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Report to Congressional Requesters

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# SPACE SURVEILLANCE

# DOD and NASA Need Consolidated Requirements and a Coordinated Plan


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**National Security and**
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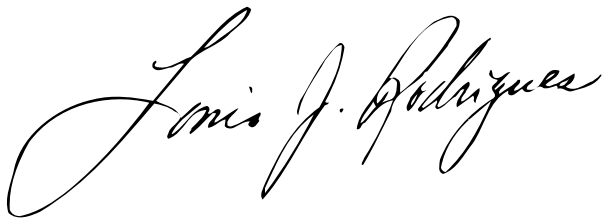
The Honorable Dana Rohrabacher
Chairman
The Honorable Robert E. Cramer, Jr.
Ranking Minority Member
Subcommittee on Space and Aeronautics
Committee on Science
House of Representatives

In response to your request, this report discusses (1) the Department of Defense's (DOD) and the National Aeronautics and Space Administration's (NASA) requirements for surveillance of space objects and (2) DOD's space surveillance capabilities to support these requirements. This report contains recommendations to the Secretary of Defense and the Administrator of NASA.

We are sending copies of this report to the Secretaries of Defense, the Air Force, the Navy, and the Army; the Administrator of NASA; the Directors of the Office of Management and Budget, the Office of Science and Technology Policy, and the Central Intelligence; and other interested congressional committees. Copies will be made available to others upon request.

If you or your staff have any questions concerning this report, please call me at (202) 512-4841. Major contributors to this report are listed in appendix IV.



Louis J. Rodrigues
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# Executive Summary

## Purpose

During the past 40 years, the number of manmade space objects orbiting the earth—active and inactive satellites and debris generated from launch vehicle and satellite breakups—has increased dramatically. Knowing what objects are in space and their locations are important because of the (1) implications of foreign satellite threats to U.S. national security and (2) hazards that such objects create for multibillion dollar space programs, especially large ones such as the International Space Station.

At the request of the Chairman and Ranking Minority Member, Subcommittee on Space and Aeronautics, House Committee on Science, GAO is providing this report on the Department of Defense's (DOD) and the National Aeronautics and Space Administration's (NASA) space surveillance requirements and DOD's space surveillance capabilities. GAO evaluated (1) how well DOD's existing surveillance capabilities support DOD's and NASA's current and future surveillance requirements and (2) the extent to which potential surveillance capabilities and technologies are coordinated to provide opportunities for improvements.

## Background

According to a National Science and Technology Council report,[1] an estimated 35 million manmade space objects are orbiting the earth. Of these objects, only about 8,000 can be routinely observed by DOD's existing space surveillance sensors. DOD and the intelligence community are interested in knowing the type, status, and location of space objects, particularly foreign satellites, as part of DOD's space control mission and other national security functions.[2] NASA is interested in accurate and timely information on the location and orbits of space objects to predict and prevent collisions with spacecraft designed for human space flight—the space station and space shuttles.

DOD and NASA rely on the U.S. Space Command's Space Surveillance Network, which is operated and maintained by the Air Force, Naval, and Army Space Commands, to provide information on space objects. The network, consisting of radar and optical sensors, data processing capabilities, and supporting communication systems, detects space

[1]This Council was established by the President in 1993 to coordinate science, space, and technology policies throughout the federal government. The President is the Council Chairman, and membership includes the Vice President and cabinet-level and other federal agency officials. See Interagency Report on Orbital Debris, November 1995.

[2]The space control mission includes four functions: surveillance to provide awareness of all activities in space; protection to ensure U.S. space system survivability; prevention to preclude an adversary the use of U.S. or third-party space systems, capabilities, and products; and, when directed, negation to deny adversaries the use of their space systems.

objects; tracks them to determine their orbits; and characterizes them to determine their size, shape, motion, and type. This information is transmitted from the sensors to two command centers for processing and maintained in a catalog, which is used for such purposes as monitoring foreign satellites and analyzing space debris.

## Results in Brief

DOD's existing space surveillance network is not capable of providing the information NASA needs to adequately predict collisions between space objects orbiting the earth and multibillion dollar space programs such as the space station. Moreover, the existing network cannot satisfy DOD's emerging space surveillance requirements, which are currently under review.

DOD's plans to (1) modernize an existing surveillance network radar system and (2) develop three new ballistic missile warning systems, which could contribute to performing the surveillance function, do not adequately consider DOD's or NASA's surveillance requirements. These four systems are separately managed by the Navy, the Air Force, and the Army. An opportunity exists to consider these systems' potential capabilities to enhance the surveillance network to better satisfy requirements and achieve greater benefits from planned investment in space sensor technology.

Despite NASA's dependency on DOD to provide space object information, the 1996 National Space Policy makes no provision for an interagency mechanism—either organizational or funding—to ensure that DOD's surveillance capabilities satisfy NASA's requirements. Overall, there is no authoritative direction, formal agreement, or clear plan on how DOD and NASA could consolidate their space surveillance requirements for a common capability. A coordinated interagency plan that considers all existing and planned space surveillance capabilities could be beneficial in making cost-effective decisions to satisfy a consolidated set of national security and civil space surveillance requirements. Unless DOD and NASA can agree on such a plan, an opportunity may be missed to simultaneously (1) achieve efficiencies; (2) better ensure the safety of the planned multibillion dollar space station; and (3) help satisfy national security needs, including the U.S. forces' future needs for space asset information.

# Principal Findings

## Existing Network Cannot Satisfy Emerging Surveillance Requirements

The U.S. Space Command cannot satisfy NASA's space surveillance requirements with the existing surveillance network. One requirement—detecting and tracking space objects as small as 1 centimeter—is linked to the potentially catastrophic effect of a collision between such an object and the space station. Another requirement—locating space objects more accurately—is not currently possible because the network's sensors and processing capability and capacity are insufficient, and DOD does not have a program to measure object location accuracy. These deficiencies necessitate an upgraded capability to the surveillance network.

In August 1997, NASA provided surveillance requirements to the U.S. Space Command that are commensurate with NASA's responsibilities to ensure the safety of human space flight. According to the NASA Administrator, these requirements reflect NASA's needs to minimize risk to human and robotic space flight and assist in recovery from mishaps of both domestic and foreign spacecraft. However, DOD and NASA have not reached agreement regarding how to satisfy these requirements.

DOD's existing space surveillance requirements have been repeatedly studied and will likely become more stringent to address emerging needs regarding future threats. DOD is concerned about timely warning to U.S. forces when a foreign satellite becomes a threat to military operations. With larger numbers of smaller size satellites (known as microsatellites) expected in the future, DOD believes the space surveillance mission will become more difficult to execute. DOD is currently reviewing its requirements.

