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Report to the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives

April 2009

GLOBAL POSITIONING SYSTEM

Significant Challenges in Sustaining and Upgrading Widely Used Capabilities

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GAO-09-325

April 2009

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GAO Accountability·Integrity·Reliability

Highlights

Highlights of GAO-09-325, a report to the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives

Why GAO Did This Study

The Global Positioning System (GPS), which provides positioning, navigation, and timing data to users worldwide, has become essential to U.S. national security and a key tool in an expanding array of public service and commercial applications at home and abroad. The United States provides GPS data free of charge. The Air Force, which is responsible for GPS acquisition, is in the process of modernizing GPS.

In light of the importance of GPS, the modernization effort, and international efforts to develop new systems, GAO was asked to undertake a broad review of GPS. Specifically, GAO assessed progress in (1) acquiring GPS satellites, (2) acquiring the ground control and user equipment necessary to leverage GPS satellite capabilities, and evaluated (3) coordination among federal agencies and other organizations to ensure GPS missions can be accomplished. To carry out this assessment, GAO's efforts included reviewing and analyzing program documentation, conducting its own analysis of Air Force satellite data, and interviewing key military and civilian officials.

What GAO Recommends

GAO's recommendations include that the Secretary of Defense appoint a single authority to oversee development of GPS space, ground control, and user equipment assets, to ensure they are synchronized, well executed, and potential disruptions are minimized. DOD concurred with our recommendations.

View GAO-09-325 or key components.

For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

It is uncertain whether the Air Force will be able to acquire new satellites in time to maintain current GPS service without interruption. If not, some military operations and some civilian users could be adversely affected.

- In recent years, the Air Force has struggled to successfully build GPS satellites within cost and schedule goals; it encountered significant technical problems that still threaten its delivery schedule; and it struggled with a different contractor. As a result, the current IIF satellite program has overrun its original cost estimate by about $870 million and the launch of its first satellite has been delayed to November 2009—almost 3 years late.
- Further, while the Air Force is structuring the new GPS IIIA program to prevent mistakes made on the IIF program, the Air Force is aiming to deploy the next generation of GPS satellites 3 years faster than the IIF satellites. GAO's analysis found that this schedule is optimistic, given the program's late start, past trends in space acquisitions, and challenges facing the new contractor. Of particular concern is leadership for GPS acquisition, as GAO and other studies have found the lack of a single point of authority for space programs and frequent turnover in program managers have hampered requirements setting, funding stability, and resource allocation.
- If the Air Force does not meet its schedule goals for development of GPS IIIA satellites, there will be an increased likelihood that in 2010, as old satellites begin to fail, the overall GPS constellation will fall below the number of satellites required to provide the level of GPS service that the U.S. government commits to. Such a gap in capability could have wide-ranging impacts on all GPS users, though there are measures the Air Force and others can take to plan for and minimize these impacts.

In addition to risks facing the acquisition of new GPS satellites, the Air Force has not been fully successful in synchronizing the acquisition and development of the next generation of GPS satellites with the ground control and user equipment, thereby delaying the ability of military users to fully utilize new GPS satellite capabilities. Diffuse leadership has been a contributing factor, given that there is no single authority responsible for synchronizing all procurements and fielding related to GPS, and funding has been diverted from ground programs to pay for problems in the space segment.

DOD and others involved in ensuring GPS can serve communities beyond the military have taken prudent steps to manage requirements and coordinate among the many organizations involved with GPS. However, GAO identified challenges to ensuring civilian requirements and ensuring GPS compatibility with other new, potentially competing global space-based positioning, navigation, and timing systems.

Contents

Figures

Abbreviations

AEP	Architecture Evolution Plan
DASS	Distress Alerting Satellite System
DOD	Department of Defense
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
IFOR	Interagency Forum for Operational Requirements
JCIDS	Joint Capabilities Integration and Development System
L2C	second civil signal
L5	third civil signal
M-code	Military Code
NASA	National Aeronautics and Space Administration
OCS	Operational Control Segment
OCX	Next Generation Control Segment
OSD	Office of the Secretary of Defense
PDOP	position dilution of precision
PNT	Positioning, Navigation, and Timing
SLR	Satellite Laser Ranging
TSPR	Total System Performance Responsibility

United States Government Accountability Office
Washington, DC 20548

April 30, 2009

The Honorable John Tierney
Chairman
The Honorable Jeff Flake
Ranking Member
Subcommittee on National Security and Foreign Affairs
Committee on Oversight and Government Reform
House of Representatives

The Global Positioning System (GPS)—a space-based satellite system that provides positioning, navigation, and timing data to users worldwide—has become essential to U.S. national security and a key component in economic growth, transportation safety, homeland security, and critical national infrastructure in the United States and abroad. GPS is integrated into nearly every facet of U.S. military operations, and the number of civil users is increasing. Other countries are now developing their own independent global navigation satellite systems that could offer capabilities that are comparable, if not superior to GPS.

The U.S. government, which plans to invest more than $5.8 billion from 2009 through 2013 in the GPS space and ground control segments currently under development, provides GPS service free of charge. The Department of Defense (DOD) develops and operates GPS, and an interdepartmental committee—co-chaired by DOD and the Department of Transportation—manages the U.S. space-based positioning, navigation, and timing infrastructure, which includes GPS. DOD also provides most of the funding for GPS.

The Air Force, which is responsible for GPS acquisition, is in the process of modernizing GPS to enhance its performance, accuracy, and integrity. The modernization effort includes GPS IIF and IIIA, two satellite acquisition programs currently underway that are to provide new space-based capabilities and replenish the satellite constellation; the ground control segment hardware and software; and user equipment for processing modernized GPS capabilities.

In light of the global economic and national security importance of GPS, the ongoing GPS modernization effort, and the international efforts to develop new systems, you asked us to undertake a broad review of the program and efforts to replenish and upgrade capability. Specifically, we assessed progress in (1) acquiring GPS satellites, (2) acquiring the ground control and user equipment necessary to leverage GPS satellite capabilities, and (3) coordinating among federal agencies and other organizations to ensure broader GPS missions can be accomplished.

To assess the acquisition of satellite, ground control, and user equipment, we interviewed Office of the Secretary of Defense (OSD) and DOD officials from offices that manage and oversee the GPS program. We also reviewed and analyzed program plans and documentation related to cost, schedule, requirements, program direction, and satellite constellation sustainment, and compared programmatic data to GAO's criteria compiled over the last 12 years for best practices in system development.[1] We also conducted our own analysis, based on data provided by the Air Force, to assess the implications of potential schedule delays we identified in our assessment of the satellite acquisition. To assess coordination among federal agencies and the broader GPS community, we interviewed OSD and DOD officials from offices that manage and oversee the GPS program, officials from the military services, officials from the Department of Transportation and other civil departments and agencies, and officials at the U.S. Department of State and at various European space organizations. We also analyzed how civil departments and agencies coordinate with DOD on GPS civil requirements, and how the U.S. government coordinates with foreign countries. Additional information on our scope and methodology is in appendix I. We conducted this performance audit from October 2007 to April 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Results In Brief

It is uncertain whether the Air Force will be able to acquire new satellites in time to maintain current GPS service without interruption. If not, some military operations and some civilian users could be adversely affected.

- Under the IIF program, the Air Force had difficulty in successfully building GPS satellites within cost and schedule goals; it encountered significant technical problems which still threaten its delivery schedule; and it faced challenges with a different contractor for the IIF program. These problems

[1] For a list of reports on best practices, see Related GAO Products at the end of this report.

were compounded by an acquisition strategy that relaxed oversight and quality inspections as well as multiple contractor mergers and moves, and the addition of new requirements late in the development cycle. As a result, the IIF program has overrun its original cost estimate of $729 million by about $870 million and the launch of the first IIF satellite has been delayed to November 2009—almost 3 years late.

- Further, while the Air Force is structuring the new GPS IIIA program to prevent mistakes made on the IIF program, the Air Force is aiming to deploy the GPS IIIA satellites 3 years faster than the IIF satellites. We believe the IIIA schedule is optimistic given the program's late start, past trends in space acquisitions, and challenges facing the new contractor. Of particular concern is leadership for GPS acquisition, as GAO and other studies have found the lack of a single point of authority for space programs and frequent turnover in program managers have hampered requirements setting, funding stability, and resource allocation.
- If the Air Force does not meet its schedule goals for development of GPS IIIA satellites, there will be an increased likelihood that in 2010, as old satellites begin to fail, the overall GPS constellation will fall below the number of satellites required to provide the level of GPS service that the U.S. government is committed to providing. Such a gap in capability could have wide-ranging impacts on all GPS users, though there are measures the Air Force and others can take to plan for and minimize these impacts.

Moreover, the Air Force has not been fully successful in synchronizing the acquisition and development of the next generation of GPS satellites with the ground control and user equipment, thereby delaying the ability of military users to utilize new GPS satellite capabilities. For example, a modernized military signal will be available for operations on GPS satellites over a decade before user equipment will be fielded that can take strategic advantage of it. The signal is designed to improve resistance to jamming of GPS. Also, because leadership for acquisitions across the space community is fragmented, there is no single authority responsible for synchronizing all procurements and fielding related to GPS.

Lastly, DOD and others involved in ensuring GPS can serve communities beyond the military have taken prudent steps to manage requirements and coordinate among the many organizations involved with GPS. However, we identified challenges in the areas of ensuring civilian requirements can be met and ensuring GPS compatibility with other new, potentially competing global space-based positioning, navigation, and timing systems.

Because of (1) the criticality of the GPS system to the military, various economic sectors, and the international community and (2) schedule risks in the current program, we are recommending that the Secretary of

Defense appoint a single authority to oversee the development of the GPS system, including DOD space, ground control, and user equipment assets, to ensure that the program is well executed and resourced and that potential disruptions are minimized. The appointee should have authority to ensure DOD space, ground control, and user equipment are synchronized to the maximum extent practicable; and coordinate with the existing positioning, navigation, and timing infrastructure to assess and minimize potential service disruptions in the event that the satellite constellation was to decrease in size for an extended period of time. After a review of a draft of this report, DOD concurred with our recommendations and provided some additional comments. The full text of DOD's comments may be found in appendix IV.

Background

GPS is a global positioning, navigation, and timing network consisting of space, ground control, and user equipment segments that support the broadcasts of military and civil GPS signals. These signals each include positioning and timing information, which enables users with GPS receivers to determine their position, velocity, and time, 24 hours a day, in all weather, worldwide. GPS is used by all branches of the military to guide troops' movements, integrated logistics support and battlespace situational awareness, and communications network synchronization. In addition, bombs and missiles are guided to their targets by GPS signals and GPS is used to locate military personnel in distress. Early in the development of GPS, the scope was expanded to include complementary civil capabilities.

Over time, GPS has become a ubiquitous infrastructure underpinning major sections of the economy, including telecommunications, electrical power distribution, banking and finance, transportation, environmental and natural resources management, agriculture, and emergency services in addition to the array of military operations it services. For instance, civil agencies, commercial firms, and individuals use GPS to accurately navigate from one point to another. Commercial firms use GPS to route their vehicles, as do maritime industries and mass transit systems. In addition to navigation, civil departments and agencies and commercial firms use GPS and GPS augmentations[2] to provide high-accuracy, three-

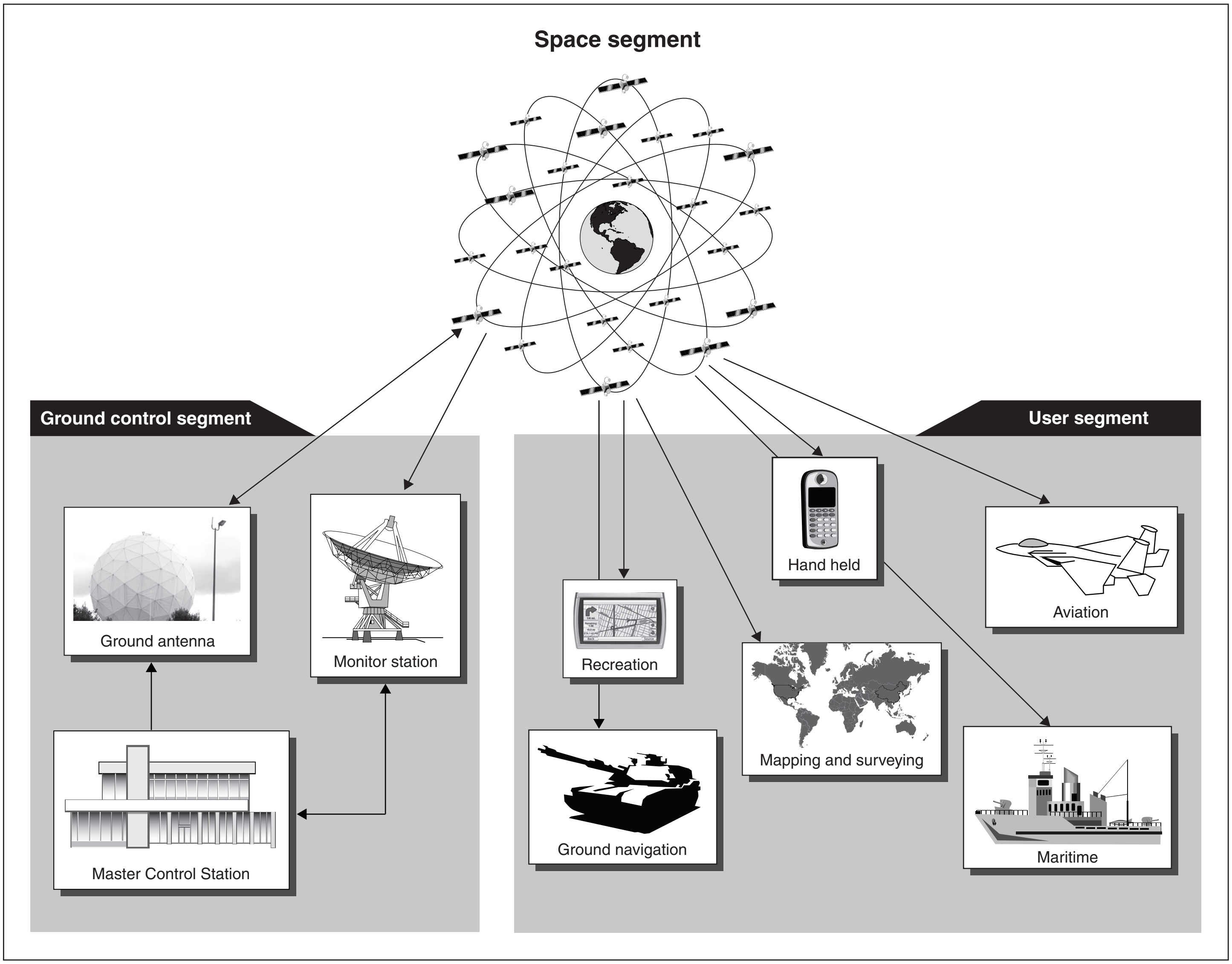
[2] GPS is augmented by ground-based or space-based navigation aids that are maintained by individual departments and agencies to provide users with improvements to the GPS navigation signal in terms of accuracy, availability, and/or integrity needs.

dimensional positioning information in real time for use in surveying and mapping. The aviation community worldwide uses GPS and GPS augmentations to increase the safety and efficiency of flight. GPS is also used in the agricultural community for precision farming, including farm planning, field mapping, soil sampling, tractor guidance, and crop scouting. GPS helps companies and governments place satellites in precise orbits, and at correct altitudes, and helps monitor satellite constellation orbits. The precise time that GPS broadcasts is crucial to economic activities worldwide, including communication systems, electrical power grids, and financial networks.

