

ITS Technology in Automotive -- Who's on First?

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ABSTRACT

This paper examines the status of important ITS technology developments at major automakers and key Tier One suppliers around the world.

Technology topics include navigation, telematics, vehicle dynamics control, parking aids, adaptive cruise control, lane departure warning, active safety systems, predictive safety systems (e.g., braking assist, collision warning, and collision avoidance), and vehicle-to-vehicle and vehicle-to-roadside communications.

Each company's ITS technical acumen is assessed and compared to its competitors. Leaders in each technical area are suggested.

The paper concludes with postulation of important future trends in automotive ITS.

INTRODUCTION

The whole notion of which organizations or firms are ahead or behind in the development and deployment of ITS products and services is almost ludicrous. After all, ITS is supposed to bring on a host of social and economic benefits, not the least of which are reductions in traffic incidents and deaths.

But the world is a competitive place. Each weekend, thousands of young men and women go onto the fields of sport to compete against one another, rack up the highest score and be declared the winner – or in some cases, the champion.

And so it is with ITS. Like any human pursuit, some people are compelled to measure their accomplishments against those of others – in similar agencies or competing companies – to see who is biggest and best.

The auto industry has been highly competitive for over a hundred years, so it is logical – almost predestined – that automakers and suppliers should peer out of their headquarters at one another to try to figure out who has done the most with ITS. Some popular ways to count success around the world's auto industry are (1) the number of new applications of technology or (2) sales

volumes in either units sold or dollars (or yen or euros) of revenue.

We prefer to look at the number of different applications of the various ITS technologies to measure the mettle of automakers and suppliers.

THE FRAMEWORK

To bring some order to the world of automotive ITS applications, we propose the following analytical framework:

	Autonomous	Connected
Driver Assistance	• GPS Navigation • Adaptive Cruise Control • Park Assist • Night Vision (Vision Enhancement)	• Telematics • Emergency Calling (Collision Notification) • Vehicle Infrastructure Integration – With Other Drivers – With Infrastructure
Vehicle and Traffic Safety	• Lane/Road Departure Warning • Lane Keeping • Sensor Fusion (enabler) • Blind Spot Monitor (Lane Change Assistance) • Pre-Collision Protection (Forward Collision Warning/Assistance) • Rear Impact Warning • Rear View Television/Obstacle Detection • Peripheral Monitoring • Drowsy Driver Warning	• Intelligent Speed Adaption • Intersection Collision Warning

Figure 1. Analytical Framework

These technology applications and their allocation around the “picture frame” are certainly open to debate. Others will have other frameworks that better suit their respective arguments.

For this analysis the areas of discrimination are (1) use – to aid the driver or to promote safety – and (2) whether the applications stand alone or need to be connected to some infrastructure off the vehicle in order to deliver the expected benefits.

There are several technology applications that have not been included here – electronic stability control and rollover warning or protection, for example. While these applications certainly provide new levels of safety enhancement they represent improvements in vehicle dynamics control rather than in ITS¹ functionality.

GPS NAVIGATION

Over the last fifteen years, on-board vehicle navigation using GPS as the main positioning engine has become essentially ubiquitous in the major auto consuming countries. As China becomes an automotive power, it too is reaching out to GPS navigation as an essential capability for commercial, government and private drivers.

Offering on-board navigation is more a marketing choice for an automaker than a matter of technical capability. Numerous navigation systems – including very capable GPS engines and highly developed routing algorithms – are available from Tier One and Tier Two automotive suppliers (mainly Japanese and European). Excellent maps can be had from American², European and Japanese digital geographic information firms.

Navigation systems are universally available in Japan in both premium and everyday automotive brands. Virtually all European premium and many mainstream cars also have navigation systems available. Many are optional extras although there are others installed as standard. Navigation systems are just starting to catch on with American automakers – Chrysler Group, Ford and General Motors all offer navigation system options on some of their cars and light trucks.

ADAPTIVE CRUISE CONTROL

Adaptive Cruise Control³, or ACC, is the “killer app” for ITS in this decade not only for its own capabilities but also for the other ITS applications that its radar is spawning – pre-collision warning and blind-spot monitoring, to name only two.

ACC uses radar – either microwave or laser (each has its own operational strengths and weaknesses) – to (1) locate a vehicle in the lane ahead, (2) determine the “target” vehicle’s distance from our “own” vehicle, and (3) calculate the relative speed between one’s own and the target vehicle. These last two dimensions are sometimes referred to as “range” and range-rate.”

There are those who would argue that ACC is a safety system and thus belongs in that “pane” of the analytical framework “window.” That notion certainly has merit. We chose the driver assist window because of the way ACC is marketed by automakers. They prefer to position ACC as a driver aid in order to avoid potential tort liability from offering a forward-collision-warning system – the promise might be greater than the deliverable.

Although Mercedes made the first offer of ACC to the retail automotive market in Europe in 1999, in fact Jaguar made the first retail delivery of ACC about a month before Mercedes.

In only a few short years ACC has expanded worldwide with offerings on numerous cars and some SUVs in Europe, America and Japan. Virtually all European auto brands offer ACC, mostly on their premium models. Japanese brands offering ACC include Daihatsu, Nissan (including Infiniti), and Toyota (including Lexus). Cadillac is the only Big Three brand to offer ACC – it’s a Delphi design based on a Raytheon sensor.