## Potential Surveillance Capabilities Are Not Sufficiently Coordinated

Four systems, which are managed separately by the military services, could be upgraded or designed to support surveillance functions. These systems are an operational Navy-funded space surveillance system and an Air Force- and two Army-funded developmental systems associated with ballistic missile defense. However, there is a lack of coordination—both within DOD and between DOD and NASA—to take advantage of these systems' potential contribution to space surveillance for serving both national security and civil space sectors.

DOD's Space Architect organization has a key role in evaluating national security space missions and capabilities for achieving acquisition and operational efficiencies.[3] Although it does not have a similar responsibility for evaluating civil space needs, NASA could participate with the DOD Space Architect organization in evaluating space surveillance needs from a broader perspective.

## Recommendations

GAO recommends that the Secretary of Defense and the Administrator of NASA, in consultation with the Director of Central Intelligence,

- establish a consolidated set of governmentwide space surveillance requirements for evaluating current capabilities and future architectures to support NASA's, DOD's, and other federal agencies' space programs and surveillance information needs and
- develop a coordinated governmentwide space surveillance plan that (1) sets forth and evaluates all feasible alternative capabilities to support human space flight and emerging national security requirements and (2) ensures that any planned funding for space surveillance upgrades is directed toward satisfying consolidated governmentwide requirements.

## Agency Comments

Both DOD and NASA provided written comments on a draft of this report. Their comments appear in appendixes II and III, respectively.

DOD generally agreed with GAO's recommendations. While DOD supports a governmentwide group to consolidate requirements, it emphasized the need for each organization to first establish individual requirements and then proceed with consolidating the requirements and sharing the cost for satisfying them. It noted that an interagency group will be required to develop a near-term policy on cost or burden sharing and a long-term policy for government and commercial organizations that may request space surveillance support. Also, DOD agreed with an interagency approach to evaluate existing capabilities, plan future architectures, and address funding responsibilities.

Although NASA did not comment on GAO's recommendations, it stated that, overall, the draft report was an accurate representation of the national requirements for space surveillance (particularly DOD's and NASA's) and

[3]The purpose of the Space Architect organization is to consolidate the responsibilities for DOD space missions and system architecture development into a single organization to achieve acquisition and future operational efficiencies. The Architect also performs this function with the intelligence community to support national security requirements.

DOD's current space surveillance network capabilities. NASA emphasized that, in August 1997, the NASA Administrator provided the U.S. Space Command with quantified space surveillance requirements. It stated that, although most of the near-term requirements are being met, three are not presently being satisfied: detecting and tracking relatively small space objects and more accurately determining the location of such objects, as discussed in this report, and notifying NASA of a space object breakup within 1 hour.

Concerning DOD's and NASA's comments about the need for a process to address requirements, the agencies have the Aeronautics and Astronautics Coordinating Board—a senior management review and advisory body—that could oversee the establishment of space surveillance requirements and the development of a space surveillance plan. The Board exists to facilitate coordination of aeronautics and space activities of mutual interest to DOD and NASA. It was established several years ago, and the memorandum of agreement was renewed in 1993 by the Deputy Secretary of Defense and the Administrator of NASA. The Director, National Reconnaissance Office, is 1 of 18 members on the Board.

Finally, DOD stated that delaying space surveillance programs, which it has funded to meet DOD requirements, to insert NASA's recently provided requirements would result in increased cost and schedule risk. GAO recognizes that some funds may be needed for system maintenance and modernization and therefore modified its recommendation to only address system upgrades. GAO believes that any funding for such upgrades should be directed toward satisfying consolidated governmentwide requirements.

# Contents

## Abbreviations

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| DOD | Department of Defense |
| GAO | General Accounting Office |
| GBR | Ground-Based Radar |
| NASA | National Aeronautics and Space Administration |
| SBIRS | Space-Based Infrared System |
| THAAD | Theater High-Altitude Air Defense |

# Introduction

Since the former Soviet Union launched its first Sputnik satellite 40 years ago, the number of manmade space objects orbiting the earth—active and inactive satellites and debris generated from launch vehicle and satellite breakups—has increased dramatically. In 1995, a National Science and Technology Council report estimated the number of space objects to be over 35 million. Although nearly all of these objects are thought to be smaller than 1 centimeter, about 110,000 are estimated to be between 1 and 10 centimeters, and about 8,000 are larger than 10 centimeters. Only the approximate 8,000 objects are large enough, or reflect radar energy or light well enough, to be routinely observed by the Department of Defense's (DOD) existing space surveillance sensors. About 80 percent of these 8,000 objects are in low-earth orbits, and the remainder are in geosynchronous and other orbits.[1]

The increasing amount of space debris creates a hazard to certain spacecraft, especially large ones like the planned multibillion dollar International Space Station,[2] which will operate in low-earth orbits. The National Aeronautics and Space Administration (NASA) is interested in accurate and timely information on the locations and orbits of space objects to predict and prevent collisions with spacecraft designed for human space flight—the space station and space shuttles. DOD and intelligence agencies are interested in knowing the type, status, and location of space objects, particularly foreign satellites, as part of DOD's space control mission and other national security functions. NASA and DOD rely on the U.S. Space Command's Space Surveillance Network, which is operated and maintained by the Air Force, Naval, and Army Space Commands, to provide information on space objects.

## Surveillance Network Functions

The surveillance network consists of radar and optical sensors, data processing capabilities, and supporting communication systems. It detects objects in space; tracks them to determine their orbits; and characterizes them to determine their size, shape, motion, and type. The network

[1]Low-earth orbits are at altitudes less than 5,500 kilometers. A geosynchronous orbit is at an altitude of about 36,000 kilometers.

[2]In Space Station: Estimated Total U.S. Funding Requirements (GAO/NSIAD-95-163, June 12, 1995), we reported that the space station would cost about $58 billion from program inception in 1985 through final assembly in space in June 2002. This cost estimate consisted of (1) $11.2 billion spent from 1985 through 1993 for designing and developing earlier versions; (2) $17.4 billion to be spent from 1994 to 2002 to complete assembly of the current design; and (3) $19.6 billion to be spent to 2002 for station-related requirements, such as space shuttle launch support. In addition, $9.4 billion was expected to be spent to 2002 by international partners, other than Russia. Finally, $45.7 billion was estimated to support 10 years of operations after 2002. NASA is updating its cost estimates, and we are reviewing them.

routinely detects and tracks objects larger than about 30 centimeters (somewhat larger than a basketball). It can sometimes detect and track objects as small as 10 centimeters (about the size of a softball), but not routinely.

The surveillance network also catalogs the approximately 8,000 space objects and includes information that describes the orbit, size, and type of object. The information is used for such purposes as (1) warning U.S. forces of foreign reconnaissance satellites passing overhead and (2) analyzing the space debris environment and the potential implications of planned space operations. All space sectors—defense, intelligence, civil, and commercial—use the catalog information.