GPS System Description

GPS operations consist of three segments—the space segment, the ground control segment, and the user equipment segment. All segments are needed to take full advantage of GPS capabilities.

Figure 1: GPS Operational System



Source: Copyright © Corel Corp. All rights reserved (map); Art Explosion; GAO.

The GPS space segment consists of a constellation of satellites that move in six orbital planes approximately 20,200 kilometers above the earth. GPS satellites broadcast encrypted military signals and civil signals. In recent years, because numerous satellites have exceeded their design life, the constellation has grown to 31 active satellites of various generations.

However, DOD predicts that over the next several years many of the older satellites in the constellation will reach the end of their operational life faster than they will be replenished, thus decreasing the size of the constellation from its current level and potentially reducing the accuracy of the GPS service.

The GPS ground control segment is comprised of a Master Control Station at Schriever Air Force Base, Colorado; an Alternate Master Control Station at Vandenberg Air Force Base, California; 6 Air Force and 11 National Geospatial-Intelligence Agency monitoring stations; and four ground antennas with uplink capabilities. Information from the monitoring stations is processed at the Master Control Station to determine satellite clock and orbit status. The Master Control Station operates the satellites and regularly updates the navigation messages on the satellites. Information from the Master Control Station is transmitted to the satellites via the ground antennas.

The GPS user equipment segment includes military and commercial GPS receivers. These receivers determine a user's position by calculating the distance from four or more satellites using the navigation message on the satellites to triangulate its location. Military GPS receivers are designed to utilize the encrypted military GPS signals that are only available to authorized users, including military and allied forces and some authorized civil agencies. Commercial receivers use the civil GPS signal, which is publicly available worldwide.

GPS Modernization

In 2000, DOD began an effort to modernize the space, ground control, and user equipment segments of GPS to enhance the system's performance, accuracy, and integrity. Table 1 shows the modernization efforts for the space and ground control segment.

Table 1: GPS Satellite and Ground Control Segment Modernization

Satellite evolution and capabilities			
Legacy (1989 - 2002)	**Current (2005 - 2012)**		**Future (2014 - 2023)**
GPS IIA/IIR	**GPS IIR-M**	**GPS IIF**	**GPS III**
• Broadcasts signals for military and civil users.	Includes IIA and IIR capabilities, plus: • 2nd civil signal • 2nd military signal • Ability to increase signal power to improve resistance to jamming	Includes IIR-M capabilities, plus: • 3rd civil signal for transportation safety requirements	Includes IIF capabilities, plus: • IIIA: stronger military signal to improve jamming resistance and 4th civil signal that is interoperable with foreign signals • IIIB: near real-time command and control via cross links • IIIC: improved antijam performance for military users

Ground control segment and capabilities		
Legacy (Various versions from 1979-2007)	**Current (Came online in 2007)**	**Future (Planned to come online with initial capabilities in 2011)**
Legacy Operational Control System (OCS)	**Architecture Evolution Plan (AEP)**	**Next Generation Operational Control Segment (OCX)**
• Centralized computer mainframe • 1970s technology	• Distributed architecture • Enables upgrades to the system • Next upgrade will control GPS IIF	• Necessary for full operation of GPS IIR-M, IIF, and III satellites • Service-oriented architecture • Connects to the broader network

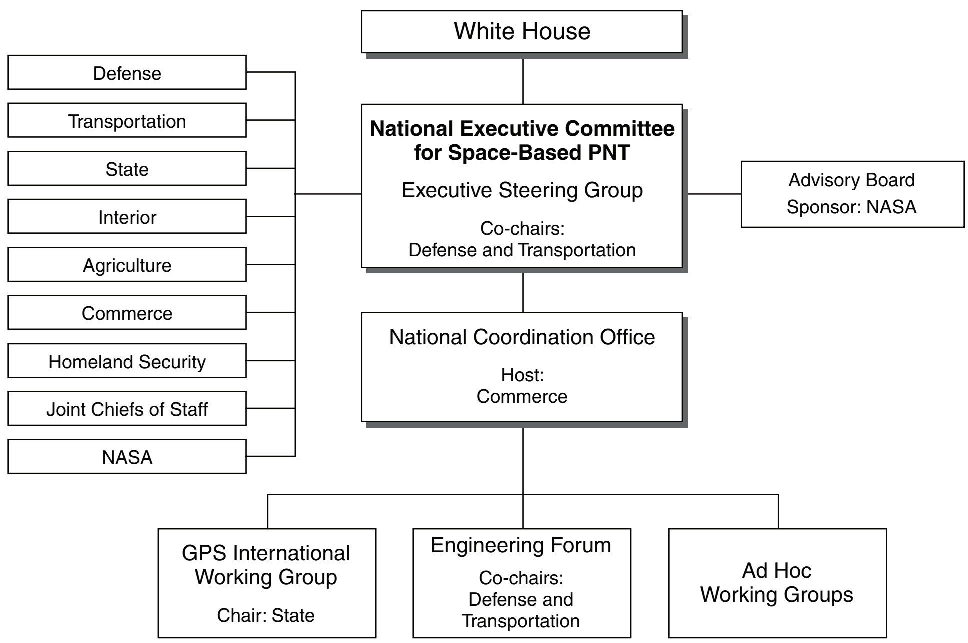
Source: GAO analysis based on DOD program information and discussions with DOD officials.

Full use of the military and civil GPS signals requires a ground control system that can manage these signals. Newer software will upgrade the ground control to a service oriented—or "plug and play"—architecture that can connect to broader networks. In order to utilize the modernized military signal from the ground, military users require new user equipment with this capability, which will be provided by the military GPS user equipment program.

Broader Management Structure

The 2004 U.S. Space-Based Positioning, Navigation and Timing (PNT) policy established a management structure to bring civil and military departments and agencies together to form an interagency, multiuse approach to program planning, resource allocation, system development, and operations. The policy also encourages cooperation with foreign governments to promote the use of civil aspects of GPS and its augmentation services and standards with foreign governments and other international organizations. As part of the management structure, an executive committee advises and coordinates among U.S. government departments and agencies on maintaining and improving U.S. space-based PNT infrastructures, including GPS and related systems. The executive committee is co-chaired by the Deputy Secretaries of the Department of Defense and the Department of Transportation, and includes members at the equivalent level from the Departments of State, Commerce, Homeland Security, Interior, Agriculture, the Joint Chiefs of Staff, and the National Aeronautics and Space Administration (NASA). Figure 2 describes the National Space-Based PNT organization structure.

Figure 2: National Space-Based PNT Organization Structure



Source: GAO presentation of National Executive Committee for Space-Based Positioning, Navigation and Timing Data.

The departments and agencies have various assigned roles and responsibilities. For example, DOD is responsible for the overall development, acquisition, operation, security, and continued modernization of GPS. It has delegated acquisition responsibility to the Air Force, though other DOD components and military services are responsible for oversight, some aspects of user equipment development, and for funding some parts of the program. The Department of Transportation has the lead responsibility for the coordination of civil requirements from all civil department and agencies. The Department of State leads negotiations with foreign governments and international organizations on GPS positioning, navigation, and timing matters or regarding the planning, operations, management, and/or use of GPS. (See app. III).

Air Force Faces Significant Challenges in Acquiring GPS Satellites

The Air Force's GPS IIF acquisition initially was not well executed, and currently poses technical problems. The Air Force is implementing lessons learned from the GPS IIF effort as it starts the GPS IIIA program. However, based on our analysis, the GPS IIIA program faces a compressed schedule along with new challenges to deliver the satellites on time. A slip in the launch of the GPS IIIA satellites could increase the likelihood that the GPS constellation will fall below the number of satellites required to provide the level of GPS service the U.S. government has committed to provide. This would not only have implications for military users but also for the larger community of GPS users, who may be less aware and equipped to deal with gaps in coverage. However, the Air Force is evaluating different approaches that could potentially reduce the risk of degrading the GPS service.

The IIF Program Was Not Well Executed, and Still Poses Technical Problems

The GPS IIF contract was awarded during an era of acquisition reform that centered on an approach called Total System Performance Responsibility (TSPR).[3] TSPR gave a contractor total responsibility for the integration of an entire weapon system and for meeting DOD's requirements. This approach was intended to facilitate acquisition reform and enable DOD to streamline a cumbersome acquisition process and leverage innovation and management expertise from the private sector. However, DOD later found that TSPR magnified problems on a number of satellite acquisition programs because it was implemented in a manner that enabled requirements creep and poor contractor performance. For GPS IIF, the TSPR approach resulted in relaxed specifications and inspections of the contractor, loss of quality in the manufacturing process, and poor-quality parts that caused test failures, unexpected redesigns, and the late delivery of parts. The contractor did not provide data on design drawings and statistical process control techniques were not used to monitor production.

[3] GAO, *Space Acquisitions: Actions Needed to Expand and Sustain Use of Best Practices*, GAO-07-730T (Washington, D.C.: Apr. 19, 2007).

According to GPS program officials, the GPS IIF program was also negatively impacted by multiple contractor mergers, acquisitions, and moves. In 1996, shortly after Rockwell won the IIF contract, the company's aerospace and defense units, including the Seal Beach, California, facility where the IIF satellites were to be manufactured, were acquired by Boeing. In December 1997, Boeing merged with McDonnell Douglas and took over its Delta launch vehicle unit in Huntington Beach, California, and subsequently GPS work was moved to that facility. In October 2000, Boeing acquired Hughes Electronics Corporation's space and communications business and related operations. Boeing took over the Hughes facility in El Segundo, California, and once again, GPS work was moved to another facility. As these events occurred, the prime contractor consolidated development facilities to remain competitive. In addition, the prime contractor lost valuable workers and knowledge, causing inefficiencies in the program.

Shortly after the IIF contract was awarded in 1996, the Air Force also added requirements. For example, the government decided to accelerate the fielding of new civil and military GPS signals. Flexible power capabilities were added to IIF several years later. These new requirements drove design changes and resulted in technical issues and cost overruns that impacted the schedule.

According to a GPS IIF program official, the combination of significant requirements additions, loss of engineering expertise, parts obsolescence, and fundamental design changes together caused the contractor to "lose the recipe" for the IIF space vehicle. In essence, by the completion of the design phase, the IIF space vehicle was to be built in a third location, by different people, in a way that was not initially anticipated. In addition, the program suffered from a lack of management continuity. Since the program's inception, the IIF program has had seven different program managers, the first five of whom only served 1 year each.

According to a former deputy program director of the GPS program office, past GPS programs seemed to operate well for a number of reasons. The programs (1) never added major modifications to ongoing programs and (2) had no qualms in terminating contractors if work did not meet standards, business practices, or major milestones. Furthermore, the GPS program performed more on-site contract management to increase communications. This approach eliminated surprises like cost and schedule overruns and held the contractor to a high level of performance. Lastly, the former director noted that it was important to balance the responsibility assigned to the program managers with the authority they needed to properly implement the program. Prior GAO reviews have identified all of these practices as essential to program execution.[4]

Air Force Improves Oversight of IIF, but Technical Issues Lead to More Delays

The Air Force has since taken action to improve the IIF program. In 2006, the program office[5] increased its personnel at the contractor's facility to observe operations and to verify that corrective measures were being taken to address deficiencies in the contractor's cost and schedule reporting system (also known as earned value management[6]). The Air Force increased the number of personnel to work on the contractor site, which included military and civilian personnel, as well as Defense Contract Management Agency[7] personnel and system engineering contractors. Greater presence at the contractor's factory has enabled the government to find out about problems as they happen and work with the contractor to come up with solutions and resolve issues quicker, according to GPS program officials.

