand access, fully-variable, multiple access system would be suitable. However, several methods were discussed:

- PCM-PSK-TDMA
- FM-FDMA with a single channel per carrier (STAR)
- PCM-PSK-FDMA, with a single channel per carrier (SPADE)
- FDM-FM-FDMA, more than one channel per carrier

Circuit assignment techniques fall into two categories: preassigned and demand assigned. For systems with small amounts of traffic per station, many possible destinations and a large number of stations, a fully variable demand assignment system is necessary for overall efficiency. A study for the developing countries in the Atlantic region show that this type of assignment would save 67% of the satellite capacity, compared with a preassigned system.

The two multiple access techniques chosen for comparison were the STAR system and the SPADE system. The following basic criteria were assumed:

a. Total noise power per voice channel, 10,000 pW psophometrically weighted, for the STAR system.

b. Noise performance equivalent to the above criteris for the SPADE PCM system. That is, a bit error rate of 1 in 10^4.

c. Rain margin for the down link was taken as 3 db.

A comparison between the two systems for the same quality of service, assuming 100 KHz per channel, indicates that the SPADE system required 8.8 dbw per channel while the STAR system requires 12.5 dbw per channel. The satellite rf power for the SPADE system for four different earth station G/T's and eight different service requirements are presented in Table 8-3.

Since frequencies cannot be reused (the spot beams overlap in places), bandwidth is at a premium. The maximum number of one way channels available in the 500 MHz satellite bandwidth at 100 KHz spacing, is 5,000, for a total of 2,500 circuits.

8.6 SATELLITES

The capabilities estimates of the several manufacturers answering the questionnaire were in fairly close agreement. Based on the launch vehicle payloads constraint the rf power data presented in Table 8-3 are estimated.

Expected state-of-the-art advances especially in the area of solar cell technology and space-qualified rf hardware will produce increases in rf power of from 0.6 to 8.8 db, depending on the satellite considered. Table 8-3 lists the present and expected total saturated rf power capability of spacecraft.

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Various Service Requirements and Earth Station G/T's Assuming a 4.3 db Back-off and SPADE Method for Telephone Demands

Services Supplied	Earth Station G/T (dbw/°K)			
	17.7	21.2	25.7	27.8
Case 1 3 TV channels (TASO 2.5) and 4400 telephone channels, 3 antenna beams	199.5	89.1	31.6	19.5
Case 2 3 TV channels (TASO 1.5) and 4100 telephone channels, 3 antenna beams	210.5	94.0	33.3	20.6
Case 3 5000 telephone channels 3 antenna beams	168.5	75.2	26.7	16.5
Case 4 1 TV channel (TASO 2.5) and 4800 telephone channels, 1-5° antenna beam (Brazil)	284.5	127.0	45.1	27.8
Case 5 1 TV channel (TASO 1.5) and 4760 telephone channels, 1-5° antenna beam (Brazil)	288.9	129.0	45.8	28.2
Case 6 4000 telephone channels 1-5° antenna beam (Brazil)	268.8	120.0	42.6	26.3
Case 7 16 TV channels (TASO 2.5) BW = 20.0 MHz, 1-5° antenna beam (Brazil)	676.5	302.0	107.1	66.1
Case 8* 16 TV channels (TASO 1.5) BW = 30.0 MHz, 1-5° antenna beam (Brazil)	650.1	290.0	102.9	63.5
Case 9 1TV (TASO 1.5) + 1650 telephone channels, 5° beam (Brazil)	127.0	58.0	20.6	12.7

*Cases 7 and 8 assume a 2 db backoff.

Table 8-4. Spacecraft Saturated RF Power Capabilities

Payload (lbs)	Present Power (Watts)	Projected Power (1970's) (Watts)
315	26	119
1240	112	645
1700	168	1220
3420	350	2210

Satellite costs are difficult to obtain. Understandably manufacturers did not commit themselves to even budgetary estimates because of the advanced time frame and the indefinite character of spacecraft design. Therefore, costs were extrapolated from current and recent costs of several spacecraft development contract studies and proposals. These are presented in Table 8-5. It should be noted that these costs are based primarily on new satellite development and do not reflect possible decreases in cost due to the procurement of then existing spacecraft designs.

Table 8-5. Space System Costs (millions of dollars)

Satellite Weight	R&D Costs	Unit Cost	Launch Vehicle	Launch Vehicle Cost
315	11.0	4.0	Thor Delta	4.5
1240	25.0	6.5	Tital IIIB/Agena	12.6*
1700	30.0	7.2	Atlas/Centaur	16.0
3420	44.0	9.4	Tital III C	20.0

*Development cost of the launch vehicle is 11.0 million dollars.

8.7 EARTH STATIONS

The primary interest of this study was concentrated on small lower cost earth stations. The diameter of the earth station antenna should be held to less than 32 feet to avoid the necessity of providing tracking capability. The stations

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should operate with uncooled front ends and be designed for easy maintenance by relatively inexperienced and untrained personnel.

Several candidate earth stations were considered as examples on which a system configuration could be based. The characteristics of the candidate earth stations are shown in Table 8-6 for earth station noise temperatures of 150°K and 600°K.

Table 8-6. Earth Station Characteristics

Antenna				Beamwidth (degrees)	
Diameter (ft)	Gain (db) 55% eff.	G/T NT = 150°K	G/T NT = 600°K	3 db	To First Null
10	39.5	17.7	11.7	1.7	3.0
15	43.0	21.2	15.2	1.1	2.0
25	47.5	25.7	19.7	0.7	1.1
32	49.6	27.8	21.8	.55	0.9

Antenna diameters below 10 feet were not considered because the beamwidth becomes too wide, causing potential interference to other satellites. Also, the earth station becomes more susceptible to terrestrial interference.

Earth station cost data were developed on the basis of system G/T, the number of TV and telephone channels required, cost of civil works, auxiliary power equipment, transmitter size, etc. A tabulation of earth station costs for various G/T's and traffic requirements are shown in Table 8-7.

Table 8-7. Earth Station Costs (x$1000)

Antenna Diameter (ft)	10		15		25		32	
Gain to Temperature Ratio (db)	11.7	17.7	15.2	21.2	19.7	25.7	21.8	27.8
TV Receive Only	50	65	65	80	76	91	91	106
TV Receive Plus 1 Voice Channel	105	120	113	128	124	139	139	154
TV Receive Plus 5 Voice Channels	179	194	179	194	185	200	190	205
TV Receive Plus 10 Voice Channels	251	266	241	256	237	252	247	262
TV Receive Plus 50 Voice Channels	609	624	612	627	601	616	590	605
TV Receive and Transmit 50 Voice Channels	751	766	742	757	709	724	692	707
1 Voice Channel Only	82	97	90	105	100	115	115	130
5 Voice Channels Only	159	174	159	174	164	179	169	184
10 Voice Channels Only	228	243	218	233	213	228	223	238
50 Voice Channels Only	588	603	593	608	603	598	573	588

8.8 CONFIGURATION

8.8.1 Planned and Existing Facilities

Existing facilities in South America are generally inadequate for current traffic loads, and therefore must be very greatly expanded and improved to handle the rapid traffic growth anticipated in the near future. The necessary planning effort for the new facilities is now underway, being sponsored by the IADB, the UNDP, and the various administrations and international agencies involved.

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At present, HF radio, VHF radio and open wire still comprise a large share of the international plant, and a majority of the national long-distance works. However, microwave is rapidly replacing HF and open wire for the longer, high-density routes. Coaxial cable is being used in a few main routes. Undersea cables are limited to the Panama-U.S. and Venezuela-U.S. circuits. Communications satellites will begin to have major importance in late 1968, and INTELSAT earth stations are scheduled by 1973 for Argentina, Brazil, Chile, Colombia, Panama, Peru, Mexico and Venezuela.

Plans for the Inter-American Telecommunications Network (ITN) will be a major factor in the development of international facilities. The ITN is made up of individual sections, owned and controlled by administrations in the countries of Latin America, but designed to operate as an integrated and fully coordinated network. A major portion of the ITN is scheduled to become operational by 1973. Section 5 of this report presents detailed information on the facilities which will make up the ITN.

Intranational facilities, local plant and switching centers are also grossly inadequate for the planned expansion. The status national planning for these facilities varies greatly among countries.

8.2 Potential Regional Satellite System Configurations

For intercontinental and international Latin American traffic a satellite system has already been designed: the INTELSAT III System. Calculations have shown that a system serving only Latin American needs would be economically viable and would result in lower channel costs then projected INTELSAT figures.

Another promising use of a regional system is for long distance intranational traffic. Since such a system would have many earth stations, they should be less expensive than the standard INTELSAT station.

Because of the relatively short distances of most population centers in Central American from the main North-South backbone, terrestrial extensions are preferable to a satellite system for intranational traffic. Thus a Central American beam is not provided initially.

The system conceived for this purpose consists of a satellite having three beams that cover three different areas of South America: centered about Brazil, Argentina/Chile, and the northwest part of the continent. Each beam would carry one TV channel plus about one-third of the total satellite telephone capacity. The satellite receive antenna can either cover all of South America, or there could be three receive beams conincident with the transmit beams.

In the first case, connection between regions is possible at the expense of increased transmitter power at all earth stations. Thus, international South American traffic could be carried as well as intranational.

In the second case, only traffic originating within a given beam could reach earth stations in that same beam. This would provide intranational traffic, and connections between countries sharing the same beam. Smaller transmitters would be required at all earth stations due to the higher gains of the spot satellite receiving beams.

The earth station distribution can be determined as a function of population density. For circuit allocation purposes the population centers were divided into four classes which are presented in Table 8-8.

Table 8-8. Earth Station Distribution and Circuit Allocations

Class	Population (Thousands)	Number of Stations	Circuits per Group
I	1-10	1,066	1
II	10-50	403	5
III	50-500	109	10
IV	over 500	16	50

The three following cases of communications services were assumed for the development of a system model:

System A is a regional satellite system with one-way television transmission and two-way telephone circuits for all towns of 10,000 population or over, covering 42.06% of the total population of South America.

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System B differs from System A in that television transmissions cover all towns of 1,000 population. Overall population coverage increases 44.95%. However, in towns of between 1,000 and 10,000 population no voice circuits are added.

In System C, telephone circuits are added to System B for towns between 1,000 and 10,000 population. The population coverage remains at 44.95%.

There are several satellite/earth station combinations which will supply the desired service. These combinations are presented in Table 8-9.

Table 8-9. Amerisat Satellite/Earth Station Combination for Cases 1, 2 & 3

Satellite (lbs)	Case	Required Earth Station Assuming: Present Satellite Power Capability	Future Satellite Power Capability
315	1, 2	32'-150°K	15'-150°K or 32'-600°K
	3	32'-150°K	15'-150°K or 25'-600°K
1240	1, 2, 3	15'-150°K or 32'-600°K	15'-150°K or 20'-150°K
1700	1, 2, 3	15'-150°K or 25'-600°K	15'-600°K
3420	1, 2	10'-150°K or 25'-600°K	Smaller Earth Station
	3	10'-150°K or 15'-600°K	than 10'-600°K

Based on the circuit allocation scheme presented in Table 8-8 and the combinations in Table 8-9, the costs of various systems designed to meet the requirements were derived. These were given in Table 6-2 through 6-5 which are repeated later in this section as Figures 8-10 through 8-13. The least expensive scheme for each coverage case are reasonable ones in the present context of comparative cost and coverage. They represent a realistic compromise between the 'revenue goal' and the 'development goal' of a regional system. The approach taken comprised three steps: (1) a regional satellite system was examined to provide television and varying degrees of voice communications capabilities related to population centers; (2) a terrestrial system (as an extension of the proposed ITN network) was examined to provide a comparison of other ways of providing the same service; and (3) the cost implication of a Latin American satellite replacing the present INTELSAT III System for intercontinental use was studies.

8.8.3 International and Intercontinental System

Cost calculations show that a Latin American regional satellite system using standard INTELSAT earth stations and an INTELSAT III capacity satellite would both meet traffic requirements and be economically viable with a space segment charge less than that projected by INTELSAT for the same time period.

8.8.4 Intranational and International South American Regional System Amerisat

Because of the importance of the cost comparisons between a regional satellite system serving intranational requirements, and a equivalent terrestrial network, the entire section from the body of the Report treating that question is repeated in this summary:

a. Such a comparison is dependent on the assumptions made.

b. Total investment costs have been calculated for each of the possible systems, and each of the satellite/earth combinations.

c. The features and coverage of systems A, B & C are described in Section 5 with telephone and television capacity divided among them:

(1) Case 1. 3 TV channels, (TASO Grade 2.5) plus 4400 telephone channels.

(2) Case 2. 3 TV channels, (TASO Grade 1.5) plus 4100 telephone channels.

(3) Case 3. 5000 telephone channels only.

Total system cost comprises:

- Unit cost of 3 satellites
- Satellite R&D cost
- Launch cost of two launches
- Earth station costs plus 12% for spares and test equipment.

This costing assumes a system life of 10 years and a satellite MTTF of 5 years. The third satellite is to be constructed, tested, and held as a spare on the ground. Launch costs include a 20% allowance for launch failure.

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If more than one regional system is implemented, or if these satellites are useful for any other satellite system, R&D costs would be apportioned over more units, thus reducing the space segment cost.

The R&D cost for the TITAN 3B Agena only has been split over six launches on the reasonable assumption that this vehicle will be used by INTELSAT for its INTELSAT IV launches and by Comsat for a domestic system.

Earth station costs were given in Table 4-14, and the number of stations of each capacity used in each system are shown in Tables 5-10 through 5-12.

These costs do not include yearly operations and maintenance for the earth stations, nor the cost of money. They do allow a comparison of total system investment costs to pick the least expensive earth station/satellite combination, and reveal the increased investment required to expand service to more towns.

Note that the least system cost combination is always the 315 pound satellite, whether one assumes present or projected satellite rf power capabilities.

Other cases and systems are possible. Consider the launching of additional satellites in future years to accommodate traffic in excess of the capacity of the single initial satellite. The incremental investment cost can be determined from the satellite and launch vehicle cost table. No more earth stations would be necessary.

Likewise, the incremental cost of serving more cities or towns can be obtained by adding the cost of the appropriate number of earth stations from the table of their costs. In essence, this is a building block approach.

Table 8-10. Total Amerisat System Costs Based on Present Satellite Capabilities (millions of dollars), Television and Telephone (Cases 1 or 2)

Satellite/E.S. Combinations	System A	System B	System C
315 lb/32' - 150°	168.5	295.1	352.4
1240 lb/15' - 150°	204.9	300.4	357.7
1240 lb/32' - 600°	201.0	309.6	366.9
1700 lb/15' - 150°	215.1	310.6	367.9
1700 lb/25' - 600°	208.0	298.8	356.1
3420 lb/25' - 600°	236.6	327.4	384.7
3420 lb/10' - 150°	245.0	322.6	388.3

Table 8-11. Total Amerisat System Costs Based on Future Satellite Capabilities (millions of dollars), Television and Telephone (Cases 1 or 2)

Satellite/E.S. Combinations	System A	System B	System C
315 lb/15' - 150°	163.5	259.0	316.3
315 lb/32' - 600°	159.6	268.3	325.6
1240 lb/10' - 150°	206.2	283.8	349.4
1240 lb/15' - 600°	196.0	273.6	330.9
1700 lb/10' - 600°	207.5	267.2	332.9

8.8.5 Telephone Service Only

If the entire capacity of the satellite is used for telephone channels at 100 KHz spacing, 5,000 can be accommodated (2,500 circuits).

Total system costs for present and future satellite capabilities are shown in Tables 8-12 and 8-13.

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Table 8-12. Total Amerisat System Costs Based on Present Satellite Capabilities, Telephone Service Only (millions of dollars)

Satellite/E.S. Combinations	Voice Only to Towns Over 10,000 Population	Voice Only to Towns Over 1,000 Population
315 lb/32' - 150°	154.6	309.9
1240 lb/15' - 150°	191.2	316.6
1240 lb/32' - 600°	187.1	324.4
1700 lb/15' - 150°	201.5	326.8
1700 lb/25' - 600°	194.4	313.8
3420 lb/10' - 150°	231.2	347.0
3420 lb/15' - 600°	221.2	328.5

Table 8-13. Total Amerisat System Costs Based on Future Satellite Capabilities, Telephone Service Only (millions of dollars)

Satellite/E.S. Combinations	Voice Only to Towns Over 10,000 Population	Voice Only to Towns over 1,000 Population
315 lb/15' - 150°	149.9	275.2
315 lb/25' - 600°	142.8	262.2
1240 lb/10' - 150°	192.4	308.2
1240 lb/15' - 600°	182.4	289.8
1700 lb/10' - 600°	193.7	291.6

These tables show system costs: that is, they include the full complement of earth stations Should additional satellites be required to supply increasing traffic requirements, the system configuration can be altered to supply fewer countries on each satellite, reaching, in the limit, one country per satellite. (Those satellites would have to be modified to provide only one-spot transmitting and receiving beam to the country, or countries, for which coverage is desired.) With separate satellites, spaced in orbit to re-use the same frequency allocation, connection between countries would not be possible. It is assumed that in this later time period, terrestrial international facilities will have improved so that they could be utilized for any international portion of the total link, thus avoiding two satellite hops and reserving the regional satellites solely for intranational service. The change in antennas should not affect the cost of these future satellites appreciably. With smaller beamwidths, slightly more than 5,000 channels can be accommodated with smaller channel frequency spacing. The incremental cost of this new multiple-satellite system can be determined by adding only the cost of the appropriate number of satellites and launches from Table 4-8 to the cost of the already installed complex of earth stations.

Table 8-14. Costs of Amerisat Regional Satellite Vs. Terrestrial Means of Serving Intranational and International South American Requirements Assuming Future Satellite Capabilities (millions of dollars)

	Capability	Least-Cost Amerisat Satellite System	Terrestrial System	
			Including ITN Cost	Excluding ITN Cost
From Table 6-3 (System A)	3 TV plus voice to towns of 10,000	$159.6	308	158
From Table 6-5	Voice only to towns of 10,000	$142.8	220	70
From Table 6-3 (System B)	3 TV to towns of 5,000 plus voice to towns of 10,000	$259.0	No equivalent	No equivalent
From Table 6-3 (System C)	3 TV plus voice to towns of 1,000	$316.3	No equivalent	No equivalent

a. For television and voice communications for towns of over 10,000 population (providing population coverage on the order of 42%), the cost for the regional satellite and terrestrial systems are comparable, even if we consider only the costs for the new spur routes which must be added to planned ITN facilities. If we are to compare the total system costs, the satellite system is 55% as expensive. Since only a fraction of this ITN system has yet been funded, this is the better comparison.

b. On the other hand, the incremental cost for providing voice only as an extension of a fully sunk ITN cost is on the order of $70 million in comparison with $142.8

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million for the new regional satellite system. However, the cost of providing voice via terrestrial means including ITN costs is $220 million.

c. There is no estimate for a terrestrial system providing the same coverage as those in Systems B and C. It would appear that the cost for an equivalent terrestrial network would be much higher than satellite systems B or C.

d. Using a regional satellite as a substitute to INTELSAT III in serving intra-Latin American and intercontinental needs, the cost advantage is reflected by 1/8 reduction in the annual space segment charges.

6.9 ORGANIZATIONAL CONSIDERATIONS

The fundamental steps involved in the development of telecommunications systems are:

- Planning
- System engineering and design
- Approval and coordination
- Management
- Technical support
- Financing

In the case of a South American regional satellite system, "AMERISAT," some of these necessary functions could be performed by exisging organizations; others might require the creation of new entities.

Among the existing organizations whose cooperation would be desirable, are:

- The International Telecommunications Union (ITU)
- The Organization of American States (OAS) and its affiliated and subsidiary groups, such as:
  - The Inter-American Telecommunications Commission (CITEL)
  - The United Nations Development Programme (UNDP)
  - INTELSAT
  - The Inter-American Development Bank (IADB)
  - The Latin American Free Trade Association (LAFTA)
  - The Central American Common Market (CACM)

There have been at least two developments in the telecommunications field that represent precedents for a regional satellite system: INTELSAT and the ITN. The former is an international organization established to provide satellite communications on a global basis, and the latter is an example of specifically Inter-American cooperation on a telecommunications project. Both point the way for cooperation among the states of Latin America in conjunction with international planning, operating and financing organizations.

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Volume I

SATELLITE-DISTRIBUTED EDUCATIONAL TELEVISION FOR DEVELOPING COUNTRIES — SUMMARY REPORT

Prepared for:

AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C.

CONTRACT AID/csd-1901

By: WILBUR SCHRAMM and WILLIAM J. PLATT

SRI Project 7150

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PREFACE

In March 1968, the U.S. Agency for International Development, in support of the President's Task Force on Communications Policy, contracted with Stanford Research Institute to study educational applications of communication satellites for developing countries. The study was designed to determine the potential of satellite-delivered educational broadcasts through analyses of two developing regions. A single large nation, India, and a multinational region, Latin America, were chosen as case studies to illustrate the scope of possible applications. The emphasis of the case studies was to be on the educational, economic, cultural, organizational, and political factors affecting the feasibility and utility of satellite communications.

This report contains an overview of the case studies. Volumes in the project series include:

Volume I: Satellite-Distributed Educational Television for Developing Countries--Summary

Volume II: Communication Satellites for Education and Development--the Case of India

Volume III: Satellite-Distributed Educational Television for Developing Countries--the Case of Latin America

Volume IV: Satellite-Distributed Educational Television for Developing Countries--Working Papers

1. Nonhardware Components of an Instructional Television System for a Developing Country
2. Considerations in Deciding Whether and How to Introduce an Educational Satellite
3. Film Versus Television in Education
4. Technical Considerations of Satellite Communication Systems for Education
5. Political Obstacles to Adoption of Educational Television
6. Economic Analysis of the Alternative Distribution Systems for Educational Television
7. The Role of Radio in Supporting Educational Television

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INTRODUCTION

Satellite communication would appear to offer potential for accelerating the modernization process in developing countries. Distant cities and villages in a single country or a multinational region can be linked by satellite as easily as adjacent cities. The source of programming can be any properly equipped transmitting ground station. The same message or lesson can be received simultaneously by all stations that are equipped to receive the satellite signal. A satellite communication network need not wait for the construction of expensive terrestrial microwave links.

The satellite technology used to distribute ETV (educational television) may therefore provide the key for solving several stubborn problems of human resources development. Not only can it overcome terrain and distance, it may also be able to reform and modernize educational systems more rapidly than would otherwise be possible, give more people access to education and training, place the best teachers within reach of large audiences, help to integrate large sectors of the population into the social, economic and cultural life of the nation or region, and contribute to international understanding. Skillfully programmed, satellite-distributed ETV may be able to overleap the literacy barrier by bringing illiterates into some participation in the modern sector. If the technology realizes only some of these promises, it can help to accelerate economic and social development.

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To explore some of the potentials of satellite communication, the U.S. Agency for International Development and the President's Task Force on Communications Policy commissioned SRI to make case studies of two developing regions. The regions India and Latin America were selected to reflect a variety of conditions, with the hope that some generalizations for other developing areas could be based on findings of the research.

India represents the case of a single nation with a population of 500 million, but sufficiently compact that it has only one time zone, while Latin America represents a multinational region in both northern and southern hemispheres and has six time zones. India is a nation of villages: 80 percent of its population reside in 568,000 villages. A larger fraction of Latin America's population is concentrated in large urban areas separated by sparsely populated rural, mountain, desert, and jungle areas.

Several types of diversity affecting the design of communication systems are present in the two case regions. In India, 15 official languages are spoken--13 of them by more than 10 million people each. These languages are built deeply into the local cultures; people in a linguistic group have been known to burn trains that come into their areas with words in another linguistic alphabet painted on the coaches. Latin America, on the other hand, has but two main languages, although many Indian languages are spoken in the interior and in the mountains. Latin America's political diversity offers a complex challenge to a communications system that can span part or all of its 23 independent nations. In both regions there is considerable agricultural diversity. There is also a range within each region and between the two regions with respect to the generally accepted indicators of modernization--industrialization, urbanization, literacy, per capita income, fractions of age cohorts enrolled in each level of schooling, and use of mass communication media. With respect to the last indicator, only 6,000 television receivers are in use in all of India, whereas over six million receivers were in use in Latin America in 1964.

In view of the characteristics of the two case settings and the respective interests of leaders to whom the study team members spoke, potentials for satellite communications technology in the two regions were examined from slighly different viewpoints. In India, an attempt was made to answer the following question: how might satellite communication technology be used to help India achieve overall development objectives, a central one of which is national integration for the many language and cultural groups? This problem was the preoccupation of the Indian leaders and planners interviewed during the field work. In Latin America, the question examined was of somewhat narrower scope, reflecting the more advanced state of broadcasting there and the concerns of Latin American officials: what can satellite communication technology contribute to the human resources development (education and training) objectives of individual countries and of the emerging Latin American community? In Latin America, there already exists for most urban areas a commercial television system and some applications of ETV.

Thus, the question examined in India was the fundamental one of proposing an entirely new national television system in the light of the availability of satellite technology. In Latin America, the question was

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FIGURE 1

STUDY DESIGN

SATELLITE-DISTRIBUTED ETV IN LATIN AMERICA

...more sharply focused on the prospects for ETV relevant to the capabilities of satellite technology.

Satellite communication technology must be studied in context. Successively wider angles of vision would show that satellite communication technology is imbedded in educational broadcasting; educational broadcasting in the overall education and training system; and the education and training system in a country or region's economic and social development program. This context dictated the designs for the case studies. The logic of this design for the Latin American study is presented in Figure 1. Human resources development objectives were considered in the light of national and regional development objectives. Opportunities for broadcast media to help in achieving these human resources objectives were identified, and estimates were made of the present and projected demand for such applications of media. Preliminary system designs appropriate to the demand estimates were prepared, using alternatives of satellite and terrestrial delivery links. Cost, feasibility, and organizational implications of the alternatives thus generated were examined. The Indian study, designed for a country with very little television, had to begin at an earlier stage of mass communication development, as Figure 2 illustrates.

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APPLICATIONS OF ETV

In several Latin American countries, ETV is already contributing to the achievement of certain priority objectives for human resources development; for example, improvement of primary education in Colombia and Venezuela, accelerated secondary education in Brazil, and the provision of secondary education to students in Mexico who would otherwise lack access to such schooling. Those applications appear to be most effective when ETV has been planned and managed as a system for pacing students and teachers as well and when special attention has been given to reception, thereby bringing the classroom teachor into full partnership with the studio teacher and program producer. This observation is supported by the growing body of research findings on the effectiveness of ETV.

ETV holds a significant, and sometimes a unique, potential for accelerating the achievement of the following development objectives stated by many Indian and Latin American leaders:

- Upgrade primary and secondary education by sharing the best teaching and the best demonstrations, thus more nearly equalizing the learning opportunities for all students.
- Modernize curriculum content throughout an entire educational system without having to wait for the training and retraining of the teaching staff.
- Reform teaching processes to encourage inquiry-oriented, problem-solving learning instead of tradional rote-memory instruction.

STUDY DESIGN

COMMUNICATION SATELLITES FOR EDUCATION AND DEVELOPMENT IN INDIA

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- Offer educational opportunities for the many who were unable to complete primary, secondary, or higher education cycles, but who now want to participate more fully in the labor force and in society.
- Strengthen the vocational and technical components of education to increase the relevance of training to employment opportunities.
- Offer new mathematics and new science instruction in secondary schools and in the basic cycles of higher education.