## Surveillance Network Evolution

Subsequent to the launch of Sputnik in 1957, DOD established a space tracking mission and a network of radars and telescopes to monitor orbiting satellites. During the 1960s, DOD built radars to support two missions—space tracking and ballistic missile warning. The Naval Space Surveillance System (known as the Fence) is a chain of radar equipment extending from California to Georgia that was constructed to detect foreign reconnaissance satellites and provide warning to Navy ships of such satellite overflights. The system is still operational, and the Navy plans to modernize it beginning in 2003 to improve its maintainability. Also, Ballistic Missile Early Warning System radars were constructed in Alaska, Greenland, and England to detect and track intercontinental ballistic missiles that could be launched at North America. A secondary mission for these missile warning radars has always been space surveillance. Finally, a prototype phased-array radar was built in Florida to support the space surveillance mission.

During the 1970s, the Air Force reactivated the Safeguard antiballistic missile phased-array radar in North Dakota. This radar provides space surveillance support as a secondary mission. Also, the Air Force began a program to build four phased-array radars (called PAVE PAWS) to detect and track submarine-launched and intercontinental ballistic missiles. The four radars—in Georgia, Texas, California, and Massachusetts—were completed in the 1980s, but the Georgia and Texas radar sites were closed in 1995. The radars in California and Massachusetts continue to operate and support space surveillance as a secondary mission.

During the 1980s, DOD acquired four Ground-based Electro-Optical Deep Space Surveillance telescopes to detect and track objects in

geosynchronous orbit because existing surveillance network sensors could not detect objects at such a distance. These telescopes provide nearly worldwide coverage but are limited to operating at night and in clear weather. Three sites, located in New Mexico, Hawaii, and Diego Garcia (in the Indian Ocean), are currently operational. A fourth site in Korea was closed in 1993 due to poor tracking conditions.

The existing space surveillance network includes 31 radar and optical sensors at 16 worldwide locations, a communications network, and primary and alternate operations centers for data processing. Appendix I discusses the surveillance network's composition and characteristics.

## National Space Policy Guidelines

The September 1996 National Space Policy includes civil, defense, and intersector guidelines related to space safety, space threats, and space debris. Specifically, the policy (1) requires NASA to ensure the safety of all space flight missions involving the space station and space shuttles; (2) requires DOD to maintain and modernize space surveillance and associated functions to effectively detect, track, categorize, monitor, and characterize threats to U.S. and friendly space systems and contribute to the protection of U.S. military activities; and (3) declares that the United States will seek to minimize the creation of space debris and will take a leadership role internationally, aimed at debris minimization.

A distinctive interconnection among these policy guidelines is that, although the increasing amount of space debris creates a hazard to human space flight, NASA has no surveillance capabilities to locate space objects. Instead, it relies on DOD's capabilities to perform this function. Despite this dependency relationship, the policy makes no provision for an interagency mechanism—either organizational or funding—to ensure that DOD's space surveillance capabilities meet NASA's requirements.

## Increasing Attention to Space Surveillance

The surveillance of space objects is receiving increasing attention from both a civil and national security perspective. Part of the reason for the increased attention is because of (1) the planned assembly of the space station beginning in 1998 and (2) DOD's recognition that its aging space surveillance network cannot adequately deal with future national security threats. In addition, DOD believes that the growing commercial space sector will result in increased requests for surveillance support.

## Debris Creates Hazard to Space Station

According to the National Research Council,[3] the chance of debris colliding with a spacecraft relates directly to the size and orbital lifetime of the spacecraft. The space station will be the largest spacecraft ever built, with length and width dimensions somewhat larger than a football field. Its total exposed surface area will be almost 10 times greater than that of a space shuttle—about 11,500 square meters compared with about 1,200 square meters. Also, the space station's orbital lifetime is expected to exceed that of a space shuttle. NASA plans to operate the space station continuously for at least 10 years. In contrast, in recent years, individual space shuttle missions have averaged about 7 per year and 11 days per mission. In future years, NASA is planning about eight shuttle missions per year. The Council concludes that the space station will face a significant risk of being struck by potentially damaging meteoroids or orbital debris.

The space station is to operate at low-earth altitudes—between 330 to 500 kilometers. According to the National Science and Technology Council, debris orbiting at altitudes up to about 900 kilometers lose energy over time through friction with the atmosphere and fall to lower altitudes, eventually either disintegrating in the atmosphere or falling to the earth. New debris is periodically added, sometimes unexpectedly. For example, in June 1996, a Pegasus rocket broke up at an altitude of about 625 kilometers, creating 668 observable objects. Also, it is likely that an unknown number of other objects were created, but they are not observable because of their small size. Such debris, as it falls toward the earth, can be expected to pass through the space station's operating altitudes.

## Potential for Increased Threats to U.S. Forces

From a national security (defense and intelligence) perspective, space surveillance provides (1) warning to U.S. forces when a foreign satellite becomes a threat to military operations and (2) information to support responsive measures. According to DOD, as the importance of space services to U.S. forces increases and the size of satellites decreases, the need for timely information about space objects expands. DOD has acknowledged that its existing surveillance network is aging, requires replacement or upgrades in the next 10 to 15 years, and is currently limited in its ability to detect and track objects smaller than 30 centimeters.

[3]This Council, part of the National Academy of Sciences, provides advice to the federal government on scientific and technical matters. See Protecting the Space Station from Meteoroids and Orbital Debris, 1997.

## Recent DOD and NASA Activities Related to Surveillance

In January 1996, the Deputy Under Secretary of Defense for Space directed the DOD Space Architect to begin a study of DOD's space control mission, including the space surveillance function. The purpose was to develop a range of architecture alternatives to satisfy national security needs to 2010 and beyond. In May 1997, the team provided its results to the Joint Space Management Board.[4] Regarding space surveillance, the team concluded that next-generation ground-based radars and potential space-based systems should be able to provide reliable near-earth tracking of space objects that are 5 to 10 centimeters in size.[5] The team expected such capabilities to improve debris awareness and ensure that an emerging class of microsatellites as small as 10 centimeters could be tracked. The Board has yet to provide directions to DOD and intelligence organizations on how to proceed regarding the space surveillance function.

In a separate action, NASA and the Air Force Space Command established a partnership council in February 1997 to study a variety of space areas of mutual interest. One area involves DOD's space surveillance network. The impetus to address this subject arose from recognizing the potentially catastrophic consequences of collisions between manned spacecraft and orbiting debris. One of the tasks is to examine ways to enhance orbital debris data collection and processing on objects as small as 5 centimeters.

## Objectives, Scope, and Methodology

The Chairman and Ranking Minority Member of the Subcommittee on Space and Aeronautics, House Committee on Science, expressed an interest in how NASA intends to ensure protection of the space station against space debris for which shielding will not be provided. As a result, they asked us to provide this report on NASA's and DOD's requirements and capabilities for detecting and tracking space objects and the existing relationships between the two agencies for carrying out their responsibilities in this area. We evaluated (1) how well DOD's existing space surveillance capabilities support DOD's and NASA's current and future surveillance requirements and (2) the extent to which potential space surveillance capabilities and technologies are coordinated to provide opportunities for improvements.