Nonetheless, the program has experienced more technical problems. For example, last year, during the first phase of thermal vacuum testing (a critical test to determine space-worthiness that subjects the satellite to space-like operating conditions), one transmitter used to send the navigation message to the users failed. The program suspended testing in August 2008 to allow time for the contractor to identify the causes of the

[4] GAO, *Best Practices: DOD Can Help Suppliers Contribute More to Weapon System Programs*, GAO/NSIAD-98-87 (Washington, D.C.: Mar. 17, 1998); *Space Acquisitions: Major Space Programs Still at Risk for Cost and Schedule Increases*, GAO-08-552T (Washington, D.C.: Mar. 4, 2008); and, *Defense Acquisitions: Results of Annual Assessment of DOD Weapon Programs*, GAO-08-674T (Washington, D.C.: Apr. 29, 2008).

[5] On July 31, 2004, the GPS program office became the GPS Wing, when the Air Force's Space and Missile Systems Center reorganized and renamed its organizations to mirror the traditional Air Force structure.

[6] Earned value management (EVM) is a program management tool that integrates the technical, cost, and schedule parameters of a contract. During the planning phase, an integrated baseline is developed by time-phasing budget resources for defined work. As work is performed and measured against the baseline, the corresponding budget value is "earned." Using this earned value metric, cost and schedule variances can be determined and analyzed. EVM provides significant benefits to both the government and the contractor. An EVM system is required on all DOD space-program-related contracts meeting certain thresholds unless waived by the DOD Space Milestone Decision Authority.

[7] The Defense Contract Management Agency (DCMA) is the DOD component that works directly with defense suppliers to help ensure that DOD, federal, and allied government supplies and services are delivered on time, at projected cost, and meet all performance requirements.

problem and take corrective actions. The program also had difficulty maintaining the proper propellant fuel-line temperature; this, in addition to power failures on the satellite, delayed final integration testing. In addition, the satellite's reaction wheels, used for pointing accuracy, were redesigned because on-orbit failures on similar reaction wheels were occurring on other satellite programs—this added about $10 million to the program's cost.

As a result of these problems, the IIF program experienced cost increases and schedule delays. The launch of the first IIF satellite has been delayed until November 2009—almost 3 years late. According to the program office, the cost to complete GPS IIF will be about $1.6 billion—about $870 million over the original cost estimate of $729 million.

In addition, in 2006 we testified[8] that diffuse leadership over military space acquisitions was another factor contributing to late delivery of capability and cost growth. We noted that the diverse array of officials and organizations involved with a space program has made it difficult to pare back and control requirements. GPS was one example we cited. According to the Air Force, in 1998 the government decided to accelerate the fielding of new civil and military GPS signals and added requirements for these signals to the IIR and IIF GPS satellites. These new requirements drove design changes and resulted in technical issues, cost overruns, and program delays.

Problems Experienced in GPS IIF Seen in Other Space System Acquisitions

The problems experienced on the IIF program are not unlike those experienced in other DOD space system acquisitions. We have previously reported that the majority of major acquisition programs in DOD's space portfolio have experienced problems during the past two decades that have driven up costs, caused delays in schedules, and increased technical risk.[9] DOD has restructured several programs in the face of delays and cost growth. At times, cost growth has come close to or exceeded 100 percent, causing DOD to nearly double its investment without realizing a better return on investment. Along with the increases, many programs are experiencing significant schedule delays—as much as 7 years—postponing delivery of promised capabilities to the warfighter. Outcomes have been so

[8] GAO, *Space Acquisitions: Improvements Needed in Space Systems Acquisitions and Keys to Achieving Them*, GAO-06-626T (Washington, D.C.: Apr. 6, 2006).

[9] GAO, *Space Acquisitions: Major Space Programs Still at Risk for Cost and Schedule Increases*, GAO-08-552T (Washington, D.C.: Mar. 4, 2008).

disappointing in some cases that DOD has gone back to the drawing board to consider new ways to achieve the same, or less, capability.

Our work has identified a variety of reasons for the cost growth, many of which surfaced in GPS IIF. Generally, we have found that DOD starts its space programs too early, that is before it has assurance that the capabilities it is pursuing can be achieved within resources and time constraints. We have also tied acquisition problems in space to inadequate contracting strategies; contract and program management weaknesses; the loss of technical expertise; capability gaps in the industrial base; tensions between labs that develop technologies for the future and current acquisition programs; divergent needs in users of space systems; and other issues that have been well documented.

We also noted that short tenures for top leadership and program managers within the Air Force and the Office of the Secretary of Defense have lessened the sense of accountability for acquisition problems and further encouraged a view of short-term success.[10] Several other studies have raised similar issues. In 2003, a study[11] conducted for the Defense Science Board, for example, found that government capabilities to lead and manage the space acquisition process have seriously eroded, particularly within program management ranks. A 2005 Defense Science Board study[12] focused specifically on the future of GPS found that the program was hampered by sometimes overlapping, sometimes disconnected roles of Office of the Secretary of Defense staff components, the Joint Staff, and the Air Force. More recently, a commission[13] formed pursuant to the John Warner National Defense Authorization Act for Fiscal Year 2007[14], concluded in 2008 that there is currently no single authority responsible for national security space—which includes GPS—below the President

[10] GAO-06-626T.

[11] Defense Science Board/Air Force Scientific Advisory Board Task Force, *Acquisition of National Security Space Programs*, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (Washington, D.C.: May 2003).

[12] Defense Science Board Task Force, *The Future of the Global Positioning System*, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (Washington, D.C.: Oct. 28, 2005).

[13] Independent Assessment Panel on the Organization and Management of National Security Space, *Leadership, Management, and Organization for National Security Space*, Institute for Defense Analysis (Alexandria, Va.: Jul. 15, 2008).

[14] Pub. L. No. 109-364 § 914.

and that within DOD authorities are spread among a variety of organizations, including the Office of the Secretary of Defense, the Air Force, the other military services, the Missile Defense Agency, and the National Reconnaissance Office with no effective mechanism to arrive at a unified budget and set priorities. A study[15] chartered by the House Select Committee on Intelligence also recently found leadership for space acquisitions to be too diffused at higher levels and that there are critical shortages in skilled program managers. While recent studies have made recommendations for strengthening leadership for space acquisitions, no major changes to the leadership structure have been made in recent years. In fact, an "executive agent" position within the Air Force which was designated in 2001 to provide leadership has not been filled since the last executive resigned in 2005.

GPS IIF acquisition problems have not been as extreme as those experienced on other efforts such as the Space Based Infrared System (SBIRS) and the National Polar-orbiting Operational Environmental Satellite System (NPOESS). At the same time, however, the program was not as technically complex or ambitious as these efforts.

DOD Is Implementing Lessons Learned from the GPS IIF Program as It Starts the GPS IIIA Program, but Schedule Is Optimistic

The Air Force is taking measures to prevent the problems experienced on the GPS IIF program from recurring on the GPS IIIA program. However, the Air Force will still be challenged to deliver IIIA on time because the satellite development schedule is compressed. The Air Force is taking the following measures:

- using incremental or block development, where the program would follow an evolutionary path toward meeting needs rather than attempting to satisfy all needs in a single step;
- using military standards for satellite quality;
- conducting multiple design reviews, with the contractor being held to military standards and deliverables during each review;
- exercising more government oversight and interaction with the contractor and spending more time at the contractor's site; and
- using an improved risk management process, where the government is an integral part of the process.

[15] House Permanent Select Committee on Intelligence, *Report on Challenges and Recommendations for United States Overhead Architecture*, United States House of Representatives (Washington, D.C.: Oct. 3, 2008).

In addition, the Under Secretary of Defense for Acquisition, Technology, and Logistics specified additional guidance for the GPS IIIA program. This includes

- reevaluating the contractor incentive/award fee approach;
- providing a commitment from the Air Force to fully fund GPS IIIA in Program Objectives Memorandum[16] 2010;
- funding and executing recommended mitigation measures to address the next generation operational control segment and the GPS IIIA satellites;
- combining the existing and new ground control segment levels of effort into a single level of effort, giving the Air Force greater flexibility to manage these efforts;
- not allowing the program manager to adjust the GPS IIIA program scope to meet increased or accelerated technical specifications, system requirements, or system performance; and
- conducting an independent technology readiness assessment of the contractor design once the preliminary design review is complete.

Table 2 below highlights the major differences in the framework between the GPS IIF and GPS III programs.

Table 2: Key Differences in Program Framework for GPS IIF and GPS III

	GPS IIF	GPS III
Requirements	Addition of requirements after contract award.	Not allowing an adjustment to the program to meet increased or accelerated requirements.
Development	Immature technologies.	Incremental development, while ensuring technologies are mature.
Oversight	Limited oversight of contractor, relaxed specifications and inspections, and limited design reviews.	More contractor oversight with government presence at contractor facility; use of military standards; and multiple levels of preliminary design reviews, with the contractor being held to military standards and deliverables during each review.

Source: GAO analysis based on discussion with the GPS program office and program documentation.

[16] The Program Objectives Memorandum (POM) is an annual memorandum submitted to the Secretary of Defense by the DOD component heads, which recommends the total resource requirements and programs within the parameters of the Secretary of Defense's fiscal guidance. The POM is a major document in the Planning, Programming, Budgeting and Execution process, and the basis for the component budget estimates. The POM is the principle programming document that details how a component proposes to respond to assignments in the Strategic Planning Guidance and Joint Programming Guidance and satisfy its assigned functions over the Future Years Defense Program. The POM shows programmed needs 6 years hence (i.e., in fiscal year 2004, POM 2006-2011 was submitted).

The Air Force's Schedule for GPS IIIA May Be Optimistic

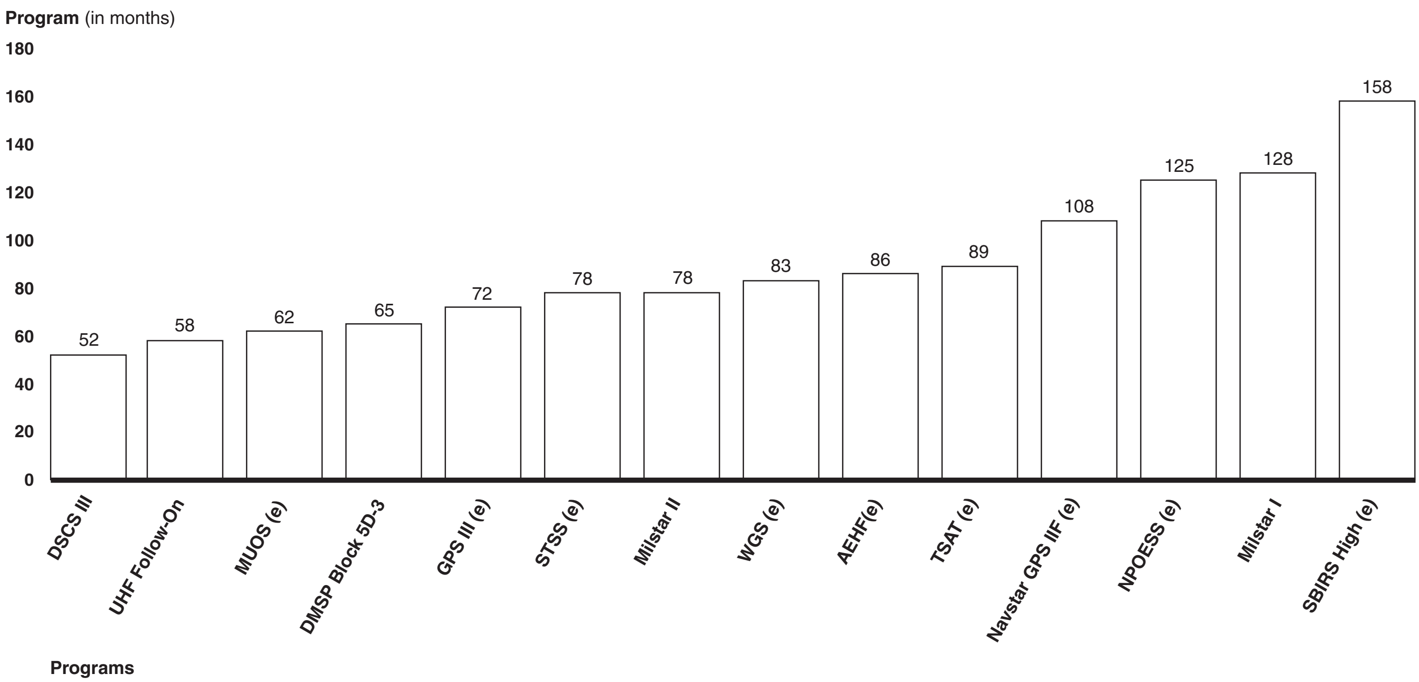
While these measures should put the GPS IIIA program on sounder footing, the program is facing serious obstacles—primarily in terms of its ability to deliver satellites on schedule. At present, the GPS IIIA program is on schedule and program officials contend that there is no reason to assume that a delay is likely to occur. They point out that the Air Force is implementing an incremental development approach and GPS IIIA, the first increment of GPS III, is not expected to be as technically challenging as other space programs. In addition, program officials point out that the Air Force began risk reduction activities in 1998, and has made a concerted effort to exert more oversight over its contractors and ensure key decisions are backed by sufficient knowledge about technologies, design, and production.

We recognize that these steps offer the best course for GPS to be completed on time. However, we believe there is still considerable risk that the schedule may not be met for the following reasons.