Numerous Tier One suppliers offer turnkey ACC systems including Continental Automotive Systems, Delphi Automotive, Denso, Hitachi, Siemens VDO Automotive, TRW and Valeo (this is only a partial list of ACC suppliers).

Second-generation ACC systems have just come to market. These new embodiments are termed “full-authority” – they operate all the way from highway speeds down to a complete stop. Gen I ACC systems cut out at around 20-30 km/h. The first of these is offered by Mercedes on its 2005 S Class – Continental is the supplier. Several other Tier One suppliers have Gen II ACC systems developed and ready for sale to automakers.

PARK ASSIST

Ultrasonic park assist is a relatively old technology application. Japanese suppliers were “shopping” ultrasonic park assist systems in America in the mid-1970s. First applied to vehicle rear bumpers to mitigate the occurrence of low-speed contact with objects and other vehicles, park assist has quickly moved to front bumpers for added protection in highly styled vehicles where the front edge may not be easily apparent to the driver.

Park assist can be found on almost all vehicle brands around the world, in all major markets. This is another example of marketing decisions setting the automotive product application limits. The technology is in place and well-proven.

There have been some applications of radar to park assist. This is a higher cost approach than ultrasonics for close-distance protection, but some applications use radar to reach an additional several meters back of the vehicle to give earlier identification of potential obstacles. Visteon and some others have fielded this.

Park assist has not been promoted as a safety device by automakers. It has only been implied that pedestrians or small children would benefit from early detection by a slowly backing vehicle. Suppliers have been more aggressive in this regard than have automakers – tort concerns again.

Denso and Toyota were among the first automotive companies to work on “total parking space definition” using several sensors to determine the length and depth of a parking space, then offering guidance to help the driver park in the space safely. Other suppliers, notably

Aisin AW and Continental, have developed systems that will use the parking space data to steer a vehicle into a parking space – the driver still controls accelerator and brakes.

Aisin's Intelligent Parking Assist was jointly developed with Toyota, and helps the driver in all reversing parking operations. By establishing the target parking position, the vehicle's parking movements are accomplished with automatic steering.

The driver need only control the speed of the vehicle. In the Toyota Prius adaptation, this means operating only the brake.

Volkswagen showed a fully automated parking concept vehicle several years ago, but it used an impossibly expensive 360-degree array of radar and ultrasonic sensors as well as a large computer to work the algorithms.

NIGHT VISION

Night vision and vision enhancement technologies have been under development since the late 1980s – several research applications were demonstrated in 1994 as part of Europe's PROMETHEUS program.

Night Vision was #2 on JD Powers' consumer research list of emerging technologies – until price was mentioned. At \$1,500, it dropped to #17.

There are two technical approaches to night vision, one using the far infrared spectrum (FIR) and another using near infrared frequencies (NIR).

Numerous suppliers have developed night vision systems. Among them are Siemens VDO, ITT, Delphi (using Raytheon technology), Autoliv (for BMW) and Robert Bosch.

General Motors was the first automaker in the world to offer night vision (FIR) as a regular production option (on some 2000 model year Cadillacs). Although the first-year take rate approached 20% for the \$2,250 option, the rate quickly dropped to 2% when it stayed stubbornly stuck. GM dropped night vision from the Cadillac DTS concluding that a business case could not be realized. The system Raytheon developed for Cadillac used an Uncooled Focal Point Array that works well at 72°F. Raytheon used a \$20 part to keep the temperature of the array stable, heating or cooling it as necessary.

Toyota has had similar experience with night vision on Lexus, where the percentage of high-end LX470 models shipped with the \$1,750 NIR option has dropped from a peak of 26% a few months ago to just 5% recently⁴.

Honda has developed what it calls the "world's first Intelligent Night Vision System" which is targeted to

reduce night-time pedestrian casualties. The system is available on the Japanese home market Honda Legend.

Honda uses FIR cameras to detect pedestrians in or approaching the vehicle's path and provides the driver with visual and audible warnings. The Intelligent Night Vision System uses images obtained from two far infrared cameras positioned in the lower section of the front bumper to detect the position and movement of heat-emitting objects and determine whether they are in or approaching the vehicle's path. Based on object's size and shape, the algorithms determine if it is a pedestrian.

The latest automakers to jump into the night vision pool are BMW (NIR) and Mercedes (FIR). Shown on the 7 Series and S Class, respectively, the systems are expected to retail in Europe for more than €2,000.

While it is arguable that night vision could be the "next big thing" in automotive features, the price will have to come down by at least half to get to the mainstream kinds of volumes that suppliers and automakers need to fulfill a sustaining business case.

LANE AND ROAD DEPARTURE WARNING

The US National Highway Traffic Safety Administration says single vehicle road departure crashes represent the most serious type of crash on national highways. There were 927,000 single vehicle off-roadway crashes in 2002 and 12,360 of them resulted in fatalities. There are many different causes of these types of crashes, including weather and vision problems, driver impairment, inattention and improper driving behaviors. Roadway departure systems alert drivers when they are drifting out of their lanes and off the roadway – and when they are approaching an upcoming curve at excessive speed⁵.

The first, and so far only, commercially available lane departure warning system has been offered by Iteris for commercial vehicles, and via a licensing agreement with Valeo for light vehicles.