Indian officials added the following objectives that television could help to attain:

- Provide a common element in experience to further the goal of national integration.
- Bring about awareness of and interest in the family planning problem more swiftly and widely than otherwise possible.
- Assist in modernizing agriculture, and in general help to make rural life pleasant and rewarding enough to keep more of the ambitious and better-educated young people in the villages, where they are so badly needed.

DEMAND ESTIMATES

For both regions, the study teams interviewed local planners and media experts to estimate the amount and types of ETV programming that would be responsive to the foregoing objectives. These estimates were projected from the present to 1980 in Latin America and to 1988 in India. In the Indian case, special attention was given to preparing an illustrative program schedule that would go as far as possible in serving the needs of each of the major language and cultural groups found in India. This schedule shows that it would be possible, using a satellite with one video and two audio channels, to furnish weekly, for each of four languages: ten hours of school programs; nine hours of teacher training, vocational training, and literacy classes; nearly four hours of news and public events; three hours of agriculture, health, and family planning programs; two hours of children's programs; and nearly six hours of general cultural and entertainment programs. Using a satellite with three video channels and receivers equipped with two audio channels for each video channel, the foregoing amount of programming could be available for each of the 12 largest language groups in India.

In Latin America, ETV programming must also be localized, but for different reasons from those in India. First, there are the differences in school calendars, with nations in the south using the southern hemisphere schedule of February to November and those to the north using the school year of September to June. Next, there is the problem of six time

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zones. And finally, there are the political considerations implicit among 17 sovereign Spanish-speaking nations, where one nation's course in history or geography may be heard in a neighboring country as propaganda.

Throughout the field work in Latin America, key personnel in education and training in each country were asked to assess the prospects for exchanging or sharing instructional programs among several countries. Most of the responses were pessimistic. Several obstacles were cited: variation in stages of economic development within Latin America; differences in political ideology and stability; differences in regional dialects and word meanings; differing interpretations of history; and the absence or weakness of educational, cultural, and economic ties between countries. (Many Latin American countries have more fully developed relationships with countries outside the continent than with their neighbors.)

A precondition for accepting common instructional programs would be efforts to harmonize curriculum content. Although committees of the Organization of American States have been formed to examine common curricular problems, only some cooperative efforts among Central American countries and beginning discussions of primary textbook cooperation among Venezuela, Colombia, and Ecuador have produced results so far. The most optimistic estimate of this study is that 25 percent of school broadcast time on Latin American satellites might be shared by 1980, given present educational diversity and political barriers.

The hours of programming per week required for the various applications of ETV can be summed to determine the number of ETV channels required. In the Indian case, three ETV channels were projected as a realistic estimate of what India can afford and use fully in the near future. These three channels can easily be accommodated on a single satellite. In the Latin American countries where ETV is expected to grow most rapidly--Colombia and Brazil--four ETV channels each were projected for 1980. Either three or two channels were projected for each of the other countries studied. For the combined needs of 15* Latin American countries, a total of 44 ETV channels are likely to be needed by 1972, and 80 ETV channels by 1980. The larger number of channels for Latin America reflects the many national requirements, the assumption that about one-quarter of programmed hours will be shared internationally, and the advanced state of television development there. Three satellites could handle the 30 channels projected for 1980: one serving Mexico, Central America, Colombia and Venezuela; one serving Brazil; and a third serving, Argentina, Bolivia, Chile, Peru and Uruguay.

The other dimension of ETV demand (in addition to hours per week of programming) is number of viewers or students served. For the Latin American case, this was estimated for participants in instructional programming, that is, for situations in which reception is organized and a classroom teacher or monitor is present. Estimates were prepared for 1968, 1972, and 1980 for each of 12 educational applications.

The product of the number of viewers multiplied by the hours per week that those viewers are engaged in watching instructional programs

* The time available for the project permitted including only 15 of the 23 Latin American countries.

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is a useful measure of demand. It is a better measure than the number of viewers unweighted by programming frequency and intensity, because some educational programs may appear only one-half hour per week, while other applications may be shown daily in both the morning and afternoon. Table 1 has been prepared from the Latin American demand estimates for 1968, 1972, and 1980 to reflect this measure of viewer hours per week. If the number of viewer hours per week is expressed as an index of 100 for 1968, the index for 1972 would be 212, and for 1980, 1,410. In other words in 12 years a 14-fold increase could be expected. The number of students reached by organized reception would increase from the present figure of 630,000 to over 10 million in 1980.

In the Indian case study, the planning for an entire television communication system put emphasis on estimating overall demand of viewers reached by public information programming and other applications supporting the objective of national integration. Therefore, estimates of viewer hours in organized reception were felt to be too speculative and were not prepared. A phased development program was prepared, however, with the goal of making television available to 80 to 85 percent of the Indian people within 20 years.

SYSTEMS COMPARISONS

Very preliminary designs of systems were prepared to provide the amounts of service responsive to the demand for ETV estimated for the next 12 to 20 years. For both India and Latin America, the following three distribution systems were designed:

- Microwave network linking ground-based stations
- Rebroadcast satellite linking ground-based transmitters
- Direct broadcast satellite linking ground transmitters with augmented television receiving sets

For Latin America, a fourth system was also designed:

- Truck or air shipment of video tapes linking groung-based stations.

The four distribution systems are illustrated in Figure 3. The alternative of video tape distribution was not considered for India, because it does not permit simultaneous national reception. Timeliness is not essential in school broadcasts, but news, public events, and other elements of a general communication service often must be timely to be effective. For India, another distribution system was examined:

- A combination of ground stations and direct broadcast from a satellite.

Table 2 is intended to summarize the performance of the four ETV distribution systems according to qualitative and quantitative criteria. A relative rating of excellent, good, fair, or poor has been assigned to

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LATIN AMERICAN DEMAND FOR ETV APPLICATIONS IN VIEWER HOURS PER WEEK: 1968, 1972, 1980
(Viewer Hours per Week in Thousands)

ETV Application	Central America			Mexico			Colombia		
	1968	1972	1980	1968	1972	1980	1968	1972	1980
Adult education	--	--	100.0	375.0	750.0	750.0	--	70.0	500.0
Teacher training, preservice	--	6.0	152.0	--	--	50.0	--	50.0	176.0
Teacher training, inservice	--	20.0	4.4	0.8	6.6	3.0	3.6	10.0	23.2
Primary education, kindergarten	--	--	165.0	--	--	600.0	--	--	175.0
Primary education	--	9.1	10,395.0	30.0	150.0	--	585.0	6,750.0	57,200.0
Secondary education	--	2,000.0	6,000.0	130.0	2,500.0	7,500.0	--	300.0	5,400.0
Technical training	--	--	20.0	--	--	60.0	--	--	50.0
Higher education, science & math	--	--	60.0	90.0	180.0	600.0	0.5	60.0	150.0
Higher education, lecture series	--	--	--	--	--	70.0	--	--	17.5
Higher education, TV college	--	--	--	--	--	45.0	--	--	--
Higher education, continuing professional	--	--	4.0	--	--	35.0	--	--	15.0
Total		2,035.1	16,900.4	625.8	3,586.6	9,713.0	5,854.1	7,240.0	63,706.7

ETV Application	Venezuela			Brazil			Argentina		
	1968	1972	1980	1968	1972	1980	1968	1972	1980
Adult education	--	--	--	200.0	480.0	1,500.0	--	--	--
Teacher training, preservice	--	--	92.0	--	--	208.0	--	--	44.0
Teacher training, inservice	0.2	0.5	11.0	--	--	34.2	--	--	2.2
Primary education, kindergarten	27.0	120.0	175.0	--	--	385.0	--	--	125.0
Primary education	225.0	1,125.0	15,625.0	60.0	180.0	30,000.0	--	--	4,625.0
Secondary education	30.0	30.0	3,250.0	22.5	60.0	3,510.0	--	--	1,200.0
Technical training	--	--	10.0	39.0	110.0	216.0	--	7.5	60.0
Higher education, science & math	--	90.0	150.0	--	--	120.0	--	2.0	300.0
Higher education, lecture series	--	--	17.5	--	--	--	--	--	35.0
Higher education, TV college	--	--	30.0	--	--	120.0	--	--	60.0
Higher education, continuing professional	--	--	10.6	--	--	--	--	--	53.0
Total	282.2	1,365.5	19,401.1	321.5	830.0	36,093.2		9.5	6,509.2

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Table 1 (concluded)

ETV Application	Bolivia			Chile			Peru		
	1968	1972	1980	1968	1972	1980	1968	1972	1980
Adult education	--	4.0	75.0	--	--	--	--	28.0	125.0
Teacher training, preservice	--	--	12.0	--	--	40.0	--	--	16.0
Teacher training, inservice	--	--	1.4	--	6.0	4.5	--	--	4.4
Primary education, kindergarten	--	--	35.0	--	--	45.0	--	--	60.0
Primary education	--	--	1,412.5	--	--	6,250.0	9.1	22.5	12,500.0
Secondary education	--	--	120.0	--	--	1,500.0	--	--	1,500.0
Technical training	--	--	--	--	--	50.0	--	--	30.0
Higher education, science & math	--	--	--	--	--	150.0	--	--	37.5
Higher education, lecture series	--	--	--	--	--	17.5	--	--	--
Higher education, TV college	--	--	--	--	--	--	--	--	--
Higher education, continuing professional	--	--	2.0	--	--	8.4	--	--	10.0
Total		**4.0**	**1,657.9**		**6.0**	**8,065.4**	**9.1**	**50.5**	**14,282.9**

ETV Application	Uruguay			Total		
	1968	1972	1980	1968	1972	1980
Adult education	--	--	--	575.0	1,332.0	3,050.0
Teacher training, preservice	--	--	16.0	--	56.0	822.0
Teacher training, inservice	--	--	0.7	4.6	43.1	89.0
Primary education, kindergarten	--	--	25.0	27.0	120.0	1,790.0
Primary education	4.0	4.0	1,500.0	6,178.1	8,240.6	139,507.5
Secondary education	--	--	450.0	132.5	4,890.0	29,430.0
Technical training	--	--	--	39.0	117.5	526.0
Higher education, science & math	--	--	7.5	90.5	332.0	1,575.0
Higher education, lecture series	--	--	--	--	--	157.5
Higher education, TV college	--	--	--	--	--	255.0
Higher education, continuing professional	--	--	--	--	--	143.0
Total	4.0	4.0	1,999.2	7,096.7	15,131.2	177,329.0
Index				100.0	212.0	1,410.0

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RELATIVE PERFORMANCE OF ALTERNATIVE DISTRIBUTION SYSTEMS

Criterion	ETV Distribution System			
	Video Tape	Microwave	Rebroadcast Satellite	Direct Broadcast Satellite
Educational				
Ability to pace and control modernization	Poor	Good	Good	Excellent
Ability to reflect local programming needs	Excellent	Fair	Poor	Poor
Psychological impetus for modernization	Fair	Fair	Good	Excellent
Encouragement for multinational integration	Poor	Fair	Good	Excellent
Potential for growth in geographical coverage	Fair	Poor	Fair	Excellent
Simultaneous reception of important events	None	Good	Good	Excellent
Management				
Simplicity of local management	Poor	Fair	Fair	Good
Simplicity of central management	Good	Excellent	Fair	Fair
Adaptability to pilot tests of software	Excellent	Fair	Poor	Poor
Indirect Effects				
Spillover benefits for local communications	Good	Excellent	Good	Poor
Opportunity to develop local industries	Excellent	Good	Fair	Fair
Reliability				
Freedom from overall system interruption	Excellent	Good	Fair	Poor
Freedom from local failures	Poor	Fair	Fair	Good
Fiscal				
Cost of covering major urban centers	Excellent	Good	Fair	Poor
Cost of covering entire country	Fair	Poor	Poor	Good
Potential for major foreign assistance	Poor	Fair	Good	Good

A

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highly the degree to which each system achieves the criterion noted. In the following paragraphs, the bases for the comparative ratings are discussed.

Ability to Pace and Control Modernization

ETV, however distributed, can be used as an instrument for reforming educational content and practices. Of the four alternative methods of distribution, those that are scheduled from the program source (for example, the nation's capital) provide more positive pacing and control than does the video tape distribution system, where the local television transmitting station broadcasts the program. Delays may occur in receiving tape from the program source. Some units of instruction may be omitted because local supervisors or teachers may be unfamiliar or insecure with the content. Thus, the video tape system does not offer pacing and control advantages inherent to the other distribution methods.

Of the centralized systems, the direct broadcast satellite was rated the highest on this criterion, because no administrative levels need intervene between program source and classroom.

Ability to Reflect Local Programming Needs

If local teachers are adequately prepared, a case can be made for allowing them flexibility in the pacing of instructional content. Here, the centralized distribution systems are at a disadvantage in relation to the video tape distribution mode. The tape can be played at times most convenient to the majority of local teachers, and it can be replayed locally two or three times for remedial work or for students who missed the first showing. Of course, replay schedules are entirely possible with the centralized systems too, but not with as great flexibility as for a locally scheduled station.

The microwave system has been given a slightly higher rating than the rebroadcast satellite, because the former has the potential to lead to the development of a more decentralized communications network and more nearly self-sufficient local television programming capability than the satellite-based system would. Television programming of local news or entertainment could be of assistance to local educational broadcasting.

Psychological Impetus for Modernization

The dramatic technology of satellite communication is more likely to capture the imagination of the people in a developing country and to implant the seeds of change than would the use of conventional technology. It can be speculated that the use of satellite techno[illegible]nspire teachers and students to make the needed [illegible] with tradition[illegible]terns. The direct broadcast satellite system was rated highest on this criterion, because the school's antennas would receive signals directly from the satellite instead of from an intermediary conventional television transmitter, thus heightening the sense of participating firsthand in advanced technology.

Encouragement for Multinational and Multicultural Integration

This criterion is related to the preceding one, in that the more localized systems of video tape or microwave distribution offer no technical imperatives for multinational or multicultural cooperation, whereas the wide coverage of satellite distribution systems requires at least technical and financial planning across national or cultural boundaries.

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the technical and financial pooling may facilitate some sharing of educational content.

The four distribution systems can be rated on this criterion according to the degree to which each requires central pooling of programming efforts for economical and effective operations.

Potential for Growth in Geographical Coverage

On this criterion, the least satisfactory system is the microwave network, which requires the construction of expensive links whenever it is decided to extend the coverage. The video tape and rebroadcast systems are about equal on this count, requiring only that a new local television transmitter (or, for fringe areas, a signal booster) be established. The most flexible system, of course, is the direct broadcast satellite, where the signal can be brought into a school or a village located anywhere within the thousands-of-miles diameter coverage of the satellite, without waiting for the construction of intermediate transmitters. This capability alone has the potential to bring national coverage to rural and village populations years, perhaps decades, earlier than would be possible with alternative systems.

Simultaneous Reception of Live Events

The timeliness of live programs received simultaneously throughout a developing region is occasionally of importance in educational broadcasting and of great importance for news and political events in a general communication network. The video tape distribution system cannot offer the capability of this count, whereas the centralized systems can. The

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direct broadcast satellite system was rated highest here, because simultaneous reception can be wherever receivers exist, whether or not a local television transmitter serves the area.

Simplicity of Local Management

Extensive video tape exchange represents a considerable local administrative burden. It is difficult to assure delivery of a large number of video tapes to subsidiary transmitting stations on time for use; yet if the time of delivery is set well in advance of use, the problems of storage and inventory are cumbersome. The local station must employ personnel who are skilled not only in inventory management and scheduling of these valuable tapes, but also in the operation and maintenance of a video tape recorder--valuable and sensitive equipment that must be carefully handled if it is to remain dependable and offer acceptable reception fidelity. Accordingly, the video tape system is rated the lowest on this criterion.

The centralized systems, where all scheduling is done at the source of programming, avoid the local administrative and logistical burden. On the other hand, both microwave and rebroadcast satellite systems require the management of local television broadcasting stations. Some specialized managerial and technical competence would be required.

The direct broadcast satellite system is rated highest of the four on this criterion, but even it requires operation and maintenance of a television receiver that has augmentation equipment necessary to receive and convert the signal directly from the satellite. Hence, it is given only a "good" rating.

Simplicity of Central Management

By this criterion, the satellite distribution systems, with their requirements for operating and maintaining complex earth stations and for keeping the satellite on station, rate lower than the terrestrial systems. Of the latter, the microwave network, once established, should be a good deal simpler to administer than the video tape exchange, which will require complex central and local management procedures for dispatching, receipt, storage, playing, replaying, and accounting for valuable video tape.

Adaptability to Pilot Tests of Software

Of the four systems, only that of video tape distribution lends itself easily to experimenting with educational broadcasting on a small scale at low cost to determine whether the technique offers important utility in comparisons with conventional instructional systems. The use of only one or two links in a microwave network could be considered a relatively modest pilot application, hence this system rates better than either of the satellite distribution methods. The satellite systems, with their enormous geographical coverage, tend to encourage all-or-none adoption, not pilot tests.

The above comments apply to situations in which the system is a single-purpose educational broadcasting system. If a telecommunications system, satellite or terrestrial, is available or is to be made available for other purposes, such as telephony or entertainment and news, it would be possible to conduct pilot tests of educational broadcasts on any of the four alternative distribution systems being compared. The organizers

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in such pilot tests would not have to be concerned about the large unused geographical capacity of the satellite systems. They would, however, have to deal with a number of technical complexities associated with satellite communication that would not have to be faced in using more conventional terrestrial systems.

Spillover Benefits for Local Communications

In considering indirect effects, the ground-based systems offer greater spillover benefits in contributing to the growth of a communications infrastructure. The direct broadcast satellite is rated poor, because only the large and expensive transmitting ground station could be a source of broadcasting. In the other systems, local transmitters that would have alternative uses for local as well as central programming would be established.

Opportunity to Develop Local Industries

The satellite distribution systems include equipment of high technology that will probably continue to require foreign procurement. The terrestrially based systems, on the other hand, employ more nearly conventional technology. It can be expected that the electronics and construction industries of at least the larger developing countries like India, Brazil, and Mexico will continue to grow and will be able to account for an increasing share of initial and maintenance procurement of conventional telecommunications systems.

The video tape distribution system was rated the highest by this criterion, because it requires the most decentralized management. The capability for managing this logistical system should have useful transfer to other local industrial management needs.

Any of the systems should encourage the building of a local or regional capability to manufacture receivers and service and maintain such equipment.

Freedom from Overall System Interruption

Satellite distribution systems are vulnerable to various kinds of interruption such as equipment faults at earth stations, drifting of the satellite off station, and satellite power failures. A satellite failure can result in the entire system being inoperable, which might pose severe readjustment strains on an educational system in which ETV had been integrated into curriculum. The direct broadcast satellite would be the most vulnerable to system failure, because no local television transmitters would be available for emergency programming of live or taped lessons.

Freedom from Local Failures

For the video tape system, which has the lowest rating on this criterion, the largest potential source of unreliability is the nonreceipt or misplacement of the particular video tape needed at a key time in the instructional sequence. The microwave and satellite distribution systems, where only one expert central crew controls the program scheduling, are less subject to local interruption than the video tape system, where less well-trained crews at each transmitting point increase the possibility of error. These systems are also subject to interruptions caused by failures of the local broadcasting station.

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None of the television systems is rated higher than "good" on this criterion, because all are vulnerable to local power interruptions or voltage fluctuations--fairly common occurrences in developing countries.

Cost Comparisons

In Table 3, five alternative distribution systems for India are compared in terms of capital and operating costs. The system called "limited TV and local radio" was designed to cover 40 to 45 percent of India's population; the other four systems were designed to cover the 80 to 85 percent of population stated as a high priority objective by Indian leaders interviewed by the study team. Because Indian requirements call for a national television communication system with simultaneous reception, the alternative of video tape distribution is not included in the systems being compared. Of the systems studied, the direct broadcast satellite proved to be the least costly, followed by the combination of ground-based stations in the cities and direct satellite broadcasts to the villages.

The combined system seems particularly appropriate for helping to meet India's need for heterogeneity of language and cultural programming. The more local stations there are, the easier it will be to produce programs for specialized local needs. At the same time, the direct broadcast satellite can be a means of bringing television to the large number of remote villages decades sooner than would be possible with only a ground-based system.

It is not easy for anyone except the purchaser to say when a cost is too great, but costs of the combination system for India were compared

Table 3

FIVE TV DISTRIBUTION SYSTEMS FOR INDIA:
TOTAL CAPITAL AND OPERATING COSTS OVER 20 YEARS
AND AVERAGE COST PER YEAR
(Millions of Dollars)

System	Capital Costs		Operating Costs		Capital and Operating Cost	
	Total	Annual Average	Total	Annual Average	Total	Annual Average
Limited TV and local radio	$169.3	$ 8.5	$155.2	$ 7.5	$324.5	$16.0
Ground-based TV	442.4	22.1	313.4	15.7	755.8	37.8
Direct broadcast satellite	433.4	21.7	202.7	10.1	636.1	31.8
Rebroadcast satellite	456.5	22.8	266.3	13.3	722.8	36.1
Ground-based and direct broadcast satellite	436.5	21.8	240.9	12.9	677.4	33.8

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with national economic indicators. As Table 4 demonstrates, the annual cost, capital plus operating, is never likely to be much greater than 1 percent of the annual expenditure on education, or .07 of 1 percent of the national income.

With respect to the composition of expenditures on any of the proposed systems for India, analysis shows that the largest portion is spent on receivers--purchase, maintenance, and replacement. In the direct broadcast satellite system, for example, receivers represent about 75 percent of capital cost, satellites themselves only about 11 percent. Even in ground-based television, receivers represent about 50 percent of capital investment.

Table 5 presents the initial and operating costs of four alternative distribution systems designed to meet an estimate of Latin America's 1980 demand for ETV. As shown by the total costs for each of the three regions making up Latin America, the video tape system shows the lowest initial and operating costs, and the direct broadcast satellite system shows the highest costs. Microwave transmission and the rebroadcast satellite systems provide fairly interchangeable service. Where microwave networks are expected to be available, this system shows the lower cost of the two; where terrain and jungle are expected to delay the construction of microwave links, as in Peru, Bolivia, and Brazil, the rebroadcast satellite system shows lower costs.

The demand estimate on which Table 5 was based was primarily an urban one, in which television service was extended in descending order of student concentrations. To test the effect of providing more nearly

Table 4

COMPARISONS OF ANNUAL COSTS OF A COMBINATION SATELLITE AND GROUND-BASED SYSTEM WITH ECONOMIC INDICATORS FOR INDIA, AT FIVE-YEAR INTERVALS

	1970-71	1975-76	1980-81	1985-86
National income (billions of dollars)	$37.5	$50.1	$67.1	$89.7
National expenditure on education (billions of dollars)	$1.5	$2.1	$3.3	$5.3
Annual cost of establishing and operating national television (billions of dollars)	$.0046	$.0193	$.046	$.0656
Education expenditure ÷ national income (percent)	3.1%	4.1%	5.0%	6.0%
Cost of national television ÷ national income (percent)	.012%	.039%	.069%	.073%
Cost of national television ÷ education expenditure (percent)	.35%	.91%	1.4%	1.2%

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Line	Cost Element	Central America A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast	A Vi... Ta...
	Initial Costs:					
1.	Broadcast stations total	$ 8,034	$ 8,034	$ 8,034	$ n.a.	$ 8,...
2.	Broadcast stations, main	n.a.	n.a.	n.a.	8,034	n
3.	Microwave	n.a.	2,669	n.a.	n.a.	n
4.	Satellite and launch I	n.a.	n.a.	3,000	7,850	n
5.	Satellite and launch II	n.a.	n.a.	n.a.	6,050	n
6.	Ground stations, transmitting	n.a.	n.a.	3,840	3,840	n
7.	Ground stations, receiving	n.a.	n.a.	0	n.a.	n
8.	Tape library - total	475	n.a.	n.a.	n.a.	
9.	Tape library - main	n.a.	410	410	410	n
10.	Studios and equipment	800	800	800	800	1,
11.	Receivers	1,890	1,890	1,890	1,890	1,
12.	Additions to receivers I	n.a.	n.a.	n.a.	10,690	n
13.	Additions to receivers II	n.a.	n.a.	n.a.	6,600	n
14.	Total I	$11,199	$13,803	$17,974	$33,514	$11,
15.	Total II	$ n.a.	$ n.a.	$ n.a.	$28,488	$ n
	Operating Costs:					
16.	Broadcast station	1,200	1,200	1,200	1,200	1,
17.	Microwave	n.a.	400	n.a.	n.a.	n
18.	Satellite and launch-II	n.a.	n.a.	623	1,370	n
19.	Ground station	n.a.	n.a.	356	240	n
20.	Tape transport	7	n.a.	n.a.	n.a.	
21.	Tape library	35	6	6	6	
22.	Program production, teacher training, set maintenance	1,450	1,450	1,450	1,450	1,
23.	Maintenance of receiver additions	n.a.	n.a.	n.a.	468	n
24.	Total	$ 2,692	$ 3,056	$ 3,637	4,734	3,

Note: n.a. = not applicable.