- First, the GPS IIIA program got off to a late start. The program was originally scheduled to begin development in August 2007. However, according to GPS program officials, the Air Force shifted funds from GPS III to other commitments in its space portfolio and to address problems in other programs. The Defense Space Acquisition Board approved formal initiation of the GPS IIIA acquisition in May 2008.
- Second, when compared to other DOD satellite programs, the GPS IIIA program schedule appears highly compressed. The Air Force is planning to launch the first GPS IIIA satellite in 2014 to sustain the GPS constellation. To launch in 2014, the Air Force has scheduled 72 months from contract award to first satellite launch. This schedule is 3 years shorter than the schedule the Air Force has so far achieved under its IIF program. In fact, the time period between contract award and first launch for GPS IIIA is shorter than most other major space programs we have reviewed (see fig. 3). Moreover, GPS IIIA is not simply a matter of replicating the IIF program. Though the contractor has had previous experience with GPS, it is likely that the knowledge base will need to be revitalized. The contractor is also being asked to develop a larger satellite bus to accommodate future GPS increments IIIB and IIIC. In addition, the contractor is being asked to increase the power of a new military signal by a factor of 10. In our opinion, there is little room in the schedule to accommodate difficulties the contractor may have in meeting either challenge. In addition, the GPS III program office still has not been able to fill critical contracting and engineering positions needed to assist in satellites design and contractor oversight—both of which functions are to receive more emphasis on this program than in the past. Consequently, the concerns that GPS IIIA could experience a delay are not unreasonable.

However, according to DOD officials, the incremental approach to GPS acquisition should significantly lower the risk of schedule delays. Nonetheless, no major satellite program undertaken in the past decade has met its scheduled goals.

Figure 3: Schedule Development from Start to Launch for Space Programs (in Months)



Source: GAO analysis based on program documentation.

Note: DSCS – Defense Satellite Communications System. UHF – Ultra High Frequency. MUOS – Mobile User Objective System. DMSP – Defense Meteorological Satellites Program. GPS – Global Positioning System. STSS – Space Tracking and Surveillance System. WGS – Wideband Global Satellite Communications. AEHF – Advanced Extremely High Frequency. TSAT – Transformational Satellite Communications System. NPOESS – National Polar-orbiting Operational Environmental Satellite System. SBIRS – Space Based Infrared System. All programs with (e) denotation used current estimated dates for launch.

- Third, we compared the Air Force's GPS IIIA schedule to best practices associated with effective schedule estimating. Past GAO work has identified nine practices associated with effective schedule estimating. We analyzed the Air Force's GPS IIIA schedule according to these practices and found that one was met, one was not met, and the other seven practices were only partially met. The practices deal with how well the schedule identifies key development activities, the times to complete these activities, as well as the amount of float time associated with each of these activities—float time is the amount of time a task can slip before affecting the critical path. Further, the practices assess how well activities have been integrated with other tasks and whether reserve times have been allocated to high-risk activities. The primary purpose of all scheduling activities is to establish a credible critical path. The best practices have been designed to support that goal. Because the GPS IIIA schedule does not follow all of the best practices, the reliability of the critical path identified in the schedule is diminished.

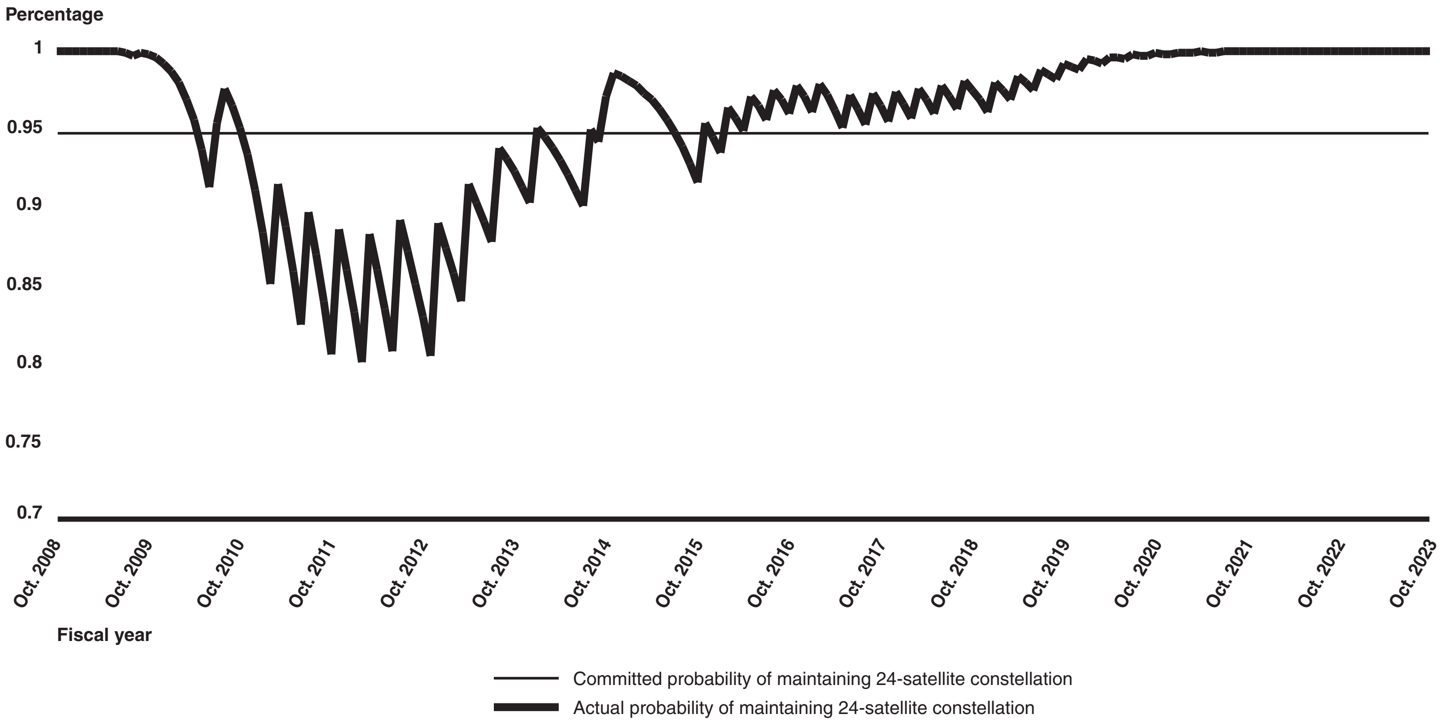
A Delay in GPS III Could Severely Impact GPS Users

Delays in the launch of the GPS IIIA satellites will increase the risk that the GPS constellation will decrease in size to a level where it will not meet some users' needs. If the GPS constellation falls below the number of satellites required to provide the level of GPS service that the U.S. government has committed to providing, some military and civilian operations could be affected. DOD is evaluating different approaches that could potentially mitigate the gap. However, procurement of additional GPS IIF satellites does not appear to be feasible.

A Delay in GPS III Could Affect GPS Constellation Performance

The performance standards for both (1) the standard positioning service provided to civil and commercial GPS users and (2) the precise positioning service provided to military GPS users commit the U.S. government to at least a 95 percent probability of maintaining a constellation of 24 operational GPS satellites. Because there are currently 31 operational GPS satellites of various blocks, the near-term probability of maintaining a constellation of at least 24 operational satellites remains well above 95 percent. However, DOD predicts that over the next several years many of the older satellites in the constellation will reach the end of their operational life faster than they will be replenished, and that the constellation will, in all likelihood, decrease in size. Based on the most recent satellite reliability and launch schedule data approved in March 2009, the estimated long-term probability of maintaining a constellation of at least 24 operational satellites falls below 95 percent during fiscal year 2010 and remains below 95 percent until the end of fiscal year 2014, at times falling to about 80 percent. See figure 4 for details.

Figure 4: Probability of Maintaining a Constellation of at Least 24 GPS Satellites Based on Reliability Data and Launch Schedule as of March 2009

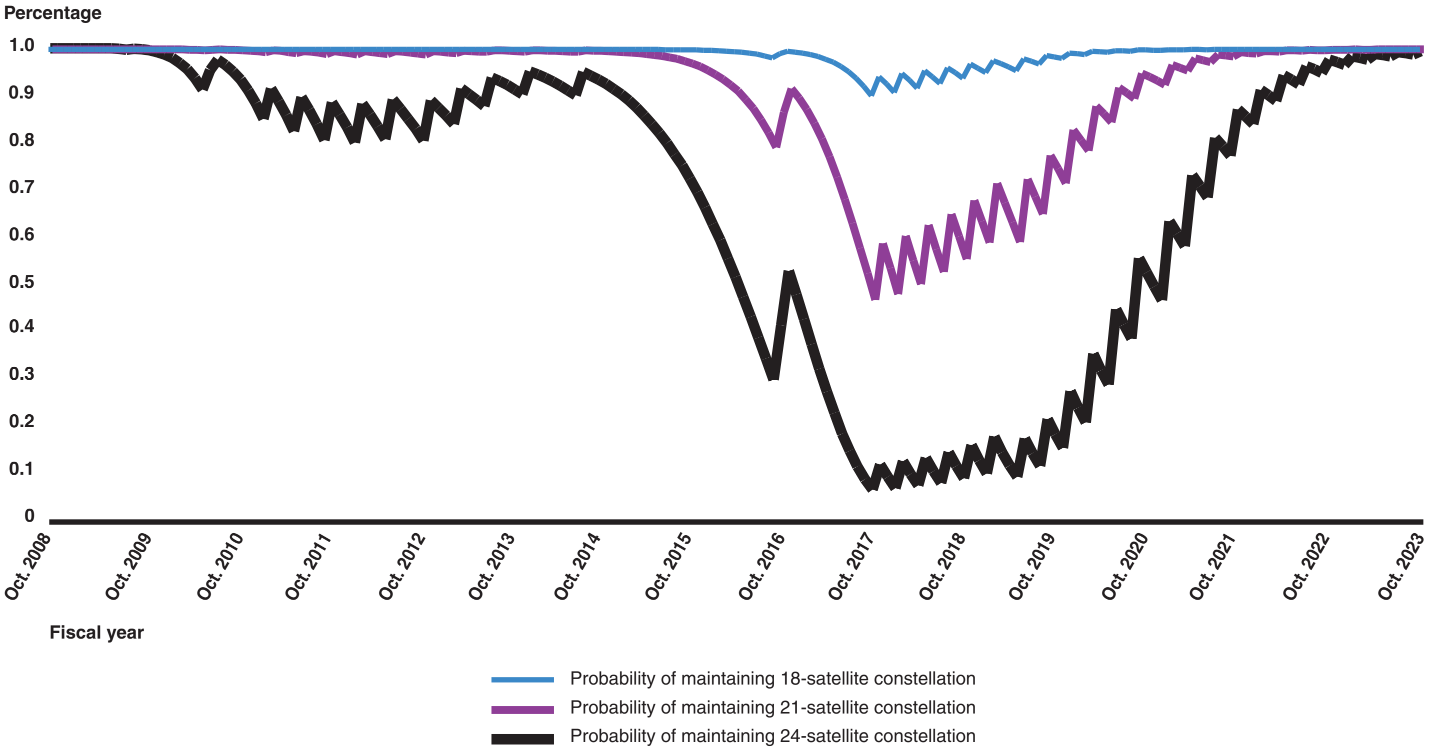


Source: GAO analysis of DOD data.

The probability curve in figure 4 was generated using unique reliability curves for each operational satellite in the current on-orbit GPS constellation, and block-specific reliability curves for each production (unlaunched) GPS satellite, including IIR-M, IIF, IIIA, IIIB, and IIIC satellites. (See app. I for a more complete description of the approach used to generate this probability curve.) Because the reliability curves associated with new blocks of GPS satellites are based solely on engineering and design analysis instead of actual on-orbit performance, this estimated long-term probability of maintaining a 24-satellite constellation could change once actual on-orbit performance data become available. For example, while the block IIA satellites were designed to last only 7.5 years on average, they have actually lasted about twice as long. If GPS IIF satellites were to last twice as long as their currently estimated mean life expectancy of 11.5 years, the probability of maintaining a larger constellation would increase, but the long-term probability of maintaining the 24-satellite constellation would not improve significantly. Moreover, program officials provided no evidence to suggest that the current mean life expectancy for IIF satellites is overly conservative.

A delay in the production and launch of GPS III satellites could severely impact the U.S. government's ability to meet its commitment to maintain a 24-satellite GPS constellation. The severity of the impact would depend upon the length of the delay. For example, a 2-year delay in the production and launch of the first and all subsequent GPS III satellites would reduce the probability of maintaining a 24-satellite constellation to about 10 percent by around fiscal year 2018. This significant gap in service would persist for about 2 years before the constellation began to recover. Moreover, this recovery—that is, the return to a high probability of maintaining a 24-satellite constellation—would take an additional 2 to 3 years. Consequently, a 2-year delay in the production and launch of GPS III satellites would most likely result in a period of roughly 5 years when the U.S. government would be operating a GPS constellation of fewer than 24 satellites, and a 12-year period during which the government would not meet its commitment to maintaining a constellation of 24 operational GPS satellites with a probability of 95 percent or better. For example, the delay in GPS III would reduce the probability of maintaining a 21-satellite constellation to between 50 and 80 percent for the period from fiscal year 2018 through fiscal year 2020. Moreover, while the probability of maintaining an 18-satellite constellation would remain relatively high, it would still fall below 95 percent for about a year over this period. See figure 5 for details.

Figure 5: Probability of Maintaining a Constellation of at Least 18, 21, and 24 GPS Satellites Based on Reliability Data as of March 2009 and a 2-Year GPS III Launch Delay



Source: GAO analysis of DOD data.

Both Military and Civilian GPS Users Would Be Affected by a Delay in GPS III

The impacts to both military and civil users of a smaller constellation are difficult to precisely predict. For example, a nominal 24-satellite constellation with 21 of its satellites broadcasting a healthy standard positioning service signal would continue to satisfy the availability standard for good user-to-constellation geometry articulated in the standard positioning service performance standard.[17] However, because the GPS constellation has been operating above the committed performance standard for so long, military and civil users have come to expect a higher level of service, even though this service is not committed to them. Consequently, some users may sense an operational impact even

[17] This availability standard establishes thresholds for both global average and worst-case position dilution of precision (PDOP), a figure of merit commonly used to quantify the "goodness" of user-to-GPS-constellation geometry.

if the constellation were to perform at or near its committed standards. In general, users with more demanding requirements for precise location solutions will likely be more impacted than other users.[18] During our interviews with military, civil, and commercial representatives, several examples of possible impacts of a smaller GPS constellation were discussed.

