Space Situational Awareness

Difficult, Expensive—and Necessary

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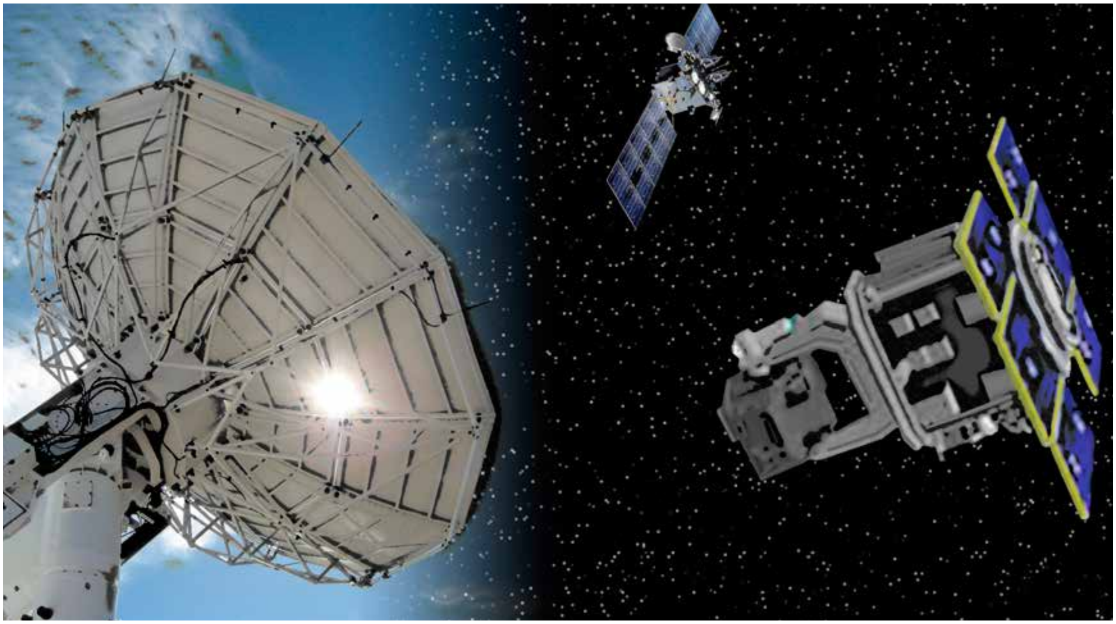

In 1990 Operation Desert Storm, which marked the first widespread use of precision-guided munitions and low-observable aircraft, introduced a new set of military technologies and capabilities. Perhaps, though, the most valuable lesson learned from that operation

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was that space assets could significantly improve military effectiveness through enhanced target identification, better damage assessment, and more efficient communications.

Since Desert Storm, the United States has spent much effort and many dollars to refine space capabilities. In particular, the Global Positioning System (GPS) became fully operational for both military and civil users to enable navigation and weapon accuracy never attained in the past. Surveillance capabilities such as the Space-Based Infrared System emerged, reconnaissance assets became more proficient, and worldwide communication bandwidths increased dramatically. Weather satellites upgraded our prediction capabilities and shortened disaster-warning times. Many of these programs benefited the civil community; primarily, though, they measurably helped the expertise of the US military. Although the Air Force deployed the major developments, both the land and sea forces profited greatly as well.

As part of the development and fielding processes, we cultivated sophisticated methods for monitoring the health, position, and operational status of space vehicles. However, the evolution and installation of sensors to warn of and identify attacks on them were somewhat neglected. Even though some people believed that such sensors were important, the programs, in general, proceeded as though their distance from the surface of the earth and their speed conveyed upon them a charmed existence.