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Table 5

LATIN AMERICAN ETV DISTRIBUTION SYSTEMS COSTS, 1980
(Thousands of Dollars)

	Served by One Satellite of 12 Video Channels										
	Mexico				Colombia				Venezuela		
D irect adcast	A Video Tape	B Micro- wave	C Rebroad- cast	D Direct Broadcast	A Video Tape	B Micro- wave	C Rebroad- cast	D Direct Broadcast	A Video Tape	B Micro- wave	C Rebroad- cast
n.a.	$ 8,646	$ 8,646	$ 8,646	$ n.a.	$ 9,273	$ 9,273	$ 9,273	$ n.a.	$6,894	$ 6,894	$ 6,894
8,034	n.a.	n.a.	n.a.	2,680	n.a.	n.a.	n.a.	1,752	n.a.	n.a.	n.a.
n.a.	n.a.	3,149	n.a.	n.a.	n.a.	3,089	n.a.	n.a.	n.a.	3,909	n.a.
7,850	n.a.	n.a.	3,060	7,970	n.a.	n.a.	3,480	9,080	n.a.	n.a.	2,912
6,050	n.a.	n.a.	n.a.	6,130	n.a.	n.a.	n.a.	7,020	n.a.	n.a.	n.a.
3,840	n.a.	n.a.	1,280	1,280	n.a.	n.a.	640	640	n.a.	n.a.	640
n.a.	n.a.	n.a.	3,192	n.a.	n.a.	n.a.	2,660	n.a.	n.a.	n.a.	3,136
n.a.	160	n.a.	n.a.	n.a.	384	n.a.	n.a.	n.a.	385	n.a.	n.a.
410	n.a.	436	436	436	n.a.	248	248	248	n.a.	208	208
800	1,067	1,067	1,067	1,067	1,334	1,334	1,334	1,334	534	534	534
1,890	1,350	1,350	1,350	1,350	3,340	3,340	3,340	3,340	1,910	1,910	1,910
0,690	n.a.	n.a.	n.a.	7,620	n.a.	n.a.	n.a.	18,900	n.a.	n.a.	n.a.
6,600	n.a.	n.a.	n.a.	4,708	n.a.	n.a.	n.a.	11,680	n.a.	n.a.	n.a.
3,514	$11,523	$14,648	$19,031	$22,403	$14,331	$17,284	$20,975	$35,294	$9,723	$13,455	$16,20
S,488	$ n.a.	$ n.a.	$ n.a.	$17,651	$ n.a.	$ n.a.	$ n.a.	$26,014	$ n.a.	$ n.a.	$ n.a.
1,200	1,600	1,600	1,600	400	1,200	1,200	1,200	200	1,400	1,400	1,40
n.a.	n.a.	417	n.a.	n.a.	n.a.	431	n.a.	n.a.	n.a.	541	n.a.
1,370	n.a.	n.a.	650	1,410	n.a.	n.a.	725	1,590	n.a.	n.a.	40
240	n.a.	n.a.	474	80	n.a.	n.a.	356	40	n.a.	n.a.	47
n.a.	6	n.a.	n.a.	n.a.	4	n.a.	n.a.	n.a.	4	n.a.	n.a.
6	41	6	6	6	35	6	6	6	35	6	6
1,450	1,580	1,580	1,580	1,580	2,236	2,236	2,236	2,236	1,513	1,513	1,51
4[illegible]	n.a.	n.a.	n.a.	336	n.a.	n.a.	n.a.	830	n.a.	n.a.	n.a.
4,734	$ 3,227	$ 3,603	$ 4,310	$ 3,812	$ 3,475	$ 3,873	$ 4,523	$ 4,902	$ 2,948	$ 4,860	$ 3,[illegible]

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ola C road- ast		Total				Served by One Satellite Brazil			
	D Direct Broadcast	A Video Tape	B Micro- wave	C Rebroad- cast	D Direct Broadcast	A Video Tape	B Micro- wave	C Rebroad- cast	D Direct Broadcast
6,894	$ n.a.	$32,847	$32,847	$32,847	$ n.a.	$12,382	$12,382	$12,382	$ n.a.
n.a.	1,339	n.a.	n.a.	n.a.	13,805	n.a.	n.a.	n.a.	4,430
n.a.	n.a.	n.a.	12,816	n.a.	n.a.	n.a.	24,228	n.a.	n.a.
2,920	7,600	n.a.	n.a.	12,460	32,500	n.a.	n.a.	12,448	16,750
n.a.	3,900	n.a.	n.a.	n.a.	25,100	n.a.	n.a.	n.a.	n.a.
640	640	n.a.	n.a.	6,400	6,400	n.a.	n.a.	1,820	1,820
3,192	n.a.	n.a.	n.a.	9,044	n.a.	n.a.	n.a.	5,320	n.a.
n.a.	n.a.	1,704	n.a.	n.a.	n.a.	574	n.a.	n.a.	n.a.
208	208	n.a.	1,302	1,302	1,302	n.a.	260	260	260
534	534	3,735	3,735	3,735	3,735	1,067	1,067	1,067	1,067
1,910	1,910	8,490	8,490	8,490	8,490	3,150	3,150	3,150	3,150
n.a.	10,810	n.a.	n.a.	n.a.	48,020	n.a.	n.a.	n.a.	21,200
n.a.	6,685	n.a.	n.a.	n.a.	29,673	n.a.	n.a.	n.a.	11,000
16,298	$23,041	$46,776	$59,100	$74,278	$114,252	$17,173	$41,087	$36,447	$48,677
n.a.	$17,216	$ n.a.	$ n.a.	$ n.a.	$ 89,369	$ n.a.	$ n.a.	$ n.a.	$38,477
1,400	200	5,400	5,400	5,400	2,000	2,600	2,600	2,600	600
n.a.	n.a.	n.a.	1,789	n.a.	n.a.	n.a.	3,521	n.a.	n.a.
600	1,300	n.a.	n.a.	2,600	5,670	n.a.	n.a.	2,600	4,280
415	40	n.a.	n.a.	1,600	400	n.a.	n.a.	700	200
n.a.	n.a.	21	n.a.	n.a.	n.a.	17	n.a.	n.a.	n.a.
6	6	146	18	18	18	76	6	6	6
1,513	1,513	6,779	6,779	6,779	6,779	2,904	2,904	2,900	2,904
n.a.	475	n.a.	n.a.	n.a.	2,100	n.a.	n.a.	n.a.	700
$ 3,934	$ 3,534	$12,346	$13,986	$16,397	$ 16,967	$ 5,597	$ 9,031	$ 8,806	$ 8,690

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Line	Cost Element	Argentina A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast	A Video Tape
	Initial Costs:					
1.	Broadcast stations total	$ 9,059	$ 9,059	$ 9,059	$ n.a.	$3,651
2.	Broadcast stations, main	n.a.	n.a.	n.a.	1,339	n.a.
3.	Microwave	n.a.	16,309	n.a.	n.a.	n.a.
4.	Satellite and launch I	n.a.	n.a.	3,134	4,218	n.a.
5.	Satellite and launch II	n.a.	n.a.	n.a.	n.a.	n.a.
6.	Ground stations, transmitting	n.a.	n.a.	640	640	n.a.
7.	Ground stations, receiving	n.a.	n.a.	4,256	n.a.	n.a.
8.	Tape library - total	379	n.a.	n.a.	n.a.	247
9.	Tape library - main	n.a.	206	206	206	n.a.
10.	Studios and equipment	800	800	800	800	534
11.	Receivers	772	772	772	772	218
12.	Additions to receivers I	n.a.	n.a.	n.a.	7,726	n.a.
13.	Additions to receivers II	n.a.	n.a.	n.a.	2,700	n.a.
14.	Total I	$11,210	$26,146	$18,867	$15,701	$4,650
15.	Total II	$ n.a.	$ n.a.	$ n.a.	$10,675	$ n.a.
	Operating Costs:					
16.	Broadcast station	1,800	1,800	1,800	200	1,200
17.	Microwave	n.a.	2,369	n.a.	n.a.	n.a.
18.	Satellite and launch	n.a.	n.a.	660	1,080	n.a.
19.	Ground station	n.a.	n.a.	520	-60	n.a.
20.	Tape transport	9	n.a.	n.a.	n.a.	3
21.	Tape library	53	6	6	6	35
22.	Program production, teacher training, set maintenance	1,246	1,246	1,246	1,246	698
23.	Maintenance of receiver additions	n.a.	n.a.	n.a.	177	n.a.
24.	Total	$ 3,108	$ 5,421	$ 4,232	$ 2,769	$1,936

Note: n.a. = not applicable.

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Table 5 (concluded)

	Served by One Satellite of 12 Video Chan									
	Bolivia			Chile				Pe		
A deo pe	B Micro- wave	C Rebroad- cast	D Direct Broadcast	A Video Tape	B Micro- wave	C Rebroad- cast	D Direct Broadcast	A Video Tape	B Micro- wave	C Road- st
851	$ 3,651	$ 3,651	$ n.a.	$6,445	$ 6,445	$ 6,445	$ n.a.	$ 7,949	$ 7,949	949
.a.	n.a.	n.a.	926	n.a.	n.a.	n.a.	1,339	n.a.	n.a.	n.a.
.a.	6,619	n.a.	n.a.	n.a.	4,350	n.a.	n.a.	n.a.	16,270	n.a.
.a.	n.a.	1,989	2,677	n.a.	n.a.	2,742	3,690	n.a.	n.a.	1290
.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
.a.	n.a.	640	640	n.a.	n.a.	640	640	n.a.	n.a.	640
.a.	n.a.	2,660	n.a.	n.a.	n.a.	2,660	n.a.	n.a.	n.a.	724
47	n.a.	n.a.	n.a.	272	n.a.	n.a.	n.a.	418	n.a.	n.a.
.a.	132	132	132	n.a.	180	180	180	n.a.	152	152
534	534	534	534	800	800	800	800	534	534	534
218	218	218	218	920	920	920	920	1,410	1,410	1,410
.a.	n.a.	n.a.	2,184	n.a.	n.a.	n.a.	9,200	n.a.	n.a.	n.a.
.a.	n.a.	n.a.	760	n.a.	n.a.	n.a.	3,202	n.a.	n.a.	n.a.
650	$11,154	$ 9,824	$ 7,311	$8,437	$12,695	$14,387	$16,769	$10,311	$26,315	699
.a.	$ n.a.	$ n.a.	$ 5,887	$ n.a.	$ n.a.	$ n.a.	$10,771	$ n.a.	$ n.a.	.a.
200	1,200	1,200	200	1,200	1,200	1,200	200	1,600	1,600	600
.a.	965	n.a.	n.a.	n.a.	557	n.a.	n.a.	n.a.	2,417	.a.
.a.	n.a.	430	690	n.a.	n.a.	570	950	n.a.	n.a.	470
.a.	n.a.	350	60	n.a.	n.a.	350	60	n.a.	n.a.	465
3	n.a.	n.a.	n a.	7	n.a.	n.a.	n.a.	7	n.a.	.a.
35	6	6	6	29	6	6	6	47	6	6
698	698	698	698	975	975	975	975	1,021	1,021	021
.a.	n.a.	n.a.	50	n.a.	n.a.	n.a.	211	n.a.	n.a.	.a.
936	2,869	$ 2,684	$ 1,704	$2,211	$ 2,738	$ 3,101	$ 2,402	$ 2,675	$ 5,044	562

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	Uruguay				Total			
	D Direct Broadcast	A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast	A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast
49	$ n.a.	$1,852	$1,852	$ 1,852	$ n.a.	$28,956	$28,956	$28,956	$ n.a.
.a.	1,339	n.a.	n.a.	n.a.	926	n.a.	n.a.	n.a.	5,869
.a.	n.a.	n.a.	630	n.a.	n.a.	n.a.	44,178	n.a.	n.a.
290	3,082	n.a.	n.a.	2,290	3,082	n.a.	n.a.	12,445	16,749
.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
640	640	n.a.	n.a.	640	640	n.a.	n.a.	3,200	3,200
724	n.a.	n.a.	n.a.	532	n.a.	n.a.	n.a.	13,832	n.a.
.a.	n.a.	195	n.a.	n.a.	n.a.	1,711	n.a.	n.a.	n.a.
152	152	n.a.	151	151	151	n.a.	821	821	821
534	534	534	534	534	534	3,202	3,202	3,202	3,202
410	1,410	164	164	164	164	3,484	3,484	3,484	3,484
.a.	14,142	n.a.	n.a.	n.a.	1,644	n.a.	n.a.	n.a.	34,896
.a.	4,925	n.a.	n.a.	n.a.	573	n.a.	n.a.	n.a.	12,160
999	$21,299	$2,745	$3,331	$ 6,163	$ 7,141	$37,353	$80,641	$65,940	$68,221
.a.	$12,082	$ n.a.	$ n.a.	$ n.a.	$ 6,070	$ n.a.	$ n.a.	$ n.a.	$45,485
500	200	400	400	400	200	6,200	6,200	6,200	1,000
.a.	n.a.	n.a.	17	n.a.	n.a.	n.a.	6,325	n.a.	n.a.
170	780	n.a.	n.a.	470	780	n.a.	n.a.	2,600	4,280
165	60	n.a.	n.a.	116	60	n.a.	n.a.	1,800	300
.a.	n.a.	1	n.a.	n.a.	n.a.	27	n.a.	n.a.	n.a.
6	6	12	6	6	6	176	30	30	30
21	1,021	771	771	771	771	4,711	4,711	4,711	4,711
.a.	324	n.a.	n.a.	n.a.	38	n.a.	n.a.	n.a.	800
462	$2,391	$1,184	$1,194	$ 1,763	$ 1,855	$11,114	$17,266	$15,341	$11,121

total national coverage, a special study was made of one country, Colombia, using a higher demand estimate for 1980, in which all Colombian cities and towns of over 10,000 population would be reached. Costs were recalculated for the video tape and the direct broadcast satellite distribution systems. Total initial costs for Colombia became $30 million for the video tape system, versus $28 million for the direct broadcast satellite system. The direct broadcast satellite thus replaces the video tape system as the least expensive system, largely because the cost of procuring television sets augmented to receive the satellite signal becomes less than the cost of constructing local television transmitters that reach relatively few students. The direct broadcast satellite system also showed lowest operating costs for the assumption of full national coverage of Colombia.

Table 6 presents the initial and operating costs of two methods of meeting the projected 1980 ETV demand for the countries studied in Latin America. To simplify the table, only the direct broadcast satellite and video tape systems were compared. Examination of the dollar cost columns shows that the satellite system makes initial and operating cost savings in broadcast stations, but that these are more than offset by costs of satellite and launch and of the television set augmentations required to receive the signal directly from the satellite. The cost of set augmentations is highly sensitive to quantity procured. If substantially more than the 75,000 sets on which this calculation was based were to be procured, this initial cost element would be considerably reduced.

The percentage distribution column in Table 6 is informative on how funds would have to be spent for either distribution system. In the video tape system, the bulk of initial expenditures is on broadcast

Table 6

COSTS OF TWO ETV
DISTRIBUTION SYSTEMS TO MEET 1980 DEMAND:
LATIN AMERICAN TOTALS AND PERCENT DISTRIBUTION BY COST ELEMENT

	Video Tape System		Direct Broadcast Satellite System	
	$000	%	$000	%
Initial Costs				
Broadcast stations	$ 74,185	73.2%	$ 24,104	14.1%
Satellite and launch	n.a.	n.a.	58,600	33.9
Ground stations	n.a.	n.a.	11,420	6.6
Tape library	3,989	3.8	2,383	1.4
Studios and equipment	8,004	7.5	8,004	4.7
Receivers	15,124	14.2	15,124	8.8
Additions to receivers	n.a.	n.a.	52,833	30.5
Total	$101,302	100.0%	$172,468	100.0%
Operating Costs (Annual)				
Broadcast stations	$ 14,200	48.9%	$ 3,600	9.8%
Satellite and launch	n.a.	n.a.	14,230	38.7
Ground stations	n.a.	n.a.	900	2.4
Tape transport	65	0.2	n.a.	n.a.
Tape library	398	1.4	54	0.1
Program production, teacher training, and set maintenance	14,394	49.5	14,394	39.2
Maintenance of receiver additions	n.a.	n.a.	3,600	9.8
Total	$ 29,057	100.0%	$ 36,778	100.0%

Note: n.a. = not applicable.

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and studios and their equipment, whereas in the direct broadcast satellite system, the largest items are for the satellite and launch and for procuring set augmentations. With respect to operating costs, the items of program production, teacher training, and set maintenance are important for both distribution systems, but in the satellite system operating funds must be set aside for successive launches every three to five years to maintain the communications capability.

The quantity of sets to be procured was almost a million in India and less than 100,000 in Latin America. Aside from the differences in the size of populations to be served, this is because only 6,000 sets are in use in India, while six million are already in use in Latin America. The difference in procurements explains much of the variation in percentage distributions of costs for the two case regions.

The following conclusions can be drawn from the several analyses made for India and Latin America:

- Video tape distribution is the least-cost system up to a high degree of saturation of urban schools.
- The direct broadcast satellite system becomes the least-cost system for population residing beyond the range of transmitters located in principal cities.
- If ETV is extended to student populations in ascending order of cost per student served, the breakeven point at which the direct broadcast satellite begins to be more cost-effective than video tape distribution lies between 35 and 60 percent of total country population, the particular point being dependent on population distribution and the presence or absence of television transmitters in outlying areas.
- Of the four distribution systems, only the direct broadcast satellite system exhibits declining unit cost per student served with increasing coverage. The other systems exhibit rising unit costs after the population residing in large and medium-sized cities and other densely populated areas has been served.

Potential for Major Foreign Assistance

With the predisposition of multilateral and bilateral donors to favor large scale technologically based assistance programs, it would appear that the satellite distribution systems might have somewhat better prospects of attracting assistance grants or loans than would the more conventional distribution systems.

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A NOTE TO PROSPECTIVE USER COUNTRIES

On the basis of these studies, the research team prepared suggestions for officials of countries or regions who are considering a major expansion of television, with or without satellites, for education and development. Briefly, the following procedure would seem advisable:

- Begin with needs, rather than with technology. The important question is whether the need to expand or upgrade instruction and information is sufficient to justify a major system development. The system should grow out of the priority needs and be tailored to meet them.
- Begin with television, rather than with satellites. The question is, can television make a significant contribution to the country's educational and development needs?
- If so, compare different systems for delivering television. Develop these systems in some detail, including some sample programming, a phasing of expansion, and an inventory of the economic, human, and technical resources that would be required. In particular, do not forget to look at systems that combine more than one method of delivery--especially the combination of ground-based and satellite television.
- Study the heterogeneity problem carefully. How can the system best be designed to meet both regional and local needs? Here, combined systems may prove especially attractive.
- Survey the resources. What will be required for development of an electronics industry, engineering and technical personnel, broadcasting personnel, extension of electric power, transportation, and teacher training? If these are not available in sufficient quantities, how can they be provided?
- Try to solve, at the beginning, the problem of organization and control. This is discussed at some length in the India case study, and it has proved to be a serious problem in numerous countries. Briefly, a major television system, with thousands of employees, requires both freedom to be creative and close contact with the substantive agencies that should participate. What is the best assignment of organizational responsibilities for these two purposes, and how should the assignment relate to the control system of government?
- Plan, if possible, a gradual expansion of the system, one step at a time. If the job is to be done thoroughly, a period of several years will be needed for: detailed planning; hiring and training; manufacture of receivers and other electronic gear; construction of stations; work on content and curriculum, scheduling, making, and testing of programs; and practice in using the new system. If time is allowed for these tasks, there will be fewer problems, fewer mistakes in the first years, and less chance for a failure. If the development is gradual and measured, the cost can be spread out more evenly, the experience and skills gained in early stages can be utilized in later stages, mistakes can be corrected, and formidable problems can be mastered before they affect an entire

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system. Ideally, the plan should be developed so that at any given stage it is possible to take stock and decide on the next step.

POLICY IMPLICATIONS FOR THE UNITED STATES

No intimate knowledge was available to the study teams regarding policy issues the United States government faces in satellite communication and in development assistance for India and Latin America. Nevertheless, on the basis of the case studies, the following suggestions are offered:

- Conserve resources vital to satellite communication systems. A need for three satellites, each with 12 video channels, has been projected to meet the 1980 educational requirements of Latin American countries. These would be in addition to the INTELSAT requirements for an Atlantic service, the domestic satellite needs of the United States (perhaps four satellites), the domestic satellite needs of Canada (now estimated at three satellites), and military needs. The estimate of one satellite for India is more modest and, indeed, may be too modest.

  Planning for satellite communications calls attention to the limited availability of frequency spectrum and of "parking slots" in space for synchronous satellites. These are world resources, and it is hoped that the policy of the United States government will be to conserve the necessary part of such resources for human resources development. International reallocation of frequencies and a basic scheme for assigning satellite "parking slots" may be required.

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- Build competence in educational and developmental television. Television for human resources development will be as effective as the kind of resources--human, technical, and economic--that are put into it. High priority should be given requests for assistance in training and retraining of teachers, broadcasters, planners, and development personnel to become familiar with and skilled in the use of television for education and development. Most of such training, of course, need not and should not be given in the United States. It should be the policy of the United States to support a limited number of excellent demonstration projects in the use of television. A project such as the program now being instituted by the government of El Salvador, with U.S. assistance, can do more to advance the potential of human resources television than a number of instances of small support to less well-planned projects. Finally, existing U.S. policy to support regional integration and cooperation in education is of great importance in making feasible the cooperative use of human resources television, whether terrestrial or by satellite. Examples of points of leverage for this purpose in Latin America are programs for intercountry harmonizing of curriculum and textbooks, implementation of the planned OAS training center in ETV, and exchange of educators and broadcasters.

- Give priority to requests from developing countries for assistance in training and retraining teachers to become effective in an instructional system of which ETV is an integral part. As an example, the training technique of microteaching is useful in meeting the dual objectives of modernizing pedagogy and orienting teachers to the power of the television medium.

- Build from strength. The aid policy of the United States in the area of developmental television and satellite educational systems should make maximum use of the extraordinary experience and resources of the United States in such areas as instructional broadcasting, space science, development planning, and social research. Much training might well be built around relatively successful projects, such as that in Samoa, Colombia, and El Salvador, all accomplished with U.S. assistance. The experience of developing regions with these new technologies should be studied carefully and reported widely, on film and on paper. In the United States, there has been probably more experience with video tape exchange (which is treated at length as an element of Latin American systems) than anywhere else in the world. Microteaching, one of the most promising devices for training teachers, has been developed here. And much of the work on communications satellites has been done here. It is worth considering what sorts of centers or other organizations in this country or elsewhere might best make some of these resources available where they can do the most good in human resources development.

- Plan software for ETV systems. One of the greatest bottlenecks in developing satellite-based television systems is likely to be the absence of planning for the software needs of these systems. In Latin America, it was necessary for the project team to make the

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demand estimates included in this report with entirely insufficient information, because projections by Latin Americans had not been made. Despite India's long tradition of planning, there was very little in existence that could be put immediately to use if the country were to decide to take up a satellite-distribution system. The important step in planning at this moment is not to repeat hardware-oriented planning studies that make gross and unwarranted assumptions about educational applications, but rather to look critically and in detail at possible educational and developmental applications of the broadcast media. Therefore, the policy of the United States should be to look favorably on requests for assistance in planning and organizing the software aspects of satellite systems.

- Encourage pilot projects. The proposed cooperation between NASA and INCOSPAR in arranging for a satellite to be made available to India for a limited period of experimentation will be useful in working out some of the hardware, maintenance, programming, and administrative questions of satellite broadcasting. This cooperation will be generally stimulating to plans for satellite systems. It seems that there is good reason for other pilot projects, especially in regions where there is a good chance of developing major satellite television systems for human resources development. For example, if it were possible to obtain another satellite under similar arrangements, particularly one having rudimentary direct broadcast capability, it might be beneficial to offer Latin Americans the chance to try it out for a time. The terms of the offer should include provision for multinational cooperation and for Latin American countries to plan and manage the program. Needless to say, assistance and advice should be made available to such projects so that as much as possible can be learned from them and these lessons can be made widely known.

- Support research on critical problems influencing effectiveness and cost. Considering the probable usefulness of direct broadcast satellites and their interesting growth potential for large scale coverage, it would be useful to direct some research toward minimizing the system cost represented by the necessary augmentation of receivers for direct reception--that is, the antenna, pre-amplifier, and feed--particularly for production in quantities between 10,000 and 200,000.

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DOMESTIC APPLICATIONS OF
COMMUNICATION SATELLITE TECHNOLOGY

INTRODUCTION

In his communications message to Congress, the President expressly directed the Task Force to examine how soon a domestic satellite system would be economically feasible, whether it should be general purpose or specialized, and whether there should be more than one system.

This paper attempts to furnish a basis upon which a Task Force position on the matter might be formulated. We describe briefly the background and salient features of the proposals, and then address what we think are the three fundamental issues:

(1) What role are satellites likely to play in meeting our domestic communications requirements?

(2) Should the U.S. establish domestic satellite operations at this time?

(3) If so, what kind of domestic program should be authorized?

(a) What should be its technical configuration?

(b) What should be its ownership structure?

(c) What regulatory framework should govern domestic satellite operations?

We summarize here our conclusions and recommendations:

1. Satellites may play a significant role in meeting our domestic communications requirements.

a. Technological developments portend potentially attractive domestic applications.

b. It is economically feasible with today's technology to provide some domestic services by satellite.

2. A number of unresolved questions concerning the use of satellites domestically make it premature to establish full-scale domestic satellite operations at this time.

a. The appropriate use of the electromagnetic spectrum by domestic satellite systems has not been adequately resolved.

b. Available data are insufficient to determine the comparative advantages of general purpose vs. specialized systems.

c. The potential benefits of satellites in a domestic setting are not known with sufficient accuracy to determine how these might best be shared in the public interest.

d. The industry structure for using satellites

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to meet domestic communications requirements could evolve in various directions.

3. A demonstration pilot domestic satellite program should be established with the following essential features:

a. The most advanced technology available should be used to obtain needed technical and operational data.

i. It should be structured so that data and experience are obtained with respect to a general purpose system and to specialized systems, particularly for users of wideband services; accordingly, it should be designed to handle both one-way services such as television distribution and two-way voice/record services.

ii. Data on potential interference between domestic satellite and microwave relay facilities should be obtained.

iii. The operational and economic feasibility of a multiple-beam satellite featuring multiple use of the allocated radio spectrum should be determined.

iv. The feasibility of service to non-contiguous areas of the U.S. should be examined.

b. There should be broad participation in the pilot program, with Comsat having primary responsibility.

i. The space segment should be owned by Comsat as trustee.

ii. Comsat, the terrestrial common carriers, and prospective users of wideband services should be eligible to participate through investment as trustees in the ground environment.

c. Comsat should be manager of the pilot program.

d. The pilot satellites should offer free satellite channels for non-commercial and instructional television programming.

e. An advisory committee should be created to protect the interests of all users.

f. The pilot program should be consistent with U.S. international commitments and related to INTELSAT in important respects.

g. The 1934 Communications Act and the 1962 Communications Satellite Act, read together, provide the legal basis for authorization of the pilot program as well as for governmental regulation and supervision.

h. Executive Branch responsibility for monitoring the pilot program should be vested in a high-level office having adequate capability for evaluating the technical,

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operational, and social aspects of the experiment.

4. The FCC should give favorable consideration to a demonstration pilot domestic satellite program along the lines described above.

BACKGROUND

On September 21, 1965, the American Broadcasting Companies, Inc. (ABC) filed an application with the FCC requesting authorization to transmit network television programs from earth stations in New York City and Los Angeles, via satellite, to ABC-owned and affiliated stations throughout the United States, including Alaska, Hawaii, Puerto Rico and the Virgin Islands. ABC also proposed to provide facilities for interconnecting non-commercial educational television stations in those areas.

Since ABC's proposed new use of space communication techniques presented basic questions of law and policy which would have to be resolved before considering its application, the Commission on March 2, 1966, returned the application, without prejudice to appropriate refiling in light of the outcome of a public inquiry which it proceeded to institute.

In its Notice of Inquiry, also adopted March 2, 1966,

the Commission invited the views and comments of interested parties on a number of specific questions -- law, policy, and the economic and technical feasibility regarding authorization of non-governmental entities to construct and operate communication satellite facilities to meet their private or specialized domestic communications needs. */

During that inquiry the Ford Foundation, stating it wished to place before the Commission the public interest in the future of non-commercial television, submitted a model of a private broadcast satellite system to provide transmission for both commercial and non-commercial television and radio programming. The proposal called for creation of a broadcasters' non-profit satellite service corporation (BNSC) to establish the satellite facilities. A major purpose of the plan would be to generate, from services to commercial users, a substantial source of funds to be used for non-commercial programming, both national and regional. BNSC would also provide free interconnection for educational stations via satellite.

In order to expand the scope of the original inquiry and obtain more specific and responsive comments from

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*/ For the text of the Commission's Notice of Inquiry see Appendix A.

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interested parties, the FCC adopted a supplemental Notice of Inquiry on October 20, 1966.*/ The Supplemental Notice sought to elicit, from existing common carriers as well as other entities intending to seek authority to provide common-carrier services, general or specialized, descriptions of their plans for using communication satellite facilities to meet domestic needs. The Commission also invited consideration of additional questions of law, policy, and economic and technical feasibility.

Four parties submitted detailed proposals for domestic satellite systems during the FCC proceeding. ABC proposed a special purpose satellite with capacity for 24 television channels. AT&T submitted a proposal for multi-purpose system to meet anticipated growth in long-distance communications requirements through 1980. Comsat also proposed a multi-purpose domestic system to be established in three phases, the first to begin in 1969. The Ford Foundation submitted plans for two model systems for television distribution, stating they were improved versions of plans submitted earlier.

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*/ For the text of the Commission's Supplemental Notice of Inquiry, see Appendix B.