[4]This Board was established by the Secretary of Defense and the Director of Central Intelligence to ensure that defense and intelligence needs for space systems and their terrestrial components are satisfied within available resources, using integrated architectures to the extent possible.

[5]DOD uses the term near earth to describe a range of altitudes that are similar to the National Science and Technology Council's definition of low earth.

To accomplish these objectives, we reviewed surveillance network studies; DOD's and NASA's surveillance requirements documents and emerging needs; reports, plans, and budgets associated with surveillance network operations, maintenance, and enhancements; and program documentation on potential capabilities. We also reviewed national space policy and interviewed DOD and NASA representatives responsible for space surveillance. We performed this work primarily at the U.S. and Air Force Space Commands, Colorado Springs, Colorado, and NASA's Johnson Space Center, Houston, Texas.

In addition, we held discussions with and obtained documentation from representatives of the Office of the Deputy Under Secretary of Defense for Space; the Joint Staff; the Ballistic Missile Defense Organization; the Office of the DOD Space Architect; the Departments of the Air Force, the Navy, and the Army; the Naval Research Laboratory; and NASA Headquarters; all in Washington, D.C.

We also acquired information from the Naval Space Command, Dahlgren, Virginia; the Air Force Space and Missile Systems Center, El Segundo, California; the Air Force Electronic Systems Center, Hanscom Air Force Base, Massachusetts; the Air Force's Phillips Laboratory, Albuquerque, New Mexico; the Army Space and Strategic Defense Command, Huntsville, Alabama; the National Oceanic and Atmospheric Administration's Office of Satellite Operations, Suitland, Maryland; the Massachusetts Institute of Technology's Lincoln Laboratory, Lexington, Massachusetts; and the University of Colorado's Aerospace Engineering Sciences, Boulder, Colorado. We visited the Air Force's Ground-based Electro-Optical Deep Space Sensor, Socorro, New Mexico; the Massachusetts Institute of Technology's Lincoln Space Surveillance Complex, Tyngsboro, Massachusetts; and NASA's Liquid Mirror Telescope, Cloudcroft, New Mexico.

We obtained written comments from DOD and NASA on a draft of this report. These comments are reprinted in their entirety in appendixes II and III, respectively. Both DOD and NASA also provided technical and editorial comments, which we have incorporated into the report where appropriate.

We performed our work from September 1996 to August 1997 in accordance with generally accepted government auditing standards.

# Existing Network Cannot Satisfy Emerging Surveillance Requirements

NASA has established some stringent space surveillance requirements to protect the space station and other spacecraft from collisions with space debris. DOD's space surveillance requirements are under review and are likely to become more stringent. Because DOD's existing space surveillance network cannot satisfy its and NASA's emerging requirements, changes in the network may be needed. NASA and DOD have held discussions over the years regarding NASA's surveillance requirements, but there is no authoritative direction, formal agreement, or clear plan on how the two agencies could consolidate their requirements for a common capability.

## NASA's Requirements to Protect the Space Station Are Stringent

During the past several years, NASA and DOD periodically discussed space surveillance requirements for the space station, but many proposed requirements were left to be determined and not formally provided as firm requirements to DOD. In August 1997, however, NASA provided the U.S. Space Command with an updated set of requirements for surveillance support that are more specific, comprehensive, and complete than previous requirements. Two of these requirements—detecting and tracking relatively small space objects and more accurately determining the location of such objects—cannot be met by DOD's existing surveillance network. In commenting on a draft of this report, NASA stated that a third requirement—notifying NASA within 1 hour of a space object breakup—also cannot be met.

### Relatively Small-Sized Space Object Information Needed

NASA has designed portions of the space station with shielding to provide protection against objects smaller than 1 centimeter. It has concluded that shielding against larger objects would be too costly. The National Science and Technology Council estimated that about 118,000 objects 1 centimeter and larger were orbiting the earth. However, DOD's surveillance network cannot routinely detect and track 110,000 (93 percent) of the objects that are estimated to be between 1 and 10 centimeters in size. The National Research Council report stated that the risk of the space station colliding with untracked debris could be lowered if more objects were tracked. The report mentioned that debris from about 0.5 to 20 centimeters in diameter was of most concern to the space station because, within this range, the debris may be too large to shield against and too small to (currently) track and avoid.

Because NASA has no location information about these relatively small sized objects, it is requiring DOD, in the near term, to routinely detect, track, and catalog all space objects that are 5 centimeters and larger and

have a perigee of 600 kilometers or less.[1] Beginning in the 2002-2003 time frame, when the space station is to be completed, NASA will require DOD to detect, track, and catalog objects as small as 1 centimeter. DOD agrees that achieving the ability to detect and track objects 5 centimeters in size would be an intermediate step to meeting NASA's needs. However, DOD stated that achieving the capability to detect and track objects 1 centimeter in size would be technically challenging.

The importance of the requirement to detect and track 1 centimeter space objects is linked to the effect of critical collisions between such objects and the space station. NASA estimates a 19-percent probability of critical collisions with objects larger than 1 centimeter during a 10-year period. Although not all collisions would be catastrophic, NASA estimates a 5-percent probability that such collisions would cause a catastrophic failure, resulting in the loss of a module or a crew member. The National Research Council emphasized that these calculations are far from exact because they are based on many assumptions such as the future debris environment, which could be higher or lower than estimated, and the effectiveness of shielding critical space station components. Also, the calculations exclude impacts on noncritical items that could potentially cause severe damage to the station.

## Accurate Space Object Location Information Needed

NASA plans to maneuver the space station to avoid collisions with those space objects that can be accurately located by DOD's surveillance network. Currently, DOD assesses the proximity of the 8,000 cataloged objects relative to an orbiting space shuttle. NASA uses these assessments to determine whether a sufficient threat exists to require a collision avoidance maneuver. Although NASA has made such maneuvers with the space shuttle, the shuttle has not been maneuvered in some instances because of concern for interference with the primary mission objective.

For safety reasons, knowing the accurate location of space objects is important in deciding when to make collision avoidance maneuvers. Also, such knowledge would help avoid making unnecessary maneuvers that would be disruptive to mission objectives, such as microgravity experiments performed on the space shuttle or space station.

To ensure accurate information on objects that are 1 centimeter and larger, in low-earth orbit, and with perigees 600 kilometers or less, NASA's requirements specifically call for sensor tracking to an orbital "semi-major

[1]The perigee of an object's orbit is the lowest point of the orbit relative to the earth.

axis" uncertainty of 5 meters or less.[2] The purpose of this requirement is to better predict possible collisions and better decide on the need for collision avoidance maneuvers. However, DOD cannot meet this requirement because the network's sensors and processing capability and capacity are insufficient, and because DOD does not have a program to measure the orbital location accuracy of the 8,000 cataloged objects.