The Valeo system installed on Infiniti products (FX, M and Q45 models) recognizes lane markings through the use of a small camera mounted behind the rearview mirror. The camera's signal and the vehicle's speed are sent to the system's microprocessor which combines the information to calculate both the distance between the vehicle and the lane marking and the lateral velocity to the lane marking. If it is determined that the vehicle is leaving the lane, a combination of visual and audible warnings are given. In some embodiments the car's braking systems are activated to help return the vehicle to its original lane.

The Infiniti LDW system is temporarily disabled by driver activation of the vehicle's turn signals, which informs the system's control unit of intended lane changes. The system also features a manual cancel switch, which

allows the driver to turn the system off when desired. The system automatically resets when the vehicle is restarted.

On the 2005 Infiniti FX 35, lane departure warning was offered as part of the DVD Mobile Entertainment System with Lane Departure Warning option package priced at \$1,750. LDW likely represents only a small fraction of the total package price.

Aisin's Lane Departure Warning System, jointly developed with Toyota, also measures the distance between a car and the white or yellow lane line but with a rear-mounted camera (which is also used by the parking assist system), and alerts the driver with an audible beep if the vehicle is about to cross a highway lane.

LANE KEEPING

Lane keeping is the next big step beyond lane departure warning. Here an electronic "big brother" applies a corrective torque to the vehicle's steering system to bring the car or truck back to the correct driving line automatically.

While no automaker has put a lane keeping system into regular production, there are numerous development programs underway at automaker and supplier laboratories.

One typical lane keeping system is being developed by Continental Automotive Systems. Like lane departure warning, lane keeping determines the vehicle position relative to the lane markings, but offers active support in keeping the vehicle centered on the lane. The driver always retains control – he or she can feel the recommended steering reaction as a gentle movement of the steering wheel, but his or her decision to act or not takes priority.

Mazda's Lane Drive Aid System automatically determines the vehicle's lateral position using a camera and provides steering assistance that helps the driver keep the vehicle in the middle of the lane. When the system judges that the vehicle is in danger of drifting out of the lane, it issues a warning.

Further, the system uses radar sensors on either side of the vehicle to monitor adjacent lanes alongside and aft of the vehicle. If the driver starts to move into a lane without realizing that a vehicle is there, the system issues a Blind Spot Warning.

Mitsubishi's Lane Trace Assist uses an on-board camera to monitor the lane dividing lines and applies a corrective torque to the electric power steering when it senses the vehicle is starting to depart from its lane.

The Lane Keeping Assistance on Toyota's Estima HEV uses electric power steering guided by a video camera

that monitors lane markers to assist steering to help keep the vehicle in the intended lane. The system constantly applies the small amount of steering effort required to keep the vehicle near the center of its lane.

SENSOR FUSION

We must take a short detour – a digression – here to talk about sensor fusion. The foregoing discussion of various driver assistance systems has covered applications based on single sensor inputs. While this is the current state of the art, we would be remiss if we didn't say something about the next generation of ITS vehicle sensors with will feature combinations of sensors working like partners to deliver richer arrays of data that drivers and their support systems need.

Denso, for one, has developed additional sensors that detect road conditions and objects ahead of a vehicle. Denso's lidar sensor (laser radar) or millimeter-wave radar sensor is used with Adaptive Cruise Control systems. The millimeter-wave radar sensor is also used in the Pre-Crash Safety Systems, which can help lessen damage in an imminent collision. A vision sensor is used in the Lane Keeping Assist system that helps the driver stay in the center of a lane.

By combining multiple sensors into a single system, more highly accurate safety systems can be created. Combining a millimeter-wave radar sensor and a vision sensor, a sensing system that recognizes the shape, size and type of object can be developed. The radar sensor detects the position and relative velocity of the object, while the vision sensor detects the type and attributes of the object.

As a result, it is possible to accurately identify the positional relationship between the object and the vehicle, as well as the object's relative movement, leading to a safety system that is better tailored to each situation.

As part of the effort to realize even more advanced safety systems, Denso is developing vision processing technology that allows the detection of pedestrians from among multiple objects.

BLIND SPOT MONITORING

Also known as lane change assistance, the goal of the blind spot monitor is to keep a driver from changing lanes when there is another vehicle aft of and to the side of one's own vehicle. This is another PROMETHEUS development that is finally "coming home."

Modern blind spot monitors use radar (some microwave, although laser seems to be increasing in popularity with developers) to look in an area in about a 90 degree arc at each rear corner of a vehicle. If the directional signal is activated, the corresponding radar looks into its

assigned area and returns a warning if there is a vehicle in the "blind spot."

Some designs put the sensor in the outside rearview mirrors. This allows for a narrower arc, but increases range requirements. This mounting alternative does give a view into more of the real "blind spot" – the area behind the driver's peripheral vision but ahead of the outside mirror's field of view.

Hella and Siemens VDO, for example, have designed a corner-mounted sensor system, while Mobileye, an Israeli company, has developed a system with the outside mirror mounting position.

Mercedes is evaluating another route with its exterior monitoring system. Cameras integrated into the housings of the outside rearview mirrors monitor traffic to the side of and behind the vehicle when it is parked. If another car or a bicycle is approaching from behind, the system will automatically disable the doors for a brief period to avoid the risk of a collision when they are opened. A warning signal sounds at the same time accompanied by a red danger symbol that illuminates in the mirror glass.