Following submission of the various domestic satellite system proposals, attention was focused on the desirability of a pilot, or demonstration, domestic satellite program, in constrast to a full-scale domestic satellite system.

The Comsat pilot program, expected to be established within 2 years, would use two satellites in synchronous orbit, each with a 5-year life. The satellites would each have a capacity of 12 color television channels, or 10,800 voice circuits when used with 42-foot antennas. Television, voice, data, telegraph, etc., could be transmitted simultaneously. Normally, both satellites would be used to provide full-time and occasional service, but if one failed the other could handle all full-time service needs of the pilot operation. Each would have a single beam, covering the continental U.S., but not Alaska, Hawaii, or Puerto Rico and the Virgin Islands.

Comsat proposed establishing two large (85-foot antennas) send/receive ground stations, one near New York City and the other near Los Angeles; two smaller (42-foot antennas) send/ receive stations, one in the Northwest and one in the Southeast; 30 receive-only stations (25 to 32-foot

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antennas) in the Pacific and Rocky Mountain time zones; and a few small transportable earth stations and transportable transmitters.

Comsat originally estimated total investment at about $58 million, of which about $15 million would be recovered by the end of the first two years, and about $37 million at the end of 5 years. Comsat estimated revenue requirements for the period 1970-1974, inclusive, at about $104 million, of which about $47 million would be required for the first two years. */

The Comsat proposal was supported without qualification by some parties but questioned by others on several grounds. A principal concern was that no interested party obtain a de facto position of dominance that would prejudice decisions to be made at the end of a pilot program. Thus the Ford Foundation and ABC opposed Comsat's pilot proposal on the ground it would give Comsat an inside track to ultimate ownership. They supported, instead, a test program conducted by a more disinterested party, such as

*/ See Appendix C. Up-to-date figures are not available, but higher costs may be anticipated. The precise cost of the space segment would depend on a variety of factors, including arrangements that might be worked out with INTELSAT. See discussion, p. 77.

NASA. */ The Ford Foundation also maintained that Comsat's proposal made insufficient provision for possible satellite communications in the public television field -- it would permit free interconnection but would not offer a source of protected program funds -- and that other technical tests, less time-consuming, could more usefully be undertaken. While supporting Comsat's program, AT&T urged that the terrestrial common carriers be authorized to own the earth stations. ABC Television Affiliates and CBS Television Network Affiliates urged that broadcast stations be allowed, individually on in groups, to own receive-only stations for television interconnection services.

Responding to comments on its proposed pilot program, Comsat argued that Ford's concern with funding public television led it to subordinate the broader public interest in domestic communications and their many uses; the Comsat proposal would meet these through a multi-purpose system,

*/ The Ford Foundation submitted a detailed plan of a possible demonstration program to be conducted by NASA as program manager, in close cooperation with other Federal agencies and all interested private parties. See Appendix D.

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giving each type of service some experience in use of the satellites and ground station facilities. Comsat also considered it undesirable to postpone the program until new frequencies above 10 GHz are assigned and new equipment developed. It noted that AT&T had supported use of the 4 and 6 GHz bands for the pilot; yet, it had greatest reason to want to avoid harmful interference to microwave facilities in those bands. Comsat believed that nothing was precluded by its program in that the facilities it proposed were as consistent with a dedicated special purpose as with a multi-purpose system, and at almost the same cost.

I. WHAT ROLE ARE SATELLITES LIKELY TO PLAY IN MEETING OUR DOMESTIC COMMUNICATIONS REQUIREMENTS?

A. Technological developments

In the early 1960's the promise of commercial communication satellites seemed limited primarily to intercontinental use as an alternative to undersea cables and high-frequency radio, and for interconnecting large numbers of countries. The pace of technological change has, however, been much more rapid than most experts would have predicted in 1960-61. The successful launch of a satellite into synchronous geo-stationary orbit in 1963 marked the beginning

of a new era. Since that time synchronous satellite technology (the type used by INTELSAT) has evolved rapidly, with corresponding reduction in the cost per unit of traffic handled. Continued technological advances such as multiple narrow-beam antennas and more powerful satellites are now on the horizon. The trends in technology and cost indicate that communication satellites can and will play a major role in providing a variety of domestic communication services, and in enlarging the capacity of present facilities to meet constantly expanding needs, particularly for distributing television and radio programs to broadcast stations.

This is not to suggest that communication satellites will revolutionize the present fabric of our already highly developed, terrestrial common-carrier network or pose a serious threat to that system. Instead, we foresee that domestic satellites probably will complement, as well as offer alternatives to, existing and improved terrestrial facilities.

Potential new uses of communication satellites in the more distant future include: (a) one-way distribution of material such as radio and television programs from one to many locations simultaneously, for rebroadcast or distribution

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to individual users; (b) relay of bulk communications such as multi-channel voice/record trunks, high-speed data, and video programs among a limited number of points; (c) relay of individual communications -- voice, data, and graphics -- among isolated or mobile users, such as aircraft and ships; and (d) various scientific and meteorological data collection distribution, and exchange services.*/

One of the most attractive features of a satellite is its adaptibility to reconfiguration in various segments of broadband transmission capability in a very short time.

Domestic satellites might, therefore, open new horizons in the dissemination and exchange of economic, medical, scientific, and educational information among businessmen, doctors, students, teachers and others.

In the near future, the most likely use of domestic satellites could involve (a) distribution of television programs to local commercial and educational broadcasting stations and to cable television distribution systems; (b) bulk telephony/record trunking; and (c) data and graphics transmission

*/ As discussed more fully in our staff study of the future of broadcasting, satellites designed to provide direct broadcast to home users, while technologically feasible, do not appear to have promising early applications.

and distribution. Other services may require further technological developments to prove attractive, although past experience in this field points to fairly rapid advance from theory to practice.

B. Economic feasibility

A principal issue raised by the various domestic satellite proposals advanced during the FCC proceeding -- and which the President specifically asked the Task Force to examine -- is one of economics. How soon will a domestic satellite system be economically feasible?

1. Estimates by the interested parties. In the FCC filings there was no consensus regarding the comparative advantages of satellites and other media either in terms of cost or rates. We stress the distinction between these two factors, since there may be a substantial discrepancy between the cost of providing a particular service and the rate charged for that service.

While various parties in the FCC proceeding submitted estimates of potential savings that could be realized by domestic satellite services, their presentations were not on a uniform basis. Thus, ABC estimated that the model system it had described would yield annual savings to the

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three television networks of about $33 million, or about $11 million per network. AT&T estimated that its proposed multi-purpose system would enable substantial savings by substitution of satellite for terrestrial facilities. Anticipated savings would be $19 million in the first year (1969), and would rise to $41 million annually by 1980. If the savings were allocated between telephone and television traffic, the latter would realize virtually all the savings in the first few years, but by 1980 more than half of the annual savings would be in the annual charges for telephony. */ The Ford Foundation submitted that, by 1970, a fully operational system along the lines it had proposed could achieve potential savings in terms of annual land-line transmission costs of up to $36 million. Comsat did not estimate the specific savings that would accrue from its original domestic satellite system proposal. It did, however, contend that if the Ford proposal and its proposal were placed on a comparable basis, annual savings for

*/ AT&T recently supplied us with a current review of their 1966 proposal, including updated cost data for the various system components. They now believe that a combined satellite-terrestrial system will still offer some savings over a comparable wholly terrestrial system during the 1969-1980 time frame, but projected savings from the use of satellites for domestic services are considerably less than anticipated earlier.

television services alone from the use of a multi-service system would be over 30% higher than the Foundation's estimates of comparable savings from its proposal.

2. Staff estimates. We attempted to make an independent judgment of the comparative economies that would be offered by a satellite and surface system, using technology and cost data supplied by interested parties and various government agencies. We used projected estimates for the early 1970's, when a domestic satellite system could be launched. Simple, but, for purposes of this inquiry, relatively satisfactory models of both satellite and terrestrial distribution systems to meet projected television distribution demand levels in the early 1970's were established. These are models of a full-scale, operational broadcast distribution system linking 250 cities in the U.S. We thought it important to examine the promise of satellites for domestic U.S. communications and recognized that a pilot program, due to its small scale, might not realize that promise fully. Due to inconsistencies in the cost data provided, lack of accurate demand figures, and the extreme simplicity of the models, the comparisons should only be considered as rough approximations.

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We chose as the basis for comparison a satellite configuration which represents a domestic variation of the INTELSAT IV satellite. The model might be considered as lying between those proposed by Comsat and the Ford Foundation for domestic use. It would provide 12 wideband transmission channels suitable for television distribution and other one-way services into each of the 4 U.S. time zones (48 channels in all) through 2 operating satellites and 1 in-orbit spare. Of these 12 channels per time zone, each receive-only earth station (of which 250 are assumed, serving the approximately 250 cities which now have television broadcast stations) would be capable of selecting any 6 at any given time through a single antenna. Four transmit/receive earth stations are assumed (1 per time zone). Each would employ dual antennas in order to access both operating satellites simultaneously, and each would be capable of originating and receiving up to 12 channels per satellite, or 24 channels total. These capacities of both satellites and earth stations are based on projected requirements in the early 1970's -- from the filings before the FCC -- to provide full network television distribution including network splits, sub-networks, ETV, and occasional services.

The terrestrial network required to provide the same level of service was computed based on a single coast-to-coast backbone route plus feeder routes to cover those cities not on the backbone. This would require a total of about 3,000 route miles of 24-channel, 2-way backbone, plus about 22,000 route miles of 12-channel, 1-way feeder routes.

The system models are described in greater detail in Appendix E. The following Table illustrates the projected cost comparisons between the satellite and terrestrial models (page 19).

In terms of the net investment required to provide equivalent services, the following general conclusions may be drawn from the above data:

(a) In a comparison based on the discounted cost of all-new facilities for each system, the satellite system would be substantially more attractive.

(b) In a comparison based on the discounted cost of all-new satellite facilities vs. a mix of new and incremental additions to existing terrestrial facilities, the satellite system would enjoy a slight advantage.

(c) In a comparison based on total cost for a

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COST COMPARISONS ($millions)

Television Distribution--12 channels per time zone to 250 cities, 12-year life

	SATELLITE	TERRESTRIAL MICROWAVE	
		New Facilities	Mix: All-new backbone, incremental feeder routes
INVESTMENT			
7 satellites @ 10.0	70.0		
Terminals: 230 @ .15		46.5	230 @ .15 46.5
20 @ .6			20 @ .6
7 launches @ 13.0	91.0		
Repeaters:			
ground stations			
250 receive @ .20	50.0		
510 @ .375		259.0	510 @ .195 167.5
20 transportable transmitters @ .25	5.0		80 @ .85
80 @ .85			
4 transmit/receive @ 2.0	8.0		
TOTAL INVESTMENT	224.0	305.5	214.0
Investment Discounted at 10% */	195.0	305.5	214.0
Annual Operating Costs (10% of equipment costs)	6.3	20.0	20.0
12-year cost	299.6	545.5	454.0

*/ This is the standard discount rate used by the Department of Defense. It is employed to take into account the fact that (unlike terrestrial microwave) not all the investment cost for the satellite system is incurred in the first year; rather, some of the satellites and launches are included as replacements later in the 12-year period.

12-year system life, which includes annual operating costs in addition to net investment, the satellite would enjoy a substantial advantage against all-new terrestrial facilities, and slightly less against a mix of new and incremental terrestrial facilities.

The foregoing comparisons, we stress, assume a full-scale operational satellite system, not a much smaller-scale pilot such as proposed by Comsat. Due to its limited scope, a pilot may be substantially less economical than corresponding terrestrial facilities, in terms of the investment required to provide equivalent services. On the other hand, if successful and if properly configured, the pilot could readily be expanded into a full-scale system.*/ The main point, at any rate, is that in terms of investment costs, satellites appear to be competitive with surface facilities.

*/ While some concern exists whether a full-scale, multi-purpose domestic satellite system could be accommodated within the spectrum now allocated for satellite services, it is generally agreed that present allocations are adequate for the kind of system for television distribution described above.

It is, of course, also important to examine comparative economies that might be possible in terms of rates, in providing broadcast distribution by satellite and by terrestrial facilities. However, we have been unable to draw meaningful conclusions on this issue simply by comparing the projected revenue requirements of a satellite system with the rates now charged by AT&T for use of terrestrial facilities. This is so because we cannot project the extent to which a satellite system will obviate the need to use terrestrial facilities. Nor can we predict with sufficient accuracy the savings that will be possible in charges for particular terrestrial services such as station interconnection (e.g., through by-passing the television operating centers).

It will be noted that our model is limited to broadcast distribution. It was not feasible to construct useful models to test the relative economies of other kinds of satellite systems, e.g., for record and voice traffic.

Television program distribution appears the most economical early use of domestic satellites, principally because of the inherent ability of the satellite to reach many points within a large geographic area simultaneously

through a single transmission facility. For two-way services, on the other hand, the substitution of satellite for terrestrial facilities is less favorable to the satellite system. The switching and terminal equipment needed for two-way services accounts for most of the cost of these services, whether the transmission be via satellite or terrestrial facilities. Relatively little switching is required for one-way services such as television distribution. The transmission cost of one-way services accounts for the bulk of total distribution cost of these services, in contrast to two-way services; thus cutting transmission costs should yield proportionately larger reductions in total distribution charges for one-way services. Satellites offer particular promise in reducing transmission costs. At the present stage of satellite technology, therefore, use of satellite capacity for television program distribution (provided there is sufficient demand) would seem to offer the most promising returns.

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This is not to say that a domestic satellite system need be exclusively dedicated to television program distribution. If excess capacity exists, or if capacity can be added to a dedicated system at lower cost than can be provided through a wholly separate system, the provision of other one-way or two-way services such as telephone trunking may be economically attractive. Services which could use off-peak hours for television distribtuion might add significantly to the overall viability of the satellite system.

II. SHOULD THE U.S. ESTABLISH DOMESTIC SATELLITE OPERATIONS AT THIS TIME?

The discussion thus far indicates that technological developments portend potentially promising domestic applications of communication satellite technology, and that even with today's technology, a domestic satellite system could offer some services economically. We examine below other considerations relevant in deciding whether the U.S. should establish domestic satellite operations at this time, and if so, how we should proceed.

A. Use of the electromagnetic spectrum

At present, commercial satellite communication systems must share the 4 and 6 GHz frequency assignments with terrestrial microwave relay systems, but there is substantial disagreement whether this shared use of common frequency bands is possible on a widespread basis without harmful interference. Opinion is divided about the number of satellites that could operate simultaneously on the same frequencies in the orbital sector available for U.S. domestic communications purposes. There is also uncertainty about the feasibility of providing satellite services in new spectrum areas above 10 GHz. These higher frequencies are not presently authorized for use by satellites because the necessary equipment has not been developed, and unresolved questions remain about propagation characteristics. Moreover, proposals have been made before the FCC to use portions of the spectrum above 10 GHz for certain terrestrial services.

In short, we do not know whether spectrum considerations will prove a limiting factor in determining the technical feasibility of full-scale domestic communications satellite operations and freedom of entry into the domestic communications satellite field.

To resolve these issues both experimental data (e.g., on interference mechanisms for operations below 10 GHz and

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on propagation conditions above 10 GHz) and analyses of a variety of possible approaches are needed. In a field where the most confident predictions can prove wrong in practice, such a resolution should be based on more operating experience.

Account must also be taken of the fact that an ITU World Administrative Radio Conference for Space Telecommunications (WARC-ST) is to be held in late 1970 or early 1971. Given the estimated 2-year lead time required to establish a domestic satellite system once it is authorized, it seems unlikely that any useful data will be developed under a domestic pilot program by the time the WARC-ST convenes. However, whatever proposals are submitted by the United States to the WARC-ST should not limit the flexibility of the anticipated experimental or operational aspects of our domestic program.

B. General purpose vs. specialized systems

Substantial disagreement exists about the comparative advantages of a general purpose domestic satellite system and one or more systems "dedicated" to specialized uses, such as radio and television program distribution.

Advocates of a "dedicated" system approach have contended that it would provide maximum efficiency and economy for their specialized interest, and that they would receive better

service than through a system having widespread and potentially conflicting responsibilities to several industries. They have said that the added complexity of a general purpose system--in both space and ground segments, and in launch-related matters--would not confer appreciable benefits for their special interest applications, but would instead compromise the economic advantages of a "dedicated" system.

The general purpose approach, supported by Comsat and the other common carriers, has been defended on various grounds. They claim that a) a general purpose system would use the frequency spectrum more efficiently, and would offer substantial economies of scale; b) economies would flow from avoiding duplication of launch vehicles, satellite research and development, procurement, earth station facilities and tracking, telemetry and command facilities, and by permitting common operation and management; c) further cost reductions would flow from reduced requirements for satellite spares and other back-up facilities; and d) it would have greater flexibility -- for example, if peak demands for individual services do not all occur simultaneously, a general purpose system would enable capacity to be conserved.

There may, however, be a middle ground: it is conceivable that essentially separate systems, for example, one for

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radio and television program distribution or other specialized services, another for general purpose services, could be operated within a framework that permits sharing of common facilities and costs where feasible. The likelihood of such an outcome will be a function of future developments in satellite technology, as they affect economies of scale and the variety and attractiveness of communication services provided by satellite.

The pilot program we propose below should shed some light on the feasibility and attractiveness of these alternatives. But if the regulatory framework were to evolve along the lines described in our staff paper on the domestic carrier industry, the ultimate determination might be left to the play of market forces in this area as elsewhere in the economy where new techniques are applied--subject, of course, to appropriate governmental regulation.

C. Sharing the benefits of satellite technology

Whether a domestic satellite system is dedicated to program distribution or some other purpose, or is a general purpose system, a question arises as to how any cost savings made possible by the new technology should be shared.

If a satellite system were operated as an integral part of the common-carrier network, the benefits could be

passed on to the public through general reductions in the carrier's rates, reflecting the reduced costs of providing services by terrestrial facilities as well as by satellite. Alternatively, the benefits could be made to accrue exclusively to the user of the satellite service, as would be the case with a specialized satellite system.

Still another approach--assuming that both common-carrier and non-common-carrier systems were authorized--would be to rely on the competitive forces of the market in such matters--as we discuss more fully in our study of the domestic carrier industry.

The first approach described above could result from strict application of the authorized-user rulings which the FCC has applied in the international field.*/ There, the FCC was concerned with a more specific issue -- the extent to which entities other than common carriers should be authorized to obtain telecommunication services directly from Comsat. While adopting a restrictive view on direct access to Comsat, the Commission sought to ensure that the carriers' rates appropriately reflected the savings offered

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*/ Authorized Users, 4 F.C.C. 2d 421 (1966), as modified by 6 F.C.C. 2d 593 (1967).

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by satellite technology by following a "composite rate" approach: rates to users should reflect the composite cost to the carrier of using both satellites and cables.

Regardless of what entity (or entities) is ultimately authorized to provide domestic satellite services, a strong argument can be made that the rationale in the authorized-user rulings is distinguishable from considerations in the domestic arena, at least for certain services. The authorized-user proceeding was concerned with international communications--an area of special sensitivity because of the economic condition of the international record carriers.

In our study of the domestic industry structure, we concluded that, while opportunities for entry into the basic message telephone switched network may be limited because of the nature of the system, there is room for liberalization of the rules governing competition in transmission systems for supplementary services such as private lines and audio and video program distribution. Non-extension of the authorized-user ruling to the domestic arena in respect of such services would be consistent with the view taken there, and might further the speedy development and use of communications satellites.

A case can be made for unqualified application of the authorized-user ruling to the domestic arena--particularly if it is concluded that, due to spectrum limitations, only one entity (e.g., a domestic counterpart to Comsat) should be entitled to establish domestic satellites. One might contend that a satellite carrier protected from satellite competition by carriers or others should not be able to siphon a very profitable part of the business of the terrestrial carriers, especially if the satellite carrier would not meet all or even a major portion of the essential public needs being met by terrestrial carriers. One might also point to the 1962 Communications Satellite Act as reflecting Congressional concern that access to satellites be available to all authorized users on a non-discriminatory and equitable basis, and that the benefits of lower rates be made available to the general public. It could be argued that only a small class of users would have sufficient traffic to justify or require direct access; the majority would not be in a position to go directly to the satellite carrier.

But even if spectrum limitations or other considerations should preclude relatively free entry into the domestic satellite field, it would not follow that direct satellite

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access by users should be circumscribed. Even if it were decided that domestic satellite service should be handled exclusively by an entity such as Comsat, it might be preferable to allow direct access to the satellite and flexibility of ownership arrangements in the ground environment, rather than to extend the authorized-user ruling to a field where it appears desirable to introduce a greater measure of competition wherever feasible. In such circumstances the established terrestrial carriers would be permitted both to engage in price competition in providing supplementary services (subject to regulatory scrutiny) and to lease satellite circuits as a complement to their terrestrial facilities as well.

Another aspect of this question concerns the desirability of subsidizing certain non-commercial interests through the operations of a domestic satellite system providing commercial services. For example, public educational broadcasting stations might be offered satellite channels free or at preferential rates, as contemplated in various domestic satellite proposals submitted to the FCC. The Report of the Carnegie Commission on Educational Television emphasizes the importance of interconnection for public television. Free satellite channels

would, in effect, constitute an important subsidy to public television -- although we recognize that the impact would be much greater if terrestrial carriers also offered interconnection facilities free or at reduced rates, as anticipated by Congress in the Public Broadcasting Act of 1967.*/ While non-commercial broadcasters may ultimately benefit as a result of reduced rates charged by common carriers for terrestrial services, it is by no means certain at this point whether such reductions will in fact come about, when they will be effective, or what the maximum benefit will be. Unless common carriers voluntarily filed amended tariffs for terrestrial service to non-commercial broadcasters, the prescription of reduced rates or free service by the Commission would require a rate-making proceeding of indeterminate length. However, if a pilot domestic satellite program were to be authorized, non-commercial broadcasting could be assured of obtaining some of the benefits envisaged in the Public Broadcasting Act by the Commission conditioning the pilot authorization on free channels or lower rates to non-commercial broadcasting.

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*/Section 396(h) of the Public Broadcasting Act of 1967 provides:

> Nothing in the Communications Act of 1934, as amended, or in any other provision of law shall be construed to prevent United States communications common carriers from rendering free or reduced rate communications interconnection services for non-commercial educational television or radio services, subject to such rules and regulations as the Federal Communications Commission may prescribe.

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The Ford Foundation has gone further and proposed that financial support for non-commercial programming be provided out of the savings from operation of a domestic satellite system for television program distribution, enabling the nation to earn, in effect, a "people's dividend" from its enormous investment in space.

There is, in principle, no conflict between the Ford Foundation proposal for a "people's dividend" and the action already taken by Congress in the Public Broadcasting Act of 1967, or other proposals for funding public broadcasting, including that advanced by the Carnegie Commission--which recommended that Congress provide Federal funds through a manufacturer's excise tax on television sets, put aside in a trust fund outside the usual budgeting and appropriations procedures.

While a sound financial basis is essential for public broadcasting, the concept of a "people's dividend" from satellite communications may pose problems. We do not yet know whether any domestic satellite program would generate sufficient savings to permit an appreciable subsidy for non-commercial programming.*/ Then, too, television

*/ To be sure the overall needs of educational and instructional broadcasting may not be met for some years, and it may be important to have an independent, steady source of funds, even if relatively modest.

distribution by domestic satellites would depend heavily on the cooperation of commercial broadcasters, who may be reluctant if a good deal of the economic incentive to use satellite services were removed. (It has been argued that this difficulty could be met by a cooperative arrangement between commercial and non-commercial broadcasters whereby commercial broadcasters had an important voice in deciding on the allotment of the "people's dividend.") Also, once the principle of a "people's dividend" was established and public broadcasting came to rely on it, there might be pressures against proposed tariff reductions by the terrestrial carriers which -- although otherwise justified -- threatened to induce the commercial broadcasters to use terrestrial rather than satellite facilities, and thereby destroy the subsidy. If satellite distribution were burdened by such a tax and distribution by terrestrial facilities were not, terrestrial carriers could enjoy a decided advantage over the satellite in competing for the commercial broadcaster's patronage.

Questions regarding the most appropriate way to finance public television are outside the scope of this paper. For purposes of the present discussion, it is sufficient to conclude that the wiser course would be a policy which put

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satellite and terrestrial technologies on an even footing, and allowed the natural advantages of each to be sought, developed, and put into service. If commercial broadcasters' operations are to support non-commercial programming, it would seem preferable, therefore, to devise a method that does not depend upon the mode of distribution employed. In any event we cannot say whether a "people's dividend" will prove feasible until experience is gained with a domestic satellite program and more data are in hand.

D. Evolution of the future domestic industry structure

Domestic satellite ownership and operations could evolve in quite different directions. Under one approach, they would be placed substantially under common-carrier control. For example, Comsat's competence could be limited to the international arena and AT&T, or the terrestrial common carriers jointly, could be given a monopoly of the space segment as well as the ground environment of any domestic satellite system. A variant of that approach would be to give Comsat or a new domestic satellite entity a monopoly of the space segment, with authority to deal only with terrestrial carriers, as is the general pattern today in the international industry as a result of the authorized-user rulings; alternatively, direct dealing with other users might be permitted.

Another approach would involve entry into the domestic satellite communications field by entities other than existing common carriers. This would be similar to the view taken by the FCC in the "Above 890" decision, where it authorized private terrestrial microwave systems. For example, broadcasters or other entities desiring to provide supplementary services might be authorized to establish satellite systems under appropriate regulatory ground rules, perhaps under cooperative arrangements or by creating new entities such as specialized common carriers.

Still another approach would be to retain for public ownership, on a permanent basis, the space segment alone of any domestic satellite system. Carriers or private entities, or both would be authorized to construct and operate earth stations working with the satellites. Under this view, the communication satellite is considered primarily a functional extension of radio propagation capability over distances and terrain unattainable through terrestrial facilities, with the

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management of the satellite accordingly entrusted to the government.*/

The considerations that should, in our view, guide long-range planning are described in our study of the domestic industry structure. In principle, and subject to appropriate limitations to conserve spectrum, we see no reason why domestic satellites could not be considered in much the same way as microwave facilities, and governed by analogous rules--with due regard to our international commitments.

Various technical, economic, and other factors will have to be weighed. Technical factors relate to the availability of frequency spectrum and potential interference

*/ Proponents of this view compare it with both government management of the electromagnetic spectrum and government construction, operation and management of highways and airways in the field of transportation, which are achieved consistently with established traditions of private ownership of commercial transportation systems. They recognize that Congress considered and rejected public ownership in the deliberations leading to passage of the 1962 Comsat Act, but argue that those deliberations were held in a vastly different context of technology and potential domestic applications than now seems imminent. Their case rests on several grounds: (1) experience has demonstrated that communication satellite development is critically dependent on high-risk government research and development; (2) there may be frequent and attractive opportunities for sharing costs among satellite programs, both communications and otherwise, which seem unlikely to be achieved except under government management; (3) regulation of private entry into the domestic satellite field is likely to be a far less effective means of rapid application of the new technology within the framework of a sound domestic communications industry structure.

problems. Economic factors include the extent to which existing facilities are available and suitable for meeting the services contemplated; and the potential economic effects on the common carriers and benefits which might result from multiple entry into the satellite field (e.g., greater competition in the equipment market, better service, and cost savings for special classes of users). But we see no inherent reason for limiting the domestic uses of satellites to common carriers exclusively. The domestic communications industry is much larger, and far more complex, than the international industry, and -- provided there are no technical limitations -- the burden must rest with those who favor restrictive rules of entry to demonstrate the wisdom of such a policy.

