United States General Accounting Office

GAO

Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, House of Representatives

May 1999

SATELLITE CONTROL SYSTEMS

Opportunity for DOD to Implement Space Policy and Integrate Capabilities

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United States General Accounting Office
Washington, D.C. 20548

National Security and
International Affairs Division

B-280224

May 17, 1999

The Honorable Jerry Lewis
Chairman, Subcommittee on Defense
Committee on Appropriations
House of Representatives

Dear Mr. Chairman:

As requested, we (1) reviewed the Department of Defense's (DOD) progress in integrating and improving its satellite control capabilities and in fostering integrated and interoperable satellite control within the government, as directed by the 1996 national space policy and (2) determined whether opportunities exist for DOD to standardize its satellite control capabilities by using commercial products and practices.

Results in Brief

DOD has made minimal progress in integrating and improving its satellite control capabilities in accordance with 1996 national space policy. In 1992, DOD identified a need for an integrated satellite control system to achieve standardization and interoperability across military services and individual satellite programs.[1] In 1995, the Air Force, which controls most of DOD's satellites, characterized its satellite control capabilities as aging, inefficient, and costly to operate. The Air Force initiated an effort to standardize these capabilities and achieve full implementation in 2003—a first step toward an integrated and interoperable DOD capability. Air Force officials chose to proceed with a conceptual design over operational alternatives. However, in 1997, the Air Force terminated this effort because of schedule delays resulting from software development problems and the additional amount of software that needed to be written. Air Force Space Command representatives are now recommending that the use of the Air Force's existing satellite control capabilities be extended to 2005 to provide time to acquire an improved capability. Until then, the Air Force will be unable to reduce approximately $400 million it spends annually to operate,

[1]In this context, standardization means cooperation among agencies for efficient use of resources and for the adoption of common, compatible, or interchangeable components or equipment. Interoperability means the ability of systems to provide services to, and accept services from, other systems and to use the services so exchanged to enable the systems to operate effectively together.

maintain, sustain, and modernize satellite control capabilities. The Navy's satellite control capabilities are not as old, inefficient, or costly to operate as the Air Force's capabilities. Although the Navy upgraded its capabilities in the early 1990s, another upgrade is planned because the company that provided the existing capabilities no longer provides software support services.

DOD has taken limited action to foster integrated and interoperable satellite control for all government space activities since it was directed to do so by the 1996 national space policy. Prior studies recommended that a high-level interagency management group be established to oversee implementation of integrated systems across agency lines. Although DOD established a senior steering group in 1998 to address national security space management and integration issues, government space agencies continue to plan for satellite control capabilities on an independent basis rather than coordinate and integrate their efforts on an interagency basis.

Considering the long-standing need to replace the Air Force's aging and costly satellite control capabilities and the Navy's more recent plan to upgrade its capabilities, DOD has an opportunity to revitalize its effort to achieve integrated satellite control by acquiring a standardized capability. A resumed search for such a capability is appropriate because it would also provide an opportunity to review Air Force satellite control decisions for future space-based infrared and communication satellite programs that are currently in development. Commercial off-the-shelf products that could perform core functions for controlling satellites are available, and several studies have advocated the use of such products. In making a selection among alternatives, DOD could reduce acquisition risk by employing best commercial practices—a key element of DOD's acquisition reform initiatives. Commercial firms place a premium on demonstrated performance before making critical decisions rather than on predicted performance, as was the case with the Air Force's 1995 selection.

We are recommending that the Secretary of Defense take actions to revitalize efforts to (1) integrate and improve DOD's satellite control capabilities, using commercial products and practices and (2) foster integration and interoperability of satellite control among government space activities.

Background

Satellite control systems are used to ensure that satellites reach their planned orbits and perform their intended missions while in orbit. There

are two types of satellite control operations—platform control and payload control. Platform controls involves monitoring the health and status and managing the operations of a satellite's physical structure, sometimes called the bus. Payload controls involves monitoring the health and status and managing the operations of a satellite's mission equipment. Specific satellite control functions consist of (1) locating satellites and receiving and processing data from them, (2) following satellites' motion over time, and (3) transmitting signals to satellites. These three functions are called telemetry, tracking, and commanding and are performed by a network of ground command and control centers, ground antennas, and communication capabilities between the centers, antennas, and satellites.[2]

There are two types of satellite control networks—common and dedicated.[3] DOD operates two common networks that provide primary or backup control for communications, environmental monitoring, navigation, and intelligence satellites. Examples include the Defense Satellite Communications System, Defense Meteorological Satellite Program, and Global Positioning System. DOD also operates several dedicated networks that control missile warning, communications, and intelligence missions. Examples include the Defense Support Program and Milstar Communications System.

The Air Force Satellite Control Network (AFSCN) is the larger of the two common networks. It supports essentially all national security (defense and intelligence) satellites during launch and early orbit periods and is used to analyze anomalies affecting orbiting satellites. For certain satellite constellations, AFSCN provides essentially all the routine control functions needed throughout the satellite systems' lifetime. AFSCN capabilities consist of two command and control centers located at Schriever Air Force Base, Colorado, and Onizuka Air Force Base, California; antennas dispersed throughout the world; and associated communications capabilities.

[2]In this report, we focused on computer systems used at command and control centers to perform satellite control functions.

[3]A common network generally performs platform control for multiple satellite constellations, allowing its ground antennas and core data processing capabilities to be shared among many satellites and therefore reducing costs. Some unique data processing capabilities, however, may be needed for a particular satellite system. A dedicated network generally performs platform and payload control for one satellite constellation; thus no sharing of its capabilities with other satellite constellations takes place. Some reasons for dedicated networks are: (1) continuous contact must be maintained with certain satellites and (2) special radio frequencies or high data rates are sometimes used.