But we should not think, for even one moment, that the increasing reliance of US military forces on space assets has gone unnoticed by potential adversaries, both military and economic. Nations both large and small have begun to develop space and antispace capabilities that fall into two broad categories: (1) assets located in space that can enhance national military capabilities or contribute to the nation's economic development, and (2) technologies and devices that can defeat or destroy American space assets. The first category includes surveillance instruments created by various nations, space-based navigation systems developed by Russia and China, and weather- and earth-sensing devices produced by countries such as India and Japan. Such assets contribute to *foreign mission enhancement* (FME). In the second category, we have seen a significant amount of work on antisatellite devices by Russia and China. Innovations in high-power laser and microwave technology, which could be used against American space assets, continue in many countries. These devices and technologies are *US mission-defeat* assets. As yet, we have seen no direct-attack weapons based in space, such as warhead-carrying missiles that could target an object on the earth's surface, but we should not completely discount the possibility of these weapons emerging in the future. As early as 1962, the Soviet Union began work on a device called the Fractional Orbital Bombardment System (FOBS). Although the Soviets did not design FOBS to place a nuclear weapon permanently in orbit, its launcher and guidance system could do just that. The project appears to have been abandoned because of accuracy shortfalls, not deployment difficulties. Development of improved reentry precision, occasioned by the need to provide services for the International Space Station, may enable the deployment of such weapons in the future. In terms of a category, we identify these devices as *direct-attack* space assets. A third category—*space debris*—has received much publicity but, as yet, has had only a minor impact on space operations. We will expand this area a bit by defining a set of dangerous objects as *passive threats*. Certainly, debris falls into this category, but it also includes items like out-of-control satellites and rockets.

The Needs of Space Situational Awareness

Although the term is a rather clumsy grammatical construct, *space situational awareness* (SSA) is a necessity for any nation that seriously bases its military and economic well-being even partly on space capabilities. SSA is the enabling of a description of the location and operation of US space assets as well as the location and function of the assets of other nations, particularly those that are, or could become, our enemies. SSA also identifies the capabilities needed for protecting US assets and for destroying or disabling those of the enemy. Frequently, a mission defeat can be just as useful as destruction while not violating treaties or providing grounds for retaliation.

We should emphasize, though, that SSA is primarily the result of inference. Technology, associated terrestrial intelligence, and prior experience can all be important contributors to the understanding of an enemy's intentions and status in space, but SSA is not an exact science.

Tracking Foreign Mission Enhancement

SSA is sometimes defined as knowledge of the position and orbit of every object in space. As demonstrated below, however, if SSA is to be a useful military concept, it must become much more than that. SSA seeks to determine the position, function, and current status of every object in space, but such a goal may exceed US capabilities. Therefore, the first attempt at SSA should involve identifying those objects associated with FME and determining their owner, capabilities, and status.

Tracking Position and Determining Function

Perhaps the most costly part of SSA is the tracking and position monitoring of space objects. We must stress, though, that tracking only supports SA. The main output of an SSA effort is determination of the capabilities of a space object and the intentions of its owner.

The primary method for tracking all objects in space entails the use of radar, which has not yet provided accurate location of and orbital information about all space objects. Even if perfect radar information were available, however, the method offers no data about the function of detected satellites. One usually infers function by tracking a satellite from launch to final orbit and associating that information with data from other intelligence sources. Apparently, possible adversary nations have not attempted to deploy radar-defeating technologies such as stealth, but given the emphasis that, say, Russia and China have placed on the development of such technology for aircraft, we should expect the appearance of these technologies in space in the future. The increasing use of shorter-wavelength radar systems by the United States makes that possibility even more likely. Therefore, America would do well to develop radar-independent tracking methods, such as lasers and coherent infrared sensors. We can improve the tracking accuracy of US satellites by replacing radar with onboard GPS sensors and including the GPS position as part of the usual downloaded information about health and status.

No tracking method can supply complete information about the function of a satellite, even if we use the inference method mentioned above. Additional data can be obtained from images of a satellite, which can show antennas and sensors associated with known devices and functions. US military laboratories have pursued optical imaging methods for decades and should continue to do so, developing techniques to yield images having a spatial resolution of one centimeter or better. Infrared imaging can provide additional information, but, again, inference is necessary. We can most likely obtain direct information about the structure and function of a satellite of interest by placing a sensor satellite in close proximity. The latter can take surface photographs of the target vehicle, monitor attitude and orbit changes, and observe its emissions, which may include radio frequency power; optical energy from far infrared to x-rays; and neutrons, protons, electrons, and other atomic and subatomic particles. In general, atmospheric attenuation prevents the observation of particle emissions from the ground unless they are very intense. One could even imagine placing two satellites on opposite sides of the target vehicle, one of them emitting x-rays or neutral or charged particles that could penetrate the structure of the vehicle and the other imaging those x-rays to form a photograph of the target's interior. We could utilize microwave imaging as well, taking care to prevent damage to the target satellite.