PRE-COLLISION PROTECTION

Current pre-collision warning systems are tied into adaptive cruise control, using the ACC's forward-looking radar to detect potential collision "targets" ahead of one's own vehicle. Typically these systems take several actions to prepare for the potential collision:

- Adjust the seat back angles of the front seats (and in some cases the rear seats) to an angle best suited for "taking" the potential collision,
- Tighten the seat belts,
- Alert the air bags to be prepared to be quickly deployed in the event of a crash, and
- Pre-load the Brake Assist system, if present, so that the brakes can be applied by the driver with maximum force.

Toyota claims to be the first automaker to have developed a radar-based collision safety system – it came out with its Pre-crash Safety System in February 2003. The system uses millimeter-wave radar and a camera to detect other vehicles and obstacles on the road ahead and warns the driver when a collision is imminent. In August 2003, Toyota added Pre-crash Brakes to the system that applies the brakes when the driver fails to react in time. In July 2004, it adopted an "image fusion" method, which adds camera-gained image information to information obtained by millimeter-wave radar. Toyota has further advanced its Pre-crash Safety System by adding a feature that monitors the

driver's alertness to determine if he or she is looking straight ahead.

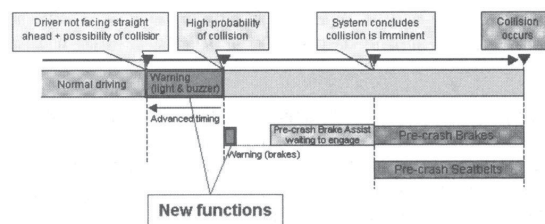


Figure 2. Toyota Pre-Crash Safety System Operation

Honda announced in May 2003 that it had developed the world's first Collision Mitigation Brake System (CMS), which predicts longitudinal collisions and assists brake operation to reduce impact on occupants and vehicle damage. This system determines the likelihood of a collision based on driving conditions, distance to the vehicle ahead, and relative speeds, and uses visual and audio warnings to prompt the driver to take preventive action. It can also initiate braking to reduce the vehicle's speed.

Mercedes' PRE-SAFE system was first announced in Europe in 2001 and came to market in 2003. Initially only adjusting the seat angles and closing the sunroof, the system was quickly expanded to include all the other functions now considered to be part of any pre-crash system.

The evolution of many of these sensor-based detection systems is toward fully automatic collision avoidance and mitigation systems.

REAR IMPACT WARNING AND PROTECTION

As has been demonstrated in the foregoing discussion, most of the attention in longitudinal car-to-car collisions has been on warning the following driver and activating protection systems in his or her vehicle.

While a number of companies have been designing sensor and activator packages to help the occupants of the leading vehicle, Mazda has been the most communicative about its developments via its SensorCar development concept.

Two optical sensors (charge coupled devices or CCDs – really small TV cameras) mounted 2.5 inches apart in the SensorCar's rear bumper monitor surrounding vehicle traffic. The CCD units send their data to a dedicated computer that compares distance, approach angles and closing rates of the other vehicles to determine whether any of them is about to collide with the SensorCar.

If the system determines that a significant rear impact is probable – contact at a closing rate of 6 mph or greater – it sounds an audible alarm from the rear audio

speakers and illuminates a warning icon to call attention to the danger.

If the approaching vehicle speed indicates that a collision is imminent, a motorized retractor tightens the front seat belts.

Mazda's rear-impact warning system needs further development and refinement to assure that it screens out all false alarms and detects all potential impacts. Once refined, it could be tied into multiple active safety systems to protect vehicle occupants or avoid accidents entirely.

REAR VIEW TELEVISION

Although closely allied with ultrasonic park assist, rear view TV provides sufficiently more information and lets the driver actually see what objects might pose a danger, or be in danger, when a vehicle is backing. Thus it has been classified as a safety system in this paper.

Rear view TV had its genesis in Japan almost a decade ago – a logical combination of Japanese expertise in making small, rugged television systems with the shared display (for navigation and convenience systems) that had previously taken up residence in the upper center part of the instrument panel. The TV camera is activated when the vehicle is shifted into reverse gear. Nissan, Toyota and Honda quickly jumped on the bandwagon.

Nissan (through its Infiniti brand) was the first Japanese company to bring rear view TV to Western markets. Toyota (through its Lexus channel) and Honda also offer the systems in North America.

The cameras are usually part of a package with other options putting total package prices in the \$2,000 to \$4,000 range. The Big Three are starting to catch up. A rear view camera system will show up as a regular production option on GM's new 2007 full-size SUVs.

Many Japanese consumer electronics firms offer rear view TV systems in the aftermarket, a trend that is spreading to North America as well. Aftermarket systems are priced between \$300 and \$700 plus installation.

PERIPHERAL MONITORING

Many automakers are looking at ways to combine the outputs of sensors looking forward, backward and to the sides into a comprehensive system that monitor all around the periphery of the vehicle – hence, the term “peripheral monitoring.”

Nissan's Around View Monitor substantially reduces blind spots by displaying a 360-degree view of the area around the vehicle on an instrument panel monitor. The

easy-to-understand images displayed in real time are helpful in supporting the driver's maneuvers when parking, by assisting the driver in steering the vehicle easily and accurately into the intended parking space. The system is a further advancement of Nissan's Rear View Monitor, Blind Spot Monitor and Lane Departure Warning applications.