The Naval Satellite Control Network (NSCN)—the smaller of the two common networks—controls different satellite constellations. NSCN is to undertake increasing responsibilities in 1999 because the control functions for a constellation of communication satellites are to be transferred from AFSCN to NSCN. NSCN capabilities consist of a primary command and control center at Point Mugu, California, with backup capabilities in Colorado and Maine; antennas in Guam, California, and Maine; and associated communication capabilities.

In a May 1996 report, we discussed opportunities for (1) standardization and interoperability among government satellite control networks and (2) cost savings and greater efficiencies through network consolidation. The three government space sectors—defense, intelligence and civil—were operating separate satellite control networks to satisfy their individual satellite program needs. These sectors were spending several hundred million dollars a year to control their satellites or missions, were planning on upgrading their satellite control systems during the next 5 years, and did not have the necessary impetus or direction for more efficient use of the nation's satellite control resources. As a result, we recommended that a national policy be developed to direct integration, consolidation, and sharing, to the extent feasible, of the nation's satellite control capabilities.[4] In September 1996, the administration established a new national space policy that included directions for DOD to (1) pursue integrated satellite control and continue to enhance the robustness of its satellite control capability and (2) coordinate with other departments and agencies, as appropriate, to foster the integration and interoperability of satellite control for all government space activities.

DOD Has Not Effectively Implemented Policy Guidelines for Satellite Control

DOD has made minimal progress in integrating and improving its satellite control capabilities in accordance with 1996 national space policy. Although the Air Force and Navy have merged some of their capabilities, the Air Force was unsuccessful in acquiring a standardized satellite control system. Also, DOD has taken limited action to foster integrated and interoperable satellite control for all government space activities, as the 1996 policy directed.

[4]Satellite Control Capabilities: National Policy Could Help Consolidation and Cost Savings (GAO/NSIAD-96-77, May 2, 1996).

Minimal Progress to Integrate and Improve DOD Capabilities

Before the 1996 national space policy was established, DOD identified a need for an integrated satellite control system, and the Air Force initiated an effort to replace its satellite control capabilities with a standardized satellite control system (SSCS). However, the Air Force's effort was unsuccessful because of system development problems, and as a consequence the Air Force has continued with the costly, aging, and inefficient existing system for some satellite programs while seeking individual solutions for others. Several government satellite control studies have been performed that contain a common approach: integrate and upgrade satellite control capabilities to achieve efficiencies and economies. The Air Force is currently reviewing approaches to revitalize its effort for a satellite control solution.

DOD has made some progress as a result of older studies, which recommended that the Air Force and the Navy merge their satellite control networks. The two services established a communications link between the main Air Force satellite operations center and the Navy satellite operations center, allowing the two services to gain access to each other's satellite control antennas. Sharing antennas has allowed the Navy to close one antenna site, and there is the potential for closing another site, thus reducing costs. However, the two networks are not interoperable because they cannot control each other's satellites or back up each other's capabilities. Therefore, relative to study recommendations, the effort can only be characterized as minimal.

Control Systems Lack Necessary Capabilities and Need Upgrading

In 1992, the U.S. Space Command—the military command responsible for DOD's space operations—identified a need for an integrated satellite control system because of several existing system deficiencies. The Command described the existing satellite infrastructure as fragmented, fragile, vulnerable, and lacking standardization and interoperability. In 1994, the Air Force Space Command—the military command that operates AFSCN and provides space support for the majority of DOD's satellites—identified the need for improved satellite control capabilities. The Command cited aging equipment, manpower and funding reductions, future satellite system requirements, and technological opportunities as reasons for needed network upgrades, stating that its network must become more responsive, standardized, and interoperable; easily expandable; and economical to operate and maintain. In 1995, the Air Force established operational requirements for new satellite control capabilities with the objective of maximizing the use of industry standards and commercial or government off-the-shelf hardware, software, and

communications if they reduce acquisition timelines and operations and maintenance costs.[5]

The existing AFSCN's command and control capabilities were designed in the early 1980s and include a centralized mainframe computer system, in contrast to a modern distributed workstation design. According to Air Force documentation, much of the software was written in old, customized, and proprietary languages that resulted in (1) lack of standardization and interoperability, (2) increasing operations and maintenance costs, and (3) difficulties in responding to system requirement changes or accommodating new systems. The Air Force budgets over $400 million annually for AFSCN operations, maintenance, sustainment, and modernization. It programmed $2.2 billion for these purposes for fiscal years 1999-2003. Currently, the engineering sustainment contract is scheduled to expire in October 2003, and it is unclear whether the network can be sustained beyond that point.[6] The sustainment contractor reported that there is moderate to high risk that several pieces of system hardware may not be supportable beyond 2003 because (1) critical parts can no longer be procured, (2) equivalent replacement parts have not been identified, or (3) capability to repair the parts no longer exists. Some Air Force representatives, however, are more optimistic that sustainment could be continued if necessary.

The existing NSCN is a distributed command and control system that was designed in the early 1990s. The Navy budgets about $19 million annually to operate, maintain, sustain, and modernize the NSCN. It programmed $95 million for these purposes for fiscal years 1999-2003. The Navy is planning to upgrade NSCN because the company that provided the existing computers is no longer providing associated software support services. Navy representatives informed us that they plan to begin evaluating system alternatives in fiscal year 2001 and complete the replacement of NSCN's data processing capabilities in fiscal year 2003.

Air Force Effort to Standardize Capabilities Was Unsuccessful

In 1995, the Air Force initiated an effort to replace the AFSCN's command and control capabilities with SSCS and achieve full implementation in fiscal

[5]In this report, the terms commercial off-the-shelf and government off-the-shelf mean products developed and produced for general and government use, respectively, that have applicability to, and use for, satellite control systems without major modification or change.