Provocative? Perhaps. But there appears to be no territorial limiting distance associated with space objects. We can identify them as valuable property, though, and make a case for compensating the owner for any damage done by a sensor satellite. Such an expenditure would be a small price to pay for detailed information about an adversary's intentions in space. Furthermore, for example, if the satellite contained a weapon of mass destruction (e.g., a nuclear device), we could employ active methods to destroy it. For chemical or biological weapons, the sensor satellite could obtain a swab from the surface of the target, analyze it on board, or return to Earth—as was the procedure with early film canisters. Expensive? Yes, but giving our enemies the upper hand in space would prove even more costly.

Communication Monitoring

Communication capabilities and operations are important factors in SSA. Even minimal information about a satellite should include a report on its communication history. Basic questions to answer are as follows: Does the satellite emit energy that appears to come from a communication system? How often does it emit such energy? With whom does it appear to communicate? What or where is the source? Does the satellite appear to receive as well as transmit? Does satellite status change following a communication session? Can the nature or details of the communication be determined? Other questions may be appropriate as well, but communication status remains a valuable source of information about the purpose and function of a satellite. Much of this data can be obtained from ground or airborne sensors, but the latter cannot compete in either detail or accuracy with satellites deployed in the same or a nearby orbit in close proximity to the vehicle under study.

Geosynchronous Orbit

The geosynchronous or geostationary orbit that rings the earth above the equator at a radius of 42,157 kilometers (km) or an altitude of 35,786 km (22,236 miles) provides a special opportunity for FME. Satellites in this orbit remain above the same point on the earth at all times. Their orbital period equals that of the earth's sidereal period—23 hours, 56 minutes, and 4 seconds. We know, for example, that the orbit contains at least four satellites of the Chinese BeiDou-2 satellite navigation system. It is also home to many communication and observation satellites used by a number of nations. The geosynchronous orbit includes approximately 600 satellites, not all of them operational or functional. Some have exhausted the fuel required to maintain the orbit, and others have failed systems. Still, because many possibilities for military applications inimical to the interests of the United States remain, the satellites deserve careful and frequent observation.

Recently, Gen William Shelton, then commander of US Air Force Space Command, announced the Geosynchronous Satellite Space Awareness Program (GSSAP), designed to place in geosynchronous orbit a sensor satellite capable of approaching a target satellite and observing its operations. Certainly this is a step in the proper direction to improve US military forces' knowledge about FME. Eventually, such sensors should track all foreign satellites, but the geostationary orbit is a logical first step, given that the GSSAP will have access to nearly 600 satellites while many low Earth orbits (LEO) and even Molniya orbits contain only one or a few satellites. Thus, GSSAP satellites will have nearly 600 times more intelligence-gathering capability than a single-orbit LEO or medium-altitude satellite. Assuredly, the Air Force and its contractors well understand that the GSSAP vehicles must possess unprecedented accuracy in terms of propulsion and positioning. A collision will result in significant political and financial problems; moreover, it could produce debris capable of contaminating a large portion of the geosynchronous orbit. Certainly, maneuvering operations will generate very tense times at the satellite control center at Schriever AFB, Colorado. The more sparsely populated orbits will demand new technologies and methods—a problem discussed to some extent below.

Low Earth Orbit and Companion Satellites

LEO presents special difficulties for the task of maintaining effective SSA. Important assets such as reconnaissance, Earth-observing, and mobile communication satellites occupy these orbits. Highly elliptical orbits, such as Molniya orbits, tend to have perigees in this range as well. Thus, altitudes between approximately 150 and 2,000 km can contain important assets that should be a part of an SSA program. Unfortunately, these orbits tend to be very sparsely populated. The United States should develop a fleet of vehicles identified as *companion satellites* designed to monitor the actions of satellites of interest that can contribute significantly to an adversary's war plans. The companions should occupy the same orbit as the satellite of interest in close proximity to observe the actions and functions of the target. It may be possible to design a generic companion satellite that will function as a monitor for a large class of foreign assets, or we may need to field a special satellite for each foreign asset. In either case, costs of construction, launch, and operation will be significant factors in deciding whether to deploy such devices. Perhaps we can reduce the required number of companion satellites by launching them into orbits that intersect those of target satellites at a point appropriate for observation. Further, we may realize some cost reductions by making the companions reusable so that they can be returned to the earth, serviced, and inserted into a new orbit.

Passive Threats

Passive threats primarily consist of objects such as debris or uncontrolled satellites or rockets. Almost always, the important factor for SSA is location. Since orbital parameters can be derived from location measurements, it is possible to determine which objects could prove dangerous to US space assets and generate warnings at proper times to stimulate defensive actions.