- The accuracy of precision-guided munitions that rely upon GPS to strike their targets could decrease. To accomplish their mission, military forces would either need to use larger munitions or use more munitions on the same target to achieve the same level of mission success. The risks of collateral damage could also increase.
- Intercontinental commercial flights use predicted satellite geometry over their planned navigation route, and may have to delay, cancel or reroute flights.
- Enhanced-911 services, which rely upon GPS to precisely locate callers, could lose accuracy, particularly when operating in "urban canyons" or mountainous terrain.

Another important consideration is that both the standard positioning service and precise positioning service performance standards assume that users have unobstructed visibility to nearly the entire sky,[19] an assumption that does not hold for the large number of users operating in moderately mountainous terrain, in the "urban canyons" of large cities, or under forest foliage.

Different Approaches Are Being Evaluated that Could Potentially Mitigate the Gap

The Air Force is aware that there is some risk that the number of satellites in the GPS constellation could fall below its required 24 satellites, and that this risk would grow significantly if the development and launch of GPS IIIA satellites were delayed. Consequently, an Air Force Space Command representative informed us that the command has established an independent review team to examine the risks and consequences of a smaller constellation on military and civil users. However, at this time, Air Force representatives believe that the best approach to mitigating the risk

[18] Some users with more demanding requirements employ GPS augmentation systems that mitigate this impact. For example, many applications using augmentations such as Satellite-Based Augmentation Systems (SBAS), which in the United States is the Wide Area Augmentation System (WAAS), have increased tolerance to degraded accuracy and availability when the constellation may be operating at minimum committed levels of availability.

[19] Both performance standards assume an unobstructed view of the entire sky except for 5 degrees above the local horizon.

is to take all reasonable steps to ensure that the current schedule for GPS IIF and III is maintained. Those steps include a commitment from the Air Force to fully fund GPS IIIA in the fiscal year 2010 Program Objectives Memorandum, and use of an incremental development approach toward meeting needs. This incremental approach would place a premium on controlling schedule risk by, among other things, deferring consideration of civil requirements for subsystems like the Distress Alerting Satellite System (DASS) and the Satellite Laser Ranging (SLR) payloads to GPS IIIB or GPS IIIC satellite blocks.

Options for developing lower-cost alternatives to current GPS satellites appear to be very limited. For example, in 2007 the Air Force Scientific Advisory Board examined whether small satellites—which can be developed more quickly and at relatively low cost—might help meet some PNT mission requirements. The board concluded that small satellites may eventually have operational utility in augmenting GPS III capabilities, with emphasis on enhancing the utility of the GPS M-code signal's capabilities against jamming. However, the need for an extensive control segment infrastructure to monitor and control these small satellite augmentations, combined with the need to develop, produce, and install user equipment, would make it very challenging to field a near-term small satellite augmentation for PNT. With respect to providing basic PNT services, the board noted that studies of PNT satellite constellations, performed at different times and by different organizations in the United States and elsewhere, demonstrate that a robust constellation of relatively powerful satellites operating at medium earth orbit is the best way to provide continuous worldwide PNT services; this is a performance set that small satellites currently cannot provide.

According to Air Force representatives, the procurement of additional IIF satellites is not feasible, and initiating development of an alternative full-scale, satellite-based PNT system appears to be impractical. Such a system would likely be very expensive and would compete with GPS III development for funding, making it harder for the Air Force to meet its commitment to fully fund GPS IIIA development. Moreover, the GPS III system development contract was awarded in accordance with an approved GPS III acquisition strategy, which selected one alternative from two competing contractors' designs; an alternative system development would be, in effect, a significant deviation from that approved strategy. Finally, it seems unlikely that the award of a separate system development contract with another contractor would have any real impact on reducing the risk of delivering GPS IIIA requirements on the current schedule.

In the event that this strategy proves unsuccessful and the schedule for GPS III slips, additional measures could be considered. For example, excluding random failures, the operational life of a GPS satellite tends to be limited by the amount of power that its solar arrays can produce. This power level declines over time as the solar arrays degrade in the space environment until eventually they cannot produce enough power to maintain all of the satellite's subsystems. However, according to Air Force representatives, the effects of this power loss can be mitigated somewhat by actively managing satellite subsystems—shutting them down when not needed— thereby reducing the satellite's overall consumption of power. It would also be possible to significantly reduce the satellite's consumption of power by shutting off a secondary GPS payload. This would buy additional time for the navigation mission of the satellite at the expense of the mission supported by the secondary payload. The 2004 U.S. Space-Based Positioning, Navigation and Timing (PNT) policy affirmed PNT as the primary mission for the GPS constellation, and stated that no secondary payload may adversely affect the performance, schedule, or cost of GPS, its signals, or services. Nevertheless, at this time the Air Force has no intention of shutting off the secondary GPS payload. Moreover, until there is a more immediate risk that the constellation will fall below its required size, there is no reason to take this step.

Military and civil users might also take steps in response to a smaller GPS constellation. While a smaller GPS constellation could result in a significant reduction in positioning and navigation accuracy at certain times and locations, these times and locations are usually predictable in near-real time. Consequently for military users, who must rely upon GPS's precise positioning service, a smaller constellation could require changes in its approach to mission planning to ensure that operations are conducted at times when GPS accuracy is relatively high, or changes in tactics employed during a mission. For example, military users could utilize a larger number of (or more powerful) munitions to achieve an equivalent level of mission effectiveness.

For civil and commercial users, one possible impact of a smaller GPS constellation could be an increased use of other positioning, navigation, and timing services, including those expected to be offered through Europe's Galileo system by the middle of the next decade. U.S. government officials at the various civil agencies and departments clearly understand what the government has committed to through GPS and they all have designed programs to function with this limit, with augmentations.

New Satellite Capabilities Will Not Be Leveraged Because of Delayed Delivery of Ground and User Equipment Capabilities

To maximize the benefit of GPS, the deployment of its space, ground control, and user equipment capabilities must be synchronized so that the full spectrum of military assets—weapons, aircraft, and ships, for example—and individual users can take advantage of new capabilities such as added protection from jamming. However, because of funding shifts and diffuse leadership, the Air Force has not been successful in synchronizing space, ground control, and user equipment segments. As a result of the poor synchronization, new GPS capabilities may be delivered in space for years before military users can take advantage of these capabilities.

Air Force Has Deferred the Delivery of Ground Control Capabilities

The Air Force used funding set aside for the ground control segment to resolve GPS IIF development problems, causing a delay in the delivery of new ground control capabilities. The GPS ground control segment has evolved over time from the Operational Control Segment (OCS) to the current Architecture Evolution Plan (AEP). GPS IIIA satellites are to be controlled by a future ground control system called Next Generation Control Segment, or OCX. OCS was supposed to control and exploit GPS IIF space capabilities. However, because of the addition of new requirements and technical issues on the IIF program, funding was diverted from OCS to GPS IIF satellite development efforts. As a result, the delivery of new ground control capabilities will occur later than originally planned.

Table 3 below illustrates satellite functions and capabilities that have yet to be made operational through the ground control segment. For example, in 2005 the Air Force began launching its GPS IIR-M satellites that broadcast a second civil signal (the L2C). Unfortunately, the ground control segment will not be able to make the second civil signal operational until late 2012 or 2013.

Table 3: Delays in Delivery of GPS Operational Functionality

Function or capability enabled	Original ground control program/version	Current or future ground control program/version	Amount of delay (in months)
GPS IIR-M satellites (first launch in 2005 & currently being launched)			
Command & telemetry for IIA & IIR and satellites, and use of additional signals	OCS Version 5.0 September 2005	OCS Version 5.2.1 September 2007	24
Command & telemetry for IIRM & IIF satellites	OCS Version 5.0 September 2005	AEP Version 5.2.2 March 2008	30
Selective Availability Anti-Spoofing Module	OCS Version 5.0 September 2005	AEP Version 5.5 September 2009	48
Second civil signal (L2C)	OCS Version 6 September 2007	OCX Block I or II September 2012/September 2013	60-72
Military code (M-code)	OCS Version 6 September 2007	OCX Block I or II September 2012/September 2013	60-72
GPS IIF satellites (first launch planned for November 2009)			
Third civil signal (L5)	OCS Version 6 September 2007	OCX Block I or II September 2012/September 2013	60-72

Source: GPS program office.

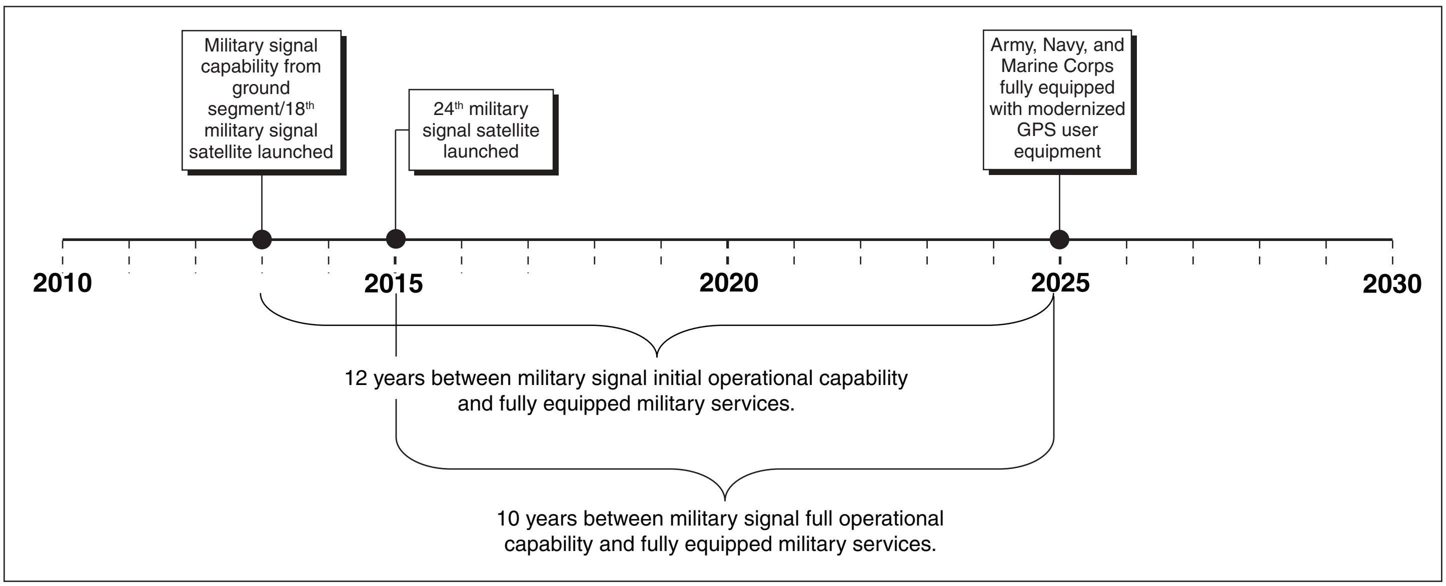
By delaying the delivery of ground control capabilities, the Air Force has created an imbalance between the capabilities offered by GPS satellites and the ability to exploit and make operational these capabilities through the ground control segment.

Synchronization Problems Will also Delay Fielding of Improved GPS Capabilities to Military Users

GPS satellites that will broadcast the modernized military signal require military user equipment capable of receiving and processing the signal so that military users can take advantage of the improved military capabilities. Before the modernized military signal can be considered initially operational, it must be broadcast from at least 18 satellites, which is expected to occur in 2013. For full operational capability, it must be broadcast from 24 satellites, which is expected to occur in 2015. Consequently, the new military signal will be made operational by the GPS satellites and ground control system in about 2013, but the warfighter will not be able to take full advantage of this new signal until about 2025—

when the modernized user equipment is completely fielded. See figure 6 for our analysis of the gap between when the modernized military signal will be available on the GPS satellites and when the military services will be able to take advantage of it.

Figure 6: Gap in the Ability of the Military to Use the Modernized Signal



Source: GAO analysis of DOD documents and discussions with DOD officials.