[6]Engineering sustainment involves design and planning for replacement, or continued supply, of parts needed to prolong a system's ability to perform its mission.

year 2003. The purpose was to establish a standard and interoperable satellite control system for multiple DOD satellite programs that was more responsive, dependable, and cost-effective than the existing system. Following an initial screening of several candidate systems that were to serve as a basis for SSCS, four were selected for detailed evaluation. They were (1) the Distributed Command and Control System (DCCS)—a conceptual system being developed for the National Reconnaissance Office; (2) Commercial Off-the-Shelf—Based Research Architecture (COBRA)—a system being used by the Air Force to control research and development satellites; (3) OS/Comet—a system being used by the Naval Research Laboratory; and (4) the Shuttle Mission Control System—a capability being used by the National Aeronautics and Space Administration (NASA). None of the four systems satisfied all requirements; therefore, modifications would have been necessary for any system chosen.

The Air Force selected DCCS as the baseline system, concluding that this developmental design (1) would provide the best architecture and functional capabilities, (2) would provide a core software system standardized over a broader group of satellite systems, and (3) would require less modification than the other candidate systems. However, according to Air Force officials involved in the evaluation process, less was known about DCCS than the other candidates. For example, DCCS had not passed its critical design review—a key point in the acquisition of a system to assess design maturity—whereas the other three candidates were operational.

The DCCS design subsequently encountered development problems, requiring design changes and resulting in schedule delays. The design changes (1) fundamentally altered the DCCS architecture, restricting the hardware that could be used and (2) substantially increased the lines of software code that Air Force officials estimated would have to be developed to derive SSCS. Because of these system development problems, Air Force officials concluded that DCCS would not meet Air Force needs or schedule. In October 1997, the Air Force terminated its SSCS effort.

By choosing DCCS instead of an operational system about which it had more knowledge, the Air Force took a significant risk and was ultimately left without a standardized satellite control capability. This choice appears inconsistent with the Air Force's 1995 requirements calling for maximum use of off-the-shelf technology. It also runs counter to the practice of leading commercial firms, which want proof that a technological concept

will work and can be delivered on schedule. Thus, the Air Force's choice to proceed with this developmental design would have likely presented too high a risk for a commercial firm.[7]

Consequences of No Standardized Capabilities

More than 1 year after the Air Force terminated its SSCS effort, no renewed effort had been formally initiated. As a consequence, AFSCN command and control operations, which the Air Force has described as costly and manpower-intensive, may need to be extended to support existing satellite programs. Also, managers for the future Space-Based Infrared System (SBIRS), who planned to use SSCS, had to continue implementing an individualized satellite control solution.

Almost all national security satellites are dependent on AFSCN to reach their intended orbit, and several existing satellite programs such as the Defense Satellite Communications System are dependent on AFSCN for routine satellite control functions. Therefore, until the Air Force replaces the AFSCN's command and control capabilities with a less costly, standardized capability, it will be unable to reduce approximately $400 million it spends annually to operate, maintain, sustain, and modernize AFSCN. Replacing these capabilities is intended to reduce operations, maintenance, and sustainment costs. Air Force Space Command representatives informed us they were recommending that a contract be awarded in fiscal year 2001 to replace the command and control capabilities in fiscal year 2005. This would be 2 years later than the original plan to achieve full implementation of SSCS. At the end of our review, formal approval and budgeting for this recommendation had not yet occurred.

Air Force managers of SBIRS—a satellite system being developed to replace an older satellite system to provide strategic and theater ballistic missile warning and defense capability—had planned to use SSCS, when it became available, as the system's core satellite control capability. Because SSCS was not expected to be available for the first phase of the program, Air Force managers made plans to use a satellite control system called SCS-21 that was being developed by the SBIRS prime contractor. They planned to transition to SSCS for the second phase. However, when the SSCS effort was terminated, the managers chose a commercial off-the-shelf version of SCS-21 that was also being provided by the SBIRS prime

[7]See Best Practices: Successful Application to Weapon Acquisitions Requires Changes in DOD's Environment (GAO/NSIAD-98-56, Feb. 24, 1998).

contractor. According to program representatives, the SCS-21 core software will provide many, but not all, the satellite control functions needed by the SBIRS program. Capabilities to address the extra functions are being added to the core software, but no changes are being made that would affect the commercial off-the-shelf properties of the core software. Although this is an individualized satellite control solution, maintaining these commercial properties should make subsequent versions of the commercially available SCS-21 core software easy to install.

Several Studies Have Been Performed, but a Solution Is Not Yet Available

Prior to the 1996 national space policy, DOD led or participated in several studies that discussed intra-agency and interagency satellite control capabilities. These studies contained a common approach: integrate and upgrade satellite control capabilities to achieve efficiencies and economies. We discussed portions of four different studies in our May 1996 report. Since the 1996 national space policy was established, DOD components have performed several other studies that address satellite control. However, they were all long-range studies, and at the end of our review in April 1999, no decisions or implementing actions had been taken on them. We discuss three examples below.

- In December 1997, the DOD Space Architect completed a satellite operations study to develop architecture alternatives for the 2010-2015 time frame in support of defense, intelligence, and civil space sector needs. The draft report included alternative assessments that both emphasized and de-emphasized interoperability. It stated that the lack of satellite operations standardization prevents resource sharing and interoperability within and between federal agencies and the commercial and international community. Although the draft report stated that increased interoperability was beneficial, it also stated that analytical attempts to quantify the value of interoperability in terms of cost and performance were inconclusive. In addition, the draft report discussed various ways of using commercial products and services for satellite operations, including advantages—cost savings, increased performance, and government personnel reductions—and disadvantages—market dependency and proprietary interest. At the end of our review in April 1999, the Architect's final report had not been released.
- In March 1998, the U.S. Space Command published its long-range plan, which represented a guide for achieving the Command's vision of how military space strategy would evolve in the 21st century, specifically to 2020. The Command stated that because the operational techniques of many military satellites closely parallel those of commercial systems,

private industry may be able to operate military systems for less money and military personnel could be transferred from satellite operations functions to core military functions. In commenting on a draft of our report, DOD officials stated that although it may be feasible for private industry to operate military satellites, the effect on national security has not been addressed.

