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

September 2010

GLOBAL POSITIONING SYSTEM

Challenges in Sustaining and Upgrading Capabilities Persist

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Highlights

Highlights of GAO-10-636, a report to the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives

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GLOBAL POSITIONING SYSTEM

Challenges in Sustaining and Upgrading Capabilities Persist

Why GAO Did This Study

The Global Positioning System (GPS) provides positioning, navigation, and timing (PNT) data to users worldwide. The U.S. Air Force, which is responsible for GPS acquisition, is in the process of modernizing the system. Last year GAO reported that it was uncertain whether the Air Force could acquire new satellites in time to maintain GPS service without interruption. GAO was asked to assess (1) the status of Air Force efforts to develop and deliver new GPS satellites, the availability of the GPS constellation, and the potential impacts on users if the constellation availability diminishes below its committed level of performance; (2) efforts to acquire the GPS ground control and user equipment necessary to leverage GPS satellite capabilities; (3) the GPS interagency requirements process; and (4) coordination of GPS efforts with the international PNT community. To do this, GAO analyzed program documentation and Air Force data on the GPS constellation, and interviewed officials from DOD and other agencies.

What GAO Recommends

GAO recommends that the Department of Defense (DOD) and the Department of Transportation (DOT) develop comprehensive guidance for the GPS interagency requirements process. DOD did not concur with the recommendation, citing actions under way. DOT generally agreed to consider it. GAO believes the recommendation remains valid.

View GAO-10-636 or key components.
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What GAO Found

The Air Force continues to face challenges to launching its IIF and IIIA satellites as scheduled. The first IIF satellite was launched in May 2010—a delay of 6 additional months for an overall delay of almost 3-½ years—and the program faces risks that could affect subsequent IIF satellites and launches. GPS IIIA appears to be on schedule and the Air Force continues to implement an approach intended to overcome the problems experienced with the IIF program. However, the IIIA schedule remains ambitious and could be affected by risks such as the program's dependence on a ground system that will not be completed until after the first IIIA launch. The GPS constellation availability has improved, but in the longer term, a delay in the launch of the GPS IIIA satellites could still reduce the size of the constellation to fewer than 24 operational satellites—the number that the U.S. government commits to—which might not meet the needs of some GPS users.

Multiyear delays in the development of GPS ground control systems are extensive. In addition, although the Air Force has taken steps to enable quicker procurement of military GPS user equipment, there are significant challenges to its implementation. This has had a significant impact on DOD as all three GPS segments—space, ground control, and user equipment—must be in place to take advantage of new capabilities, such as improved resistance to jamming and greater accuracy. DOD has taken some steps to better coordinate all GPS segments. These steps involve laying out criteria and establishing visibility over a spectrum of procurement efforts. But they do not go as far as GAO recommended last year in terms of establishing a single authority responsible for ensuring that all GPS segments are synchronized to the maximum extent practicable. Such an authority is warranted given the extent of delays, problems with synchronizing all GPS segments, and importance of new capabilities to military operations. As a result, GAO reiterates the need to implement its prior recommendation.

The GPS interagency requirements process, which is co-chaired by officials from DOD and DOT, remains relatively untested and civil agencies continue to find the process confusing. This year GAO found that a lack of comprehensive guidance on the GPS interagency requirements process is a key source of this confusion and has contributed to other problems, such as disagreement about and inconsistent implementation of the process. In addition, GAO found that the interagency requirements process relies on individual agencies to identify their own requirements rather than identifying PNT needs across agencies.

The Department of State continues to be engaged internationally in pursuit of civil signal interoperability and military signal compatibility, and has not identified any new concerns in these efforts since GAO's 2009 report. Challenges remain for the United States in ensuring that GPS is compatible with other new, potentially competing global space-based PNT systems.