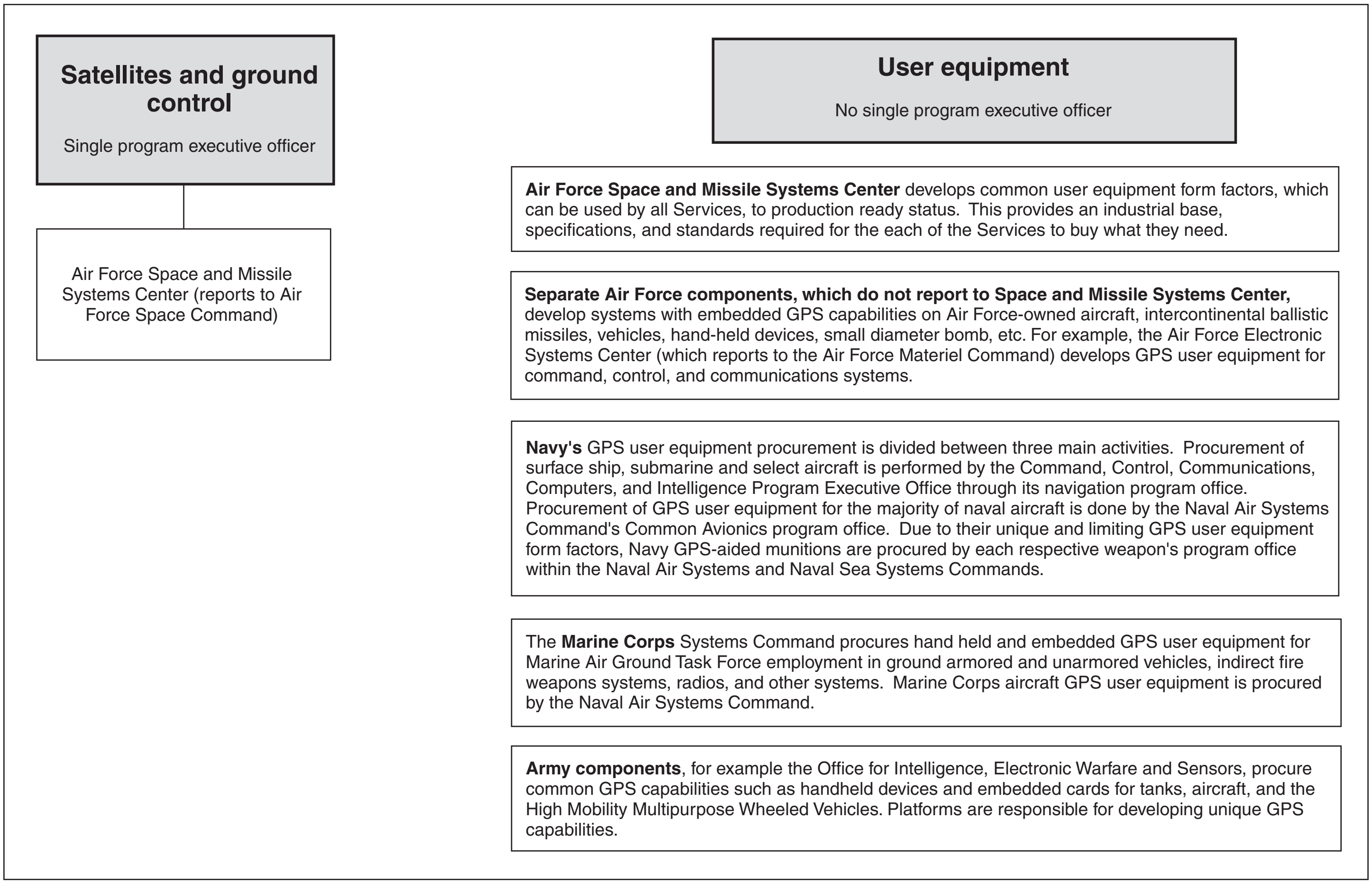
Funding and Technical Issues Have Delayed User Equipment Development, but the Air Force Is Seeking to Accelerate Development

The Air Force will spend the next several years developing prototype cards and production-ready receiver hardware for selected platforms within the space, air, ground, and maritime environments. Even after this is done, the services will still need to add the new user equipment to other platforms, which could take 10 or more years. This is due to the fact that the integration and installation of the new user equipment on the remaining platforms has to be coordinated with existing upgrade schedules for those platforms. As a result, the services' ability to achieve a joint military navigation warfare capability, an essential element in conducting future military operations, may not be realized until 2025 based on user equipment delivery schedules.

Funding issues are a contributing factor in the delay in fielding new user equipment. According to Air Force officials, the GPS program office focused on developing the satellites, particularly when technical problems arose. Funding was diverted from the user equipment program to the GPS satellite program to fix problems, which resulted in delays in the development and acquisition of the user equipment.

Diffused leadership has been particularly problematic in terms of DOD's ability to synchronize delivery of space, ground control, and user equipment assets. The responsibility for developing and acquiring GPS satellite and associated ground control segments and for acquiring and producing user equipment for selected platforms for space, air, ground, and maritime environments falls under the Air Force's Space and Missile Systems Center. On the other hand, responsibility for acquiring and producing user equipment for all other platforms falls on the military services. Figure 7 illustrates how the responsibilities for developing, acquiring, and producing GPS user equipment are divided among the services.

Figure 7: Responsibilities Among the Military Services for Procurement of GPS User Equipment



Source: GAO presentation of DOD data.

Because different military services are involved in developing user equipment for the weapon systems they own and operate, there are separate budget, management, oversight, and leadership structures over the space and ground control and the user equipment segments. As such, there is no single authority responsible for synchronizing all the procurements and fielding related to GPS. A 2008 U.S. Strategic Command Functional Solutions Analysis, conducted to provide recommendations for solutions to positioning, navigation, and timing gaps, noted that the Air Force is responsible for developing and integrating military GPS user equipment for select platforms, and that integration and testing of these platforms is required to be complete so that the user equipment is available for procurement when the military signal becomes operational. However, this analysis showed no military service program office commitment of resources for procuring military GPS user equipment in service programming documents. Furthermore, DOD's management attention has been focused on delivering space capabilities. Only recently has DOD begun to shift its focus by recognizing that the user equipment segment needs to play an equal role in the overall GPS synchronization effort.

Efforts to Speed up Delivery of User Equipment Face Obstacles

There have been various recommendations to accelerate the fielding of modernized military user equipment, though there are obstacles in the way of implementation. In October 2005, the Defense Science Board[20] recommended that DOD initiate an aggressive program to introduce antijam enhancements as soon as possible. In August 2006, OSD issued a GPS User Equipment Development and Procurement Policy, which mandated that certain equipment categories have the modernized GPS user equipment by the time the 24th military code satellite is declared operational. In June 2007, representatives from the Combatant Commands, U.S. Strategic Command, and U.S. Joint Forces Command requested that an aggressive schedule be established for all GPS segments to achieve military code initial operational capability by fiscal year 2013. In March 2008, the Joint Requirements Oversight Council recommended that the Air Force adjust the development and acquisition of the modernized GPS user equipment to ensure that warfighters can use space-based capabilities. Recommendations included amending programmatic schedules and funding profiles to incorporate military code capabilities at or before the initial operational capability date.

To accelerate the delivery of the new user equipment, the Air Force increased the user equipment budget by $272 million for fiscal years 2009 through 2011. In the conference reports accompanying the Department of Defense Appropriation Act for Fiscal Year 2008 and the National Defense Authorization Act for Fiscal Year 2008, conferees recommended an additional $63.2 million in funding for GPS user equipment. However, the additional funds will not speed up development of the new user equipment to a large extent, because the program office is experiencing technical issues in developing the prototype cards. The major technical issue is with

[20] Defense Science Board Task Force, *The Future of the Global Positioning System*, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (Washington, D.C.: Oct. 28, 2005).

the difficulty in moving to a new security architecture, Protection of Navigation, which will provide information assurance.

According to a GPS program office official, OSD, the Air Staff, U.S. Strategic Command, Air Force Space Command, and the GPS program office are looking at ways to get some of the modernized military user equipment to the field sooner. However, there are challenges with this approach, particularly because certain security requirements—antispoof,[21] antijam, and antitamper—should be met before user equipment can be fielded in conflict situations. According to an official at the GPS program office, meeting these security requirements is proving to be technically challenging, and attempting this at an accelerated rate is risky.

Prudent Steps Taken so GPS Can Meet Broader Needs but Challenges Exist in Coordinating Requirements and Ensuring Compatibility

GPS has produced dramatic economic and security improvements both for the United States and globally. Ensuring that it can continue to do so is extremely challenging given competing interests, the span of government and commercial organizations involved with GPS, and the criticality of GPS to national and homeland security and the economy. On the one hand, DOD must ensure military requirements receive top priority and the program stays executable. In doing so, it must ensure that the program is not encumbered by requirements that could disrupt development, design, and production of satellites. On the other hand, there are clearly other enhancements that could be made to GPS satellites that could serve a variety of vital missions—particularly because of the coverage GPS satellites provide—and there is an expressed desire for GPS to serve as the world's preeminent positioning, navigation, and timing system. In addition, while the United States is challenged to deliver GPS on a tight schedule, other countries are designing and developing systems that provide the same or enhanced capabilities. Ensuring that these capabilities can be leveraged without compromising national security or the preeminence of GPS is also a delicate balancing act that requires close cooperation between DOD, the Department of State, and other institutions.

Because of the scale and number of organizations involved in maximizing GPS, we did not undertake a full-scale review of requirements and coordination processes. However, we reviewed documents supporting

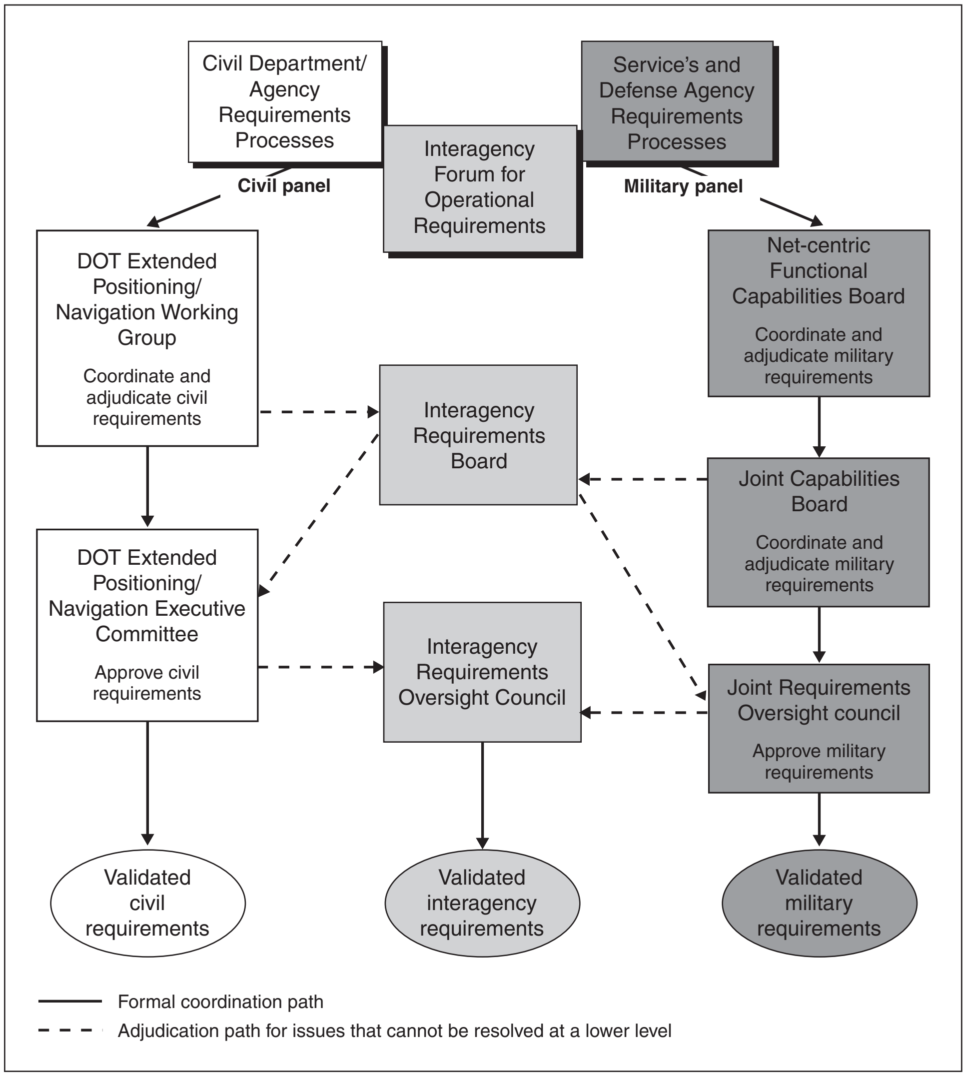
[21] Antispoofing is a process of encrypting one of the codes broadcast by the satellites. This prevents an enemy from predicting the code sequence and using that prediction to generate a code that could be used to deceive a GPS set. The set would believe the deception code to be real and could falsely calculate its position.

these processes and interviewed a variety of officials to obtain views on its effectiveness. While there is a consensus that DOD and other federal organizations involved with GPS have taken prudent steps to manage requirements and optimize GPS use, we also identified challenges in the areas of ensuring civilian requirements can be met and ensuring that GPS is compatible with other new, potentially competing global space-based positioning, navigation, and timing systems.

The Process for Approving GPS Civil Requirements Is Rigorous but Untested

The 2004 U.S. Space-Based Positioning, Navigation and Timing (PNT) policy provides guidance for civil involvement in the development of requirements for the modernization of GPS capabilities and the requirements process includes an entry point for civil requirements. This entry point is the Interagency Forum for Operational Requirements (IFOR), working groups consisting of a civil and a military panel. The IFOR receives proposed GPS requirements from civil agencies and assists in developing and validating them. From this point, the proposed requirement follows a DOD and civil path to validation with involvement from various interagency boards and councils. Figure 8 illustrates this formal process for submitting, considering, and validating civil GPS requirements.

Figure 8: Interagency Process for Submitting and Validating GPS Requirements



Source: GAO presentation of Department of Transportation and U.S. Air Force data.

While the process for approving civil requirements on GPS has existed since 2001, DOD and civil agencies consider it rigorous but relatively untested because no civil unique requirements have completed the initial step in the process. Civil agencies have submitted two proposed requirements to the process; however, these requirements are not directly related to the GPS mission. Instead, they would add hardware to the GPS satellites and thus are considered secondary mission requirements.

However, according to civil agencies, the analyses and documentation called for under the process are confusing and time-consuming.

While GPS remains critical to national security and military operations, government policy calls for GPS planning to consider integration of civil requirements for the civilian infrastructure. The process for considering civil GPS requirements is intended to maintain fiscal discipline by ensuring only critical needs are funded and developed. Specifically, the process requires that civil agencies internally identify and validate their proposed requirements, and conduct cost, risk, and performance analyses. Our past work has shown that requirements add-ons are a major source of acquisition instability. In this case, the formal process also requires that the agency proposing the requirement pay the costs associated with adding it to the GPS III satellites, thereby forcing agencies to separate their wants from needs.