- In November 1998, the Air Force Scientific Advisory Board issued a report titled, "A Space Roadmap for the 21st Century Aerospace Force," which included an assessment of satellite operations. One of the report's findings was that commercial satellite ground operations are far less people-intensive and far more efficient overall than military systems, representing an important potential source of savings. In elaborating, the report stated that existing military satellite operations were costly, mostly proprietary, user unfriendly, increasingly difficult to support, and difficult to upgrade. The report recommended that (1) opportunities be evaluated to make selective investments in commercial off-the-shelf software packages for legacy satellite systems and (2) best commercial practices be used to acquire future satellite control systems.

Given the consequences of terminating SSCS, Air Force Space Command representatives are reviewing alternative approaches to acquire modern satellite control capabilities. Specifically, they are (1) looking for an approach to replace existing capabilities by 2005, (2) proposing to sustain existing capabilities beyond the sustainment contract expiration date of October 2003 until the replacement is available in fiscal year 2005, and (3) attempting to identify viable options to accelerate replacement of existing capabilities to fiscal year 2003. No decisions had been made on these matters at the end of our review in April 1999, and the Air Force was no closer to identifying and implementing a standardized and interoperable satellite control system than it was in 1995.

Limited Action to Foster Integrated and Interoperable Government Satellite Control

DOD has taken limited action to foster integrated and interoperable satellite control for all government space activities, as directed by the 1996 national space policy. Representatives within the Office of the Secretary of Defense and the Departments of the Air Force and the Navy informed us that no formal coordination of such satellite control matters had taken place. In July 1998, the Secretary of Defense and the Director of Central Intelligence established revised procedures for the management of national security (defense and intelligence) space programs and activities. In commenting on a draft of our report, DOD acknowledged that greater effort should be applied toward satellite control integration and

interoperability and anticipated placing greater emphasis during the years 2000 to 2005. However, DOD commented that similar commitment must be made by other government agencies involved in space activities to achieve success.

Prior studies recommended that a high-level interagency management group be established to oversee implementation of integrated systems across agency lines. We made a similar recommendation in our May 1996 report. The revised national security management procedures for space included establishing a National Security Space Senior Steering Group to address space management and integration issues. However, government space agencies continue to plan for satellite control capabilities on an independent basis rather than coordinate and integrate their capabilities on an interagency basis. For example, NASA recently contracted to consolidate its space operations, including satellite control, at several research centers with the long-term objective of increasing operational effectiveness and efficiencies at reduced costs. According to NASA officials, other agencies were not involved in the process of assessing alternatives to achieving consolidated space operations at NASA's centers, although other agencies, including DOD, have expressed interest in NASA's activities.

Integrating satellite control capabilities on an interagency basis is feasible. For example, under a separate national policy established in 1994, the President directed convergence of DOD's meteorological satellite system and the Department of Commerce's National Oceanic and Atmospheric Administration's (NOAA) environmental satellite system. NOAA provides the primary satellite operations capability at its control center in Suitland, Maryland, for both satellite systems. DOD provides backup satellite operations capability for its system at Schriever Air Force Base, Colorado. In commenting on a draft of this report, DOD officials emphasized that this satellite system convergence constituted significant action to foster integrated and interoperable satellite control and has achieved certain monetary advantages. However, they claimed that integrating the operations of these systems has resulted in unclear lines of authority, less timely military decision-making, and increased coordination requirements, thus complicating military space planning. Such integrated operations may require government agencies to revise their procedures and practices, but should afford them an opportunity to achieve significant cost savings.

DOD Has an Opportunity to Revitalize Integrated Satellite Control Effort

DOD has an opportunity to integrate Air Force and Navy satellite control networks by revitalizing the effort to acquire a standardized satellite control capability. Such an effort would be timely, considering the Air Force's need and the Navy's plans to replace each of their satellite control capabilities by 2003. Commercial off-the-shelf products that perform core satellite control functions and that have a demonstrated record of performance are available. Several satellite control studies have advocated the use of such products.

Resumed Search for Standard Core Capability Is Timely

The Air Force has an opportunity to resume its search for a standard satellite control system. The unsuccessful attempt to replace its existing capabilities with SSCS merely prolonged the retention of an aging and costly system. The Air Force could consider introducing a replacement capability in 2003, when the existing engineering sustainment contract expires.

Also, now is an opportune time to review the SBIRS satellite control decision made in 1997. Based on a fiscal year 2000 budget decision, DOD plans to delay the first launch of SBIRS by 2 years—from 2002 to 2004. Although the SCS-21 system may still be suitable for SBIRS, the planned program delay has reduced the urgency of making a final satellite control choice. It has also created an opportunity to consider other alternatives that may have wider application for DOD satellites.

A decision needs to be made about what satellite control capabilities to use for two future DOD communication satellite systems—the Gapfiller Super High Frequency and Advanced Extremely High Frequency. DOD expects to begin acquiring these satellite systems during the fiscal year 2001 time frame. If a standardized satellite control system is not selected in time to accommodate these satellites, the Air Force may be placed in a position of having to (1) modify its existing capabilities or (2) acquire individual satellite control solutions. Both choices would be undesirable.

Commercial Products Could Provide Core Capability

As discussed in the previous section, several studies over the years have advocated the use of commercial products to provide standard core capability for satellite control functions. Most of these studies have recognized that the government does not perform such unique satellite control functions that commercial products could not satisfy requirements. The most recent of these studies, by the Air Force Scientific Advisory

Board, claimed that selective use of commercial off-the-shelf products could have big payoffs. The Air Force is currently acquiring different commercial satellite control packages for the Global Positioning System and SBIRS. Although these and other alternatives are available, the Air Force is not currently considering them to satisfy multiple satellite control requirements. We discuss four examples below.