Toyota and Mazda are also experimenting with peripheral monitoring. Image-processing technology enables their systems to detect and warn the driver about children and obstacles within the vehicle's blind spots and to detect and warn the driver about vehicles that are approaching from either side.

Subaru has been researching for at least a decade the use of binocular vision systems for hazard detection and monitoring. Subaru's “eyes” are its frontal recognition sensors, which are adapted from Subaru's Sensor Fusion technology in its Active Driving Assist system. It includes a pair of stereo cameras, as well as a millimeter-wave radar unit from the Legacy Touring Wagon 3.0R.

The stereo camera has been improved as have its recognition algorithms. Processing speed has been accelerated in the new stereo cameras and recognition has been enhanced. In addition, the camera unit and its controller are now packaged together in one module to be more compact and lower cost.

The new stereo camera device can not only detect multiple objects (cars, pedestrians, bicycles), road traffic lines, and conditions (climate changes, light changes, and other conditions), but it also calculates the distance between the car and an object (even at night) as well as the inter-vehicle speed.

DROWSY DRIVER WARNING

Considering the number of traffic incidents and injuries that can be ascribed to driver inattention and drowsiness, it is amazing to see how long it has taken technological solutions to come to fore.

Drowsy driver detection is another of those PROMETHEUS technologies that was demonstrated in vehicles in the mid-1990s. Early systems tried to use changes in the steering wheel reversal rate to predict when a driver was tired (tired drivers correct less often), but these were unable to avoid a high rate of false positive indications (drowsiness was indicated even though the driver was actually alert).

Later experiments tried video detection, using small TV cameras to watch the driver's face the check the location of certain facial features, such as the outboard edges of the eyes and mouth, or eye blink duration and frequency. This technology has continued in development. In the US, Carnegie Mellon University has done extensive work in this area.

The Johns Hopkins University has done work using a 24-GHz transceiver both to illuminate the head and upper torso of the driver. The technique monitors and quantitatively measures several indices, such as the general activity level, the speed, frequency and duration of eyelid closure, the rate of heartbeat and respiration, by analyzing the Doppler components present in the reflected signal.

A drowsy index is calculated based on general activity. As fatigue sets in, this activity will drop below a certain level. A warning can be given at this time notifying the person that he or she is becoming sleepy.

A supplemental index monitors the eye activity for changes associated with increased levels of drowsiness and for eye closure. This second index allows for warnings of increasing intensity as the onset of sleep occurs.

Toyota's Pre-Crash Safety System, discussed earlier, comes closest to using sensors to check driver condition, even if Toyota's system determines only head position, not sleepiness or other inattention.

Watching the driver – to detect drowsiness or operation under the influence – is an increasingly popular topic with law enforcement, regulators and automakers because the inattentive or impaired driver is the cause of a large fraction of injury and fatal auto crashes in all developed countries.

Denso is among the leaders among Japanese suppliers for its work on technology that will detect the driver's condition, such as facial recognition, blink and closed eyes detection, and electrocardiograph measurement. Facial recognition identifies an individual by taking a picture with a camera and processing the image.

Blink and closed eyes detection applies different processing to images taken of the driver in order to measure eyelid aperture and detect any lack of attention from sleepiness.

Electrocardiograph measurement is not as far along as the driver monitoring technique, but is envisioned to measure the driver's heart rate through electrodes installed in the steering wheel, then display results on the car navigation monitor or transmit them to an external location such as a physician or family member.

Let's change focus now from autonomous systems to the "connected systems", those that need some electronic link to the roadside or other infrastructure to operate.

TELEMATICS

The telematics industry in Japan is dominated by Toyota and its G-Book, just as General Motors's OnStar dominates in the US.

Toyota recently initiated G-BOOK ALPHA, a more advanced telematics service that consolidates "safety and security", "driving intelligence" and "amusement".

In the event of a traffic accident or medical emergency, the HELPNET service (standard feature) connects users to a dedicated operator and enables summoning of ambulance or other assistance with an onboard microphone. Some new Toyota models come with a system that automatically connects to the operator if the air bags are activated. If there is no response from inside the vehicle, the operator will call for an ambulance.

Optional (e.g., Lexus) G-Security detects breaking into vehicles and tracks vehicle position. For "driving intelligence", the G-BOOK ALPHA service is equipped with a new "G-Route Search" function that combines traffic information from the Vehicle Information and Communication System (VICS) with past statistical data to forecast road traffic conditions and suggest routes that avoid traffic congestion.

The "amusement" area includes Toyota's on-demand car audio system. When vehicles are shipped, encrypted data for more than 10,000 songs are made available on the navigation system's hard drive with a digital rights management system. The customer can then download and purchase a decryption key from a network for the musical pieces that he or she wants to enjoy.

Mazda recently adopted Toyota's G-BOOK ALPHA after its own attempt at offering proprietary telematics failed.

Nissan continues to offer its own Telematics system. CARWINGS provides a host of helpful services such as fastest route calculations based on statistical traffic data, real-time traffic updates, weather reports and news. The system supports e-mail notification of the driver's present location, live operator assistance for destination searches and navigation system questions and emergency roadside assistance services, among other services. The current CARWINGS system also provides seamless communication through the use of a Bluetooth-enabled mobile phone.