Civil Agencies Find the GPS Requirements Process Confusing

According to the civil agencies that have proposed GPS requirements, the formal requirements approval process is confusing and time-consuming. Specifically, they stated that DOD's documentary and analysis standards are new to civil agencies and therefore difficult and time-consuming for them to manage. Some agencies have reported that it is costly for them to pay for the more detailed supporting analyses requested by DOD. For example, one civil agency had to withdraw and resubmit a proposal for new GPS requirements because it lacked necessary information, including a cost-benefit analysis. Furthermore, civil agencies' submitted requirements have necessitated that DOD perform further studies on compatibility and integration issues to ensure that the proposed requirements will not adversely affect the primary GPS mission.

The two civil requirements that have entered the requirements process are the Distress Alerting Satellite System (DASS) and the geodetic[22] requirement implemented by Satellite Laser Ranging (SLR). Both are joint civil and military mission requirements and would be potential secondary payloads on GPS. DASS is an electronic unit that will receive beacon signals identifying a distressed individual's location and transmit this location data to emergency responders. The SLR laser retroreflector, which weighs less than 7 pounds, is being considered for inclusion starting with increment IIIB satellites. Scientists would aim a laser to the reflector

[22] Geodetic refers to the use of geodesy for measurements. Geodesy is the science of measuring and monitoring the size and shape of the Earth.

to more precisely determine the satellite's position, ultimately allowing for more precise measurements on the ground. This SLR capability would support users who need to make very accurate measurements for scientific applications.

- Distress Alerting Satellite System: The Coast Guard submitted the DASS requirement to the IFOR in 2003. Early in the review process, a debate on whether DASS was a civil or military requirement ensued. The IFOR decided to have military and civil panels review the requirement and resubmit it through the Joint Capabilities Integration and Development System (JCIDS) process. It took a total of 5 years to resolve the debate and prepare and resubmit the package. In July 2008, the civil agencies submitted DASS requirements and an analysis of alternatives to the IFOR for review. To date, a decision has not yet been made as to if and when the capability will be inserted on GPS satellites.

- Satellite Laser Ranging: In April 2007, NASA submitted the SLR requirements package along with an analysis of alternatives to the IFOR. The IFOR officially accepted the SLR package into the IFOR process in August of that year. However, in June 2008, DOD opposed implementation of the SLR capability due to integration and compatibility concerns with the GPS satellites. A joint Air Force and NASA working group was established to resolve the integration and compatibility issues and report back to the IFOR by June 2009 prior to moving the requirement from the IFOR into the JCIDS process.

DASS supporters have stated that the GPS constellation is the ideal platform for search and rescue capabilities. The current search and rescue capability is expected to degrade by 2017 and completely fail by 2020. More urgently, supporters say that the Canadian government's offer to provide DASS hardware at a $90 million cost savings to the United States must be acted upon by August 2009 or Canada may provide this component to a developing foreign satellite navigation system. The SLR capability, until recently, existed on two GPS satellites. One satellite was decommissioned, and hence according to NASA does not meet its or other civil agencies' needs to perform scientific and geodetic applications. According to NASA, the SLR would need to be implemented on most of the GPS constellation to meet geodetic requirements for science and other user requirements. If the DOD does not include DASS and SLR on GPS satellites, U.S. users of these capabilities may be dependent on foreign systems which already include, or have plans to include, both DASS-like and SLR capabilities in their satellite navigation systems.

Coordinating GPS Activities with the International Community also Presents Challenges

The U.S. government—specifically the State Department—is faced with challenges in ensuring GPS is compatible and interoperable with other new, potentially competing global space-based positioning, navigation, and timing systems. While the U.S. government has engaged a number of other countries and international organizations in cooperative discussions, only one legally binding agreement has been established. Furthermore, some U.S. manufacturers of GPS receivers stated that European Union manufacturers may have a competitive advantage over U.S. companies with respect to the manufacture and sale of Galileo-capable receivers, though officials with the European Commission disagree. In addition, Department of State officials have expressed concerns over the limited number of technical experts available to support activities under these cooperative arrangements. Without these resources, officials are concerned that it may be difficult to continue to ensure the compatibility and interoperability of foreign systems.

Joint Statements of Cooperation Made and One Agreement Established

The United States has made joint statements of cooperation with Australia, India, Japan, and Russia to promote compatibility and interoperability and mutual interests regarding the civil use of GPS and its augmentations[23] and established an executive agreement with the European Community (see table 4 for a list of types of cooperative arrangements with other countries).[24] The joint statements and executive agreement were sought to avoid interference with each others' systems, and to facilitate the pursuit of common civil signals. Under the national space-based PNT policy, it is the Department of State's role to promote the civil aspects of GPS and its augmentation services and standards with foreign governments and other international organizations. The Department of State leads negotiations with foreign governments and international organizations regarding civil and, as appropriate, military space-based PNT matters including, but not limited to, coordinating interagency review of international agreements with foreign governments and international organizations regarding the planning, operation, management, and or use of the GPS and its augmentations. While most of the cooperative arrangements are joint statements that express the parties'

[23] Augmentation systems are U.S. government global and regional systems that are maintained by individual departments and agencies to provide users with improvements to the GPS navigation signal in terms of accuracy, availability, and/or integrity needs.

[24] Although China is developing a space-based positioning, navigation, and timing system, the United States has not established a formal bilateral relationship with China. For the purposes of this report, "cooperative arrangements" is used to mean joint statements of cooperation and executive agreements.

intent to cooperate on GPS-related activities, the United States and the European Commission have established an executive agreement that is considered binding under international law.

Table 4: U.S. Cooperation with Foreign Entities on Satellite Navigation

	Cooperative arrangement/effective dates			
Country	Executive agreement	Joint statement	No agreement	Date signed
Japan		√		1998
EU	√			2004
Russia		√		2004
Australia		√		2007
India		√		2007
China			√	na

Source: GAO analysis of U.S. Department of State data.

U.S. and European Commission Working to Address Concerns Regarding Access to Galileo Information

According to the executive agreement with the European Community, subject to applicable export controls, the United States and the European Commission are to make sufficient information concerning their respective civil satellite-based signals and augmentations publicly available on a nondiscriminatory basis, to ensure equal opportunity for persons who seek to use these signals, manufacture equipment to use these signals, or provide value-added services which use these signals.

In 2006, the European Commission publicly released draft technical specifications for its open service. The draft document requests manufacturers to obtain a commercial license from the European Commission to sell and import products designed to work with the European satellite navigation system, Galileo. While this licensing requirement applies to all manufacturers, some U.S. companies stated that some foreign user equipment manufacturers who are members of the Galileo consortia may have an unfair advantage over U.S. companies. This is because the Galileo consortia currently have access to testing hardware and may be able to introduce their products more quickly into the marketplace once they are granted a commercial license.

Officials with the European Commission told us that they do not believe the license restrictions or the knowledge gained from testing the Galileo systems are discriminatory. They further stated that the restrictions in obtaining a commercial license to sell user equipment apply to all companies, not just U.S. companies and they have not yet issued licenses to any company. In the meantime, a U.S. and European Commission working group on trade and civil applications is discussing the licensing issue.

However, U.S. firms have raised concerns to the Department of Commerce (Commerce) on the lack of information from the European Commission relating to the process for obtaining a license to sell Galileo equipment. According to Commerce, U.S. firms have asserted that they are not aware of how, where, or when to apply for such a license, despite repeated inquiries to the U.S.-European Commission trade working group and direct contacts with European Commission officials—and the timeline for the licensing process is unknown. Commerce further noted that U.S. manufacturers wanting to enter the Galileo market are hesitant to invest in technology that is not officially licensed and that could possibly be banned from sale. It takes industry 18 to 24 months to develop a market-ready receiver, and the first operational Galileo satellite is scheduled for launch in 2010. U.S. firms are concerned they will not have their products ready by that time and will lose their market share to European companies with inside access to technology and/or licensing information.

State Officials Believe International Efforts Lack Dedicated Resources

According to Department of State officials, the department lacks dedicated technical expertise to monitor international activities. The Department of State relies on a small pool of experts from DOD and the seven civil agencies represented on the National Executive Committee for Space-Based PNT. These experts are often in high demand because they work on other GPS-related activities and in some cases have other assigned duties that are unrelated to GPS. According to the Department of State, in many cases these experts and those in other agencies must continually justify to their managers that their attendance at international meetings is important. Given the progress made in working with foreign governments to establish arrangements, share information, and ensure compatibility and interoperability with GPS, Department of State officials would like DOD and civil agencies to dedicate funding and staff positions to international activities accompanied by a sustained level of senior management support and understanding of the importance of these activities. Without an expanded pool of technical expertise and related resources, Department of State officials stated they are concerned that ongoing international efforts to ensure compatibility of foreign systems with GPS could be jeopardized.

Conclusions

GPS has enabled transformations in military, civil, other government, and commercial operations and has become part of the critical infrastructure serving national and international communities. Clearly, the United States cannot afford to see its GPS capabilities decrease below its requirement, and optimally, it would stay preeminent. Over the past decade, however, the program has experienced cost increases and schedule delays. While the Air Force is making a concerted effort to address acquisition problems, there is still considerable risk that satellites will not be delivered on time, leading to gaps in capability. Focused attention and oversight are needed to ensure the program stays on track and is adequately resourced, that unanticipated problems are quickly discovered and resolved, and that all communities involved with GPS are aware of and positioned to address potential gaps in service. But this is difficult to achieve given diffuse responsibility over various aspects of the GPS acquisition program. Moreover, disconnects between the space, ground control, and user equipment components have significantly lessened the military's ability to take advantage of enhancements, particularly as they relate to assuring the continuity of service during military engagements. Without more concentrated leadership attention, such disconnects could worsen, particularly since (1) both the ground control and user equipment programs have been subject to funding shifts to pay for problems affecting the satellite segment, and (2) user equipment programs are executed by separate entities over which no one single person has authority. Lastly, ensuring that GPS can continue to produce dramatic improvements to civil agencies' applications, calls for any weaknesses that are identified in the civil agency GPS requirements process to be addressed.

Recommendations for Executive Action

Because of the criticality of the GPS system and potential delays, and given the importance of GPS to the civil community, we are making the following recommendations.

- We recommend that the Secretary of Defense appoint a single authority to oversee the development of the GPS system, including DOD space, ground control, and user equipment assets, to ensure that the program is well executed and resourced and that potential disruptions are minimized. The appointee should have authority to ensure DOD space, ground control, and user equipment are synchronized to the maximum extent practicable; and coordinate with the existing positioning, navigation, and timing infrastructure to assess and minimize potential service disruptions should the satellite constellation decrease in size for an extended period of time.

- We recommend that the Secretaries of Defense and Transportation, as the co-chairs of the National Executive Committee for Space-Based Positioning, Navigation and Timing, address, if weaknesses are found, civil agency concerns for developing requirements, and determine mechanisms for improving collaboration and decision making and strengthening civil agency participation.

Agency Comments and Our Evaluation

DOD concurred with our first recommendation to appoint a single authority to oversee the development of the GPS system, including space, ground control, and user equipment assets, to ensure that the program is well executed, resourced, and that potential disruptions are minimized. DOD stated that it has recognized the importance of centralizing authority to oversee the continuing synchronized evolution of the GPS. According to DOD, the Deputy Secretary of Defense has reaffirmed that the Assistant Secretary of Defense for Networks and Information Integration (ASD NII)) is designated with authority and responsibility for all aspects of the GPS. DOD further stated that the U.S. Air Force is the single acquisition agent with responsibility for synchronized modernization of GPS space, ground control, and military user equipment.

In concurring with our recommendation on appointing a single authority to oversee the development of the GPS system, DOD asserts that ASD NII is designated with authority and responsibility for all aspects of GPS, and that the Air Force is the single acquisition agent responsible for synchronizing GPS segments. In addition, responsibility for acquiring GPS military user equipment acquisitions falls under various officials within the military services. We agree that given the diversity of platforms and equipment variations involved, it would not be realistic for the Air Force to unilaterally produce a “one-size-fits-all” solution. However, this does not obviate the need for a single authority to oversee the development of all GPS military user equipment to better ensure greater coordination with deployed satellite capabilities. Without an approach that enables a single individual to make resource decisions and maintain visibility over progress, DOD is at risk of facing the same issues in synchronizing the delivery of GPS assets and wasting capability that will be available in space but not on the ground. In addition, DOD may still want to consider establishing a means by which progress in developing the satellites and ground equipment receives attention from the highest levels of leadership that is the Secretary and perhaps the National Security Council, given the criticality of GPS to the warfighter and the nation, and the risks associated with not meeting schedule goals.

DOD concurred with our second recommendation to address, if weaknesses are found, civil agency concerns for developing requirements and determine mechanisms for improving collaboration and decision making, and strengthening civil agency participation. DOD acknowledged that it employs a rigorous requirements process and is aware of the frustration civil agencies face when using this process. DOD further indicated that it worked to put in place an interagency requirements plan, and is currently in the process of jointly coordinating the Charter for an Interagency Forum for Operational Requirements to provide venues to identify, discuss, and validate civil or dual-use GPS requirements. Finally, DOD noted that it will continue to seek ways to improve civil agency understanding of the DOD requirements process and work to strengthen civil agency participation. We support DOD's efforts to inform and educate other civil agencies on the requirements process. As it undertakes these efforts, DOD should ensure that it is taking a more active role in directly communicating with civil agencies to more precisely identify concerns or weaknesses in the requirements process.

The full text of DOD's comments may be found in appendix IV. We also received technical comments from the other departments and NASA, which we incorporated where appropriate.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution of it until 8 days from the report date. At that time, we will send copies of this report to the Secretaries of Defense, Agriculture, Commerce, Homeland Security, Interior, State, and Transportation; the National Aeronautics and Space Administration; and interested congressional committees. The report will also be available at no charge on the GAO Web site at http://www.gao.gov.

If you have any questions about this report or need additional information, please contact me at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. The major contributors are listed in appendix V.