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Abbreviations

CAM	Control Account Manager
CWBS	Contractor Work Breakdown Structure
DASS	Distress Alerting Satellite System
DOD	Department of Defense
DOT	Department of Transportation
EELV	Evolved Expendable Launch Vehicle
EVM	earned value management
FAA	Federal Aviation Administration
FNET	Finish No Earlier Than
FOUO	For Official Use Only
GPS	Global Positioning System
IFOR	Interagency Forum for Operational Requirements
IMP	Integrated Master Plan
IRP	Interagency Requirements Plan
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Council
L1C	fourth civil signal
L2C	second civil signal
L5	third civil signal
M-code	Military Code
NASA	National Aeronautics and Space Administration
NSPD-39	National Security Presidential Directive No. 39
OCS	Operational Control Segment
OCX	Next Generation Control Segment
PNT	positioning, navigation, and timing
SAASM	Selective Availability Anti-Spoofing Module
SLR	Satellite Laser Ranging
SNET	Start No Earlier Than
SOW	Statement of Work
SVN-49	satellite vehicle number 49
WBS	Work Breakdown Structure

United States Government Accountability Office
Washington, DC 20548

September 15, 2010

The Honorable John F. 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 (PNT) 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. The Department of Defense (DOD) develops and operates GPS, and an interdepartmental committee—co-chaired by DOD and the Department of Transportation (DOT)—manages the U.S. space-based PNT infrastructure, which includes GPS. The U.S. Air Force, which is responsible for GPS acquisition, is in the process of modernizing GPS to enhance its performance, accuracy, and integrity. Effective modernization depends on aligned delivery of new capabilities from satellites, the ground control segment, and user equipment.

In April 2009, we reported on a range of issues related to GPS,[1] including the development of satellites, ground control, and user equipment necessary to leverage GPS capabilities and the coordination among federal agencies and other organizations to ensure that GPS missions can be accomplished. We reported that it was uncertain whether the Air Force would be able to acquire new satellites in time to maintain current GPS service without interruption, and that some military operations and some civilian users could be adversely affected. In addition, we reported that military users faced a potential delay in utilizing new GPS capabilities because of poor synchronization of the development of the satellites with development of the ground control and user equipment. We also reported that DOD and civil agencies involved in ensuring that GPS can serve communities beyond the military took prudent steps to manage GPS

[1] GAO, *Global Positioning System: Significant Challenges in Sustaining and Upgrading Widely Used Capabilities*, GAO-09-325 (Washington, D.C.: Apr. 30, 2009).

requirements and coordinate among the many organizations involved with GPS, but we identified challenges in ensuring that civilian requirements can be met. Finally, we identified challenges in ensuring that GPS was compatible with other new, potentially competing global space-based PNT systems.

In our prior report, we recommended that the Secretary of Defense appoint a single authority to oversee the development of GPS, 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. Furthermore, we specified that the appointee should have the authority to ensure that all GPS segments are synchronized to the maximum extent practicable. DOD concurred with this recommendation. In concurring with our recommendation, DOD asserted that the Assistant Secretary of Defense for Networks and Information Integration has 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, after our 2009 report, DOD created the Space and Intelligence Office within the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics to ensure that all three segments of GPS stay synchronized in the development and acquisition processes. However, that office does not have authority over all user equipment. We also recommended that if weaknesses are found the Secretaries of Defense and Transportation should address civil agency concerns for developing requirements, improve collaboration and decision making, and strengthen civil agency participation. Both DOD and DOT concurred with this recommendation. DOD noted that it would seek ways to improve civil agency understanding of the DOD requirements process and would work to strengthen civil agency participation. DOT indicated that it would work with DOD to review the process and improve civil agency participation.

In light of our previous findings and the importance of GPS, you asked that we review the program this year. In response, we assessed (1) the status of the Air Force's efforts to develop and deliver new GPS satellites, the availability of the GPS constellation, and the potential impacts on users if the constellation availability diminishes below its committed level of performance; (2) efforts to acquire the GPS ground control and user equipment necessary to leverage GPS satellite capabilities; (3) the GPS interagency requirements process; and (4) coordination of GPS efforts with the international PNT community.