EMERGENCY CALLING

Also known as Automatic Collision Notification, this is probably one of the most sought-after features from modern telematics systems – the ability to have an on-board mobile phone automatically call emergency services in cases when an air bag deploys.

General Motors added this feature to its OnStar system, receiving wide acclaim from traffic safety professionals and the car and light truck-buying public. GM has, of course, already installed its call centers in North America to handle "ACN" and other calls (but has closed the one center it had previously opened in Europe),

The European Commission has made “eCall” a priority application in its vast new “eSafety” program. In the European vision, eCall is an emergency call either generated manually by vehicle occupants or automatically via activation of in-vehicle sensors when an accident occurs. When activated, the in-vehicle eCall system establishes a voice connection directly with the relevant Public Service Answering Point which is a public authority or a private eCall center. At the same time, a minimum set of data – including key information about the accident such as time, location and vehicle description – is sent to the Public Service Answering Point operator receiving the voice call. The minimum set of data may also contain the link to a potential Service Provider by including its IP address and phone number⁷.

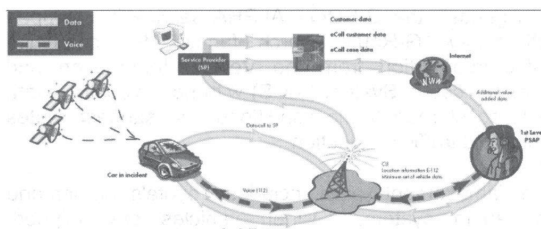


Figure 3. European eCall Network Operation

Mercedes launched its own call-center-based telematics system – TELEAID – which is capable of receiving eCall alerts from vehicles and relaying emergency requests to the appropriate public agencies. Fiat also operates a small telematics call center for its customers in Italy.

Japan has had a more unified approach to emergency calling. The Japanese police have been promoting the Universal Traffic Management Systems (UTMS). The Help System for Emergency Life Saving and Public Safety (HELP) is one of subsystems of UTMS.

Emergency calls from mobile phones have been increasing very rapidly in Japan with the expanding use of mobile phones, and account for more than half the total number of emergency calls. It is difficult to identify the location of a caller and this can delay an emergency vehicle's arrival.

In the HELP system, when an incident occurs while driving, an in-vehicle unit and a cellular phone automatically transmit caller location information obtained from GPS to the operation center, and then automatically activates voice communication.

HELP reduces the time lag from occurrence to reporting of an accident by 40% (from 15 minutes to 9 minutes). All command and control centers of prefectural police headquarters in Japan are equipped to receive location and other information obtained from the HELPNET center. HELP is available everywhere in Japan.

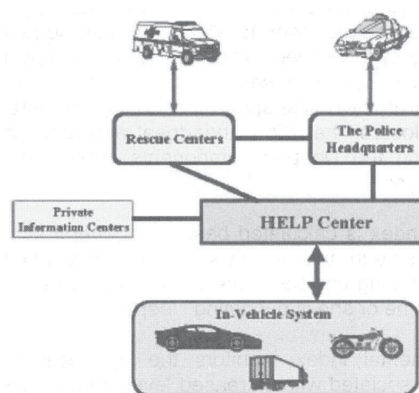


Figure 4. Japanese HELP Emergency Calling System

In order to further improve HELP, automakers in Japan are being encouraged to provide in-vehicle units equipped with the HELP system in all new cars⁸.

VEHICLE INFRASTRUCTURE INTEGRATION

VII is a brave (and bold) comprehensive initiative to connect all the cars in the United States with each other and with the roadside (and thus a variety of incident management and emergency services).

The notion behind VII is fairly simple. If vehicles (or their drivers) can be made aware of the intentions of other vehicles (and their drivers) it may be possible to keep these vehicles from running into each other and thus reduce (or eliminate) traffic incidents and the resultant injuries and deaths. Similarly, if vehicles can communicate in real-time with the roadside infrastructure a variety of safety, emergency and convenience features can be made available to the driver and vehicle passengers.

The VII initiative enjoys support from US federal government, a number of trade and research groups, and the principal automakers doing business in North America (both traditional and “new” domestic manufacturers).

Current efforts are focused on determining if the investment necessary to equip new vehicles and the roadway infrastructure with communications is warranted and can be synchronized between the public and private sectors. Studies are underway to achieve at least proof-of-concept for the technology and to develop business cases sufficient to convince public and private sector leaders to invest.

A project to make VII ubiquitous across the United States is probably of greater magnitude than the construction of the Eisenhower Interstate Highway System. No one knows for sure what the total investment would be in a comprehensive network of

roadside units that would communicate with and relay messages to vehicles moving on the road. The computer network to process in real time the millions of asynchronous communications between vehicles and infrastructure has yet to be defined.

Nor has anyone figured out how the more than 3,000 road agencies in the US will be convinced to install and operate the roadside units. Perhaps there is a private sector role here.

A similar idea is being pursued in Europe by the Car2Car Consortium among others. The Car2Car Communication Consortium was organized by European vehicle manufacturers and is open to suppliers, researchers and other partners. The Car2Car Communication Consortium wants to improve traffic safety and efficiency by means of inter-vehicle communications.

The Car2Car Consortium hopes to establish an open European industry standard for Car2Car communication systems based on wireless LAN components and to guarantee European-wide inter-vehicle operability. The development of active safety applications is being promoted through the specification, prototyping and demonstration of the Car2Car system. The Consortium also plans to develop realistic deployment strategies and business models to speed-up market penetration.