E. International commitments

The relationship between domestic satellites and the global satellite system is of considerable significance. Accordingly, in considering an appropriate institutional framework for domestic communication satellites, we must examine how they might be related to INTELSAT under the present interim arrangements and under the definitive arrangements to be negotiated in 1969.

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The role of domestic satellite systems has not been a principal focus for study under present INTELSAT arrangements and, as a matter of policy, it would appear imprudent to take action domestically that could have an unsettling effect on the forthcoming INTELSAT negotiations. A "green light" on full-scale domestic satellite operations, by common carriers as well as other entities, as opposed to a more modest pilot program could be subject to misunderstanding by members of INTELSAT. The question of liberal entry into the domestic satellite field cannot be divorced from consideration of our INTELSAT policies and, for the present, is one we should approach with caution.

F. What are the options?

The above discussion indicates a number of unresolved technical, economic, and other policy questions concerning domestic applications of communications satellite technology. We assess here three basic policy options that are available: defer establishment of a domestic system until these questions are resolved; authorize a fully operational domestic system (or systems); establish a demonstration pilot program.

1. Defer establishment of a domestic satellite system

Proponents of this view argue that there do not appear to be overwhelming economies in any domestic satellite system

with today's technology (although they concede that some economies might be possible, particularly in television distribution). They consider that approval of any domestic system, however avowedly provisional, may prejudice a variety of options, e.g., a determination that satellites should not be used for domestic service because of other more attractive technological alternatives, or because of frequency spectrum problems. They also point to unknowns concerning the future relationship between domestic and other kinds of specialized satellite systems and the global satellite systems under the definitive arrangements for INTELSAT, negotiation of which is scheduled to begin in 1969, as an added reason for delay.

These considerations seem to be outweighed by others. Most interested parties in the FCC proceeding see promise in the application of communication satellite technology to meet at least some domestic needs, although they have differed on a number of specific issues. Some have even expressed a willingness to participate in one kind of domestic system or another. While their reasons for being ready to invest in a domestic system may not be wholly congruent with the public interest, their views are entitled to weight. And

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while our own independent estimates do not indicate any substantial economies in the very near term from domestic satellite services, neither do they show that some of these services--particularly television distribution--would necessarily be uneconomical.

A fear of prejudicing ultimate determinations regarding domestic applications can be exaggerated, since a properly constituted domestic program could offer some valuable technical, operational, and other data while preserving most of our options regarding eventual resolution of the principal issues.

Then too, inaction does not promote our objectives in INTELSAT. Quite the contrary: it may ignore opportunities for cooperation with INTELSAT in ways that benefit the global system. (This matter is discussed more fully below. See p. 77.) While the question of the relationship of domestic systems to the global system will be an important issue in the 1969 definitive arrangements negotiations, it would be undesirable to delay a U.S. decision regarding a domestic satellite program until those negotiations are concluded--if a prompt start toward a domestic system is otherwise desirable, and if the domestic program is carefully planned

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in light of our commitments to the global system. It seems clear that, while the 1964 INTELSAT agreements embody a commitment by members not to participate in competing systems, a domestic system need not "compete" with the global system, and can be established consistent with a member's obligations to the global system.

Inaction would also forego the benefits of the insights that potential users and operators, as well as policy makers, might gain from a prompt start.

Finally, other concrete benefits might be derived from a prompt start. We should not ignore opportunities to gain experience that can be shared with other nations, particularly those with underdeveloped terrestrial systems for whom satellites may have great attraction as a substitute for, or complement to, expanded terrestrial facilities.

2. Establish a fully operational domestic system (or systems)

One might argue that, if industry is willing to risk its capital on full-scale domestic satellite operations, it should be permitted to do so, and further, that if a number of parties come forward, each application should be given fair consideration subject to spectrum considerations and applicable rules on interconnection with the switched network

and the like. In other words, we should treat domestic satellite applications in much the same way as applications for microwave construction.

There are various objections to adoption of this approach today. First, we do not have adequate data on potential interference problems between satellites and terrestrial systems, and on the adequacy of present spectrum resources to future satellite needs. While such questions might be considered on an ad hoc basis by the FCC, as it acts upon applications filed, a number of other uncertainties exist regarding domestic uses of satellites, particularly the foreign policy considerations noted earlier. The comparative economic advantages of satellite and terrestrial facilities for serving various communication needs are far from clear, and will only be understood after operational experience has been gained in providing satellite services. It is one thing to allow freer entry today in the use of microwave--a tried technology--but quite another to apply the same rule to a wholly untried technology (domestically) where the interested parties are in substantial disagreement.

It is, in short, questionable whether a suitable environment exists today for permitting full-scale domestic satellite operations, perhaps with rules of entry that rely

heavily on market mechanisms, as described more fully in our study of the domestic carrier industry. To be sure, a healthy environment for rapid technological advance, as in the computer field, may best be achieved over the long-run by avoiding artificial inhibitions and unnecessary governmental restrictions. But we must recognize that approval of any fully operational system at this time might well prematurely fix domestic communication satellites into a particular institutional and operational framework, create an irreversible pattern, and foreclose valuable options regarding future arrangements.

3. Establish a demonstration pilot program

On balance, we are persuaded that a demonstration pilot program, tentative and limited in scope, would offer a number of concrete benefits.

We saw earlier that technological developments portend potentially attractive domestic application, and that with today's technology, it would be economically feasible to meet some domestic communications requirements by satellites. A start is therefore clearly justified, and a modest demonstration pilot is a logical first step toward full-scale operations. It will permit us to test the waters without going so far and so fast that irreversible decisions are made. We may even find

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that satellites are not attractive domestically. But the cost of the pilot. taking into account its ability to provide commercial communications services, would have been negligible--roughly comparable to a few miles of a modern highway. We see little benefit in delay. It does not appear that technical developments within the next few years are likely to affect the attractiveness of a pilot authorized today. And, of course, new technological developments are to be expected at any stage.

The economic questions which the domestic use of satellite raise have already been discussed; actual operational experience with a limited domestic system should clarify the costs of such communication better than hypothetical computations, and yield important information on the problems of integrating satellites into the existing framework of terrestrial facilities.

While one could use a satellite system in precisely the same manner as a microwave relay system (i.e., to provide a series of individual point-to-point links between pairs of earth locations), it lends itself to more flexible usage. Thus, in television distribution from one location to many locations, the satellite by-passes, rather than duplicates,

the elaborate terrestrial point-to-point grid. On the other hand, it is not yet clear whether the satellite system will be more flexible than the terrestrial when there is a desire to provide for many two-way access points, network "splits", and sub-networks. Answers to these questions will come only through actual experience in an operational environment.

Experience would also be helpful in assessing acceptance of satellite distribution by users accustomed to the microwave relay mode. Although there are technical differences between the modes, the net effect of these differences on consumer preference is difficult to gauge. Television reception may, for example, be better at long distance by satellite due to fewer relay points. On the other hand, the time-delay factor may prove an impediment to using a domestic satellite system for telephony.

A decision to begin with a pilot program, provided it uses sufficiently advanced technology, could have a stimulating effect on communication satellite research and development. It should lead to renewed efforts in areas of particular interest for specialized applications, such as pointing accuracy of satellite antennae and multiple-beam techniques.

A pilot program, even though modest in scope, would provide facilities for significant commercial operations.

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For example, Comsat has proposed the use of two satellites in synchronous orbit, each having a 5-year life and capacity of up to 12 color television channels or 10,800 voice circuits. Television, voice, data, telegraph, etc., could be transmitted simultaneously. */

The program could also support non-commercial broadcasting and various other public interest projects such as instructional television. Each of the pilot proposals contemplates free satellite capacity for public or educational broadcasting stations. Comsat, a claimant for participation in a pilot program, has offered to participate in experiments, conducted under government auspices, concerning the practicability and economic advantage of using communications satellites to interconnect educational television and radio stations.

An attractive feature of having channels in the pilot satellites available for non-commercial use is that they can be used during prime time evening hours by educational television stations for distribution to home audiences, and during the day for classroom purposes. School boards and local

*/ A full-scale satellite system such as we considered in the model described earlier might provide twice as many television channels per satellite, at a relatively small increase in space segment cost.

and State departments of education must decide how to integrate into local curriculums television material programmed and transmitted from central sources. Questions of sharing costs and responsibilities of educational programming among hundreds of local schools, and making television sets and other physical facilities available, would also have to be resolved. One benefit of a pilot program would be to provide a better idea of the magnitude of these problems on the ground, and the degree to which a satellite system can provide a useful means of distribution to classrooms.

Though only a modest beginning, a pilot domestic satellite program affords an opportunity to experiment with the present regulatory and institutional structure of our domestic communications industry. By enabling prospective users of broadband services such as broadcasters to participate in the program we could test their willingness and capacity to shoulder the burdens involved, gain experience in the satellite mode, and reduce reliance on the terrestrial carriers. To the extent that these users are permitted to obtain satellite circuits directly, without going through the terrestrial carriers, the pilot program would help test the feasibility of direct competition in long-haul transmission

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and of direct access by users to satellites--both novel in light of current regulatory practice. */ The pilot might be expected to stimulate the terrestrial carriers' efforts to improve the technology and reduce rates for surface facilities. It might point the way to new regulatory policies or confirm the soundness of existing policies.

By establishing a domestic pilot program consistent with the objectives of the 1964 INTELSAT agreements--through an understanding with INTELSAT, and by relating the domestic program to the global system in important respects--the U.S. would be taking a constructive step in furthering international cooperation.

Most significantly perhaps, a pilot program should yield the kind of data, particularly regarding use of the frequency spectrum, that will prove helpful in reaching decisions on full-scale applications of satellite technology for meeting domestic communications requirements.

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*/ It has been suggested that the introduction of meaningful competition into the domestic communications market should be identified as the basic policy issue calling for deployment of a pilot program. While we propose a pilot program that should provide important data on the feasibility of increased competition in the supplementary services such as program distribution, firm conclusions on the subject will require a base of operational experience.

We do not mean to suggest that such a modest program will provide sufficient data to justify a permanent commitment at the end of the pilot to a particular technical or institutional mode. Systemic flexibility should be a continuing underlying philosophy of industry regulation. But we do believe that far more enlightened choices will be possible a few years hence, after experience with the pilot is in hand. Authorization at that time of full-scale domestic satellite operations should raise fewer difficulties than any full-scale domestic satellite system or systems authorized today. And authorization of the pilot need not preclude possible authorization of other systems, provided, of course, the technical uncertainties discussed earlier are adequately resolved and such action does not adversely affect the economic viability of the demonstration project.

III. ASSUMING THAT A DEMONSTRATION PILOT PROGRAM SHOULD BE ESTABLISHED, WHAT SHOULD BE ITS ESSENTIAL FEATURES?

A. Technical Requisites

Satellite technology is developing at a rapid pace. A pilot program that failed to exploit the most advanced technology available may not provide the needed technical

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and operational data for making judgments about how to proceed at the end of the pilot program. The facilities used in such a pilot would also be less attractive for use in any subsequently authorized system. Accordingly, authorization of the pilot should be conditioned on a requirement that the parties employ appropriate advanced technology, and that they devote reasonable time and expense to procuring technical data and conducting the experiments necessary or useful for reaching ultimate decisions regarding a full-scale domestic system or systems. The pilot should not, on the other hand, be burdened with unnecessary features that would cause undue delay or destroy its attractiveness to private investors.

We believe that the pilot can yield valuable scientific and operational data and at the same time prove viable from a commercial point of view. These goals do not in our view appear irreconcilable. While we anticipate a pilot program that is principally operational, rather than experimental, we do not expect any of the technical features discussed here to involve expenses that (a) could not fairly be imposed on those authorized to participate in the program (who, presumably, would reflect such

expenses in their rates to users), or (b) the participants would be unwilling to undertake. However, should it become apparent that a domestic satellite program would be attractive only if it contained capabilities for experimentation having little or no commercial value (at least in the short run), it would be appropriate to consider government financing for such experimentation, provided that such financing is consistent with NASA financing and does not involve wasteful duplication.

1. Dual purpose design. The principal area where substantial cost savings may be likely in the near future from a domestic satellite system is television program distribution. Moreover, a dedicated, non-carrier system could provide an alternative to the present ownership and operational framework of our domestic communications industry in television program distribution. But since a dual purpose pilot program would not involve substantially greater cost than one designed basically for program distribution, it seems unwise to pass up the chance to experiment with satellites for various domestic

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communication services. */ A properly structured, dual purpose pilot would ensure that cost savings made possible in particular services are appropriately reflected in the rates charged for such services.

While the pilot program would, in effect, be general purpose, it should be structured to test, to the extent feasible, the advantages of a system dedicated to television distribution. This requires using receive-only and transmit/receive earth stations of different sizes and performance criteria, testing various networking and subnetworking operational approaches (including the use of centrally controlled and/or user controlled switching systems and remote originating facilities), and maintenance of accounting procedures designed to segregate costs so as to facilitate later determinations regarding the feasibility of a general purpose and specialized system.

The broadcast and general purpose operations should be conducted independently within the framework of a single

*/ In particular, it would be useful to test the feasibility of two-way telephone service by satellite, as well as a two-way service employing a combination of satellite and microwave for long-haul portions of the circuit.

pilot program, and should share common satellite facilities. Each may need a basic share of total capacity; however, in the interests of economies of overall pilot operations, flexibility is preferable to a rigid division of channels for the full-time exclusive use of either system, or for particular classes of users. The general purpose operations may be very small at the start, */ and the needs of broadcasters, both commercial and non-commercial, may not dictate full-time channel requirements. Indeed, new network and program sources might be discouraged if required to pay for full-time channels when interconnection is needed for only brief periods during the day, especially during prime viewing time.

2. Interference measurements and sharing criteria. Data on potential interference between domestic satellite and microwave relay facilities should be obtained. To this end, receive-only earth stations should be established in both urban and non-urban areas so that interference

*/ In deciding on facilities for use in the pilot, consideration should be given to the possibility that carriage of telephone traffic by satellite on a large scale may require moving to new frequencies above 10 GHz.

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from terrestrial microwave facilities can be monitored. Transportable ground station equipment should be deployed in metropolitan areas congested with terrestrial microwave facilities to test the severity of mutual interference and ways to avoid such interference.

We cannot overemphasize the importance of prompt action to develop and improve criteria for frequency sharing by communication satellite systems and terrestrial communications systems. The pilot program will provide some useful data in these respects. But, independently of the pilot, there is a need for prompt efforts by government and industry, as discussed more fully in other staff papers. These should be undertaken as soon as possible so that sufficient data will be available to guide the pilot program and for making sound judgments about potential problems that might arise from shared use of common frequency bands on a widespread basis.

3. Channel multiplication by spectrum re-use. The use of multiple-antenna beams from the satellite, each covering separate geographical areas and providing some re-use of the available frequency assignments, has considerable promise as a way to increase channel capacity

of an individual satellite and of orbital space as a whole, thereby reducing overall cost per channel of satellite service and achieving greater communications capacity from the electromagnetic spectrum. The development and operational demonstration of such a multiple-beam spectrum re-use capability may be the most significant technical and economic features which could be incorporated in the pilot program. The staff believes that inclusion of such a capability would be highly desirable and should be explored carefully -- a view concurred in by NASA engineers and other experts in satellite technology. It could be made a condition precedent to any pilot authorization. The FCC should, of course, seek the advice of NASA as to its feasibility.

4. Service to non-contiguous areas. The Comsat pilot does not contemplate coverage of Alaska, Hawaii, Puerto Rico or the Virgin Islands. The Ford proposal would include transmission of television to these areas via separate antenna beams. Alaska is not served by satellite today, but its Congressional delegation has expressed strong interest in the inclusion of Alaska in any domestic pilot program. Hawaii is served by INTELSAT, mainly for telephony

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to and from mainland U.S. and more distant points in the Pacific. A very small amount of INTELSAT's Hawaii traffic consists of relatively high-cost television transmission of special events. An earth station will soon be completed in Puerto Rico, permitting satellite communications between the U.S. and Puerto Rico (and, by surface interconnection, to the Virgin Islands).

We believe that in any order approving a pilot project in principle and setting out general policy guidelines, the FCC should note the desirability of providing satellite service to these non-contiguous areas and require that the parties examine the feasibility of such service. However, in view of technical uncertainties, it would be premature in the preliminary order to decide whether separate antenna beams to permit such service should in fact be provided in the pilot satellites. There is need to compare the technical and economic feasibility of service between the mainland and these areas through a domestic satellite and through INTELSAT facilities. With respect to Alaska, there is an additional factor -- whether its internal needs may best be served through

INTELSAT's global satellites, a domestic satellite, or some other mode of communications.

The question of serving these areas also bears upon our INTELSAT commitments. Although there can be no quarrel with the goal of treating them as integral parts of a U.S. domestic communications network, we would wish to meet legitimate concern by INTELSAT about diversion of traffic from existing or planned INTELSAT facilities.

5. Support for non-commercial and instructional television. As noted earlier, the pilot demonstration proposals pending before the FCC contemplate providing free satellite capacity for public or educational broadcasting stations. The Commission should condition authorization of the pilot program on the provision of such capacity free or at reduced interconnection rates.

B. Participation in the Program

Perhaps the most difficult question is that of ownership of the facilities needed for the pilot program. It would be inconsistent with the premises of a pilot

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program to structure ownership in such a way as to foreclose experimenting with various alternative modes of organization.

Ideally, the pilot program should be controlled by a completely neutral and disinterested entity, lest the pattern of ownership of the eventual fully operational system be prematurely fixed. Although, as the Ford Foundation has suggested, NASA is such an entity, there appear to be practical obstacles to NASA's undertaking the project. While NASA could technically provide the space segment, it is not equipped to test the commercial and operational feasibility of domestic satellite services, and would probably need authorizing legislation to do so. Should Congress be asked to appropriate public funds for a project when private interests are willing and able to commit the necessary resources? And seeking

new legislation could cause considerable delay in domestic use of satellites. */

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*/ It has been suggested that certain operational opportunities that might be worthy subjects of experiment -- such as public television networking -- would only tax and possibly destroy the profit potential of a pilot program operated commercially. To be sure, the pilot program we envisage would only offer satellite interconnection for public television free or at reduced rates; it would not provide these stations with free terminal facilities as well. However, providing them with such facilities is wholly compatible with the pilot program we propose. NASA management of a demonstration program would not appear to facilitate that opportunity; funding by Congress would be required in either case.

Similarly, opportunities to experiment with satellites in developing Alaska's communications -- another desirable goal to some -- are not affected by entrusting operation of a pilot program to private enterprise. To be sure, Comsat or any other private entity operating a pilot satellite program could not fairly be asked to serve Alaska if this would undermine the commercial feasibility of the pilot. However, if the objection is that the government should subsidize the communications of Alaska or any other non-contiguous area of the nation, that seems wholly attainable within the framework of a pilot operated by private enterprise. In either case, Congressional action would be required.

We recognize that authorization of the pilot to private enterprise may have some drawbacks. NASA management of the pilot might, for example, preserve a greater degree of flexibility in terms of later exercise of the option of government ownership of domestic satellites. However, we feel that, on balance, the advantages of a prompt start under private auspices more than offset the disadvantages.

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One alternative would be to create a new private corporation to own and operate the pilot program, as Congress created Comsat in 1962. This new entity might be a non-profit corporation. However desirable in the abstract, this suggestion raises serious practical problems. Formation of such an entity would undoubtedly delay initiation of any pilot project. The history and current problems of Comsat illustrate the difficulties that can be encountered by creating a new entity in a situation of uncertainty as to what the future holds. For example, one would not even know what kind of entity would be appropriate in the domestic satellite field -- a broadcast distributor or a multi-purpose carrier -- until the pilot period was over. It seems premature to create a new domestic satellite entity at this time. As explained below, we think that Comsat, under proper conditions, is a sufficiently suitable candidate for principal responsibility in the pilot system.

Any entity that controlled a pilot program might have an advantage in seeking a place in a subsequent follow-on system over those who did not participate or whose participation was more limited. This potential risk is

tolerable, we believe, if, among the realistically available candidates, Comsat is given primary responsibility. We have recommended in another staff report that Comsat should become the nucleus of a new U.S. international transmission entity with no domestic affiliations. If this is what the future holds, Comsat would be a fully credible trustee.

Under the Comsat pilot proposal investment, ownership and management experience would be concentrated in only one interested party, except for the possibility of earth station participation by terrestrial carriers -- who also advocate ultimate authorization of a general purpose common carrier system.

To be sure, Comsat, aware of the inappropriateness of freezing the ownership and regulatory structure at this stage, proposes to operate the pilot project as a trustee or steward, leaving open the ultimate pattern of ownership. Comsat's proposal, however, contemplates commercial operations (albeit on a much smaller scale than

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its original proposal), and an investment ($58 million */) that is very substantial in relation to Comsat's total net investment of $70.6 million (as of 12/31/67). Experience indicates that, once a company is permitted to invest so heavily in a project, the government is reluctant to insist on divestiture at a later stage. This may be a risk even where, as here, the company purports to assume full and knowing risk of loss and to act as "trustee." There is, accordingly, some doubt that Comsat would at some later time lose control of the pilot or vacate the field -- particularly if the international industry is not restructured as we have proposed. Ordering Comsat to sell its domestic satellite system could drastically reduce Comsat's base. Once Comsat was actually operating a domestic satellite system, it might

*/ Comsat's share of the total investment would be reduced considerably if the Commission licensed all or a portion of the ground segment to other entities.

be unfair to abort or curtail its role when the result would seriously harm the stockholders. Comsat, finally, is the creation of the Federal Government and some would argue that the government could hardly "let it down" in such an abrupt fashion.

We do not doubt that the Commission, were it to approve the pilot project, would emphasize the purely provisional character of its authorization. Our point is not that the Commission could not later alter course (as it did in the initial "earth station" decision*/ where, however, the stakes to Comsat were much smaller), but that a decision now may create a momentum which may be difficult to arrest later. At the least, the burden of persuasion would shift--realistically, if not legally--to those who preferred a different pattern.

Nor does it seem adequate to say that the Comsat pilot project will constitute only one of possibly several satellite systems and that alternative regulatory approaches can be tried in others. This assumes that demand in the near future will be sufficient to support additional

*/ 38 F.C.C. 1104 (1965), reaff'd, F.C.C. 66-176 at 5 (Feb. 25, 1966)

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systems. We have no basis for confident prediction on that score. Even if that assumption were warranted, moreover, Comsat would be in good position to ensure a continuation of its monopoly. Expanding Comsat's pilot system would seem the easier, the more natural, and perhaps the cheaper way of meeting new increments of demand than creation of additional systems. Moreover, as the sole private entity having any experience in satellite communications, Comsat would seem the logical candidate to extend the scope of those communications. Finally, assuming the pilot was a success, Comsat could fairly argue that it should be rewarded by being permitted to grow.

In short, Comsat would have an entrenched position, a headstart over competitors, and strong leverage in pushing for an enlarged general purpose system that would preclude others, perhaps for a considerable period of time, despite the possible desirability of other rules regarding ownership and entry. Then too, while the carriers represented on its board may not exercise control over the

corporation's policies, they have strong influence. If Comsat expects, in the long run, to become the nucleus of a single U.S. international transmission entity, there is a risk it would not pursue the domestic pilot program with the same vigor as would an entity that had to establish itself in a field now dominated by the terrestrial carriers.

Since there is little doubt that the pilot project will in fact have a very substantial influence on the future regulatory pattern of the domestic satellite industry, the project should be designed to meet these concerns. Several steps seem warranted.

First, in announcing approval of the pilot project, the Commission should make clear that all ownership arrangements authorized for the pilot are strictly provisional and subject to modification. It should also stress that present regulatory policies should not be assumed automatically to govern the domestic satellite industry; for example, the extension of the authorized-user rationale to the domestic arena should be a matter for consideration de novo.*/ By proceeding this way, maximum flexibility will be preserved

*/ See infra, p. 71, n. 2 and accompanying text.

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in tailoring regulation to the particular needs of a domestic satellite industry.

The Commission should also insist that the pilot project be so structured that subsequent modification of the ownership arrangements would not work undue hardship to the parties involved. Otherwise, divestiture or some other substantial alteration of the proposed arrangements might not be practical, even if the Commission had formally reserved the right to effect such changes. Specific provision should thus be made to allow participants in the pilot program to recover any investment with a reasonable return on that investment. This is not to say the participants would be protected against risk of loss should the pilot project be a commercial failure. That risk they are apparently willing to assume. But if the venture leads to further development, the participants should be assured against loss should their interest in the domestic satellite system be transferred to other entities.

There remains the question whether arrangements for the pilot should involve spreading investment and experience

among various parties to ensure further that the pilot program is a truly provisional one that gives no party an undue "leg up."

We envisage three basic components in the pilot program: (1) the space segment--satellites and associated facilities; (2) fixed send/receive earth stations, both large and small; and (3) special purpose facilities for wideband services, including receive-only, and portable send/receive stations. The first two components are essential both to provision of a variety of two-way communications services and to distribution of broadcast programs. Special purpose stations particularly interest broadcasters and others who need wideband communication services. These stations would encompass both fixed receive-only and portable send/receive facilities designed to provide data on the feasibility of by-passing the extensive switched terrestrial network for broadcast program origination, regional networking, and similar activities; they could be used for a variety of demonstrational and experimental purposes.

Ideally, it might be useful to structure the pilot project as a consortium of all those who are seriously

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interested in entering the communication satellite field--not just common carriers, or broadcasters. This might increase the likelihood that the program yields the maximum data needed to explore all feasible alternatives in using satellites for domestic communications, not merely the application preferred by some, and that all contestants for a future role in domestic satellites would, by participating in the pilot, start at more or less the same point in terms of staking out a claim to participation in the mature domestic satellite industry. We recognize, however, that a broadly based, multi-party consortium could present serious organizational problems, and lead to considerable delay in implementing the pilot program.

It has been argued that Comsat and broadcaster interests should share ownership of the space segment. In this view such joint ownership would be most consistent with the notion of a pilot: by providing experience with a partly specialized system; by giving broadcasters essential operating experience; by ensuring satellite system design and characteristics that fairly meet the needs of broadcasters -- needs that will probably account for a substantial part of a domestic satellite system; by preserving

flexibility in ownership arrangements; and by ensuring a pricing system closely related to the costs of particular services.

We are skeptical about the feasibility and, indeed, the desirability of such a joint arrangement. It could prove administratively cumbersome and cause troublesome organizational problems at the outset and serious delays in execution. These potential disadvantages, in our view, are not outweighed by the alleged benefits.

We believe Comsat is well qualified to establish and maintain the space segment as trustee.

The principal benefits arguably flowing from broadcaster ownership of part of the space segment -- experimentation with the feasibility and advantages of a specialized broadcast-only system, preservation of flexibility in ownership arrangements, and ensuring a proper pricing system -- need not be lost by entrusting the whole space segment to Comsat. To achieve these goals Comsat should be required to offer satellite channels directly to broadcasters and other users of wideband services, to keep separate records on the various services it provides, and to price all

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services, where desirable, according to their direct and fairly allocable costs.

The broadcasters would not derive substantial operational experience as a result of space segment ownership; NASA will launch the satellite(s), and the other "operational" aspects of the space segment are rather limited -- mainly telemetry, command and control functions, which the broadcaster would probably not wish to undertake in any event.