Another set of passive threats, sometimes not included in SSA estimates, are those from high-energy particles and photons. These particles may be generated by natural events such as solar storms or caused by events like nuclear explosions in the atmosphere or in space. In either case, detection by space assets would most effectively determine the characteristics and possible dangers of such threats.

Facilities

All of the tasks mentioned above call for a significant amount of equipment and numbers of personnel to enable their functions. One item not emphasized but necessary for an effective SSA is a facility for controlling assets and sensors, displaying and analyzing sensor information, and giving the proper people a place to freely discuss the information at hand. This information center should also have access to current intelligence that can be related to actions in space associated with the world geopolitical situation.

The authors believe that this important part of an SSA system too often has been neglected by those who plan for and appropriate such facilities. This situation must be rectified if the United States wishes to maintain an effective presence in space. Obviously, the planning and construction of these facilities should closely involve people who analyze and use the SSA information. An addition to SSA sensors, the new space fence on Kwajalein Island offers a significant improvement in the ability to locate both active and passive threats. Too often, however, the US military tends to view a new, improved capability as a reason for ending its support and upgrade of facilities. We sometimes indoctrinate our people, particularly those responsible for building new installations, into believing that the new capability is a suitable end for developments in the field.

Nothing could be more counterproductive. Seldom is a new system the absolute best that we can do, even using current technology. We must constantly and routinely reevaluate all facilities as we observe the emergence of new technologies and changes in the world's political situation that may indicate a need for new and better capabilities. Even if immediate changes are not possible, such evaluations can serve as guides for research and development.

Space Situational Awareness as a Career Field

Given the variety and number of topics described above, it should be clear that expertise in SSA comes neither quickly nor easily. Individuals with less than a decade of experience in the art will probably find themselves ineffective at describing space conditions important to the defense of the United States in a way that is understandable and useful to combatant commanders. (The word *art* indicates that SSA is not an exact science.) The keys to effective performance are education and experience. Education in space technology, though necessary, is not sufficient. A good understanding of geopolitics may be just as important as an understanding of foreign satellite technology. A set of checklists is unlikely to provide much useful SSA although they may contribute to the total knowledge of those responsible for constructing a valuable SSA.

As mentioned above, SSA is as much a matter of inference as of data gathering. Probably, no one will be perfect at it, and few will be better than acceptable. Very likely, those who have an aptitude for the art will be readily identifiable. They should be encouraged by appropriate recognition and promotion, and their assignment to the subject for an entire Air Force career is appropriate—a procedure usually identified as a career field. Surely, it is at least as important as, say, personnel management as far as the security of the nation is concerned.

Conclusion

It should be clear that although location and orbital information are essential parts of SSA, its ultimate goal is to define the function and status of space objects as well as the intentions of their owners. Radar and optical observations are significant, but they are not likely to provide a complete picture that enhances the defense of the United States. SSA is a varied, complex, and substantial activity that can boost the military capabilities of American forces. The US military should pursue it actively with the assignment of enough forces and budget allocations to make it effective. SSA, perhaps, is a good example of the observation attributed to Thomas Jefferson, among others, that "eternal vigilance is the price we pay for liberty." ✪

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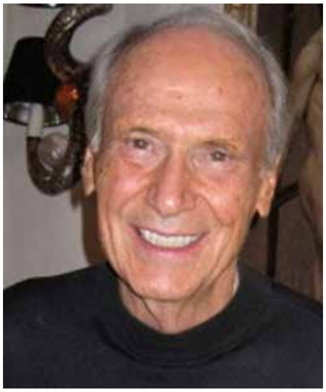
Dr. McCall (BEE, Georgia Institute of Technology; MEE, New York University; PhD, Princeton University) has served as chief scientist, Air Force Space Command; laboratory fellow, Los Alamos National Laboratory; and chairman, USAF Scientific Advisory Board. He helped found the Inertial Fusion Program at Los Alamos and was a consultant to the Department of Energy for inertial fusion issues. In 1995 Dr. McCall directed the *New World Vistas* study requested by the secretary and chief of staff of the Air Force, widely regarded by the defense community as a guide for the development of twenty-first-century weapons for the Air Force. He has received the Department of Energy's E. O. Lawrence Award for contributions to national security, the Air Force Association's Theodore von Karman Award for technical achievement, the Department of Defense Distinguished Public Service Award, and the Secretary of the Air Force Exceptional Service Award with oak leaf cluster.



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