The radio system for Car2Car is derived from the standard IEEE 802.11 (Wireless LAN). As soon as two or more vehicles are in radio communication range, they connect automatically and establish an ad hoc network. The range of a single Wireless LAN link is limited to a few hundred meters, so every vehicle is also a router that allows sending messages to farther vehicles via multi-hop. The routing algorithm is based on the position of the vehicles and is able to handle fast changes of the ad hoc network topology⁹.

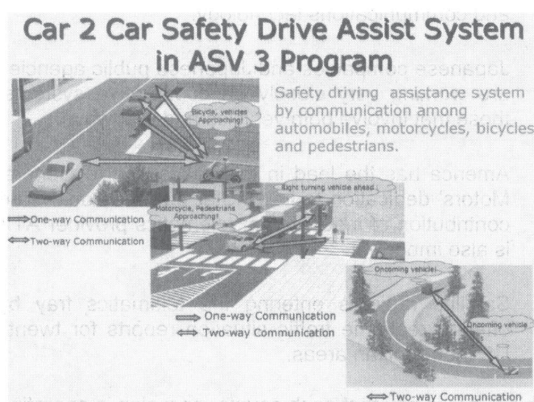


Figure 5. Vision of Car-to-Car Communication in Japan

Japan has integrated the notion of vehicle-to-vehicle and vehicle-to-roadside communication into its Advanced Safety Vehicle program. ASV-3 (the third ASV program)

is reaching its conclusion. Demonstrations of the various architectures and technologies are on-going in 2006¹⁰.

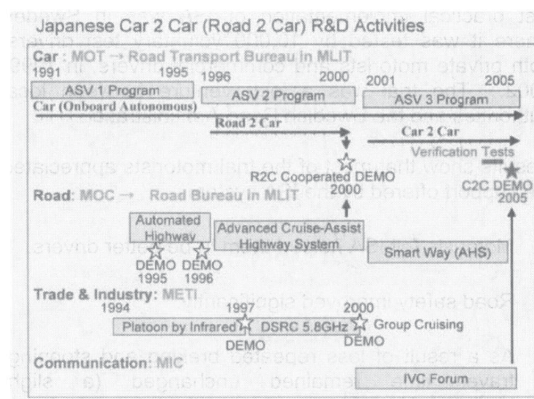
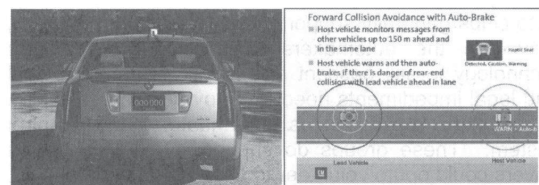


Figure 6. Japanese Car-to-Car R&D Activities

General Motors (Cadillac) and BMW recently demonstrated vehicle-to-vehicle (V2V) communications without benefit of any external communications infrastructure. These respective manufacturers' research cars talked to one-another via an 802.11p WLAN operating in the 5.9 GHz band. Vital information about vehicle location, status (e.g., stopped) and the nearby surroundings (e.g., its raining) were transmitted back to following vehicles so their drivers could take appropriate action. Vehicle location was by GPS, but relative (car-to-car) rather than absolute (on the surface of the planet), so relative positioning error was about one foot.



GM equipped one Cadillac with collision avoidance systems that advised the driver when another vehicle was in its blind spot or applied the car's brakes with full authority in case a collision with another V2V-equipped vehicle was eminent.

INTELLIGENT SPEED ADAPTION

Viewed by some as the ultimate automotive invasion by "Big Brother" and by others as a logical and necessary move to improve traffic safety, Intelligent Speed Adaption (or ISA) provides on-board advice to drivers to slow down or in extreme embodiments takes control of the vehicle throttle and actually slows the car or truck down to the posted legal speed limit.

The technology of “smart road signs”, capable of transmitting instructions to passing vehicles via some form of short-range communication architecture was part of another of those pesky PROMETHEUS projects. The first practical implementation of ISA was in Sweden where it was tested by 10,000 voluntary test drivers, both private motorists and commercial drivers, in 1999-2002. The trial was a joint venture between local authorities and the Swedish Road Administration.

Results show that most of the trial motorists appreciated the support offered by the ISA system.

- Motorists felt ISA helped them to be better drivers.
- Road safety improved significantly.
- As a result of less repeated braking and stopping, travel time remained unchanged (a slight improvement was noted) despite lower maximum speeds.
- A more even driving speed helped reduce fuel consumption and emissions.
- There was a very high level of acceptance for ISA in urban areas.
- Drivers believed that ISA was the best available measure, along with police surveillance, to solve road safety problems on streets in built-up areas compared with physical measures such as road humps¹¹.

Other European countries are experimenting with ISA including The Netherlands and the UK. While national auto clubs generally support continued experimentation, they and the automakers are concerned that the technology is still nascent and additional technological and legal impediments need to be overcome before ISA is ready for application as a mandatory traffic control system. These groups do support a rollout in which drivers could opt to volunteer to use.

INTERSECTION COLLISION WARNING

Our final ITS technology application for examination is intersection collision warning. While traffic incidents at intersections are of concern to every traffic agency, they are of particular concern in Japan where many urban intersections can involve small, narrow streets crossing much wider and busier main roadways. In addition, there are many “blind” intersections that are particularly dangerous for crossing vehicular traffic as well as pedestrians.

