1.0 Introduction

Sensors provide data and information which lead to increased knowledge about various physical phenomena, materials, and objects of importance to the military. Knowing more and knowing it sooner than the enemy provides an advantage and motivates the goal of acquiring "near perfect" knowledge of the battlefield as well as overall global situation awareness at any time and under any weather condition. This is a key challenge for the Air Force. The often cited explosive change in the field of information technology provides the solution to this challenge and with expected developments in technology over the next 20 years, the goal of information dominance is realistically achievable.

From a military point of view, the task of dealing with information is often treated in terms of four main functions: (1) information collection, (2) information transport, (3) information management/decision making, and (4) information protection and denial. Sensors are an important part of this much larger information and weapon system and primarily serve the information collection function. They must operate in concert with other elements and within the constraints of the overall system including very short reaction timelines for some weapon applications.

Sensors represent a very broad class of measurement systems. As will be described in more detail later in this Volume, sensors can exploit the full electromagnetic spectrum, detect various forms of mechanical energy, for example, seismic and acoustic, and physically sample and analyze a diverse set of chemical and biological components. Moreover, sensor systems can be operated from a variety of platforms in space, in the air, on the surface or below the surface of the earth. The sensors can be operated from stationary or moving vehicles that can be inhabited or not. Indeed, many of the sensors of the future will be transported by mechanical crawling roach or flying bumblebee-like devices.

Applications of sensors are also extremely diverse. In addition to the notion of real-time, global knowledge (omnipresence), sensors have a host of traditional roles including targeting, threat warning, battle damage assessment, flight weather forecasting, and monitoring of clandestine manufacturing. One key military goal is related to denying a sanctuary for the enemy. This motivates the development of radar systems that can image buried targets or targets concealed by foliage. Similarly, laser sensors for detecting and analyzing vibrations and effluents from underground facilities are important as part of an overall approach to counter-proliferation. Sensor systems for these and other challenging military needs will be discussed in subsequent sections of this Volume.

In the future, we will continue to move from centralized and independently operated sensors to large arrays of sensors in space, on high altitude UAVs, and distributed miniature sensors and tagging devices that are internetted and operated in an integrated fashion. Some of these sensor concepts involve distributing the small component sensors (flying, crawling, or fixed-implanted) by means of LO aircraft or by special operations forces in some situations. The use of distributed and coordinated arrays of small sensors is one way to improve overall performance while increasing survivability and reducing cost.

Sensors are an essential element of virtually every Air Force weapon and support system. The hardware and software associated with sensing functions are generally major, and sometimes predominant contributors to the performance, reliability, supportability, and cost of such systems. Many of the technologies associated with sensors are in a state of rapid evolution and will remain so for the foreseeable future. Moreover, many sensing functions and devices that are important to the Air Force have counterparts in commercial and industrial applications. This combination of ubiquity, operational impact, technology leverage, and dual use potential makes the subject of sensors especially important to the themes of *New World Vistas*.

Opportunities to cooperate in the development and utilization of commercial sensing systems are vast. The growing interest in commercial satellite remote sensing systems and plans for collecting fine resolution panchromatic, multispectral, and eventually synthetic aperture radar imagery provide the opportunity to purchase these data for military purposes. The capabilities of these commercial systems need not be duplicated, but rather can serve as part of the overall mix of sensor systems serving the military. Similarly, the development of intelligent, autonomous inspection systems for industrial operations involves a wide variety of sensors and associated recognition systems that are directly related to military applications. Small sensors based on MEMS and SAW devices are being developed to produce very small, low cost industrial instruments for chemical detection and analysis. These “chemistry lab on a chip” devices have obvious application in counter-proliferation. These and many other commercial cooperation opportunities bode well in our quest to field affordable sensor systems.

In concert with the *New World Vistas* theme of “identifying fields of rapid technological change that are likely to revolutionize the 21st century,” the objective of this Volume is to describe new sensor concepts and technologies which, if pursued, will have strong impact in satisfying important military needs in the future in terms of greatly improved performance and/ or affordability. Opportunities to cooperate with commercial developments and dual use implications are also important factors in identifying the key sensor concepts and technologies to be pursued.

The Sensors Panel followed a dual path approach during the course of this study leading to the information presented in this Volume. One path of the approach involved studying representative operational military tasks and then determining significant challenges for sensors of the future. We then identified future sensor concepts and enabling technologies to satisfy these needs. As a parallel path, we also reviewed a sample of current sensor technology development activities occurring in industrial, university, and government laboratories and finally selected those sensor technologies that we judged to have the greatest military impact.

In order to set the stage for a description of sensor concepts and enabling technologies, it is important to define the steps in the general sensing process, including the basic step of transduction as well as steps related to signature extraction, assessment (location, tracking, classification, correlation), and interactions with users, other sensors, and stored data. Section 2 describes this **sensing process** from a broad point of view in order to avoid conventional constraints on our thinking and to motivate a fundamental and comprehensive examination of sensor needs and approaches to satisfy those needs. This section also provides a taxonomy of sensors and sensor architectural considerations to be used as a context for subsequent portions of this Volume.

In most sensing situations, improved performance in terms of increased confidence in decisions and improved system reliability and availability can be achieved by combining data from multiple sensors or combining time-sequenced measurements from a single sensor. This combining of data to increase the temporal, spatial, and spectral dimensionality of the sensing process is often called "**sensor correlation and fusion**" and is the subject of Section 3 of this Volume. The basic data fusion process is defined along with a description of the various categories of data fusion. The section concludes with a summary of important challenges and opportunities that are associated with sensor correlation and fusion.

Section 4 presents a description of seven **representative operational tasks** associated with key Air Force missions and a set of challenging sensor needs derived from these tasks, and indicates some future sensor concepts and related enabling technologies that would satisfy these needs. This top down approach was taken to generate stressing needs for sensors and to stimulate the identification of new sensor concepts.

The development of new improved sensor system concepts can occur due to improvements in components and basic design approaches. Another very effective approach involves the integration of multiple sensors to achieve improved overall performance through cooperative operation of an internetted set of orchestrated sensors. Seven **illustrative sensor system concepts** are described in Section 5. These concepts were selected to indicate the power of integrated sensor operation and the enabling technologies needed for implementation.

Section 6 describes the **sensor technology** that we believe will be important for the Air Force in the coming decades. This description emphasizes areas where we expect substantial change from current practice and also discusses developments that can be expected from commercial efforts. The technology areas considered in this section are derived from the enabling technologies identified in Sections 4 and 5 and from other technology development activities that we believe offer opportunities for the Air Force.

Finally, **conclusions and recommendations** prepared by the Sensors Panel of *New World Vistas* are presented in Section 7 of this Volume. The conclusions portion summarizes several over-arching trends and opportunities that have emerged from this study, and the recommendations portion of this section identifies a set of specific actions that the Air Force should take over the next few years to exploit the trends and opportunities to gain real benefit in the future.