To assess the status of DOD's efforts to develop and deliver new GPS satellites, including the recently developed GPS IIF satellites and the GPS

IIIA satellites that are under development, we interviewed DOD officials who manage and oversee the GPS program; reviewed and analyzed program plans and documentation related to cost, requirements, program direction, acquisition schedules, and launch schedules; and reviewed some of the GPS IIIA space vehicle development schedules and compared them with relevant best practices. To assess the availability of the GPS constellation, we conducted our own analysis based on GPS reliability data provided by the Air Force and assessed the implications of potential schedule delays. To assess potential impacts on users if the constellation availability diminishes below its committed level of performance, we obtained information from all military services and key civil agencies and departments. To assess the progress of efforts to acquire the GPS ground control and user equipment, we interviewed officials who manage and oversee these acquisitions; reviewed documentation regarding the delivery of capabilities and equipment; and assessed the level of synchronization among satellites, ground systems, and user equipment. To assess the GPS interagency requirements process, we reviewed policy and guidance on the GPS interagency requirements process, identified the status of civil requirements, analyzed documents, and interviewed DOD officials from offices that manage and oversee the GPS program and officials from DOT and other civil departments and agencies. To assess coordination efforts with the international global PNT community, we interviewed officials at the Department of State and at the GPS Wing. Our work is based on the most current information available as of April 16, 2010. Additional information on our scope and methodology is in appendix I. We conducted this performance audit from July 2009 to September 2010 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.

Background

GPS is a global PNT network consisting of space, ground control, and user equipment segments that support the broadcasts of military and civil GPS signals. Each of these signals includes 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 began operations with a full constellation of satellites in 1995. Over time, GPS has become vital to military operations and 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. GPS is used by all branches of the military to guide troop movements, integrate logistics support, enable components underlying battlespace situational awareness, and synchronize communications networks. In addition, U.S. and allied munitions are guided to their targets by GPS signals and GPS is used to locate military personnel in distress.

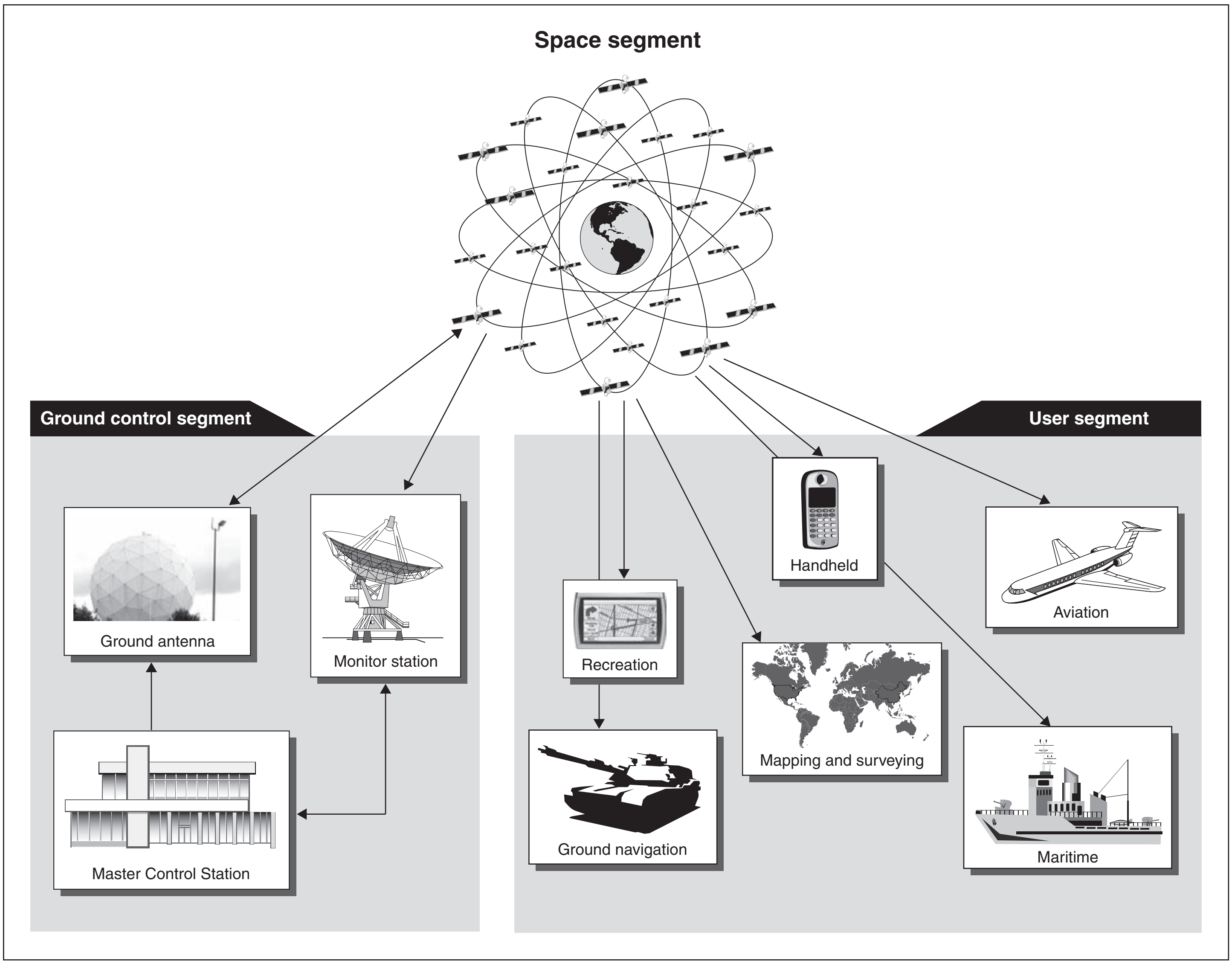
Civil agencies, commercial firms, and individuals use GPS and GPS augmentations[2] to accurately navigate from one point to another. Commercial firms use GPS and GPS augmentations to route their vehicles, as do maritime industries and mass transit systems. In addition to navigation, civil departments and agencies and commercial firms use GPS and GPS augmentations to provide high-accuracy, three-dimensional positioning information in real time for use in surveying and mapping and other location-based services. The aviation community worldwide uses GPS and GPS augmentations to increase the safety and efficiency of flight. GPS and GPS augmentations are also used by the agricultural community for precision farming, including farm planning, field mapping, soil sampling, tractor guidance, and crop scouting; the natural resources management community uses GPS for wildfire management and firefighting, pesticide and herbicide control, and watershed and other natural resources asset management. GPS is increasingly important to earth observation, which includes operational roles in weather prediction, the measurement of sea level change, monitoring of ocean circulation, and mitigation of hazards caused by earthquakes and volcanoes. 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.