- One alternative system is COBRA, which was developed by an Air Force Space and Missile Center research office as a low-cost means of controlling research satellites. The COBRA system consists of multiple commercial off-the-shelf products integrated to form a whole satellite control capability. It was designed to control different types of satellites—a distinct advantage when searching for a standardized system to support multiple types of national security satellites. According to Center representatives, COBRA has been used to control three different research satellites and is to be used to control others. It also has demonstrated some capability to control DOD operational satellites such as the Milstar communication system and is currently controlling nonoperational Defense Support Program and Defense Satellite Communication System satellites. An earlier version of COBRA was not chosen as SSCS because the Air Force believed that more software modification would have been required than with the DCCS candidate.
- A second alternative is a system called OS/Comet, which is a commercial off-the-shelf product that the Air Force is currently acquiring to provide core satellite control capability for the Global Positioning System. To accommodate the unique characteristics of the satellite system, capabilities are being added to work with OS/Comet but no modifications are being made to the OS/Comet software. OS/Comet was developed to control satellite systems at the Naval Research Laboratory's Blossom Point Tracking Facility, where it is still being used. It is now being made available by the development contractor as a commercial off-the-shelf product. Like the COBRA system, OS/Comet was a candidate for SSCS but was not chosen because the Air Force believed that more software modification would have been required than with the DCCS candidate. However, as an indicator of OS/Comet's value, the Iridium company selected the system to control its constellation of 66 commercial communication satellites.
- A third alternative is a system called SCS-21, which the Air Force is currently acquiring to control SBIRS satellites. Similar to the COBRA system, SCS-21 includes commercial off-the-shelf products integrated into a package to provide core satellite control capabilities. The SBIRS

contractor is adding capabilities to accommodate the unique characteristics of the satellite system, but no modifications are being made to the SCS-21 software. NASA representatives told us that they plan to use SCS-21 under a consolidated space operations contract as the core satellite control software at several research center, including Goddard Space Flight Center, which controls numerous scientific satellites.

- Although we did not perform an exhaustive search, nor do we endorse any specific commercial product, other commercial satellite control systems are available. One such standard system is Epoch 2000. According to the developer, this off-the-shelf system was developed through the experience in designing and implementing special control systems for NASA's scientific satellites and NOAA's environmental satellites. It is a modern, distributed software system that can be used with many commercial hardware architectures and is being used to control a variety of commercial communications satellites and government scientific and resource monitoring satellites. The developer told us that the functions performed by satellite control systems are not substantially different among different satellite systems. Air Force Space Command representatives told us that several private firms have offered to demonstrate their commercial satellite control products.

Best Commercial Practices Could Reduce Acquisition Risk

As discussed above, in its effort to acquire SSCS, the Air Force selected a conceptual system as a baseline, which had not passed its critical design review and for which little was known, and ultimately encountered development problems. Three other candidate systems were operational but were not chosen. This approach is not consistent with best commercial practices, in which a premium would have been placed on demonstrated performance when selecting a product to be acquired. Instead, the Air Force selected a product according to the product's predicted performance rather than its known performance.

In our February 1998 report, we noted that early in system development, leading commercial firms gained more knowledge than DOD about how well a prospective system would satisfy performance, cost, and schedule requirements. This is because commercial firms essentially complete the discovery process, accumulating knowledge and eliminating unknowns about the system before major milestones such as critical design review are passed. The first step—ensuring that technology is sufficiently obtainable to warrant starting the program—is critical. DOD often accepts more

unknowns in its programs than commercial firms and understates the risks associated with these unknowns.

Conclusions

DOD has not effectively implemented the guidelines for satellite control as set forth in the 1996 national space policy. DOD needs to integrate its satellite control capabilities to reduce costs and inefficiencies. This could be done through standardization and interoperability. Considering the Air Force's need and the Navy's plan to upgrade their satellite control capabilities, now is an opportune time for DOD to consolidate these individual efforts to achieve an integrated approach. A sound plan toward this end would consider using commercially available products and making a selection based on best commercial practices employed by leading firms to reduce acquisition risk.

DOD has taken limited action to foster integrated and interoperable satellite control for all government space activities. Under 1996 national space policy guidelines, DOD is obligated to coordinate with other departments and agencies, as appropriate, regarding integration and interoperability of satellite control. DOD's recently established National Security Space Senior Steering Group could be a useful mechanism for guiding and overseeing such integration and interoperability. However, the Senior Steering Group's effectiveness at fostering interagency satellite control integration and interoperability has yet to be demonstrated. It would be timely for the Senior Steering Group to determine whether DOD's plans to replace its satellite control capabilities could be integrated with NASA's efforts to consolidate its satellite control operations.

Recommendations

We recommend that the Secretary of Defense direct the Secretaries of the Air Force and the Navy to (1) consolidate their plans to replace existing Air Force and Navy satellite control capabilities and (2) consider using commercial off-the-shelf satellite control products and best commercial practices in making a selection among alternative systems to satisfy core satellite control requirements, thus limiting the need for unique capabilities. We also recommend that the Secretary direct the Under Secretary of Defense for Acquisition and Technology; the Under Secretary of Defense (Controller/Chief Financial Officer); and the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence to only consider funding requests for such replacement efforts that make

maximum use of commercial products and practices to achieve integrated satellite control capabilities within DOD.

We further recommend that, in consonance with the development of DOD's plans to replace its satellite control capabilities, the Secretary take the lead in ensuring that the National Security Space Senior Steering Group serves as the forum for fostering and overseeing the integration and interoperability of satellite control for all government space activities in accordance with 1996 national space policy guidelines.