## DOD's Requirements Are Under Review and Likely to Become More Stringent

During the 1980s and early 1990s, the U.S. and Air Force Space Commands repeatedly studied different aspects of space surveillance needs and requirements, but not in a comprehensive manner. Command representatives told us that the lack of emphasis on space surveillance during this period was due to its lower priority compared with other missions, such as ballistic missile defense.

In 1994, the U.S. Space Command assessed its surveillance requirements, which had last been validated in 1985. The results showed that the requirements were loosely stated or inferred, had little supporting rationale, and did not address future threats. This assessment led to another study, completed by the Air Force Space Command in 1995, that established new space surveillance requirements. However, these requirements were never validated by the Joint Requirements Oversight Council—DOD's authoritative forum for assessing requirements for defense acquisition programs.

In early 1997, the U.S. Space Command determined that the 1995 Air Force surveillance requirements contained insufficient detail and justification and, as a result, initiated another requirements review. In June 1997, the Command emphasized that space surveillance is the foundation for all functions that are performed in space and thus requested updated surveillance requirements from defense, intelligence, and civil space sector users, stating that the requirements must be quantitatively linked to the needs of the warfighter and the Command's assigned civil support responsibilities. The final product is to be a space surveillance requirements annex to the Command's space control capstone requirements document. This document, which is still in draft form, emphasizes the necessity of (1) timely space surveillance assessments relative to hostile actions in space, foreign reconnaissance satellite overflights, and operational capabilities of foreign satellites and (2) accurate information about space object size and orbital locations.

[2]Because most space objects have elliptical orbits, the longer radius of the ellipse is known as the semi-major axis.

Upon completion of this effort, the space surveillance requirements are to be reviewed and validated by the Joint Requirements Oversight Council.

The DOD Space Architect used the U.S. Space Command's draft capstone requirements as a basis for performing its space control architecture study. The study observed that U.S. forces expect timely characterization of space threats; that is, forces expect to be warned in a timely manner when a foreign satellite is a threat to their theater of operations. However, the study concluded that, with the trends in satellite growth indicating not only more satellites but also smaller and more compact satellites (known as microsatellites), the task of distinguishing the attributes and status of orbiting objects with both ground- and space-based sensors becomes more difficult.

## Process for Establishing Consolidated Requirements Is Not Clear

DOD has a well-defined process for establishing its own requirements. However, because NASA is not a participant in this process and depends on DOD to provide space surveillance capabilities, it is not clear how NASA can ensure satisfaction of its surveillance requirements. First, although the 1996 National Space Policy implies that DOD should provide such surveillance capabilities, and the U.S. Space Command acknowledges its civil space sector responsibility in this area, the policy does not provide directions to ensure that DOD satisfies NASA's requirements. Second, although NASA has provided requirements to the U.S. Space Command, DOD and NASA have not reached agreement as to how or when these requirements might be satisfied. Third, the DOD Space Architect organization's study of space surveillance, which included both the defense and intelligence space sectors, noted that detecting and tracking space debris down to 1 centimeter (NASA's requirement) could be important to the safety of manned space systems, but that the requirement is not a high priority for DOD. Thus, there is no authoritative direction, formal agreement, or clear plan on how the two agencies could consolidate their requirements for a common capability.

## Conclusions

The civil and national security (defense and intelligence) space sectors have a common interest in space surveillance, and there may be an increasing interest by the commercial space sector. Better information is needed regarding the size, location, and characterization of space objects than the existing space surveillance network can provide.

NASA's space surveillance requirements are commensurate with its responsibilities to ensure the safety of human space flight, but these requirements have not been acted upon by DOD. DOD's space surveillance requirements continue to be reviewed and will likely become more stringent.

Unless DOD and NASA can establish a consolidated set of national security and civil space surveillance requirements, an opportunity may be missed to (1) better ensure the safety of the planned multibillion dollar space station and (2) help satisfy national security needs, including U.S. forces' future needs for space asset information.

## Recommendation

We recommend that the Secretary of Defense and the Administrator of NASA, in consultation with the Director of Central Intelligence, establish a consolidated set of governmentwide space surveillance requirements for evaluating current capabilities and future architectures to support NASA's, DOD's, and other federal agencies' space programs and surveillance information needs.

# Potential Surveillance Capabilities Are Not Sufficiently Coordinated

DOD's plans to modernize the existing Naval Space Surveillance System (known as the Fence) and develop three new ballistic missile warning systems do not adequately consider NASA's or DOD's emerging space surveillance requirements. The Fence modernization effort would not provide an enhanced capability, but instead would only install modern components while continuing to satisfy DOD's current requirements. The development efforts for three missile warning systems do not adequately consider DOD's or NASA's emerging space surveillance requirements. Also, these four separate efforts are not sufficiently coordinated. Greater coordination could result in more informed decisions regarding the best combination of capabilities to satisfy a consolidated set of emerging national security and civil space surveillance requirements.

## Radar System Plan Does Not Address Emerging Surveillance Requirements

Beginning in fiscal year 2003, the Navy tentatively plans to incrementally replace components of the Fence with modern components because of the system's age and relatively high maintenance costs. However, this effort is not currently funded and will not enhance the system's present capability to detect and track space objects smaller than about 30 centimeters. According to DOD and NASA, the Fence could be upgraded to detect most near-earth space objects larger than 1 centimeter by changing its operating radio frequency from the existing very high frequency band to the super-high frequency band and by locating it near the equator. Such an upgrade could aid in satisfying both NASA's requirement related to small-sized space objects and DOD's emerging requirement related to microsatellites.

However, according to Naval Space Command officials, such an upgrade has not undergone comprehensive study. In addition, they stated that a radio frequency change (1) is not needed to satisfy existing DOD surveillance requirements and (2) would have a significant effect on the surveillance network's data processing needs. In commenting on our draft report, DOD stated that the possibility of obtaining funds to upgrade the Fence to meet NASA's 1 centimeter requirement is not high because DOD has no comparable requirement.

## Missile Warning Plans Do Not Address Emerging Surveillance Requirements

Historically, DOD acquired various sensors to satisfy missions other than space surveillance and then capitalized on their inherent capabilities to satisfy the surveillance mission. This collateral mission concept enabled DOD to perform two missions with the same sensors. Examples included ballistic missile early warning radars to detect and track intercontinental

ballistic missiles and submarine-launched ballistic missiles and other radars to track space launch vehicles. DOD's Space-Based Infrared System (SBIRS), Ground-Based Radar (GBR), and Theater High Altitude Air Defense (THAAD) radar are future ballistic missile warning systems that could contribute to performing the space surveillance function as a secondary mission.

## Infrared Satellite System

DOD plans to develop a low-earth orbit satellite component within the SBIRS program, referred to as SBIRS-Low, to provide missile tracking support to both national and theater ballistic missile defense programs. In May 1997, the Under Secretary of Defense for Acquisition and Technology testified before a congressional panel that SBIRS-Low could also perform much of the space surveillance function, allowing some existing terrestrial surveillance sensor sites to be closed and eliminating some surveillance network gaps in space coverage,[1] such as in the Southern Hemisphere. Although DOD believes that the planned SBIRS-Low design would provide an inherent space surveillance capability, its specific capabilities for this function have not been determined.