In the typical embodiment, information on intersections that are without traffic signals is gathered from car navigation system data. Images from the vehicle's cameras are analyzed to detect stop lines and stop signs. Based on the vehicle's speed and distance to the

stop line the system determines whether the vehicle is traveling at a speed that will enable it to stop by the time it reaches the stop line.

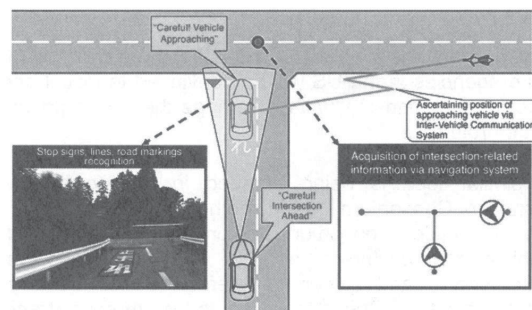


Figure 7. “Smart” intersection with “smart” vehicles

If the vehicle is going too fast, the system delivers an audio warning while signaling the driver to slow down with the application of gentle, intermittent braking.

Once the automobile has come to a stop, the Inter-Vehicle Communication System detects the position of any approaching vehicles and assists the driver in determining whether it is safe to proceed through the intersection¹².

CONCLUSION – WHO IS REALLY “ON FIRST?”

The foregoing discussion paints a very broad picture of which ITS developments that impact cars and trucks are being pursued by whom and where.

There are several general conclusions:

- European automakers, notably those in Germany, are developing and fielding a plethora of automotive safety systems that make use of modern computer and communications technology.
- Japanese companies and Japanese public agencies are working very closely on cooperative systems, those that involve both vehicles and roadways.
- America has the lead in telematics due to General Motors' dedication to its OnStar business unit. The contribution of independent telematics provider ATX is also important.
- Satellite radio is entering the telematics fray by offering real-time traffic situation reports for twenty US metropolitan areas.

This is not to say that each country or region is operating with tunnel vision. On the contrary, there is research (mostly) and development work (some) on every technology application in every region.

There is also a popular notion that some premium vehicles built by European and Japanese companies are "de-contented" when they are exported to North America because "Americans don't understand technology – they are afraid of it." This is not entirely true – for example, Nissan maintains its ITS applications when it sends Infiniti-branded products to America.

When it comes to vehicular applications, there are several conclusions evident:

- Premium vehicles "have all the luck" when it comes to applying ITS technologies. The principal exception to this rule is Ultrasonic Park Assist which is widely applied around the world – because it's cheap.
- One can find similar pricing and application practices with GPS navigation, but in this case its feature content that drives the price. Higher priced, premium vehicles have more features on their navigation systems – color displays, hard-disc drive data storage and route planning algorithms. A small car's navigation system, on the other hand might have a monochrome display, flash card or CD memory and position location.
- European and Japanese premium marques have most of the applications because their domestic buyers are technologically aware and want (and in some cases demand) new safety and convenience enhancing technologies.
- Nissan brings to market a variety of technological wonders – cars and light trucks absolutely laden with multiple, high-capability, high-value ITS applications.

On the supplier side, virtually every Tier One supplier who trades in automotive electronics is developing some ITS systems. In Europe its Continental AG, Siemens VDO Automotive and Valeo. In Japan, the lead is with Denso, Aisin and Hitachi, but many others are also active. The US effort is led by Delphi with the foregoing European and Japanese firms also very active.

If you want to see the future face of new automotive technology in general and ITS in particular, watch Mercedes, Toyota and Honda. These companies have little fear of technological risk – in fact, they seem to revel in it – because at the end of the day it brings them image and, in the long term, image brings customers, revenue and profits.

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- ¹ ITS is defined in this paper as the application of modern computer and communications technology to road transportation.
- ² In this paper the terms "America" and "American" refer to all of North America – the USA, Canada and Mexico.
- ³ Adaptive Cruise Control has also been called "active cruise control" or "intelligent cruise control" in other literature and automotive publicity and sales materials.
- ⁴ *Business Week Online*; September 14, 2005
- ⁵ NHTSA Vehicle Safety Rulemaking and Supporting Research Priorities: Calendar Years 2005-2009 – Update January 2005
- ⁶ The Johns Hopkins University, Applied Physics Laboratory
- ⁷ eCall Toolbox; SCOPE eSafety Observatory; ERTICO
- ⁸ Morita, Masatoshi; "Current Status and Future Plans for HELP"; International Telecommunications Union; March 2005
- ⁹ The Car2Car Consortium
- ¹⁰ Furukawa, Yoshimi; "Overview of R&D on Active Safety in Japan"; undated (2004 or 2005)
- ¹¹ "ISA for increased social responsibility and competitiveness"; Swedish Road Association; undated
- ¹² "Honda Completes Development of ASV-3 Advanced Safety Vehicles"; Honda press release; September 5, 2005

CONTACT

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Mr. Conover is active in numerous professional organizations including the Society of Automotive Engineers, the Intelligent Transportation Society of America (having served on its Board and Executive Committee), and the Board and Organizing Committee for the ITS World Congress, as well as local and national charitable and community organizations.

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