Then too, we need not fear that if Comsat alone were responsible for the space segment, satellite design would be adverse to the best interests of the broadcasters. The FCC could insist on general agreement to a technical system plan by prospective participants in the program as a condition of granting licenses to establish particular facilities. It might, for example, call on Comsat to submit such a technical plan after consultations with other interested parties, and ensure any party the right to file objections to the technical plan filed by Comsat, or indeed a plan of their own, prior to entertaining applications for particular facilities. Since the FCC would have power to insist on appropriate modifications in any proposed technical plan, we are not persuaded that an investment in the space

segment by parties other than Comsat is needed to protect their interests. It would hardly be in Comsat's own best interests to produce a technical plan that discourages user interest in satellite service. In the last analysis, it will be up to government to exercise the vigilance required to ensure that the technical design of the pilot is optimal to meet the objectives of the project.

It might be easier to implement a "people's dividend," should that later prove desirable, if Comsat alone were responsible for the space segment. Also, if broadcasters have a major ownership interest in the space segment, it might prove difficult to accommodate entry of new full-time or occasional networks in the face of pressure by existing broadcasters to protect their markets against competition. While, in principle, regulatory provisions can be included to require non-discriminatory access to all potential users, the burden of enforcement could prove severe. If Comsat owned the whole space segment as trustee and dealt at arms length with all users, non-discriminatory access to the space segment might be more easily assured.

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While there is some doubt about the feasibility of a joint ownership for the space segment of the pilot program, and about the attractions of such an arrangement, the picture could change, either through a change in posture of the present parties to the proceeding, or by the entry of other parties. If so, we do not suggest that the FCC preclude the possibility of an equity interest in the space segment by entities other than Comsat.

We stress that the above recommendation of exclusive Comsat ownership of the space segment as trustee does not reflect a judgment that it is entitled to such ownership as a matter of "right," under the 1962 Communications Satellite Act.

There remains the question of ownership of the ground environment. Comsat officials have made clear that they would prefer exclusive responsibility for the entire pilot, for reasons that include speed of implementation, economy, and technical factors such as systemic integrity.

However, Comsat recognizes that under the 1962 Satellite Act (on which it bases its claim) other common carriers might also be authorized by the FCC to construct and operate earth stations, alone or jointly with Comsat.

While Comsat has stressed the complexity of the strictures within which it has been forced to operate (including earth station management), noting that such arrangements do not enhance the efficiency of its operations, our understanding is that Comsat would consider participation in a pilot in which other carriers shared ownership of the earth stations used in the program.

If the common carriers were permitted to share ownership of the special purpose stations as well as the fixed send/receive stations, we would be particularly concerned with the possibility of prejudice to key questions that would have to be decided at the end of the pilot period: whether a domestic satellite system should be general purpose or specialized, or whether there should be more than one system; and whether entities other than common carriers should be authorized to participate in domestic satellite systems.

This would appear to suggest two principal options: one, to permit only Comsat to invest in the ground facilities used in the pilot; the second, to permit spreading of investment in and experience with earth stations among various interested parties in a manner not subject

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to the objections raised above to carrier participation in ownership of earth stations.

The first option has obvious attractions. It would facilitate prompt establishment of the program, by avoiding complicated ownership arrangements. Then too, considerations of systemic integrity, centralized operations, efficiency, and economy would appear to favor naming a single entity to establish and operate all facilities used in the program. If that entity were Comsat, we could be reasonably assured that it would press development of the system to demonstrate the attractions of the satellite mode and maximize the competitive opportunities for satellites (provided it were required to offer services directly to certain users). Nor is there reason to believe that Comsat would unfairly favor a general purpose mode to the detriment of, say, broadcasters. If Comsat did not offer them service at attractive terms, it might risk losing customers for the most profitable services of the pilot -- television program distribution. Actual operating experience may not add measurably to the broadcasters' ability to make a case for a specialized system later. Strict accounting of the costs of broadcast distribution

services (both space and ground segments) could guard against any possible bias by Comsat toward general purpose operations. Finally, it might be hard to move to a unified general purpose system later if ownership of the pilot facilities were fragmented.

While the above arguments have merit, the advantages of broad participation in the pilot seem to outweigh the advantages of a single participant.

A principal consideration is that there is a very serious doubt whether -- as discussed above -- Comsat would later be dislodged if it has sole responsibility for the pilot. We have already noted that satellite technology may offer unique promise as an economical means of providing broadcast services. The broadcaster's needs are sufficiently substantial to warrant consideration of a special system, and they have expressed active interest. We cannot be sure that the broadcasters and other users of wideband services would exercise an option, if offered, to participate through investment in the pilot facilities. (They may wish to establish merely a token investment participation.) Offering them an opportunity to participate would test their willingness and capacity to shoulder the economic,

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technical, and administrative burdens involved. And should they participate, their ownership interest would be tangible evidence that no options on alternate ownership arrangements are in fact foreclosed by the pilot project.

While we concede that facility of operation, augmentation, and maintenance would probably be simplified were Comsat to be sole participant in the pilot, we think that such problems as may flow from diverted ownership and authority are manageable. */ To ensure that no special problems are presented, we would urge the FCC to supervise the arrangements for construction and operation of all facilities used in the pilot program (particularly those which, as proposed below, would be open to user ownership) so that (1) no undue burdens are placed on the

*/ One of the purposes of experimenting with divided space/ground ownership is to assess the impact of such problems. Divided ownership would not be a complete novelty: Comsat, manager of the INTELSAT space segment and the U.S. earth stations, has no direct control over the foreign earth stations that operate with INTELSAT satellites. And, as noted, Comsat is apparently willing to share with other carriers ownership of earth stations used in the pilot program.

pilot program as a result of divided ownership, and (2) Comsat as Program Manager of the pilot (see below) has the necessary authority with respect to all earth stations to ensure their technical compatibility with other facilities used in the program and to monitor, coordinate, and evaluate their operations within the framework of the overall program.

Permitting broadcasters and other potential users of wideband services to own and operate ground equipment should offer maximum opportunities for them to test the advantages of the satellite mode and reduce reliance on the terrestrial carriers, provided that they also have a right of direct access to the entity responsible for the space segment. This is an indispensable condition, in our view. */ The cost of the necessary equipment is modest, and the technological skills required should be well within the capacity of broadcast stations. We also believe that competition among equipment suppliers and in providing communications services to the public -- principal

*/ We see no basis for distinguishing between broadcasters and other users of wideband services in this connection.

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policy objectives expressed in the 1962 Act -- could be strengthened by broad participation in the pilot program.

We think it premature to lay down a specific plan of earth station ownership. The Task Force might recommend that the FCC, in its initial statement of policy regarding a pilot program outline the conditions and procedures under which specific applications would be entertained.

The following arrangements for the ground environment would appear feasible:

Send/receive stations. Comsat and the terrestrial common carriers could share ownership as trustees, with Comsat acting as manager of each of the initial stations under effective decision-making procedures. Since these stations would be used for broadcast operations as well as for provision of other services, procedures should be established so that, again, charges for particular services reflect, insofar as possible, only their direct and fairly allocable costs.

Suggestions have been made that ownership of these stations be open to any interested party, whether or not a common carrier. We question the desirability of such an

approach -- at least for the pilot program. It could unduly complicate ownership arrangements. In any case, we are not aware of any party interested in ownership of these stations who would be excluded under our proposal. Our approach would not preclude later approval of proposals by interested parties to construct earth stations for private line services, with direct access to Comsat for satellite service. Nor would adoption of our approach preclude different ownership arrangements in any subsequent follow-on system -- that should be a question for consideration de novo.

Special purpose facilities. Comsat and prospective users of wideband services (e.g., commercial broadcasters, non-commercial and instructional television interests, other public service interests, and other users) might be invited to file applications for the establishment and operation of these facilities (again, as trustees).

Where appropriate, machinery should be provided to ensure that prospective users obtain non-discriminatory access (e.g., by creation of specialized common carriers). To ensure against undue delay, the Commission might give all interested parties a reasonable time within which to

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come forward with plans for the establishment and operation of these facilities. If others failed to come forward, Comsat might be authorized to establish all the special purpose facilities. And even if the broadcasters and other users indicated an interest, Comsat might be permitted to establish supplementary facilities if consistent with the goals of the pilot program. Additionally, Comsat might be authorized to establish these facilities for subsequent sale or lease to broadcasters and others.

We recommend that, in ruling on the applications filed, the FCC balance, on the one hand, the need for a prompt start on an efficiently run pilot that avoids undue complexity, and on the other hand, the advantages of broad participation.

C. Manager of the Pilot Program

With ownership and operational responsibility shared along the foregoing or similar lines, there would be need for central coordination of the program to ensure technical and operational compatibility and fulfillment of the program's objectives. This role -- overall program manager -- should be entrusted to Comsat. Where disputes are not resolved, the matter could be brought before the

Commission. And, if need be, the institutional arrangements could be modified at a later stage of the pilot program.

D. Creation of an Advisory Committee of Users

We have recommended a demonstration pilot program with a view to avoiding complicated and cumbersome ownership, operational and managerial arrangements. However, the many diverse interests in the FCC proceedings can and should be protected. Specifically, we recommend that an Advisory Committee of users be created. It might, for example, be established under the joint aegis of the Commission and the Executive Branch unit designated by the President to monitor the pilot program. This would in no sense involve any derogation of the Commission's responsibilities with respect to the program.

The Advisory Committee, in which all interested parties could be represented, would be an appropriate forum for consultations with the entities designated to participate in the actual operations of the program.

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Through the Advisory Committee, all interested parties could make their views and needs known on such matters as satellite design, earth station characteristics and location, use of facilities, and rates. It should, accordingly, be promptly established once a decision to proceed has been made. The requirements of all interested parties could be incorporated in the applications filed; or, the Commission could grant licenses to the participants conditioned upon inclusion of such modification as might be appropriate to meet the needs of other parties.

The Advisory Committee would be a particularly useful forum for non-commercial and instructional users. The satellite capacity made available to them could be used for various public interest projects and experiments. For example, the National Library of Medicine has proposed a Biomedical Communications Network to provide better information and education to the medical community, with satellites used on an experimental basis

for interconnection within the network. */ This and other proposals could be explored in the Advisory Committee during the pilot program.

E. Conformity with U.S. International Commitments

Neither the United States nor other countries will be likely to surrender vital sovereignty over domestic communications. But the international community has a legitimate interest in the use of satellites for domestic purposes. The United States must, for instance, adhere to the rules and regulations of the International Telecommunication Union in its use of satellites for domestic communications purposes.

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*/ The project would be conducted in several phases. The first phase would concentrate on use of communication satellites for education purposes, especially through television. Five cluster points of health activity have been isolated which, if linked via communications, would interconnect some 50% of the physician population of the nation. (These are the Los Angeles area, the New York-Boston area, Washington, D.C., the Atlanta area, and either Chicago, Houston, or Detroit.) Satellite interconnections between these sites utilizing 25-30 foot antennas for transmit and receive purposes with ground connections to dedicated medical educational networks, or to public ETV/ITV systems, should permit more effective and less costly communications in support of specialized medical education. Such an experiment might be a valuable component of the pilot project.

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A basic question concerns the relationship between a pilot domestic satellite program (and, ultimately, a full-scale domestic satellite system or systems) and INTELSAT -- how we view our commitment to the global system under present arrangements; and, looking ahead, the relationship of specialized satellite systems to the global system under the definitive arrangements.

We should in no case take action incompatible with the goals of the global satellite system. Domestic satellites should, therefore, be consistent with INTELSAT's proposed use of the frequency spectrum and orbital space; and they should cause no harmful interference with the global system.

Our basic choices in going ahead are:

(1) Ask INTELSAT to establish the pilot satellites under the same rules governing the satellites established as regular increments to the INTELSAT segment; (2) proceed wholly outside of INTELSAT, except for technical coordination with the global system; (3) proceed within the framework of INTELSAT by reaching a prior understanding with INTELSAT regarding the compatibility of the pilot program with the global system and the mutual benefits that could

flow from a relationship between the two (e.g., shared common development costs).

The place for domestic communication satellite systems under present INTELSAT arrangements is not well settled. Accordingly, it has been suggested that we choose the first route -- establish the pilot satellites in the same way as satellites established as regular increments to the INTELSAT space segment -- to ensure against harmful proliferation of domestic and regional systems that might lead to the destruction of INTELSAT in its present form. However, recent ICSC discussions did not support the view that separate domestic satellite systems are necessarily incompatible with present INTELSAT arrangements; a U.S. paper tabled in INTELSAT recommended that separate domestic systems be recognized, and the President's message establishing the Task Force explicitly acknowledged this alternative. Thus, authorization of a separate domestic system would do no more than implement a policy which the United States has already recommended for INTELSAT, and one which would be permissible under the 1964 arrangements; it would not mark a new departure in policy.

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Moreover, we have found that the potential threat of proliferation is exaggerated, and that powerful forces are at work that will continue to support the development of the global system. A separate domestic system would neither obviate our reliance on INTELSAT's Atlantic and Pacific satellites for our international communications needs, nor involve duplication of facilities, nor affect INTELSAT's ability to provide basic global coverage.

On the other hand, establishing a domestic system as a regular INTELSAT increment would create severe economic distortions. For example, it has been estimated that, if the domestic system were established in this manner, U.S. "ownership" of INTELSAT could (assuming investment is proportional to use) rise from about 43% annually to about 89% annually in the 1970-1975 time frame, because of the large volume of traffic in the domestic system, thus increasing the already dominant position of the U.S. in INTELSAT. Finally, there are objections to this approach based on domestic considerations. For one thing, it would, as a matter of domestic law, complicate considerably how we structured the program, and Comsat -- on the basis of the 1962 Satellite Act and

1964 INTELSAT Agreements -- could assert a legal right to ownership of the space segment instead of acting merely as a "trustee."

It does not follow, however, that we should choose the second route -- proceed wholly outside of INTELSAT, except for technical coordination with the global system. There is substantial uncertainty as to the effect of our taking this route; it might, for example, serve to encourage centrifugal tendencies in INTELSAT. In view of the U.S. role in and commitment to the global system, we should proceed circumspectly in establishing a domestic program. Then too, even if the dangers of proliferation are exaggerated, it seems undesirable to ignore opportunities for cooperation with INTELSAT in ways that could benefit the global system. Accordingly, we question the desirability of proceeding wholly outside of INTELSAT.

Instead, we recommend the third alternative -- establishing the pilot program within the framework of, and through an understanding reached with, INTELSAT. Our looking to INTELSAT in connection with a domestic program would affirm the consortium's central role and encourage other nations to look to INTELSAT for guidance and basic

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planning. By going to INTELSAT, technical coordination of the pilot program with the global system can be enhanced, and the possibilities explored for related development of the pilot program and the INTELSAT system in a way that offers mutual benefits and thus strengthens both systems. A principal attraction relates to the possibility of sharing common research and development costs of INTELSAT satellites and the pilot satellites. Other areas of potential mutual benefit should also be explored, such as shared use of INTELSAT's control and telemetry facilities for the domestic program, joint contracting for launch facilities, maintenance of common satellite spares and back-up facilities, and possibly a joint procurement program for satellite hardware.

This course would meet legitimate concerns about harmful proliferation of satellite systems, establish the useful precedent that a nation planning a specialized satellite service look first to INTELSAT and work out with the organization an arrangement that fully recognizes and protects the interests of the global system, and show that INTELSAT has sufficient flexibility to adjust to individual national needs in a manner that does not jeopardize its own future.

F. Legal Authority and Governmental Regulation

The 1934 Communications Act and the 1962 Communications Satellite Act, read together, provide the legal basis for authorization of the pilot domestic satellite program recommended herein, as well as for governmental regulation and supervision of the program. */

Comsat has adequate legal authority under the 1962 Act to participate in the pilot. There need be no conflict for the Corporation in fulfilling its responsibilities as the U.S. participant in the global satellite

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*/ Section 401 of the Satellite Act provides: "The corporation (Comsat) shall be deemed to be a common carrier within the meaning of section 3(h) of the Communications Act of 1934, as amended, and shall be fully subject to the provisions of title II and III of that Act. The provision of satellite terminal station facilities by one communication common carrier to one or more other communications common carriers shall be deemed to be a common carrier activity fully subject to the Communications Act. Whenever the application of the provisions of this chapter shall be inconsistent with the application of the provisions of the Communications Act, the provisions of this chapter shall govern." 47 U.S.C. § 741 (1964) (emphasis added).

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system and its responsibilities as "trustee" in the pilot domestic program. */

The Federal Communications Commission will have broad regulatory authority under both Acts. Its powers under the 1934 Act are extensive, and apply to such matters as use of particular frequencies, construction of communications facilities, and rates and financial matters. The 1962 Satellite Act provides further guidance for the Commission in its administration of the provisions of the 1934 Act, as amended and as supplemented by the 1962 Act, with respect to satellite communications.

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*/ While recognizing the definitive impact of the 1962 Act over Comsat's role in commercial communication satellite systems, we do not take the position that Comsat (or, indeed, any other entity) may claim a position of right to the space or ground segments of a purely domestic system. In any case, it is not necessary to enter that issue -- a center of controversy in the FCC proceeding -- for purposes of the pilot program.

Congress adopted the 1962 Satellite Act in an earlier era of communication satellite technology. While it anticipated the possibility of domestic satellite service, Congress provided only limited guidance in this respect (Sec. 102(d)). It may wish to examine whether additional legislation would be useful to govern the provision of domestic communication satellite services.

Certain provisions of the 1962 Act have meaning only in the context of the global system -- e.g., Section 201(c)(3), which related to the establishment of commercial communications to foreign points.

However, it would be an unduly restrictive interpretation of the Act to view its provisions regarding governmental regulation and supervision as applicable only to the INTELSAT system. While some of the provisions regarding governmental regulation and supervision might be construed as expressly applicable only to the satellite system envisaged by the 1962 Act -- that is, the INTELSAT global system -- their logic extends to any commercial communication satellite system in which the U.S. participates. */ Congress cannot have intended

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*/ Thus, the FCC is responsible under the 1962 Act for: insuring effective competition, nondiscriminatory use and access, and technical compatibility; prescribing accounting regulations and systems and engaging in ratemaking procedures to insure that the economies made possible by the system are appropriately reflected in rates; approving the technical characteristics of the system; insuring against additional facilities that are not required by the public interest, convenience, and necessity; and requiring additional facilities that are so required. See Section 201(c)(1)-(6) and (9)-(10), 47 U.S.C. §721(c)(1)-(6) and (9)-(10) (1964).

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in 1962 to prescribe a pattern of governmental responsibilities for regulation and supervision of communication satellites that is wholly inapplicable to domestic satellites.

The role of the Executive Branch with respect to communication satellites is broadly conceived and reaches almost every aspect of Comsat's functions under the 1962 Act. This Act, together with the 1934 Act, provides the cornerstone for delineation of governmental responsibilities with respect to commercial communication satellites and, accordingly, to the pilot program. The President is responsible under the 1962 Act for coordinating the activities of governmental agencies with responsibilities in the field of telecommunications, so as to ensure full and effective compliance with the policies of the Act. */ The President could also be expected to exercise, to the extent applicable to the pilot program, his other responsibilities under the 1962 Act: to aid in planning

*/ As recommended in an earlier section of this report, the pilot should be fully compatible with the INTELSAT system and related to it in important respects. If established in this way, the pilot would be fully consistent with -- and indeed, would further -- the policies of the Satellite Act.

and development, and to foster the execution of a national program for the establishment and operation of the system; to provide for continuous review of all phases of the development and operation of the system; to ensure that relationships with foreign governments or entities or with international bodies are consistent with the national interest and foreign policy of the United States; and to so exercise his authority as to help attain coordinated and efficient use of the electromagnetic spectrum and the technical compatibility of the system with existing communications facilities.

NASA has a responsibility under the Act to cooperate with Comsat in research and development to the extent deemed appropriate by the Administration in the public interest. NASA could, therefore, be expected to cooperate in the research and development connected with the pilot, in which Comsat will have a central role. NASA could also perform other functions with respect to the pilot program that it now performs under the 1962 Act in connection with the global system: consultation and advice on technical characteristics of the system; assistance in research and development by furnishing, on request and on a reimbursable

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basis, such satellite launching and associated services as the Administration deems necessary; furnishing on request and on a reimbursable basis, satellite launching and associated services required for the establishment, operation, and maintenance of the pilot system; and to the extent feasible, furnishing other services on a reimbursable basis connected with the establishment and operation of the system. */

In examining the role of the Executive Branch it should also be noted that Section 403 of the 1962 Act **/ makes provision for the Attorney General to seek judicial measures necessary or appropriate to ensure adherence to the policies, purposes, and provisions of the Act. Finally, the 1962 Act ensures accountability to Congress of activities and achievements under the pilot program. The President, Comsat, and the Federal Communications Commission each submit annual reports under the Act.

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*/ See also 42 U.S.C. § 2452, 2473(a) and 2473(b)(5).

**/ 47 U.S.C. 743 (1964).

Thus, Congress has provided the necessary legislative framework for comprehensive governmental regulation and supervision of the pilot program. It would, however, be useful to issue an Executive Order along the lines of Executive Order 11191, of January 4, 1965, to make explicit the responsibilities of the various agencies of the Executive Branch with respect to the pilot program. While there is in our view no present need for further legislation to govern domestic applications of communication satellite technology, we do not rule out that such legislation may be desirable at a later stage.

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IV. CONCLUSIONS

The theme of this paper has been that we need more data and experience about domestic use of commercial communications satellites before wise and informed decisions can be made about the structure and framework of any mature domestic satellite industry. The pilot program should be structured to yield the needed data and experience, as we have tried to indicate throughout. But in terms of future policy decisions, that is not sufficient -- the government must also have and use the capability to evaluate its results. Data will be obtained in a variety of areas -- technical, operational, and social, including inter alia, cooperative sharing by space and terrestrial services to minimize frequency interference; re-use of the frequency spectrum by narrow-beam antennas; problems of integrating satellite services with terrestrial facilities; user acceptance of satellite services, including assessment of impact of the time delay factor; feasibility of regional networking and by-passing manned television operating centers; installation and annual operating costs of the various components of the satellite system, and cost projections for expanded operations; feasibility of general purpose and specialized

systems, or some combination thereof; support of non-commercial operations; and value of satellite facilities for educational broadcasting and specialized government users such as HEW.

At the end of the pilot program*/ it will be timely to consider the broader issues involved: the future role of domestic satellites, and whether they offer sufficient promise to justify continuation beyond the pilot period; whether domestic satellites should be general purpose or specialized or both, and whether there should be more than one system; and the ownership and regulatory framework that should govern domestic satellite operations.

To assist in evaluating the results of the pilot program and making future decisions in these areas effectively, a continuing Executive Branch role would be

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*/ Comsat anticipates it will take about 2 years to establish the program, from the date of authorization. It would be useful to fix a definite time period, calculated from the time the pilot program is established, at the end of which the program would be thoroughly reviewed. While the satellites used in the pilot are expected to have a design lifetime of more than 5 years, that seems unduly long for a true pilot program. Two to three years should be a reasonable length of time within which to achieve the limited objectives of the pilot.

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highly desirable. This responsibility -- which we conceive as one of "monitoring" the progress of the pilot program, without derogating from the legal responsibilities of the FCC -- should be vested at a high level in the Executive Branch. By monitoring the progress made under the pilot program, the responsible office would be able to assist the President in making an independent evaluation of the future of domestic applications of satellite technology, and of appropriate institutional arrangements. The office should advise and assist in structuring all aspects of the pilot program, gather and assess the data and information acquired during the program, and undertake any independent studies or projects needed to make timely recommendations upon conclusion of the program.

The program we have outlined should be promptly implemented; a start appears feasible within fiscal 1969. We recommend that the Task Force urge the FCC to give it favorable consideration. The Commission might first issue a statement of general policy outlining the conditions under which formal applications would be entertained. If those conditions are not met, the desirability of authorizing a domestic pilot program should be reconsidered.

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APPENDIX A

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D. C. 20554

FCC 66-207
80142

In the Matter of the	)	
	)	
Establishment of domestic non-common carrier communication-satellite facilities by non-governmental entities.	)	DOCKET NO. 16495

NOTICE OF INQUIRY

By the Commission:

1. The Commission has before it an application filed by the American Broadcasting Companies, Inc. (ABC) for the establishment of a domestic TV program distribution system using a synchronous satellite. An opposition to the application has been filed by the Communications Satellite Corporation and a reply thereto has been filed by ABC. Under the proposal, programs would be transmitted from earth stations located in New York City and Los Angeles to ABC-owned and affiliated stations throughout the United States, including Hawaii and Alaska, and Puerto Rico and the Virgin Islands. The application also proposes to provide facilities for the interconnection of non-commercial educational TV stations in these same areas.

2. The ABC application is technically defective as it fails to comply with various provisions of Parts 2, 21 and 74 of the Commission's Rules and Regulations. The Commission has, therefore, informed ABC that its application cannot be accepted for filing at this time and the application is being returned to ABC without prejudice to an appropriate refiling thereof in light of the outcome and disposition of the inquiry that we are instituting.

3. The Commission has a statutory responsibility to study new uses for radio and generally encourage the larger and more effective use of radio in the public interest (e.g. Section 303(g) of the Communications Act of 1934, as amended). However, proposals for the construction and operation of communication-satellite facilities by entities for the purpose of meeting their private or specialized domestic communication requirements present significant questions as to the compatibility of such proposals with the purposes, policies and objectives of the Communications Satellite Act of 1962 and as to their technical and economic feasibility. Therefore the Commission believes that the public interest would be served by obtaining the views and

highly desirable. This responsibility -- which we conceive as one of "monitoring" the progress of the pilot program, without derogating from the legal responsibilities of the FCC -- should be vested at a high level in the Executive Branch. By monitoring the progress made under the pilot program, the responsible office would be able to assist the President in making an independent evaluation of the future of domestic applications of satellite technology, and of appropriate institutional arrangements. The office should advise and assist in structuring all aspects of the pilot program, gather and assess the data and information acquired during the program, and undertake any independent studies or projects needed to make timely recommendations upon conclusion of the program.

The program we have outlined should be promptly implemented; a start appears feasible within fiscal 1969. We recommend that the Task Force urge the FCC to give it favorable consideration. The Commission might first issue a statement of general policy outlining the conditions under which formal applications would be entertained. If those conditions are not met, the desirability of authorizing a domestic pilot program should be reconsidered.

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APPENDIX A

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D. C. 20554

FCC 66-207
80142

In the Matter of the	)	
	)	
Establishment of domestic non-common carrier communication-satellite facilities by non-governmental entities.	)	DOCKET NO. 16495

NOTICE OF INQUIRY

By the Commission:

1. The Commission has before it an application filed by the American Broadcasting Companies, Inc. (ABC) for the establishment of a domestic TV program distribution system using a synchronous satellite. An opposition to the application has been filed by the Communications Satellite Corporation and a reply thereto has been filed by ABC. Under the proposal, programs would be transmitted from earth stations located in New York City and Los Angeles to ABC-owned and affiliated stations throughout the United States, including Hawaii and Alaska, and Puerto Rico and the Virgin Islands The application also proposes to provide facilities for the interconnection of non-commercial educational TV stations in these same areas.

2. The ABC application is technically defective as it fails to comply with various provisions of Parts 2, 21 and 74 of the Commission's Rules and Regulations. The Commission has, therefore, informed ABC that its application cannot be accepted for filing at this time and the application is being returned to ABC without prejudice to an appropriate refiling thereof in light of the outcome and disposition of the inquiry that we are instituting.