The Air Force plans to initiate SBIRS-Low development in fiscal year 1999, launch the first satellite in fiscal year 2004, and ultimately procure up to 24 or more satellites to establish an operational constellation that would provide worldwide coverage. Although the SBIRS program office has begun to investigate the feasibility of space-based space surveillance, it currently does not plan to develop the SBIRS' surveillance capabilities because the necessary operational requirements have not been established. Until these requirements are established, DOD can only point to the potential capabilities provided inherently by the ballistic missile warning design.

## Missile Defense Radars

The Army is developing two new phased-array radar systems—the GBR to support national missile defense and the THAAD radar to support theater missile defense. Army project officials stated that on the basis of limited analyses, GBR and THAAD radars each may have inherent space surveillance capabilities that could support NASA's and DOD's emerging requirements. They stated that GBR, for example, could (1) detect and track space objects that are approximately 1 centimeter or less and (2) maintain 1,000 simultaneous tracks of these objects compared with only several hundred tracks that phased-array radars in the existing surveillance network can

[1]This testimony was presented before a joint session of the Subcommittee on Military Research and Development and Subcommittee on Military Procurement, House Committee on National Security.

maintain. Similarly, the officials stated that the THAAD radars could track, characterize, and discriminate objects while performing their autonomous search function. Finally, the officials stated that the GBR and THAAD radars could be used during peacetime for space surveillance while maintaining readiness for combat.

As with SBIRS-Low, neither GBR nor THAAD is currently required or specifically designed to perform space surveillance functions. Army officials stated that, although the U.S. Space Command was briefed about GBR's ability to perform collateral missions, including space surveillance, the Command had not established operational requirements for space surveillance applicable to either GBR or THAAD.

By fiscal year 1998, the Army plans to have a GBR prototype in operation. A national missile defense deployment decision is expected in fiscal year 2000, which may include plans for GBR deployment in 2003. Regarding THAAD, the Army currently has two test radars and plans to award an engineering and manufacturing development contract in 1999 for two radars with more capability. It expects to deploy as many as 12 mobile THAAD radars worldwide.

## Lack of a Coordinated Plan

The Air Force Space Command's 1995 space surveillance study observed that the surveillance network evolved without a master plan. The space surveillance mission did not have as high a priority as other missions, and DOD capitalized on the inherent capabilities of sensors that were designed for purposes other than surveillance. The lack of such a comprehensive plan creates difficulties in assessing operational capabilities to satisfy requirements, particularly when the need arises to evaluate emerging requirements that are increasingly stringent.

The DOD Space Architect's May 1997 space control study assessed a mix of space surveillance capabilities. The study observed, for example, that a modest radio frequency enhancement to the existing Naval Space Surveillance System, costing roughly $200 million, is feasible for tracking space debris as small as 2 to 5 centimeters. The study also observed that the timing is right to evaluate the presumed inherent space surveillance capabilities of SBIRS-Low to determine if those capabilities could actually be provided. Although GBR and THAAD were not specifically addressed in the study, it indicated that a system with similar generic capability would be stressed to achieve NASA's 1 centimeter requirement. Finally, the study

suggested that several technology efforts be continued to provide a hedge against an uncertain set of future space control threats and priorities.

A significant point in the Space Architect's study was that NASA's 1 centimeter requirement would be both technically challenging and expensive. In its comments on our draft report, DOD stated that the requirement is not considered feasible within current budget constraints. Until the Joint Space Management Board provides directions regarding the study's results, implementation plans will not be prepared. Even then, the plans may not sufficiently address NASA's needs without agreement between DOD and NASA.

## Conclusions

NASA relies on DOD for space surveillance support, and both agencies need improved surveillance capabilities. However, four DOD systems that could provide such capabilities—the Naval Space Surveillance System, SBIRS-Low, GBR, and THAAD—lack sufficient coordination, both within DOD and between DOD and NASA. The three missile defense sensors (SBIRS-Low, GBR, and THAAD) could provide a collateral space surveillance capability, a concept DOD has successfully used over the years. In times of constrained budgets, capitalizing on ways to satisfy multiple missions with the same resources appears to be prudent.

A coordinated plan between DOD and NASA that considers all existing and planned capabilities could be beneficial in making cost-effective decisions to satisfy a consolidated set of emerging national security and civil space surveillance requirements. Without a coordinated plan, DOD and NASA would not be taking advantage of potential efficiencies. The DOD Space Architect, along with NASA and the intelligence space sector, could provide a means for developing such a plan.

## Recommendation

We recommend that the Secretary of Defense and the Administrator of NASA, in consultation with the Director of Central Intelligence, develop a coordinated governmentwide space surveillance plan that (1) sets forth and evaluates all feasible alternative capabilities to support human space flight and emerging national security requirements and (2) ensures that any planned funding for space surveillance upgrades is directed toward satisfying consolidated governmentwide requirements.

# Surveillance Network Composition and Characteristics

The space surveillance network presently includes 31 DOD and privately owned radar and optical sensors at 16 worldwide locations, a communications network, and primary and alternate operations centers for data processing. Most of the sensors are mechanical tracking, phased-array, and continuous-wave radars, but optical telescopes are also used.

The most common radar type is a mechanical tracker with a movable antenna, whereby energy is transmitted into space and reflected by a space object back to the same radar antenna. A phased-array radar consists of thousands of individual antennas that produce and steer energy beams to different locations in space. A continuous-wave radar system consists of several transmitters and receivers, each placed in a different physical location across a horizontal plane. The Naval Space Surveillance System, consisting of six receivers and three transmitters located at sites from California to Georgia, is a continuous-wave system. Telescopes, such as the Ground-based Electro-Optical Deep Space System, detect light reflected from space objects and track the objects using this reflected light.

The various network sensors' support to the space surveillance mission are categorized as being dedicated, collateral, or contributing. Dedicated sensors support the space surveillance mission as their primary purpose. Collateral sensors primarily support other missions, such as ballistic missile warning or launch vehicle range support, but also provide space surveillance capabilities. Contributing sensors are used under a contract or an agreement to support the space surveillance mission only when requested by the U.S. Space Command.

All space surveillance data needs are coordinated through the Space Control Center, located at Cheyenne Mountain Air Station in Colorado, or the alternate control center, located at the Naval Space Command in Virginia. These control centers direct the network sensors to collect data on a space object's orbital position. Such data can provide information about the time that the space object is observed, its angle (elevation) from the point of observation, its direction (azimuth) from true north, and its distance (range) from the sensor. Information about a space object's physical properties, such as size, shape, motion, orientation, and surface materials, can also be obtained.