Cristina T. Chaplain
Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To assess the Global Positioning System (GPS) satellite, ground control, and user equipment acquisition programs and determine whether GPS capabilities are being synchronized, we reviewed and analyzed program plans and documentation related to cost, schedule, requirements, program direction, and satellite constellation sustainment, and compared programmatic data to GAO's criteria compiled over the last 12 years for best practices in system development. We also interviewed officials from Air Force Space and Missile Systems Center GPS program office; Air Force Space Command; Office of the Joint Chiefs of Staff; Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics; Assistant Secretary of Defense Office of Networks and Information Integration; United States Strategic Command; 2nd Space Operations Squadron; and the services.

To determine the extent to which the Air Force had effectively developed and maintained the GPS IIIA integrated master schedule, we reviewed the program's schedule estimates and compared them with relevant best practices to determine the extent to which they reflects key estimating practices that are fundamental to having a reliable schedule. In doing so, we interviewed GPS program officials to discuss their use of best practices in creating the program's current schedule.

To assess the status of the GPS constellation, we interviewed officials from the Air Force Space and Missile Systems Center GPS program office, Air Force Space Command, and the 2nd Space Operations Squadron. To assess the risks that a delay in the acquisition and fielding of GPS III satellites could result in the GPS constellation falling below the 24 satellites required by the standard positioning service and precise positioning service performance standards, we obtained information from the Air Force predicting the reliability for 77 GPS satellites—each of the 31 current (on-orbit) and 46 future GPS satellites—as a function of time. Each satellite's total reliability curve defines the probability that the satellite will still be operational at a given time in the future. It is generated from the product of two reliability curves—a wear-out reliability curve defined by the cumulative normal distribution, and a random reliability curve defined by the cumulative Weibull distribution. For each of the 77 satellites, we obtained the two parameters defining the cumulative normal distribution, and the two parameters defining the cumulative Weibull distribution. For each of the 46 unlaunched satellites, we also obtained a parameter defining its probability of successful launch, and its current scheduled launch date. The 46 unlaunched satellites include 2 IIR-M satellites,[1] 12 IIF satellites, 8 IIIA satellites, 8 IIIB satellites, and 16 IIIC satellites; launch of the final IIIC satellite is scheduled for March 2023. Using this information, we generated overall reliability curves for each of the 77 GPS satellites. We discussed with Air Force and Aerospace Corporation representatives, in general terms, how each satellite's normal and Weibull parameters were calculated. However, we did not analyze any of the data used to calculate these parameters.

Using the reliability curves for each of the 77 GPS satellites, we developed a Monte Carlo simulation[2] to predict the probability that at least a given number of satellites would be operational as a function of time, based on the GPS launch schedule approved in March 2009. We conducted several runs of our simulation—each run consisting of 10,000 trials—and generated "sawtoothed" curves depicting the probability that at least 21, 24, 27, and 30 satellites would still be operational as a function of time. We compared the results for a 24-satellite constellation with a similar Monte Carlo simulation that the Aerospace Corporation performed for the Air Force. We confirmed that our simulation produces results that are within about 2 percent of the Aerospace Corporation's results for all times between October 2008 and April 2024. Using 10,000 trials per run, the results of different runs of the same Monte Carlo simulation can vary by about 1 to 2 percent; consequently we concluded that we had successfully replicated the Aerospace Corporation's results. We then used our Monte Carlo simulation model to examine the impact of a 2-year delay in the launch of all GPS III satellites. We moved each GPS III launch date back by 2 years. We then reran the model and calculated new probabilities that at least 18, 21, and 24 satellites would still be operational as a function of time.

To assess impacts of a potential GPS service disruption on particular types of military and civil GPS users, we interviewed numerous military and civil GPS representatives and reviewed studies provided by civil agencies.

[1] We completed our analysis prior to the successful launch of the first of these two IIR-M satellites on March 24, 2009.

[2] Monte Carlo simulation refers to a computer-based analysis that uses probability distributions for key variables, selects random values from each of the distributions simultaneously, and repeats the random selection over and over. Rather than presenting a single outcome—such as the mostly likely or average scenario—Monte Carlo simulations produce a distribution of outcomes that reflect the probability distributions of modeled uncertain variables.

To assess the coordination and collaboration among federal agencies and the broader GPS community, and to determine the organization of the PNT community, we analyzed documents from and conducted interviews with officials in Washington, D.C. at the Office of the Assistant Secretary of Defense for Networks and Information Integration; SAF/USA (Air Force Directorate of Space Acquisitions); National Aeronautics and Space Administration; the Departments of Transportation, State, Commerce, and Homeland Security; the Space-Based National PNT Coordination Office; and the U.S. GPS Industry Council. We also interviewed a private sector GPS expert at Stanford University, and GPS industry representatives. To analyze how the U.S. government coordinates with foreign countries on GNSS (Global Navigation Satellite Systems), we met with representatives of and reviewed documents from the U.S. Department of State and European Space Agency (ESA) in Washington, D.C. To obtain information on efforts by Australia, China, Japan, and Russia to develop GNSS, we met with Department of State officials, reviewed materials provided by these countries' representatives at GNSS conferences, and consulted the official government space agency Web sites. We also traveled to Europe to meet with experts in satellite navigation at the European Space Agency, French Space Agency (CNES), European Commission Directorate-General for Energy and Transport Satellite Navigation Unit, and European GNSS industry experts. In addition, we attended a conference in Berlin, Germany to learn about international coordination on PNT systems and applications.

We conducted this performance audit from October 2007 to April 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: International Global Satellite Navigation Systems

In addition to the Global Positioning System (GPS), there are other space-based global navigation satellite systems (GNSS) in operation and in development. Russia has a system, GLONASS (Global Navigation Satellite System). There are currently 20 GLONASS satellites in orbit, and the Russians expect to have a full constellation of 24 satellites in orbit by 2010 and ultimately to expand to a 30-satellite constellation. The European Union (EU) is developing its own GNSS program, Galileo. Originally started as a public-private partnership, the program now is completely funded by the public sector. The EU has 2 test satellites in orbit now, and plans to have a 27-satellite constellation with 3 spares by 2013. China also is in the process of developing its own GNSS, Compass (also called Beidou). China currently has 3 satellites in orbit, and plans to increase the constellation for coverage of the Asia-Pacific region by 2010 and for worldwide coverage by 2015. Table 5 lists the non-U.S. global navigation satellite systems currently in development.

Table 5: Non-U.S. Global Navigation Satellite Systems Currently in Development

System name	Country	Number of active satellites	Number of planned satellites	Planned date of full operation	Interoperable signals
Galileo	European Union	2 test satellites	27	2013	Interoperable L1C signal
GLONASS	Russia	20	30	2011	Interoperable L1C signal
Compass/Beidou	China	3	35	Regional coverage in 2010	Compatible and interoperable with GPS, no broadcast on L1C at this time

Source: GAO analysis based on information from foreign program presentations.

Appendix III: Cooperation Between U.S. and Foreign Entities

During 2007, the Department of State signed joint statements of cooperation in the use of the Global Positioning System (GPS) with Australia and India. The Australia joint statement expresses the parties' intention to promote interoperability between GPS and Australia's Ground-based Regional Augmentation System and Ground Based Augmentation System. The India joint statement expressed the parties' intention to promote GPS and India's GPS and GEO-Augmented Navigation system. An executive agreement with the European Community and its member states has been in effect since 2004 that expresses the intention that GPS and Galileo will be interoperable at the user level for the benefit of civil users around the world. This cooperation has resulted in working groups that are reviewing technical, trade, and security issues. The technical issues described in the executive agreement involve GPS-Galileo radio frequency compatibility and interoperability and the design and development of the next generation of systems. For trade, a working group is determining how to maintain nondiscriminatory trade practices in the global market for goods and services related to space-based PNT, and a group was appointed to review the security issues concerning GPS and Galileo.

The United States and Russia initiated cooperation in 2004, with the parties expressing their intent to work together to maintain and promote civil interoperability at the user level between GPS and Russia's GLONASS system. Two working groups have been established to address: (1) radio frequency compatibility and interoperability for enhanced PNT and (2) technical interoperability between the search-and-rescue capabilities planned for GPS and GLONASS.

The United States and Japan have had a relationship since signing a joint statement in 1998. In the joint statement, the parties expressed their intent to promote and facilitate civilian uses of GPS. Japan is developing MTSAT-based Satellite Augmentation System (MSAS), a geostationary satellite system similar to the U.S. Wide Area Augmentation System. The United States and Japan most recently met in November 2008 to discuss the civil use of GPS and Japan's MSAS and Quasi-Zenith Satellite System.

Appendix IV: Comments from the Department of Defense

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APR 2 4 2009

NETWORKS AND
INFORMATION INTEGRATION

Ms. Christina Chaplain
Director, Acquisition and Sourcing Management
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441 G Street, NW
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Dear Ms. Chaplain:

This is the Department of Defense (DoD) response to the GAO draft report, GAO-09-325, 'THE GLOBAL POSITIONING SYSTEM: Significant Challenges in Sustaining and Upgrading Widely Used Capabilities,' dated March 12, 2009 (GAO Code 120696).

The Department fundamentally concurs with the findings and recommendations expressed in the GAO report. However, factors relating to the longevity of the Global Positioning System (GPS) program and the complexity of its implementation across the range of military and civilian users require that our concurrence be augmented by clarifying comments, which have been provided separately.

GPS developmental satellites were initially launched over thirty years ago. The system has evolved successfully through at least three generations of spacecraft, ground control systems, and military user equipment. During that time, GPS has become one of the most widely used systems in the world for military and civilian positioning, navigation and timing (PNT) purposes and sets the example for other nations seeking to provide similar services.

In the United States, GPS is a fundamental enabler of national security and economic infrastructures, enhancing efficiency and improving safety and effectiveness of virtually all operations. As the cornerstone of our National PNT Architecture, it is the centerpiece around which future PNT services will evolve. The Department is fully aware of our responsibility with respect to GPS and is committed to maintaining and improving the services it provides. In that regard, DoD seeks the support of the Congress in maintaining stability of GPS funding to enable synchronized modernization of the next generation of GPS space, ground control, and user equipment that is now underway.

We have determined that the report is unclassified and has been cleared for open publication. Our point of contact for this review is Mr. Raymond Swider, (703) 607-1122, raymond.swider@osd.mil.

for
Ronald C. Jost
Deputy Assistant Secretary of Defense
(C3, Space & Spectrum)

Enclosure

GAO DRAFT REPORT DATED MARCH 12, 2009
GAO-09-325 (GAO CODE 120696)

"THE GLOBAL POSITIONING SYSTEM: SIGNIFICANT CHALLENGES IN SUSTAINING AND UPGRADING WIDELY USED CAPABILITIES"

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommends that the Secretary of Defense appoint a single authority to oversee the development of the Global Positioning System (GPS) system, including space, ground, and user assets, to ensure that the program is well executed and resourced and that potential disruptions are minimized. (p. 43/GAO Draft Report)

DOD RESPONSE: Concur with comment. The Department has recognized the importance of centralizing authority to oversee the continuing synchronized evolution of the GPS. To that end, the Deputy Secretary of Defense has reaffirmed that the Assistant Secretary of Defense for Networks and Information Integration (ASD(NII)) is the Department's Principal Staff Assistant to oversee Positioning, Navigation, and Timing, and, specifically, is designated with authority and responsibility for all aspects of the Global Position System (GPS). This designation is contained in Department of Defense Directive (DoDD) 4650.05, issued on February 19, 2008. A formal Department of Defense Instruction is now in final coordination to further define the oversight processes to be employed in executing DoDD 4650.05, and completion is expected by May 2009. Further, under oversight of the ASD(NII), the U.S. Air Force is the single acquisition agent with responsibility for synchronized modernization of GPS space, ground control, and military user equipment. The Air Force acquires and operates the GPS space and control segments and provides the fundamental system design and security requirements necessary for acquisition of GPS user equipment and applications in support of diverse missions across the Department. Given the diversity of platforms, and equipment form factors involved, it is impossible for the Air Force to unilaterally produce a "one-size-fits-all" solution applicable to all DoD missions.

RECOMMENDATION 2: The GAO recommends that Secretary of Defense, as one of the Position Navigation and Timing executive committee co-chairs, address, if weaknesses are found, civil agency concerns for developing requirements and determine mechanisms for improving collaboration and decision making and strengthening civil agency participation. (p. 43/GAO Draft Report)

DOD RESPONSE: Concur with comment. The Department is aware that we employ a rigorous requirements process in support of our extensive operational and acquisition responsibilities and that the process is a source of frustration for civil agencies without similar processes in place. In an effort to address the issue, we have worked with the civil agencies to put in place a GPS Interagency Requirements Plan, jointly approved by the Vice Chairman of the Joint Chiefs of

Staff, who is in charge of our process, and the Department of Transportation (DOT), acting on behalf of all civil agencies. Further, we are now in the process of jointly coordinating the Charter for an Interagency Forum for Operational Requirements (IFOR) to provide meeting venues to identify, discuss, and validate civil or dual use GPS requirements for inclusion in the DoD GPS acquisition process. Finally, we sponsor educational outreach opportunities for civil agencies to become more fully acquainted with the DoD requirements process, including a day-long "Requirements Process Summit" jointly conducted by the Joint Staff and DOT on April 29, 2008. We will continue to seek ways to improve civil agency understanding of the DoD requirements process and work to strengthen civil agency participation.

Appendix V: GAO Contacts and Staff Acknowledgments

GAO Contact

Cristina T. Chaplain (202) 512-4841 or chaplainc@gao.gov

Staff Acknowledgments

In addition to the contact named above, key contributors to this report were Art Gallegos (Assistant Director), Greg Campbell, Jennifer Echard, Maria Durant, Anne Hobson, Laura Hook, Sigrid McGinty, Angela Pleasants, Jay Tallon, Hai Tran, and Alyssa Weir.

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