3. The Commission has a statutory responsibility to study new uses for radio and generally encourage the larger and more effective use of radio in the public interest (e.g. Section 303(g) of the Communications Act of 1934, as amended). However, proposals for the construction and operation of communication-satellite facilities by entities for the purpose of meeting their private or specialized domestic communication requirements present significant questions as to the compatibility of such proposals with the purposes, policies and objectives of the Communications Satellite Act of 1962 and as to their technical and economic feasibility. Therefore the Commission believes that the public interest would be served by obtaining the views and

comments of interested parties on these questions as a means of determining what further actions, if any, are warranted by the Commission in this area.

4. Accordingly, comments are invited on the following specific questions:

(a) Whether, as a matter of law, the Commission may promulgate policies and regulations, looking toward the authorization of non-governmental entities to construct and operate communication-satellite facilities for the purpose of meeting their private or specialized domestic communications requirements. This proceeding is not concerned with the question of whether communications common carriers may be authorized to construct and operate communication-satellite facilities for domestic purposes. (Parties submitting comments in this matter should do so in separate legal briefs);

(b) The effect or impact of any such authorizations upon the policies and goals set forth by the Communications Satellite Act and upon the obligations of the United States Government as a signatory to the Executive Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System;

(c) Whether, as a matter of policy, it would be in the public interest to grant such authorizations considering:

(1) The amount of frequency spectrum now available for the communication satellite service under the Commission's Rules;

(2) The extent to which terrestrial facilities are or may be available to provide the services contemplated;

(3) The potential economic effects on common carriers; and

(4) The potential benefits (e.g. improved quality and reduced cost of service) which might result from the grant of such authorizations;

(d) Is it technically feasible to accommodate the space service contemplated, in light of the requirement:

(1) That the power flux density produced at the earth's surface in the band 3700-4200 Mc/s by emissions from a space station employing wide-deviation frequency (or phase) modulation, not exceed -149 dbW/m^2 in any 4 kc/s band for all angles of arrival, nor a total of -130 dbW/m^2 for all angles of arrival;

(2) That the power flux density produced at the earth's surface in the band 3700-4200 Mc/s by emissions from a space station employing other than wide-deviation frequency (or phase) modulation, not exceed -152 dbW/m^2 in any 4 kc/s band for all angles of arrival;

(3) That earth stations receiving signals from space stations in the band 3700-4200 Mc/s be so located with respect to the existing common carrier microwave complex in that band that they are not subjected to harmful interference from such terrestrial microwave systems;

(4) That transmitting earth stations in the band 5925-6425 Mc/s:

(a) Not exceed a mean effective radiated power of 45 dbW in any 4 kc/s band in the horizontal plane; and

(b) Not cause harmful interference to the existing common carrier microwave complex in the same band.

(e) Other relevant matters to which the respondents wish to address themselves.

5. It is recognized that the matters raised are unique and complex and the respondents should be afforded adequate time in which to prepare meaningful comments. Accordingly, it is requested that comments be submitted to the Commission by August 1, 1966, and reply comments by October 1, 1966. An original and 19 copies of all comments and reply comments and briefs shall be furnished the Commission. The Commission will consider all such comments, reply comments and briefs, as well as other relevant information before it, prior to taking further action in this matter.

FEDERAL COMMUNICATIONS COMMISSION

Ben F. Waple
Secretary

Adopted: March 2, 1966

Released: March 3, 1966

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APPENDIX B

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D. C. 20554

FCC 66-929
90132

In the Matter of	)	
	)	
Establishment of domestic communication-satellite facilities by non-governmental entities.	)	DOCKET NO. 16495

SUPPLEMENTAL NOTICE OF INQUIRY

By the Commission: Commissioner Cox voting to add a paragraph restricting consideration to matters on the record; Commissioner Loevinger absent.

1. On September 21, 1965, the American Broadcasting Companies (ABC) requested an authorization in the Auxiliary Radio Broadcast Services to construct and operate a communications satellite system for television broadcast distribution in the United States. We returned the application to ABC without prejudice on March 2, 1966, and adopted on that day a Notice of Inquiry (FCC 66-207) into the questions raised by it, i.e., the compatibility with the Communications Satellite Act, and the technical and economic feasibility of establishing domestic non-common carrier communication satellite facilities by non-governmental entities.

2. Briefs and comments were timely filed by 19 parties on or before August 1, 1966. Among the comments submitted were novel concepts and proposals concerning domestic common carrier service via satellite. In this regard, the Ford Foundation submitted a proposal to create a corporate entity which would furnish satellite facilities for the transmission of commercial and educational television program material, with charges to be made for those services provided to commercial users, and part of the profits and revenues therefrom to be devoted to the support of educational broadcasting. The initial Notice herein expressly limited the scope of the inquiry by providing that it "is not concerned with the question of whether communications common carriers may be authorized to construct and operate communication-satellite facilities for domestic purposes." The Public Notice released September 8, 1966 (FCC 66-799), gave recognition to the necessarily broadened scope of the Inquiry and, our order to afford sufficient time for the preparation of comment on or counter-proposals to the additional matters raised by the filings herein, extended the date for submitting reply comments to November 30, 1966. Finally, provisions were made for the filing of further reply comments on or before December 30, 1966.

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3. The purpose of this Supplemental Notice is to clarify the intent of the Commission in its Public Notice of September 8, 1966 as to the nature and scope of the additional matters which interested parties are invited to address in further comments herein. Accordingly, in addition to comments on the proposals and concepts already submitted, comments are invited as to the following matters:

(a) The Commission desires to have, to the extent they are available, descriptions, from existing carriers responding to this inquiry, as well as other entities intending to seek authority to provide common carrier services, general or specialized, of their plans for using communication satellite facilities to meet domestic needs; and

(b) Whether, as a matter of law, there is any restriction on the Commission's power to authorize any communications common carrier or carriers to construct and operate communication satellite facilities for domestic communications services;

(c) Assuming legal authority, under what circumstances should the Commission issue such authorizations, and to whom (one carrier, more than one carrier, two or more carriers jointly), having due regard for, among other things:

(1) The comparative advantages of communication satellites and other communication media in meeting domestic communications needs;

(2) The effects on charges for, and quality and adequacy of, present and future public communications services;

(3) The anticipated volume of domestic communications needs through 1980, and the portion thereof that can and should be satisfied through the use of communication satellite facilities in view of expected technological developments in all media;

(4) The comparative advantages and disadvantages of meeting domestic needs (i) through the facilities of the global system; or (ii) through a separate system or systems;

(5) The effect or impact of any such authorizations upon the policies and goals set forth by the Communications Satellite Act and upon the obligations of the United States Government as a signatory to the Executive Agreement Establishing Interim

Arrangements for a Global Commercial Communications Satellite System.

(d) Whether the type of entity and service contemplated by the Ford Foundation proposal may be licensed under present statutes, and, if not, the type of legislation that would be required.

3. For the most part, comments filed thus far have not been fully responsive to the technical questions raised in the first Notice of Inquiry as to the adequacy of existing allocations to the communication satellite service or as to the electromagnetic interference to and from both present and projected operations of the global commercial communication satellite system and the domestic fixed public services sharing the same frequency bands. The latter question is complicated further by the fact that the plenary assembly of the CCIR (Oslo, June 1966), has recommended changes in the technical criteria applicable to the power flux density delivered at the earth's surface from space stations. Therefore, pending resolution of the legal status of the Oslo criteria vis-a-vis those criteria now in the international Radio Regulations, interested parties, in responding to the questions raised in our prior notice and herein (which include the technical questions explicitly set out in our prior notice), should direct their responses to both the present and Oslo criteria. Additionally, to permit an evaluation of the impact from proposed systems, parties should indicate as fully as they now can the planned positioning of space stations on the equator for the system under consideration if equatorial stationary satellites are involved.

5. Reply comments and comments on the above questions should be submitted to the Commission by November 30, 1966, and further reply comments by December 30, 1966. It is requested that an original and 50 copies of all reply and further reply comments be furnished to the Commission by parties filing in this proceeding.

FEDERAL COMMUNICATIONS COMMISSION

Ben F. Waple
Secretary

Adopted: October 20, 1966

Released: October 21, 1966

APPENDIX C

Excerpts from Comsat's
Reply Statement in FCC Proceedings on the
Establishment of Domestic Communications
Satellite Facilities by Non-Governmental
Entities (FCC Docket #16495)
March 31, 1967

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II. COMSAT'S PILOT DEMONSTRATION PROPOSAL

It is important to note that all of the technical proposals made by the parties to this proceeding contemplate certain common, minimum requirements for a ground environment, requirements which would be needed in the long run for a single multi-service system or for one or more dedicated systems. The demonstration facilities which Comsat proposes that the Commission authorize would be so designed that they can be absorbed eventually in a long-term complex for the furnishing of commercial service after the termination of their use for pilot demonstration purposes. Comsat would acquire specific sites and the necessary equipment as trustee for the party or parties who are ultimately chosen to acquire, own and operate long-term domestic facilities. The arrangements would be fashioned to avoid prejudicing, in any way, the interests of the eventual owner or

owners or the extent of their participation.*

The necessary steps in providing these facilities and the possible uses of them are summarized below:

Comsat proposes that the Commission convene a conference of the interested carriers, educational and commercial broadcasters, HEW, NASA, The Office of Telecommunications Management, NET, The Ford Foundation, and other appropriate interested entities, for the purpose of reaching agreement with respect to the specific number of earth stations, their characteristics and locations which would best serve a demonstration model for domestic services. These consultations, to be carried out expeditiously, would look toward establishing a demonstration complex

---

* An obvious precedent for this type of arrangement can be found in the history of the ownership and operation of earth stations. In 1965, the Commission (Report and Order, Docket No. 15735, 38 FCC 1104) authorized Comsat to construct, own and operate three initial earth stations in the United States. That decision was categorized as "interim" and was made without prejudice to any ultimate resolution of the question of earth station ownership. In December of 1966, this policy was modified in the Second Report and Order (FCC 66-1133, Mimeo. No. 91927), which provides, again on an interim basis, for the three existing as well as future earth stations to be owned and operated on a joint basis among Comsat and the several United States international carriers.

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permitting a regional network for educational television and for commercial broadcasting and permitting transcontinental telephone, data, and other communications.

The initial objective of the program will be to make non-commercial television and general communications by satellite available throughout the Pacific and Rocky Mountain time zones, with direct access from New York. Commercial television and general communications services would be accommodated at commercial rates. One television channel through the satellite and earth stations in each time zone would be provided under arrangements that would permit the service to be free of charge to educational broadcasting. Sufficient capacity will be provided for experiments and particular demonstrations, as well as for long-distance services. The extent and uses of the capacity to be made available for demonstration purposes will depend upon the outcome of our consultations with the DTM, HEW, NASA, and the other interested organizations whom we have mentioned. It is contemplated that the earth station installations to be established will be so located that the commercial television networks will find it economically desirable to obtain service through the system.

As a minimum, it is our present view that two earth stations with 85-foot diameter antennas for two-way traffic will be required, one convenient to New York City and one in California. In addition, there would be needed approximately 30 receive-only stations situated in the Pacific and Rocky Mountain time zones. Their locations would make a feasible pattern for commercial networking as well as for non-commercial programming of New York or West Coast origin. One or two additional earth station installations, each with a larger antenna of a diameter of approximately 42 feet, may also prove to be desirable. Comsat is willing to finance and construct all of these facilities, since it is clear that any permanent multi-service system, or separate systems, for domestic services that Congress or the Commission is likely to authorize would have to include at least these stations.

Comsat also would be prepared to furnish one operational satellite of appropriate design, and to utilize a portion of its capacity to provide one channel in each time zone for non-commercial educational television. As we have said, Comsat would do its part to enable such channels -- whether they be used for television, radio or

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data purposes -- to be provided at no charge, as present Commission powers or future legislation may permit. Comsat would also have available an additional satellite as a spare or backup.

It is important to mention that such satellites may be obtained either through the INTELSAT development program or independently, whichever promises to be the more desirable from all points of view. In this respect Comsat has at least as wide a choice of sources and technology for satellite procurement as any other domestic entity. In any event there is no need to await the conclusion of the 1969 Definitive Arrangements for INTELSAT before going forward with a domestic Pilot Demonstration Model. The demonstration model should go forward with expedition, and the facilities in the model can be accommodated to the shape of the domestic service that Congress and the Commission may evolve and of the Definitive Arrangements that the Executive may propose and guide us toward.

We would hope that the details of this demonstration program could be agreed to and authorized with sufficient expedition so that Comsat could initiate actions in the late spring or early summer of this year with respect to the site selection and acquisition and the procurement of major equipment items. When proposals are received and evaluated, Comsat would apply to the Commission for appropriate construction permits.

The important thing, as we see it, is to begin now to take the steps necessary to assure that needed facilities will be available for experiments, demonstrations, and the service we have described. Initiating such steps need not and should not wait until the large issues involved with long-term domestic communications services are definitively settled.

If the Commission should approve Comsat's proposal, as we urge it to do, the greatest care would be taken, and the Commission's regulatory jurisdiction can further assure, that construction of the demonstration model would provide a ground environment that will satisfy several important requirements. It will well serve the President's program for non-commercial television; it will illuminate the broader problems of satellite communications; and it will not prejudice the interest of whoever might be the permanent owner of the facilities. The question

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of what additional facilities may ultimately be required by a long-term plan for commercial operations, either on a dedicated or a multi-service basis, is not a problem which must be resolved at this time.*

Comsat believes that its organization, experience and statutory mission uniquely qualify it to initiate such a Pilot Demonstration Program.

Accordingly, Comsat requests that the Commission adopt a statement of interim policy which approves the foregoing outlines of a Pilot Demonstration Program and calls for appropriate steps toward the development of such a Program. To this end, the Commission may wish to consider the initial step of convening a conference of appropriate interested entities, including the Director of Telecommunications Management, HEW, NASA, the carriers, the networks, the

* The thirty TV receiving stations in the two western time zones could be used in broadcast networks, and the large two-way stations on the east and west coasts would be available for TV or voice/data or both, in any permanent plan. Their uses would equally fit a single multi-service satellite system, or separate dedicated systems.

Ford Foundation and the Carnegie Commission, for the purpose of agreement on earth station requirements and specifications. Subsequent actions of the Commission, directed toward the establishment of a Pilot Demonstration Model, could be initiated on motion of the Commission or pursuant to applications of Comsat or other parties interested in the experiments, demonstrations, and services.

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Excerpts from appendices attached to Comsat's July 26, 1967 amplification of its proposed pilot program

Table I

Characteristics of Earth Segment

Number of Antennas	Type of Antenna	Service	Area Location
4	85-foot	Receive and transmit 12 color TV channels or equivalent message channels or combinations	Los Angeles (2) New York (2)
2	42-foot	Receive and transmit Multi-point message channels Color TV	Northwest Southeast
30*	25/32-foot	**Receive color TV	Pacific Time Zone Mountain Time Zone

Note: All stations can also receive the program audio and other broadcast services (radio, press, etc.).

* Dependent on service requirements of TV broadcasters.

** Design of some of these stations will be such as to incorporate future limited color TV transmit capability.

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DOMESTIC PILOT SYSTEM
Revenue Requirements 1970-1974 Inclusive
(Thousands of Dollars)

	1970	1971	1972	1973	1974	Total 1970-19
Recovery of investment	$ 7,444	$ 7,444	$ 7,444	$ 7,444	$ 7,444	$ 37,22
Operations and maintenance	4,060	4,060	4,060	4,060	4,060	20,30
Return	6,477	5,584	4,691	3,798	2,904	23,45
Income taxes @ 50%	6,477	5,584	4,691	3,798	2,904	23,45
Total Revenue Requirement 1970-1974 incl.	$24,458	$22,672	$20,886	$19,100	$17,312	$104,42

DOMESTIC PILOT SYSTEM
Average Investment and Required Return 1970-1974 Inclusive
(Thousands of Dollars)

	1970	1971	1972	1973	1974
Investment - Space:					
Net Investment - beginning of year	$35,700	$30,090	$24,480	$18,870	$13,260
Recovery of investment	5,610	5,610	5,610	5,610	5,610
Net Investment - end of year	$30,090	$24,480	$18,370	$13,260	$ 7,650
Average net investment - space	$32,895	$27,285	$21,675	$16,065	$10,455
Investment - Ground and Program Mgt.					
Net Investment - beginning of year	$22,000	$20,166	$18,332	$16,498	$14,664
Recovery of investment	1,834	1,834	1,834	1,834	1,834
Net Investment - end of year	$20,166	$18,332	$16,498	$14,664	$12,830
Average net investment - ground and program management	$21,083	$19,249	$17,415	$15,581	$13,747
Total Average net investment	$53,978	$46,534	$39,090	$31,646	$24,202
Required Return @ 12%	$ 6,477	$ 5,584	$ 4,691	$ 3,798	$ 2,904

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DOMESTIC PILOT SYSTEM
Annual Operation and Maintenance Expenses
(Thousands of Dollars)

	Stations	Personnel	Expenses
85-foot stations			
Salaries and station overhead	2	32	$ 560
Utilities and taxes			272
Spare parts			572
			$1,404
42-foot station			
Salaries and station overhead	2	10	$ 175
Utilities and taxes			96
Spare parts			73
			$ 344
25/32-foot stations			
Salaries and station overhead	30	21	$ 368
Utilities and taxes			141
Travel			252
Spare parts			251
			$1,012
Total direct station expense			$2,760
General and administrative expense			1,300
Total			$4,060

Table II

Preliminary Details of Satellite

ITEM	DESCRIPTION
Launch Vehicle Type	Capable of placing approximately 2000 lbs. into a transfer orbit with apogee at synchronous altitude over the equator. Capability comparable to Atlas-Agena or Titan-Agena.
Satellite Position	Approximately 100°W
Satellite Attitude Stabilization	± 0.2°
Station Keeping	± 0.1°
Orbital Inclination	± 0.1°
Power Source	Solar Array Storage batteries to permit operation during eclipse periods
Antenna Coverage	Single beam - Continental United States and portions of Canada and Mexico
Polarization	Circular - Both LH and RH used
Number of Transponders per Satellite	12
Transmit Frequency Range	3700-4200 MHz
Receive Frequency Range	5925-6425 MHz
EIRP per Transponder	37.5 dBW - on axis
Usable RF Bandwidth	35-40 MHz per transponder

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Table III

Preliminary Characteristics

of

Earth Stations

Item	Earth Station Type		
	85-foot	42-foot	25/32-foot
Antenna Tracking	*Automatic Feed Tracking	*No Tracking	*No Tracking
Receive G/T	40.7 dB/°K	29.5 dB/°K	24.5/25.6 dB/°K
Low Noise Receiver	Cooled Parametric Amplifier	Un-cooled Parametric Amplifier	Un-cooled Parametric Amplifier
Receiver Bandwidth	500 Mhz	500 Mhz	500 Mhz
Transmit EIRP			
TV	75.4 dBw	75.4 dBw	--
Message	86.8 dBw (1800 chls/carrier)	71 dBw**	--
Transmit Antenna Gain	61 dB	55 dB	--
Transmit Bandwidth	500 Mhz	500 Mhz	--

*Course angular changes accomplished by pre-set pointing positions.

**Based on the use of TDM (Time Division Multiplex) with 4-phase PSK.

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Table IV

Link Parameters

Parameter	TV		Trunk Message
	Major	Minor	
Up Link - 6 GHz			
Earth Station Antenna Diameter - ft.	85	25	85
(1) Earth Station on Axis EIRP - dBw	75.4	73.4	86.8
Dry Atmosphere Path Loss - dB	199.3	199.3	199.3
Satellite Receive Antenna Beamwidth	U.S. Coverage	U.S. Coverage	U.S. Coverage
Satellite on Axis G/T - dB/°K	-0.5	-0.5	-0.5
Allowed Off Beam Losses - dB	3.0	2.0	3.0
Resulting Up Link C/T - dB/°K	-127.4	-128.4	-116.0
Down Link - 4 GHz			
Satellite Transmit - Antenna Beamwidth	U.S. Coverage	U.S. Coverage	U.S. Coverage
Satellite on Axis EIRP - dBw	37.5	37.5	37.5
Dry Atmosphere Path Loss - dB	196.3	196.3	196.3
Earth Station Antenna Diameter - ft.	85	25	85
Earth Station on Axis G/T - dB/°K	40.7	24.5	40.7
Allowed Off Beam Losses - dB	3.0	2.0	3.0
Resulting Down Link C/T - dB/°K	-121.1	-136.6	-121.1

(1) [illegible] results are obtained for the 32-foot antenna station (G/T = [illegible] allowed off-beam losses of 3.0 dB.

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Table IV (Continued)

Parameter	TV Major	TV Minor	Trunk Message
Overall System			
Up Link C/T - dB/°K	-127.4	-128.4	-116.0
Down Link C/T - dB/°K	-121.1	-136.3	-121.1
(2) System C/T - dB/°K	-120.5	-137.0	-122.3
Number of Satellite Trans/Rec. Beams	1	1	1
Number of Transponders per Satellite (each giving 37.5 dBw)	12	12	12
Usable RF Bandwidth per Transponder MHz	35	35	35
Overall System - TV			
System S/N (Pk-Pk/weighted Noise) - dB	56	56	-
(3) Emphasis and Noise Weighting Advantage - dB	13	13	-
Video Bandwidth - MHz	4.2	4.2	-
Required System C/T - dB/°K	-139.2	-139.2	-
Required RF Bandwidth (Carson) - MHz	32.0	32.0	-
(4) Required RF Bandwidth for Sound - MHz	1.0	1.0	-
Allowance for Spreading - MHz [to comply with (-152 + θ/15) dBw/m^2/4kHz]	1.2	1.2	-
Receive Threshold - dB	10.0	10.0	-
Obtained Dry Atmosphere Margin - dB (With spreading)	14.9	6.4	-
Excess Dry Atmosphere S/N above 56 dB-dB	10.7	2.2	-
Number of TV Channels per Satellite (with above characteristics)	12	12	-

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Table IV (Continued)

Parameter	TV Major	TV Minor	Trunk Message
Overall System - Message			
System S/N (weighted) - dB	-	-	52.5
Pre-emphasis - dB	-	-	3.0
Noise Weighting - dB	-	-	2.5
Peak to RMS Loading - dB	-	-	10
Multichannel Loading	-	-	-15 + 10 log n (n = number of message channels)
(5) Number of Message Channels Obtained (Per Transponder)	-	-	1800
Required RF Bandwidth - MHz	-	-	35
Receiver Threshold - dB	-	-	10
Obtained Dry Atmosphere Margin - dB	-	-	20.9

(1) [illegible] number
(2) [illegible] resulting from system signal distortion has been neglected, since its contribution to these parameters is negligible.
(3) [illegible] weighting of 10 dB has been used.
(4) [illegible] RF carrier for sound has been assumed.
(5) [illegible] message channel denotes a one-way nominally 4 kHz wide channel [illegible] able for voice or record communication.

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Table V

Illustrative Pilot Program
Service Distribution

Quantity Estimate	Use
3 Color TV Channels	Commercial TV (ABC CBS NBC) for Mountain Time Zone
3 Color TV Channels	Commercial TV (ABC CBS NBC) for Pacific Time Zone
1 Color TV Channel	ETV (NET) Mountain Time Zone
1 Color TV Channel	ETV (NET) Pacific Time Zone
3,600 Trunk Voice Channels	Message-Private Line: New York/Los Angeles
800 Multi-point Channels	Message-Private Line: New York/Los Angeles/ Northwest/Southeast
13 Color TV Channels (or equivalent Message - Private Line)	Occasional (Cultural, Instructional, Industrial, Government, Experimental and SNI) and Protection Channels.

Broadcast services (radio, press, etc.) are also included.

APPENDIX D

Excerpts from the Ford Foundation's Reply Comments of December 12, 1966, and Further Comments of September 18, 1967, in FCC Proceeding on the Establishment of Domestic Communications Satellite Facilities by Non-Governmental Entities

(FCC Docket #16495)

FORD FOUNDATION PROPOSAL FOR

A NATIONAL TEST SATELLITE PROGRAM

A number of questions have been raised regarding the feasibility and consequences of the Foundation's proposal and the Comsat Technical Plan.

> The common carriers claim that domestic communication satellites will interfere with terrestrial transmission unless the number of ground stations is small. Our studies, including the IBM study published in Volume III of this Submission, indicate the contrary, but we appreciate the importance of the problem to AT&T and others.
>
> The responsible officials of the FCC, the Office of Telecommunications Management and other government agencies are increasingly concerned by growing demands on the frequency spectrum.
>
> The domestic networks, who will be the primary users of a domestic satellite system, desire reassurance regarding the feasibility and reliability of the switching and interconnection services they will require.

While the Foundation believes it would be in the public interest for the Commission to authorize BNS-type operations without delay, we understand from discussions with the FCC, NASA, OTM, Comsat and others that serious thought is currently being given to the possibility of launching a test satellite. If a test program is undertaken, it should be conducted so as to minimize delay in the establishment of a domestic communications-satellite system.

The Foundation assumes that a test program designed to measure interference within the allocated frequencies, to determine the most efficient use of the frequency spectrum and to test commercial and non-commercial network

operations and instructional television would be administered by the government, in cooperation with private interests. We believe that NASA best satisfies the need for objective, disinterested management. Other federal agencies that would presumably participate in the program include FCC, OTM, HEW, DOD, and the National Bureau of Standards of the Department of Commerce; the private interests include the carriers, the networks, Comsat, the satellite system manufacturers, and the private foundations concerned with non-commercial and instructional broadcasting.

The Foundation is keenly aware of the burden that the management of such a program would impose on NASA. It is outside the scope of NASA's presently planned activities. It might require several years of work. Generous support from the Congress would be vital since substantial funds not otherwise available would be required. Yet the reward would be great. The demonstrated technical and managerial capacity of NASA and its central role in the civilian space program would provide powerful assurances of the validity of the findings, and the involvement of NASA would help dramatize for the nation the enormous benefits that the space program can offer to our children and to ourselves.

NASA could also enable a swifter beginning to be made in demonstrating the potential of non-commercial and instructional television. With the Application Technology Satellites Series (ATS), NASA is already engaged in a testing program. The first spacecraft has just been launched and subsequent launches are called for approximately every six months up to and including a fifth launch. In the ATS Series there are spin-stabilized satellites.

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(ATS-B and ATS-C) which may be free for other test uses by mid-1967. We believe this spacecraft could probably be used for some interference testing and could almost certainly be used for early pilot operations of non-commercial and instructional television through the satellite.*

We understand that there are other advanced ATS programs scheduled for the 1969-1970 time period whose form can probably be modified to accommodate not only their presently planned missions but also the additional measurements required to determine whether the satellite signals will interfere with terrestrial facilities.

The Foundation strongly recommends that existing programs and existing spacecraft be used wherever possible, and modified as required, both for testing and pilot operations.

But interference measurements can begin without the satellite. Mobile vans and aircrafts can be equipped to make measurements around existing torrestrial facilities. A transportable prototype earth terminal can be sited near such facilities. Satellite operations can then be simulated and measured under a wide variety of climatological conditions, and with varying levels of power and techniques for modulation and energy dispersal. Measurements should be made not only of field strengths but also of the subjective effects of interference.

---

* Another alternative might be to modify the existing ATS prototype spacecraft which might further the test program at a lower cost.

If interference measurement and pilot operations cannot ride "piggy back" on an existing program then it may be necessary to undertake the design of a new satellite. Experts consulted by the Foundation recommend a satellite containing 6-8 repeaters each capable of relaying one broadcast quality television channel. Two satellites would be constructed, the second to be launched when use of the first justifies additional capability. If only one satellite functions successfully, it alone would be adequate to complete the necessary testing and to provide a useful degree of networking experience. The signals would be transmitted in two beams, one to the eastern half of the continental United States, and the other to the western half.