About one-third of the network sensors provide data on space objects only in near-earth altitudes (5,875 kilometers and less), about one-third only in

deep space, and about one-third in both near earth and deep space. Table I.1 lists the network sensors by category, with the sensor types and detection ranges by locations.

**Table I.1: Space Surveillance Sensor Locations, Types, and Detection Ranges**

| Sensor location | Sensor type | Sensor detection range |
|---|---|---|
| **Dedicated support to space surveillance mission** | | |
| Diego Garcia, Indian Ocean | 3 telescopes | Deep space |
| Eglin Air Force Base, Florida | 1 phased-array radar | Near earth and deep space |
| Maui, Hawaii | 6 telescopes | 4 deep space and 2 near earth and deep space |
| Western and southern U.S. locations for the Naval Space Surveillance System | 1 continuous-wave radar system | Near earth |
| Socorro, New Mexico | 3 telescopes | Deep space |
| **Collateral support to space surveillance mission** | | |
| Antigua, British West Indies | 1 mechanical tracker radar | Near earth |
| Ascension Island, South Atlantic Ocean | 2 mechanical tracker radars | Near earth |
| Beale Air Force Base, California | 1 phased-array radar with 2 faces | Near earth |
| Cape Cod Air Force Station, Massachusetts | 1 phased-array radar with 2 faces | Near earth |
| Cavalier Air Force Station, North Dakota | 1 phased-array radar | Near earth |
| Clear Air Station, Alaska | 1 mechanical tracker radar | Near earth |
| Fylingdales, England | 1 phased-array radar with 3 faces | Near earth |
| Oahu, Hawaii | 1 mechanical tracker radar | Near earth |
| Thule, Greenland | 1 phased-array radar with 2 faces | Near earth |
| **Contributing support to space surveillance mission** | | |
| Kwajalein, Marshall Islands | 4 mechanical tracker radars | Near earth and deep space |
| Tyngsboro, Massachusetts | 3 mechanical tracker radars | Near earth and deep space |

# Comments From the Department of Defense

Note: GAO comments supplementing those in the report text appear at the end of this appendix.


ACQUISITION AND TECHNOLOGY

OFFICE OF THE UNDER SECRETARY OF DEFENSE

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WASHINGTON DC 20301-3000

OCT 0 8 1997

Mr. Louis J. Rodrigues
Director, Defense Acquisition Issues
National Security and International
Affairs Division
U.S. General Accounting Office
Washington, DC 20548

Mr. Rodrigues:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "Space Surveillance: DOD and NASA Need Consolidated Requirements and a Coordinated Plan", dated September 10, 1997 (GAO Code 707209), OSD Case #1464.

The detailed DoD comments on the draft report recommendations are provided in the enclosure. Suggested technical changes were provided separately. The DoD appreciates the opportunity to comment on the GAO draft report.

Sincerely,

Gil I. Klinger
Acting Deputy Under Secretary of Defense (Space)

GAO DRAFT REPORT - DATED SEPTEMBER 10, 1997
(GAO CODE 707209) OSD CASE 1464

"SPACE SURVEILLANCE: DOD AND NASA NEED CONSOLIDATED REQUIREMENTS AND A COORDINATED PLAN"

DOD COMMENTS ON THE GAO RECOMMENDATIONS

Recommendation 1: The GAO recommended that the Secretary of Defense and the Administrator of the National Aeronautics and Space Administration (NASA), in consultation with the Director of Central Intelligence (DCI), jointly establish a consolidated set of Government-wide space surveillance requirements to serve as a basis for evaluating capabilities to support NASA's manned space programs and DOD's and other Government agencies' information needs on space assets. (p. 6, p. 22/GAO Draft Report)

Now on pp. 5 and 20.

DOD Response: Partially concur. While the DOD supports a Government-wide group to consolidate requirements, we also believe that the recommendations need to go a step further in defining individual responsibilities for NASA, DCI, and DOD. Specifically, each organization needs to develop individual requirements, then proceed with consolidating these requirements and sharing the cost for resolution of the requirements. An interagency working group will be required to develop near-term policy on cost/burden sharing and a long-term space surveillance policy, not only among the various Government agencies, but also among commercial activities which may request DOD support. Previous working groups have been established to define consolidated requirements before, but they failed because the individual agencies were not all sufficiently prepared to bring their various requirements forward and properly represent their needs. It is critical for each agency to fully comprehend and stand behind their own needs prior to coordinating with other agencies.

See comment 1.

Additionally, it must be recognized that the DOD and NASA requirements for space surveillance have very different emphases. The DOD needs timely surveillance data for space control and intelligence, while NASA is primarily concerned with flight safety. Though not mutually exclusive, they are very different needs and mission areas. Capabilities to support one area generally provide limited support to the other. NASA and DOD must ensure that these additive requirements are truly synergistic and affordable.

Finally, it should be noted that the draft report appears to be concerned only with the sensors required to support space surveillance, vice the total system of processing nodes and communications systems which are critical in tasking sensors, correlating the data collected, and disseminating various related products to users. Additionally, the requirements for missile warning have not been adequately discussed resulting in a difficulty in reconciling or adjudicating the space surveillance and missile warning functions requirements. These important factors must be considered as we all proceed throughout the requirements development process.

See comment 2.

See comment 3.

Now on pp. 5 and 24.

Recommendation 2: The GAO also recommended that the Secretary of Defense and the Administrator of NASA, in consultation with the Director of Central Intelligence, jointly develop a coordinated Government-wide space surveillance plan that sets forth and evaluates all feasible alternative capabilities in a time frame sufficient to support the space station and emerging national security requirements, and prior to committing funds for existing surveillance sensor modification. (p. 6, p. 28/GAO Draft Report)

See comment 4.

DOD Response: Partially concur. The DOD agrees with an interagency approach for evaluating existing capabilities, planning future architectures, and addressing funding responsibilities to meet validated requirements. However, it must be recognized that we are now at the beginning of fiscal year 1998, and there is no planned additional funding for fiscal years 1998-2000 to act upon non-DOD requirements and architectures not already identified. It is not likely, regardless of available funding, that the DOD would be able to sufficiently upgrade sensors, processing capabilities, and supporting communication systems, in time to fully support the space station in the year 2002. Additionally, the DOD has presently developed and funded space surveillance maintenance and modernization programs. These programs are necessary to meet validated DOD requirements, ease maintainability issues, and help to lower life cycle costs. Delaying these programs to insert recently provided NASA requirements will result in an unacceptable level of increased cost and schedule risk. Lastly, the DOD already has existing joint processes and infrastructure to address requirements and implement plans for space surveillance. Therefore, the DOD should lead in the plan development and coordinate with other Government agencies.

The following are GAO's comments on DOD's letter dated October 8, 1997.