Agency Comments and Our Evaluation

In written comments on a draft of this report, DOD agreed that more integrated satellite activity should take place within DOD as well as across defense, civil, and commercial space sectors. It stated that integrated operations can lead to increased standardization, resulting in lower satellite acquisition and operation costs. However, DOD pointed out that such integration pursued primarily for the benefit of monetary savings has the potential of limiting the ability of military forces to effectively carry out their assigned missions. DOD officials emphasized the need to ensure military control over such satellite integration. We agree that both cost savings and the necessary military control are important and recognize that integrated operations present new management challenges.

DOD commented that our draft report made several accurate observations of recent and ongoing DOD satellite control planning and operational activities but did not properly highlight some significant strides or realistic obstacles. For example, DOD mentioned (1) the termination of fractured and duplicative operations of communications satellites by the Air Force and Navy and (2) satellite control compliant efforts, specifically the convergence of DOD's meteorological and the Department of Commerce's environmental satellites that was initiated prior to the establishment of the 1996 national space policy. These actions are discussed in the report.

DOD emphasized that fiscal realities cannot be ignored, stating that replacing legacy systems is expensive and requires proper planning and budgeting. We discussed the Air Force's effort to standardize its satellite control capabilities, which began in 1995, and stated that since terminating this effort in 1997, the Air Force has not formally initiated renewed efforts. We believe an opportunity now exists for DOD to renew its effort to standardize these capabilities using commercially available products and agree that effective planning and budgeting are critical.

DOD partially agreed with our recommendation that the Secretary of Defense direct the Secretaries of the Air Force and the Navy to consolidate their satellite control replacement plans and consider using commercial off-the-shelf products and best commercial practices in making a selection. DOD commented that it would not want to migrate toward a "monolithic" satellite control capability, and we agree that such a capability may not be the optimum solution. Instead, DOD stated that the question is how to structure architectures so that national security and civil interests are appropriately addressed and so that interoperability and commonality are balanced against security requirements to protect DOD systems from intrusion. DOD also stated that any resulting architecture should be built incrementally and that consolidating satellite control capabilities is an appropriate step in that direction. In doing so, DOD expects to take advantage of increasing commercial space activity and to pursue commercial off-the-shelf solutions for satellite control. We agree that structuring architectures for controlling multiple types of satellites could be difficult. Also, we believe that DOD's intention to employ commercial capabilities to address such diverse requirements is sound and that greater efficiencies should be achievable by using a common core of satellite control software capabilities.

DOD partially agreed with our recommendation that the Secretary of Defense provide directions to only fund satellite control replacement efforts that are designed to achieve integrated capabilities. DOD suggested (1) adding the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence to implement those directions and (2) including a reference to making maximum use of commercial products and practices. We agreed and modified our recommendation.

DOD agreed with our recommendation that the Secretary of Defense take the lead in establishing an interagency mechanism to provide a forum for fostering and overseeing the integration and interoperability of satellite control within the government. DOD commented that significant actions in this regard have been taken, citing a memorandum of understanding by the Secretary of Defense and Director of Central Intelligence dated July 31, 1998, for national security space management. The memorandum implements revised procedures for the management of DOD and intelligence community space programs and activities as directed by a Presidential Decision Directive. The memorandum establishes a National Security Space Senior Steering Group, directing that all interested national security and civil agencies be invited as members in the Senior Steering Group's deliberations, and a National Security Space Architect. We are

aware of this revised management structure and believe it could provide the proper interagency mechanism to fulfill the intent of the 1996 national space policy. Accordingly, we modified our recommendation to identify the Senior Steering Group as the appropriate interagency forum. However, the revised management structure had only been in effect for about 9 months when we completed our review in April 1999, and its effectiveness at fostering interagency satellite control integration and interoperability was yet to be demonstrated. Toward this end, it would be timely for the Senior Steering Group to determine whether DOD's plans to replace its satellite control capabilities and NASA's efforts to consolidate its satellite control operations could be integrated.

DOD's comments on a draft of this report are reprinted in their entirety in appendix I. DOD also provided technical comments on the draft report, which we incorporated as appropriate.

Scope and Methodology

To review DOD's efforts to integrate and improve its satellite control capabilities, we evaluated Defense, Air Force, and Navy plans, requirements, programs, budgets, and studies associated with current and future satellite control capabilities. To review DOD's efforts to foster integrated and interoperable satellite control within the government, we discussed the extent of interagency actions with defense and civil agency representatives. To identify opportunities for integrating satellite control, we discussed the status and capabilities of government-owned and commercially available products for satellite control with several government agency and private organization representatives.

We performed our work primarily at the Air Force Space Command, Colorado Springs, Colorado, and at several Air Force Space and Missile Systems Center offices at El Segundo, California; Albuquerque, New Mexico; and Colorado Springs, Colorado. To obtain additional information and explanations, we met with representatives from the Office of the Secretary of Defense; Department of the Air Force; Department of the Navy; Office of the DOD Space Architect; and NASA in Washington, D.C. We also obtained information from the U.S. Space Command, Colorado Springs, Colorado; Naval Space Command, Dahlgren, Virginia; NASA's Goddard Space Flight Center, Greenbelt, Maryland; NASA's Johnson Space Center, Houston, Texas; NOAA's Satellite Operations Center, Suitland, Maryland; Naval Satellite Operations Center, Point Mugu, California; and Naval Research Laboratory's Satellite Tracking Facility, Blossom Point, Maryland.

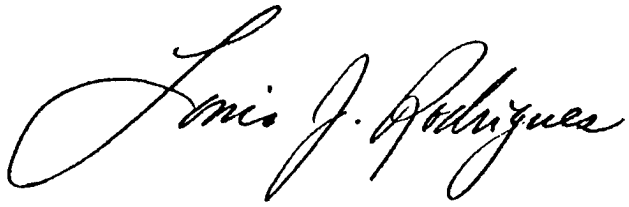
To obtain information on the availability and applicability of commercial satellite control products, we held discussions with officials representing Integral Systems, Incorporated, Lanham, Maryland; Raytheon Systems Company, Aurora, Colorado; Lockheed Martin Space Operations Company, Houston, Texas; and Software Technology, Incorporated, Alexandria, Virginia, and Denver, Colorado. These companies have developed satellite control systems for the various government organizations included in our review as well as for commercial satellite system operations.