Whether the piggy back approach is used or a new satellite design proves necessary, the following ground equipment would be useful for conducting pilot operations:

2 network terminals with transmitting and receiving capability

6 affiliate terminals with transmitting and receiving capability

2 mobile terminals with transmitting capability

18 mobile terminals with receiving capability

20 remote schoolhouse terminals with receiving capability

This ground equipment can be used later for an operational satellite system and thus should <u>not</u> be regarded as a cost of the test program.

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The first three types of terminals would be primarily used by the commercial and non-commercial television networks in the production and distribution of programs, and in testing various network configurations. One of the network or affiliate terminals would be used on a time-shared basis to originate instructional programs. The 18 mobile receiving terminals would be used for instructional television purposes to demonstrate satellite program distribution to non-commercial stations and to classrooms for instructional use. The 20 schoolhouse terminals would be so placed as to evaluate a wide-area operational direct-to-school transmission system.

The network terminals would be located at New York and Los Angeles. The affiliate terminals would be used by the networks to feed established regional microwave networks and to permit insertion of regional commercials. Each terminal would simultaneously serve all networks, including non-commercial stations.

The two mobile transmitting terminals would be used by the networks at points of remote program origination, relaying these programs via the satellite.

As suggested by Hammett and Edison, an instructional television demonstration and evaluation program would occupy one or two satellite channels and would require the 18 mobile receiving terminals and the 20 schoolhouse terminals. Each mobile terminal would be a complete, self-sufficient television demonstration system consisting of an antenna, a

dual-channel receiver, a video distribution system, and approximately 50 color television monitors to be placed in classrooms and auditoriums. Traveling with the terminals would be an operations team consisting of two technicians to install, operate, and maintain the equipment and several trained demonstrators to work with teachers and administrators.

All 20 schoolhouse terminals would be placed at schools in a single geographical region. They would remain there for periods of a year or more, in order to integrate the programs they provide into the school curricula. Access to the available channel or channels could be time shared between state educational entities transmitting programs only to schools in their respective states and a regional body organized to test the feasibility of cooperation on a wider scale.

Directly, or through a corporation formed for the purpose, the Foundation would be prepared, if a test program is undertaken, to consider how it may contribute toward:

Training personnel in non-commercial networking operations through the satellite

Training teachers and educational administrators in the more effective use of instructional television

Making available programs for both non-commercial and instructional television

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TESTS WITHOUT SATELLITES - CATEGORY 1

1.1 Scatter-path Interference Coupling

The mode of interference which appears most likely to limit the usefulness of satellites in domestic communications is the coupling of energy from terrestrial common-carrier microwave transmitters into satellite earth terminal receivers via scattering from weather phenomena, airplanes, etc. in the earth's atmosphere. Studies by Comsat and by IBM, filed previously in this proceeding, have indicated that careful study would be required to locate suitable sites in congested microwave areas, but a system so designed could operate without causing or suffering excessive interference. Preliminary measurements of interference have now been performed by the FCC. Although analysis of the data from these experiments is not yet complete, it appears that questions have been raised that are not adequately answered by present theory, and that mechanisms not considered in the studies may be responsible for interference levels significantly higher than previously predicted.

To provide the factual information necessary, a new test program should be undertaken which is designed to facilitate identification and separation of the effects of different scatterers and propagation modes, to guard against propagation by mechanisms which will not be important to a communications satellite system, to provide data at elevation angles which are more typical of those to be expected in a domestic system, and to obtain data under a wider range of climatological and geographical conditions than is presently available.

An experiment designed to determine the coupling loss as a function of time for nationwide allocation purposes should include measurements made in all of the significant climate types of the United States. An adequate test would include sites on the Eastern Seaboard, the Gulf Coast, the Midwestern Plains, the High Desert, and the Pacific Coast.

The experiment would be designed to measure basic transmission loss of up to 270 db, or approximately 20 db greater than would be of importance to domestic communication satellite systems. Careful planning would be required to permit identification and separation of the various propagation modes, and differentiation between the antenna main- and side-lobe responses.

A single 30-foot diameter receiving antenna, two 6-foot receiving antennas, and four transmitters with 10-foot antennas would be employed for each test unit. The receiving antenna would be located in an excavation designed to suppress reception at elevation angles below approximately 35 degrees so that waves propagated horizontally through the atmosphere, such as by surface ducting, would not lead to erroneous results.

The 30-foot receiving antenna would scan continuously through 360 degrees in azimuth and nod between 35 and 50 degrees in elevation. The two 6-foot antennas would be located at the receiving site to detect surface ducting. They would be oriented in two fixed directions approximately 90 degrees apart in azimuth. Two transmitters would be located in each of the two directions at distances of 100 and 200 miles. Each transmitter unit would consist of a crystal controlled oscillator and 10-watt power amplifier, with a 10-foot dish antenna as described previously. To measure the scattering when the main beams have a common volume, all transmitting antennas would oscillate in synchronism with the rotation of the receiving antenna so as to illuminate common volumes ranging up to 100,000 feet. On alternate scans of the receiving antenna, the transmitting antennas would remain fixed and pointed toward the receiving antenna. This could determine if significant coupling can exist in the absence of a common volume. Equipment at each receiving site would consist of the antennas described above, receivers, and a twelve-channel recorder.

Test locations should be chosen so that a maximum of weather information is available in the test area. It would also be desirable to locate the receiving antenna near a sensitive weather radar in a nearby frequency band so that the monostatic radar returns could be compared with scattering data. The cost for each test unit is estimated to be approximately $140,000. However, with careful design and planning, at least $50,000 of this could be recovered by employing the antennas during later phases of the satellite test program.

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September 18, 1967

Suggested Technical Tests

The Foundation's December 12, 1966, submission proposed a communications satellite test program using existing satellites in NASA's Application Technology Satellites Series and called attention to some tests that could be conducted without using satellites. To determine more precisely what could be learned by such tests, and at what costs and over what period of time, the Foundation sought the expert counsel of the Stanford Research Institute (SRI) and Hammett & Edison.

After careful study, both SRI and Hammett & Edison, acting independently, concluded that there are tests, less expensive and less time-consuming than the Comsat program, that can usefully be undertaken before a full scale program costing tens of millions of dollars is warranted. * For example, one critical question is the extent to which scattering of interfering energy by weather and other phenomena will limit the choice of sites for ground stations. Studies by Comsat and IBM indicated that this was not a serious problem. The results of recent experiments by the FCC raise the opposite possibility. The proposed test outlined at paragraph 1.1 of the Hammett & Edison appendix would explore this question further.

The attached studies by SRI and Hammett & Edison differ in detail and occasionally in approach, but the range of tests they suggest are similar. Other experts who have reviewed their studies at our request share their conclusions.

* In his February message, the President directed the Administrator of NASA to conduct experiments on the requirements of a domestic communications satellite system, in cooperation with other interested Government agencies. We understand that, at the request of the Office of Telecommunications Management, NASA is now preparing a precise engineering study of these experiments; OTM expects to receive the study on or about November 1.

Some of the tests outlined in the two studies can be completed within a year so that the results will be available to the Task Force and the responsible Congressional Committees in the course of their deliberations. Others, although not complete, will provide useful data within that time. Since Comsat's pilot program will not be in operation until after the Task Force reports, it cannot provide data and experience useful in the deliberations of the Task Force.

Although a number of the suggested tests could be undertaken by a Government agency or a private party on its own initiative, there are obvious merits to a coordinated program in which all interested parties participate. It might be useful to bring such parties together for the purpose of developing, executing, and funding a coordinated program of tests. Possible sources of funds include the parties to this proceeding and the research and development budgets of interested Government agencies.

Finally, all agree that conservation of the frequency spectrum is one of the most important goals of communications satellite development. Hammett & Edison have suggested that satellite transmission of television and radio signals in the Television Auxiliary Broadcast Service rather than in the common-carrier bands may relieve the threatened congestion. A brief paper outlining this idea is attached as Appendix C. Opinions to date from both Government sources and private industry suggest that the idea has merit and deserves more intensive study.

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APPENDIX E

SYSTEM MODELS FOR DOMESTIC SATELLITE AND TERRESTRIAL TELEVISION DISTRIBUTION

I. INTRODUCTION

In assessing the desirability of authorizing a satellite system -- pilot or operational -- for providing commercial domestic communications services within the continental United States, one basic concern is the potential economic viability of such a system, vis-a-vis alternative terrestrial systems. To test this viability, a model of one possible fully operational satellite system has been developed, based on what would appear to be the technology available in the 1970-73 time frame and a minimum communications requirement which might be provided by such a system. A complete microwave network capable of providing this identical service was also postulated. Each of these systems was completely priced using data obtained from various equipment manufacturers, Comsat, AT&T, as well as from the FCC filings in Docket 16495. These costs were

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then discounted to determine present value, and adjusted for annual operating and maintenance, to arrive at final figures which could be realistically compared. The results are tabulated in Table 1. The assumptions upon which these models and costs were developed, and the analysis undertaken, are described in the following sections.

II. ASSUMPTIONS - SATELLITE SYSTEM

A. Service Provided

The service requirement assumed is the simultaneous distribution of 48 video programs (12 in each U.S. time zone) to those cities which are termed standard metropolitan statistical areas -- as defined by the U.S. Census Bureau -- or which have a television broadcast station. These 48 video programs are assumed to have originated at, or have been routed through, 4 major locations -- one per time zone -- and to be capable of interconnection in any manner within the space segment; i.e., any program from any of the 4 sources could be directed to any of the 4 time zones, or a single program could be simultaneously directed to any number of time zones. These video programs are assumed to incorporate network distribution (including delayed broadcasts for time zone differences), network splits and

subnetworks, regional (i.e., time zone or smaller) networks, and educational television programs. The total number of channels corresponds approximately to estimates by Comsat and the Ford Foundation for television distribution service in the early 1970's.

The number of individual receiving locations served by this system is assumed to be 250; each location is assumed to require reception of any 6 of the 12 programs beamed into that time zone at a particular time, with flexibility to alter the mix of received programs at will.

The choice of television distribution as the basis for comparison was made for several reasons:

(a) nearly all major respondents to the FCC inquiry (e.g., Comsat, Ford Foundation, AT&T) are in general agreement that major savings in a domestic system would be in the video distribution service, i.e., where one or more wideband signals are delivered simultaneously to a number of receive-only locations;

(b) the absence of switching, networking, or two-way terminal equipment for this type of service rendered it relatively easy to model; this would not hold true for any large-scale telephony service; and

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(c) the differences which now exist among various interests as to the practicality of using the 4 and 6 GHz frequency bands for domestic services do not appear to apply to television distribution -- i.e., wide-area, wide-bandwidth one-way coverage; indeed, there seems fair agreement among all FCC respondents that these bands would continue to serve such needs even if other satellite services were moved to higher-frequency (e.g., above 10 GHz) regions.

B. Satellite Configuration

To meet these service requirements, a satellite configuration has been chosen which represents a domestic variation of the basic INTELSAT IV configuration, with characteristics somewhat intermediate between the configurations proposed by Comsat and the Ford Foundation. Briefly, these characteristics include:

(1) A dual-beam transmitting antenna, each beam covering a single U.S. time zone within its 3 db radiation contours, with the two beams displaced by 1 time zone. Orthogonal polarization of the two antennas or antenna feeds required to achieve dual spectrum use is assumed.

(2) 24 separate transponders per satellite (12 per transmitting antenna beam) each covering a bandwidth of

about 40 MHz maximum and therefore capable of carrying a full video program including audio. These transponders would operate in the 500 MHz spectrum allocation at 4 GHz, which would be used twice in a single satellite by transponders operating through separate antenna beams.

(3) A receiving system capable of accepting a total of 24 video inputs from any combination of earth stations in the 4 time zones and routing each of these video inputs to either one or both of a specified pair of transponders which are each connected to separate transmitting antenna beams. */

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*/ This receiving and routing capability may be achieved in any of several ways, e.g.,
(a) a single, U.S. coverage antenna employing a 1,000 MHz spectrum allocation for uplink operation;
(b) two U.S. coverage antennas each employing separate 500 MHz spectrum allocations (e.g., present spectrum allocations at 6 and 8 GHz, 6 and 7 GHz, 7 and 8 GHz, or broader allocations at 6 GHz alone);
(c) a multiple-beam, time zone coverage antenna employing dual use of the 500 MHz allocated spectrum at 6 GHz and more sophisticated switching within the satellite.
Either of these approaches is technically feasible within the time frame of this analysis; the exact choice will be a matter of comparative economics, spectrum allocations, sharing criteria, etc., which are as yet unresolved. Whatever the choice, it appears to have little impact on satellite system economics.

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The basis for selecting this particular satellite configuration is as follows:

(1) A multiple-beam configuration, capable of using the basic 500 MHz spectrum allocation at 4 GHz twice within the continental U.S., appears technologically feasible within the 1970-75 time frame.

(2) Such a configuration, by providing twice the number of video channels as a full U.S. coverage configuration capable of only a single use of the allocated spectrum should offer appreciable savings in per-channel cost as well as more efficient spectrum use.

(3) Television distribution, in particular, appears to follow a time-zone pattern for both national network programs as well as "regional" programs, sub-networks, etc.

C. Satellite Implementation and Scheduling

This is a very difficult area, and any assumptions are bound to elicit challenges. In order to make reasonable comparisons, it appeared desirable to consider a "system life" essentially equal to the longest-lived major element of each system. As it were, both earth stations and terrestrial microwave facilities are assumed to have useful lives of about 12 years; therefore this was taken as system

life for both. The life of satellites, however, is considerably less well-known than normal electronic systems, and the possibility of either partial or total failure is also relatively unknown, while the impact is potentially great. This leads to several crucial assumptions: (1) the satellite electronics should be fully redundant internally; (2) a "hot spare" satellite should be maintained in orbit as backup to the operational satellites; (3) a considerably shorter lifetime -- e.g., 6 years -- should be assumed for the spacecraft, requiring one replenishment cycle during the 12-year system life; (4) a spare satellite and launch vehicle should be maintained on the ground at all times; and (5) at least 1 launch failure should be assumed during the system life.

We stress these assumptions with regard to the satellites themselves for very good reasons, for a large part of costs in the satellite system which was postulated results from redundant satellite and launch costs. Any significant changes in these assumptions could cause corresponding changes in the systems philosophy and hence in the system cost.

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Basically, the satellite implementation philosophy which emerged was: 3 satellites (2 operational, 1 spare) would be launched initially, with 1 reserve on the ground plus a reserve launch vehicle; by the end of roughly 6 years, one or more of these satellites would have expired or been sufficiently degraded that additional satellites would be required. Over the next 3-4 year period, a total of 3 additional satellites would be launched, gradually replacing all those in orbit. While this would presumably leave 1 satellite spare on the ground, there is some probability that 1 of the 6 previous launches would result in failure, requiring the launch of all 7 by the end of the 10th year. This would leave no spare on the ground during the last 2 years, although a hot spare in orbit would still exist. Presumably, if the system were a continuing one an additional spare would be procured prior to this time. However, this would likely be chargeable to a succeeding time period, reflecting the fact that the 2 operational and 1 hot spare would likely provide some additional service beyond the 12-year limit. The total satellites and launches for a 2-satellite system having a 12-year total system life are thus estimated as 7.

D. Earth Station Configurations

Two earth station configurations were postulated, one for transmit/receive and the other for receive-only operation. Given the high ERP of the assumed satellite resulting from the use of multiple, narrow-beam radiation patterns; and the assumed station-keeping and pointing accuracy of this satellite; it appears that 42' diameter, non-tracking (i.e., re-positionable only) earth station antennas and uncooled parametric receivers would be adequate for the 4 transmit/receive stations. Although some of the satellite configurations postulated are capable of accepting all 48 video inputs from any one or any combination of earth stations, it is assumed that each of the 4 major stations would supply no more than 24 video signals (12 per satellite) through 2 separate antennas.

For the 250 receive-only stations, it was assumed that 25-30' non-tracking antennas and uncooled receivers would be satisfactory; it was further assumed that these could be located either at or within line of sight of the locations served, so that long terrestrial interconnections were not required. Each earth station was assumed to have 100% redundant uncooled parametric amplifiers and 33% redundant

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electronics chains throughout. It was further assumed that, of the 12 programs beamed into each time zone via this satellite configuration, any given receive-only earth station would receive no more than 6, although this may be any 6 and the mix may vary at any time. This reflects the view that most receive-only stations will serve no more than 3 or 4 separate networks at a given time, plus perhaps 1 ETV network plus 1 specialized program (e.g., sports network, ITV, etc.).

III. ASSUMPTIONS -- EQUIVALENT TERRESTRIAL MICROWAVE SYSTEM

For comparison purposes, a terrestrial microwave network model capable of providing the identical service postulated above was prepared. This model network consists of a "backbone" route between Los Angeles, Denver, Chicago, and New York (locations of the 4 transmit/receive stations in the satellite model) which simulates the interconnection possibilities between these points via the satellite; and separate "feeder" or branch routes within each time zone to simulate the distribution capabilities of the satellite within these areas. The main backbone route should contain 48 two-way video channels, representing the maximum interconnection capability of the satellite between these locations;

recognizing it is unlikely that all 48 channels would ever be filled from a single location (e.g., Los Angeles or New York), even though the satellite itself could accommodate such a requirement, we have halved the design capacity of the backbone route, to 24 two-way channels (this is also reflected in the consideration of transmit/receive earth stations as previously noted). Each feeder route would contain 12 one-way video channels, equivalent to the one-way distribution capacity of the satellite system.

TD-2 and TH microwave relay systems were used as a basis for this network, assuming an average tower spacing of 30 surface miles. The total number of route miles required to interconnect the 250 locations chosen was: Feeder routes -- 22,164 miles; main route -- 2,984 miles. A total of 250 terminals (one for each location served) plus 590 repeater stations were required to cover this mileage, based on the actual routes postulated. Of these, 230 terminals have 12-channel, one-way capability; 20 terminals have 24-channel, two-way capability; 510 repeaters have 12-channel, one-way capability; and 80 repeaters have 24-channel, two-way capability.

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IV. Cost Comparisons

A. Satellite System

For the satellite system, cost data was obtained from Comsat, Hughes Aircraft, NASA, and the various FCC filings for a domestic satellite system. These cost data may be summarized as follows:

	Low	High	Assumed
Earth Stations			
30', 6-channel, receive-only	$190K	198K	$200 K
Dual 42', 24-channel, transmit/receive	---	---	$ 2 million
Satellites	Low	High	Assumed
6 satellites (including R&D)	$47.2M	58.4M	$10M/satellite
launches (NASA)	---	---	$13M/satellite

B. Terrestrial System

TD-2 Repeater -- 12-channel, 1-way	$375K
TD-2 Terminal -- 12-chanel, 1-way	150K
TD-2 Repeater -- 12-channel, 2-way	575K
TD-2 Terminal -- 12-channel, 2-way	300K
TH Repeater -- 12-channel, 2-way (added to TD-2 route)	300K
TH Terminal -- 12-channel, 2-way (added to TD-2 route)	300K

COST COMPARISONS ($millions)

Television Distribution--12 channels per time zone to 250 cities, 12-year life

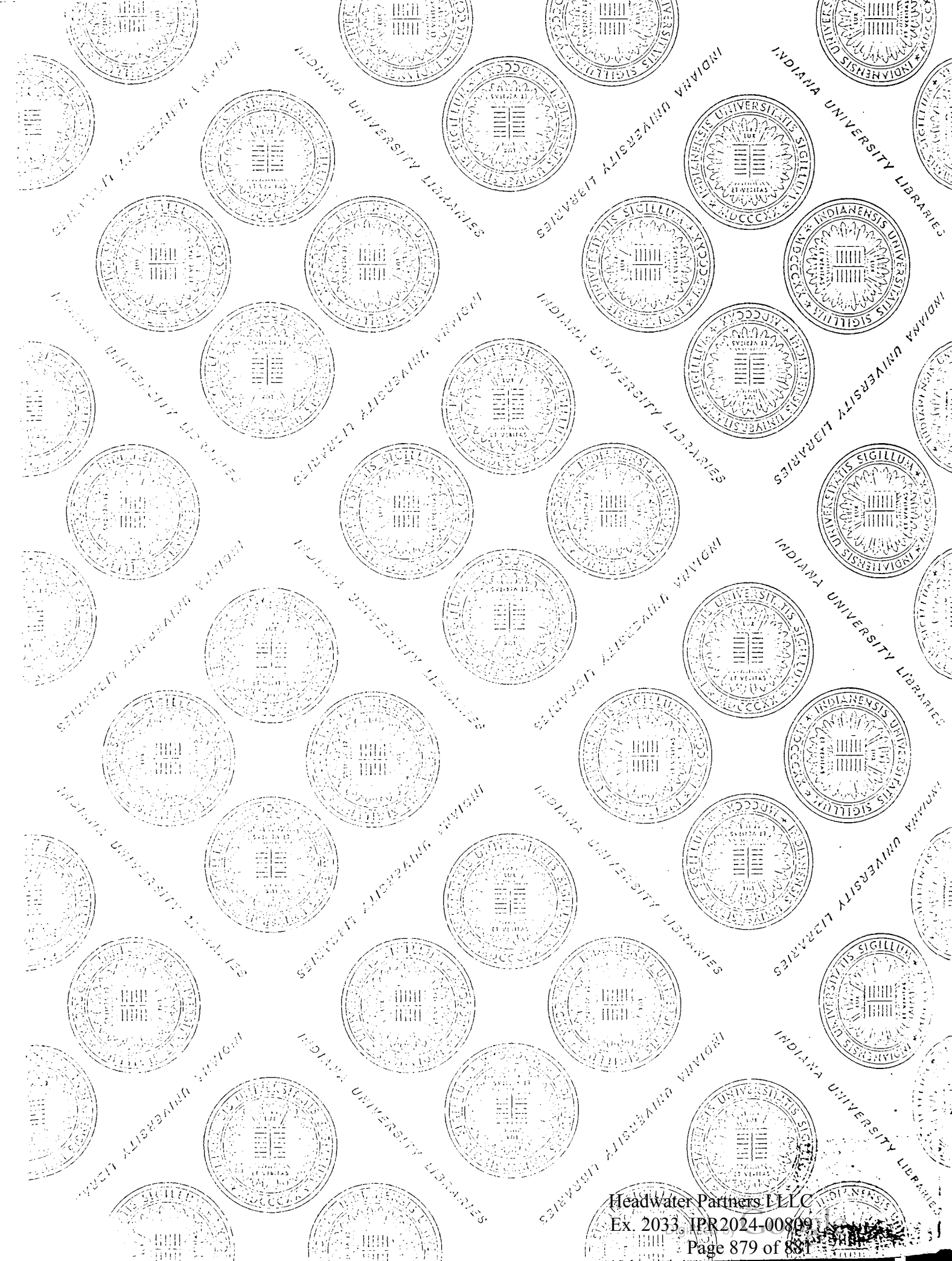
	SATELLITE	TERRESTRIAL MICROWAVE	
		Mix: All-new backbone, incremental feeder routes	New Facilities
INVESTMENT			
7 satellites @10.0	70.0	Terminals: 230 @ .15 20 @ .6	46.5
7 launches @13.0	91.0		
Ground stations 250 receive @ .20 20 transportable transmitters @.25 4 transmit/receive @2.0	50.0 5.0 8.0	Repeaters: 510 @ .375 80 @ .85	259.0
TOTAL INVESTMENT	224.0		305.5
Investment Discounted at 10%	195.0		305.5
Annual Operating Costs (10% of equipment costs)	6.3		20.0
12-year cost	299.6		545.5

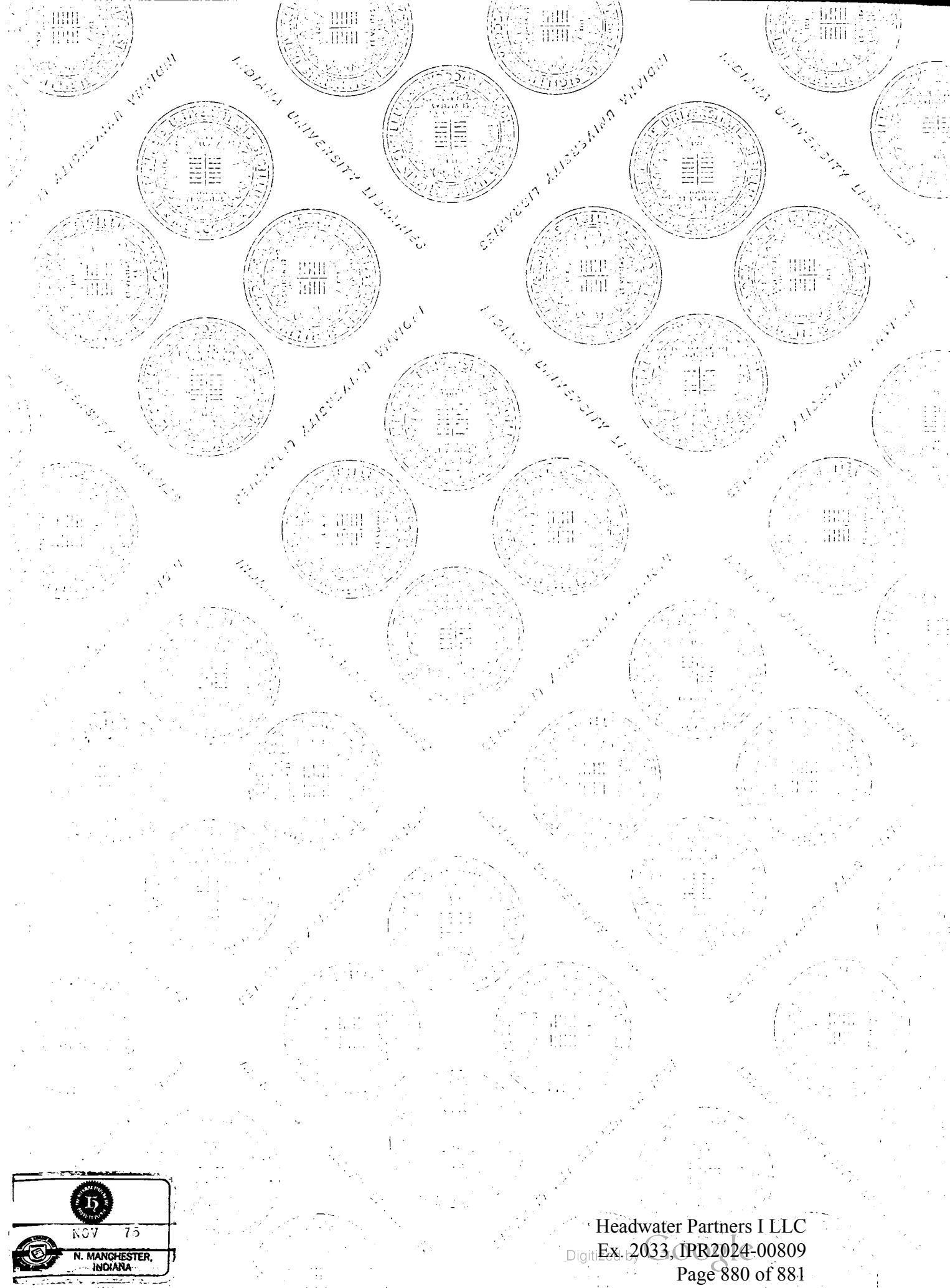
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