

Aerospace Sensor Systems and Applications

SHMUEL MERHAV



Springer

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With 193 Figures



Springer

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Library of Congress Cataloging-in-Publication Data
Merhav, Shmuel.

Aerospace sensor systems and applications / Shmuel Merhav.

p. cm.

Includes bibliographical references and index.

ISBN 0-387-94605-5 (hardcover)

1. Avionics. 2. Detectors. 3. Aeronautical instruments.

4. Space vehicles—Guidance systems. I. Title.

TL695.M47 1996

629.135—dc20

95-51161

Printed on acid-free paper.

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Production managed by Hal Henglein; manufacturing supervised by Joe Quatela.

Camera-ready copy supplied by the author.

Printed and bound by Braun-Brumfield, Inc., Ann Arbor, MI.

Printed in the United States of America.

9 8 7 6 5 4 3 2 1

ISBN 0-387-94605-5 Springer-Verlag New York Berlin Heidelberg SPIN 10515995

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Introduction and historical background

The purpose of aerospace sensors is to provide all the necessary information on the *variables and parameters* of the flight system for the execution of the mission at hand. A *mission* is generally defined in three dimensional space. Sometimes, on adding the fourth 'dimension', namely, time, a four-dimensional space is defined. In contrast to the three spatial coordinates which can increase or decrease, time always grows. The recent concept of 4-D guidance has special significance in coordinating flight paths such as in air traffic control or in space rendezvous operations, where the notions of 'here-now' or 'there-then' assume paramount importance.

As compared to the first generation aircraft at the turn of the century, which were equipped with a compass, a barometric altimeter, and a relative air speed sensor, a modern military aircraft or airliner is equipped with hundreds of sensors at all levels of the flight system. As such, they have become an integral part of it, not only in regular operation but also in preflight procedures for maintenance and safety. It is paradoxical that by introducing components and subsystems with more sophisticated technologies and a myriad of sensors for monitoring their performance and safety, a situation of diminishing returns may be created. This may be so, because in view of their large numbers, a failure in any of them easily causes a mission abort even if an imminent catastrophe is not necessarily indicated. It is therefore not surprising that along with the ever-increasing demands for accuracy and precision, research and development efforts continue to seek improved technologies for better reliability and maintainability. Currently, one already occasionally encounters the term 'unlimited' for the item MTBF (mean time between failures) in the data sheet of an aerospace sensor.

Modern aerospace sensors are direct descendants of the discoveries of physical laws in theoretical and experimental physics in the seventeenth and eighteenth centuries followed by the avalanche of revolutionary inventions in the nineteenth and early twentieth centuries.

At this point, it is enough to recall only a few of the most salient milestones in order to appreciate the direct link between the late twentieth century technology of aerospace sensors and systems and the discoveries in physics and the inventions that followed. Thus, for example, Torricelli's discovery of atmospheric pressure in 1643 was quickly followed by Pascal's invention of the barometric altimeter in 1647 and consequently by his discovery during 1647–1654 of the properties of our gaseous atmosphere. Newton's discovery of the law of gravitation in 1687, his first law on the conservation of momentum, and his second law, that force equals the rate of change of momentum, laid the foundation for the much later development of the accelerometer at the turn of this century following the invention of the seismometer by Milner in 1883. Other principal examples are the early invention of a steam-powered vertical

1

Principles and Elements of Measurement Systems

1.0 Introduction

This Chapter introduces the basic principles that underlie measurement devices and systems and the essential functions of their elements. The devices and their interconnections are described in generic form. Thus, a common conceptual framework is provided for a variety of existing aerospace sensors. The underlying requirements for standards and reference values are introduced, and the principal classes of measurement devices are defined, including passive, active, contact, remote, deflection, and balance. Characteristics, imperfections, and principal error sources are also defined.

The purpose of a device or instrument is to provide an output that represents, in a useful way, the magnitude of a physical quantity. The term useful implies that the quality of the representation is compatible with system requirements and constraints such as accuracy, precision, response time, repeatability, reliability, cost, volume, and weight. It is the knowledge and understanding of the parameters and properties underlying performance and tradeoffs that provide the designer with the skills to make the most rational choice of sensors or, if necessary, to specify new designs within the state of the art or to initiate new development.

1.1 Elements in open-loop instruments

Instruments, sensors, and systems

By *open-loop* devices, we mean that their output has no effect on their input. A number of elements and components purposefully interconnected constitute a *measurement device* or *instrument*, is often referred to as a *sensor*. These terms are essentially synonyms, and their usage depends on the context. For example, an altimeter is sometimes referred to as a sensor and sometimes as an instrument. The preferred term is related to the nature of its usage. If the altimeter functions in direct association with the pilot, it will, as a rule, be viewed as an *instrument* and as such it might be one of many on the instrument panel in the aircraft cockpit. However, if it is part of an automatic *altitude-hold* system, it will be referred to as a *sensor*. In general, any measurement device commonly intended for manipulation by a human operator, however simple or complex, will be referred to as an instrument.