We performed our review from May 1998 through April 1999 in accordance with generally accepted government auditing standards.

We are sending copies of this report to Senator Daniel K. Inouye, Senator Carl Levin, Senator Ted Stevens, Senator John W. Warner, Representative John P. Murtha, Representative Ike Skelton, and Representative Floyd D. Spence in their capacities as Chairs or Ranking Minority Members of Senate and House Committees and Subcommittees. We are also sending copies of this report to the Honorable William S. Cohen, Secretary of Defense; the Honorable F. Whitten Peters, Acting Secretary of the Air Force; the Honorable Richard Danzig, Secretary of the Navy; the Honorable Jacob Lew, Director, Office of Management and Budget; and the Honorable George J. Tenet, Director of Central Intelligence. Copies will also be made available to others upon request.

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

Sincerely yours,



Louis J. Rodrigues
Director, Defense Acquisitions Issues

Contents

Abbreviations

AFSCN	Air Force Satellite Control Network
COBRA	Commercial Off-the-Shelf—Based Research Architecture
DCCS	Distributed Command and Control System
DOD	Department of Defense
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NSCN	Naval Satellite Control Network
SBIRS	Space-Based Infrared System
SSCS	Standardized Satellite Control System

Comments From the Department of Defense

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

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
6000 DEFENSE PENTAGON
WASHINGTON, DC 20301-6000

COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE

April 12, 1999

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

Dear Mr. Rodrigues:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "SATELLITE CONTROL SYSTEMS: Opportunity for DoD to Implement Space Policy and Integrate Capabilities," dated March 2, 1999 (GAO Code 707353/OSD Case 1762).

Overall, the Department agrees that more integrated satellite activity should take place within the Department of Defense (DoD) as well as across the DoD, civil, and commercial space sectors. We fully support that integrated operations can lead to increased standardization across systems resulting in fewer costs in satellite acquisition and operations. However, we point out that integration pursued primarily for the benefit of monetary savings has the potential of limiting military capability to timely employ forces. Such integration must not hamper the ability of military forces to effectively carry out assigned missions.

While the draft report makes several accurate observations of recent past and ongoing DoD satellite control planning and operational activities, it fails to properly highlight many significant strides, as well as some very real obstacles. The first of these are the successes achieved in efforts to implement the Future Integrated Architecture Study (FITAS) that allow the Air Force and Navy to end fractured and duplicative operations of communications satellites. Secondly, DoD not only strongly supports prior and current GAO recommendations, as well as National Space Policy directives, but has initiated many compliant efforts even before such recommendations and directives were issued. Finally, regardless of the lofty nature of a stated goal, fiscal realities cannot be ignored. Replacing legacy systems is expensive, and must be properly planned and budgeted, in a fiscally restrained environment.

It is worth noting that DoD has been extremely proactive in engaging the participation and support of National and Civil Agencies, as well as industry, in achieving its goals. The DoD Office of the Space Architect (now the National Security Space Architect (NSSA)), has been a leader in these efforts to define and articulate a cost effective and integrated satellite control capability among the government agencies. The NSSA has been extremely cognizant of the need to plan an orderly transition to an integrated cost-effective solution, while maintaining the health, welfare and integrity of a rather large number of current on-orbit systems. The NSSA's

Satellite Operations Architecture development effort has been completed, and its recommendations are in final coordination. This architecture sets long-term goals that will influence near term modernization and budgetary planning.

Detailed comments in response to the recommendations are provided in the enclosure. Suggested technical changes for accuracy and clarification were provided separately.

The Department appreciates the opportunity to comment on the draft report.

Sincerely,

Robert M. Nutwell, RADM, USN
Deputy Assistant Secretary of Defense
(C3ISR and Space Systems)

Enclosure

GAO DRAFT REPORT - DATED MARCH 2, 1999
(GAO CODE 707353) OSD CASE 1762

"SATELLITE CONTROL SYSTEMS: OPPORTUNITY FOR DOD TO IMPLEMENT SPACE POLICY AND INTEGRATE CAPABILITIES"

Now on p.15.

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense direct the Secretaries of the Air Force and the Navy to (1) consolidate their plans to replace existing Air Force and Navy satellite control capabilities and (2) consider using commercial off-the-shelf satellite control products and best commercial practices in making a selection among alternative systems to satisfy core requirements, thus limiting the need for unique satellite control capabilities. (p.23/GAO Draft Report)

See comment 1.

DOD RESPONSE: **Partially Concur.** The report does not adequately acknowledge interoperability efforts which have already been accomplished. Projects have been completed which allow both the Navy and National Oceanic and Atmospheric Administration (NOAA) accesses to the Air Force Satellite Control Network (AFSCN). However, in terms of migrating toward a monolithic satellite control capability, we non-concur. The recently completed NSSA Satellite Operations Architecture study recommends that primary satellite telemetry and commanding should be performed "in band" via the connectivity used for mission operations. This should allow for a reduction in the current SCN infrastructure, as it would primarily be maintained for Low Data Rate (LDR), Launch, Early Orbit & Anomaly resolution (LEO&A) functions. Additionally, the NSSA recommendation to move toward more satellite autonomy will also significantly reduce the frequency and duration of satellite contacts for tracking purposes. This will further reduce requirements on the SCN and facilitate infrastructure reduction. The question becomes how to structure architectures so that military, civil, and national interests are appropriately addressed, even in crisis situations. Further, interoperability and commonality needs to be balanced against security requirements to protect DoD systems from outside intrusion. The resulting architecture and process should be built over time and incrementally, and consolidating satellite control capabilities is an appropriate step in that direction. Since commercial activity in space is increasing, competition is driving down the costs of the commercial systems, and the options for human-machine interface (HMI) across these systems are also increasing. We are leveraging off this phenomenon and more effectively reducing manning and skill levels. Additionally, DoD is actively pursuing commercial off-the-shelf solutions for satellite control. For example, the Integrated Satellite Control System planned for Military Satellite Communications (MILSATCOM) utilizes commercial off-the-shelf integrated systems. Also, the Space and Missile Systems Center Test and Evaluation Directorate (SMC/TE) employs an open architecture, Commercial off-the-shelf systems (COTS)-based telemetry, tracking, and commanding system to provide 24 hours/day, 7 days/week command and control of DoD Research and Development (R&D) satellites via the AFSCN, and is being actively evaluated for lessons learned and applicability to Air Force Space Command (AFSPC) missions.