## GAO Comments

1. Unless DOD and NASA reach an agreement on requirements and cost or burden sharing for space surveillance, NASA may have to decide what degree of risk would be acceptable to its interests if surveillance network improvements are not made. Interagency agreements have been reached on other programs. For example, a memorandum of agreement for the National Polar-Orbiting Operational Environmental Satellite System was signed by the Secretaries of Commerce and Defense and the Administrator of NASA in 1995 that established a joint requirements process. It also provided directions for developing acquisition, technology, operations, funding, and organizational management plans. Regarding funding, the agreement established that a cost-sharing approach would be used for common requirements and that unique requirements would be funded by the appropriate agency.

2. We made adjustments in our report to refer to the surveillance network, where applicable, rather than just the surveillance sensors.

3. We are aware that the DOD Space Architect's 1997 space control study included a recommendation to separate the space surveillance function from the missile warning function. Initially, this could take place through procedural changes, and subsequently, through software and hardware modifications associated with planned system upgrades. The stated purpose was to reduce costs of surveillance that are otherwise required for a rigorous missile warning software certification process.

4. We are aware of various joint processes and infrastructure within DOD that could be used for plan development and coordination with other government agencies. However, for space surveillance, NASA has an important interest. The Aeronautics and Astronautics Coordinating Board—a senior management review and advisory body to DOD and NASA to facilitate coordination of aeronautics and space activities of mutual interest—may need to address this subject.

# Comments From the National Aeronautics and Space Administration

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

National Aeronautics and
Space Administration
**Office of the Administrator**
Washington, DC 20546-0001


OCT 10 1997

Mr. Louis J. Rodrigues
Director
Defense Acquisition Issues
National Security and International
Affairs Division
General Accounting Office
Washington, DC 20548

Dear Mr. Rodrigues:

Thank you for the opportunity to review and comment on the recent draft report entitled, "Space Surveillance, DOD and NASA Need Consolidated Requirements and a Coordinated Plan." This letter is to clarify and update a number of points made in the report as well as to provide a more in-depth perspective on the nature of space surveillance requirements.

Overall, the report is an accurate representation of the national, in particular DOD and NASA, requirements for space surveillance and the capabilities of the current Space Surveillance Network operated by DOD. Our major comments merely reflect the actions of the NASA Administrator within the past month to respond to a request from the Commander of U.S. Space Command soliciting the Agency's quantified space surveillance needs. In the Administrator's letter of August 27, 1997, he provided the Agency's space surveillance requirements for the near-term, midterm, and long-term. Most of the near-term requirements are being met, and NASA is quite pleased with the long history of communications and cooperation between different elements of DOD and NASA in this field.

Enclosed you will find specific and general observation comments for your consideration. Please contact John C. Mankins at 358-4659, if further assistance is required.

Sincerely,

J. R. Dailey
Acting Deputy Administrator

Enclosure

General Observations on the GAO Report: Space Surveillance
DOD and NASA Need Consolidated Requirements and a Coordinated Plan

In response to your request for a review of the Draft Report, NASA has the following general observations. A number of smaller editorial suggestions and corrections are marked in the text using Microsoft Word Revisions.

The tenor of the report suggests that the USSPACECOM is not meeting NASA's requirements. In fact, they are meeting the largest number of NASA's current requirements; there are only three that are not being satisfied at present. The requirement for 5-centimeter detection and tracking up to 600 kilometers is not being met because it is beyond the capability of current sensors as presently operated. The requirement for 5-meter determination of the semimajor axis is not currently being assured but may be within current capability with modified procedures. The requirement for notification within 1 hour of a breakup event is not currently met on a routine basis but may be approached with modified procedures; to be achieved routinely would require additional sites.

A comprehensive list of NASA's requirements was sent to General Estes, USCINCSPACE, on August 27, 1997, in response to his June 18, 1997, request to NASA and all other users that they provide the command with their current and future requirements. A copy of the NASA response was furnished to Mr. Gallegos electronically. All of those requirements are being satisfied with the exception of the three noted above.

See comment 1.

The report is silent on the effects of the reduction of sensors that has taken place in recent years. While still adequate to support NASA's requirements, the system's margins have been reduced substantially. Specifically, if Cavalier is closed, as has been proposed repeatedly in recent years, the catalog would rapidly deteriorate if Eglin were taken out of service by a hurricane. The effect of such an event on the catalog was demonstrated by the outage in 1995. Over 200 satellites were lost for 5 to 30 days.

Now on p. 19.

See comment 2.

The report infers on page 21 under PROCESS FOR ESTABLISHING CONSOLIDATED REQUIREMENTS IS NOT CLEAR that there has not been a process for DOD to understand and respond to NASA requirements. There have been formal Memoranda of Agreement between both Johnson Space Center (JSC) and Goddard Space Flight Center and USPACECOM for many years. The most recent JSC Memorandum (June 1996) provides for the formal support of both Shuttle and International Space Station operations. There are also a number of Executive agency forums for NASA and DOD coordination of requirements. In the context of two independent organizations, each with broad range of other responsibilities, the level of cooperation and support has been notably good. There is, however, no congressional forum in which the coordinated requirements of the DOD, NASA, and other agencies for space surveillance and other common interests is addressed.

Since the space surveillance network was defined by military requirements and funded by the DOD, it satisfies those requirements more effectively than it does NASA's requirements. Within the existing system capability, its operations on behalf of NASA have been effective.

See comment 3.

It should be noted in the PURPOSE section of the executive summary that the debris hazard to the multibillion dollar space program is more than the manned spaceflight elements. In paragraph two it should be noted that NASA has no space surveillance instruments; its research instruments only generate sampling data on debris and meteoroids.

September 1997

The following are GAO's comments on NASA's letter dated October 10, 1997.

## GAO Comments

1. In chapter 1, we briefly discussed DOD's closing of certain sensor sites that support space surveillance—the results of which apparently have not seriously affected DOD. To the extent that the system's margins have been reduced, particularly relative to NASA's requirements, interagency consolidation of requirements and coordination of a capabilities plan is further justified.

2. We are aware of several memorandums of agreement between NASA and DOD. The 1996 agreement for support of the space shuttles and station is written in general terms, dealing with working relationships and the exchange of available information. Although such an agreement is essential, the process for agreeing on stringent, quantified space surveillance requirements, the quality of information to be provided, and how surveillance network improvements are to be made and who pays for them, still has to be addressed. As discussed in our comments to DOD's response on our draft report, the Aeronautics and Astronautics Coordinating Board—a senior management review and advisory body to DOD and NASA to facilitate coordination of aeronautics and space activities of mutual interest—may be the proper forum for this subject.

3. We state in the report that NASA is dependent on DOD for space surveillance.

# Major Contributors to This Report

| | |
|---|---|
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# Related GAO Products

Space Station: Estimated Total U.S. Funding Requirements (GAO/NSIAD-95-163, June 12, 1995).

Space Station: Delays in Dealing With Space Debris May Reduce Safety and Increase Costs (GAO/IMTEC-92-50, June 2, 1992).

Space Program: Space Debris a Potential Threat to Space Station and Shuttle (GAO/IMTEC-90-18, Apr. 6, 1990).

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