Now on pp.15 and 16.

RECOMMENDATION 2: The GAO also recommended that the Secretary of Defense direct the Under Secretary of Defense for Acquisition and Technology and the Under Secretary of Defense (Comptroller) to only consider funding requests for such replacement efforts that are designed to achieve integrated satellite control capabilities within DoD. (p.23/GAO Draft Report)

DOD RESPONSE: **Partially Concur**. Recommendation 2 should be restated as follows: "We also recommend that the Secretary of Defense direct the Under Secretary of Defense for Acquisition and Technology, the Under Secretary of Defense (Comptroller), and the Assistant Secretary of Defense (Command, Control, Communications and Intelligence) to only consider funding requests for such replacement efforts that make maximum use of commercial products and practices to achieve integrated satellite control capabilities within DoD". The GAO recommendation as written would have been good guidance 6 years ago when we started this effort and there were no commercial products in the market place. Now, there are a number of high quality products to fly satellites. They have been demonstrated and are being used to fly R&D and non-operational Defense Satellite Communications System (DSCS) and Defense Support Program (DSP) satellites. The National Aeronautics and Space Administration (NASA) is also buying COTS systems to fly their satellites. DoD is committed to going commercial as evidenced by adding capability to a developmental laboratory facility at Schriever Air Force Base, so that 50th Space Wing operators can be involved up front with the adaptation of the COTS solution to replace the command and control system for MILSATCOM. The Navy will also continue the use of COTS systems. Commercialization will enhance standardization, as various products have already demonstrated their ability to fly different satellites. It will also ensure the lowest cost, as this area is now one where there is competition in the market place. However, as was pointed out in our response to Recommendation 1, a monolithic command and control solution for all satellites is not the optimum solution. As noted, the DoD Space Architect performed an analysis of the cost effectiveness of dedicated versus common satellite control solutions, and was unable to substantiate any cost savings for common solutions.

See comment 2.

Now on p.16.

RECOMMENDATION 3: The GAO further recommended that in consonance with developing DoD's plans for integrating its networks, the Secretary of Defense take the lead in establishing an interagency management mechanism to provide a forum for fostering and overseeing the integration and interoperability of satellite control within the Government, in accordance with National Space Policy guidelines. (p.23/GAO Draft Report)

DOD RESPONSE: **Concur**. Significant actions have already been undertaken in this regard. The Secretary of Defense and the Director of Central Intelligence signed a Memorandum of Understanding (MOU) for National Security Space Management on 31 July 98. This MOU implements revised procedures for management of National Security (DoD and Intelligence Community) space programs and activities as directed by Presidential Decision Directive (PDD/NSC-49), including the establishment of a National Security Space Senior Steering Group (NSS-SSG). This forum is designed to address broad national security space management and integration issues, provide policy guidance to the National Security Space Architect (NSSA), review architecture proposals, and advise on issues regarding stakeholder equities. The NSS-SSG is tri-chaired by the Assistant Secretary of Defense (Command, Control, Communications and Intelligence) (ASD (C3I)), the Deputy Director of Central Intelligence for Community Management (DDCI/CM), and the Director for Force Structure, Resources & Assessments, The

Joint Staff (Joint Staff/J8). The MOU also directs that all interested National Security and Civil Agencies will be invited as members in NSS SSG deliberations. This appears to be the forum to accomplish the GAO's recommendation.

The following are GAO's comments on the Department of Defense's (DOD) letter dated April 12, 1999.

GAO Comments

1. DOD's comment about its recently completed satellite operations architecture study refers to a proposed recommendation contained in a draft of the Architect's report that the satellite control functions for individual satellite systems should be integrated with the systems' mission operations in the same radio frequency band. This comment concerns communications between satellites and ground command and control centers. Our review did not focus on this linkage. Instead, we focused on the computer systems located at the ground centers that process the data necessary to perform satellite control functions. In addition, we are aware of the proposed recommendation in the Architect's draft report regarding the establishment of satellite autonomy goals to reduce the amount of needed ground operations. Although at the end of our review in April 1999 the Architect's final report had not been released, DOD officials provided no information that would alter our assessment.

2. DOD noted that the Space Architect performed a cost-effectiveness analysis of dedicated versus common satellite control solutions and was unable to substantiate any cost savings for common solutions. We observed in a draft of the Architect's report that, in an attempt to quantify differences between common and dedicated infrastructures, both of which included satellite mission and satellite control functions, the study team found that there was no significant life-cycle cost or performance differences between the two approaches. Although the consistency of these two statements is unclear, our review did not focus on the merits of dedicated versus common infrastructures. We focused on satellite control ground processing, irrespective of the type of infrastructure. In consonance with our approach, DOD stated that since commercial activity in space is increasing (1) there are a number of high-quality commercial products in the marketplace that are capable of controlling DOD satellites and (2) commercialization will enhance standardization and ensure lowest cost because of competition.

Major Contributors to This Report

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