[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 integrity needs.

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. (See fig. 1.)

Figure 1: GPS Operational System



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

The GPS space segment is a constellation of satellites that move in six orbital planes approximately 12,500 miles above the earth. GPS satellites broadcast encrypted military signals and unencrypted civil signals. The baseline constellation consists of satellites occupying 24 orbital slots—4 slots in each of the six orbital planes. However, because the U.S. government commits to at least a 95 percent probability of maintaining this baseline constellation of 24 satellites, the typical size of the constellation is somewhat larger. Moreover 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, reducing satellite availability, and potentially reducing the accuracy of the GPS service.

The GPS ground control segment comprises the Master Control Station at Schriever Air Force Base, Colorado; the Alternate Master Control Station at Vandenberg Air Force Base, California; 6 dedicated monitor stations; 10 National Geospatial-Intelligence Agency monitoring stations; and 4 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 U.S. Naval Observatory Master Clock monitors the GPS constellation and provides timing data for the individual satellites. The U.S. Naval Observatory Master Clock serves as the official source of time for DOD and a standard of time for the entire United States.

The GPS user equipment segment includes military and commercial GPS receivers. A receiver determines 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 efforts 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 segments.

Table 1: GPS Satellite and Ground Control Segment Modernization

Satellite evolution and capabilities			
GPS IIA/IIR (first launch 1990/1997)	**GPS IIR-M (first launch 2005)**	**GPS IIF (first launch 2010)**	**GPS III (first planned launch 2014)**
• Broadcasts signals for military and civil users	Includes IIA and IIR capabilities, plus • Second civil signal • Second military signal • Ability to increase signal power to improve resistance to jamming	Includes IIR-M capabilities, plus • Third civil signal for transportation safety requirements	Includes IIF capabilities, plus • IIIA: Stronger military signal to improve jamming resistance and fourth civil signal that is compatible 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 Operational Control System (various versions 1979–2007)	**Architectural Evolution Plan (came online in 2007)**	**Next Generation Control Segment (planned to come online in 2015)**
• Centralized computer mainframe • 1970s technology	• Distributed architecture • Enables upgrades to the system • Controls GPS IIF satellites	• Necessary for operation of GPS IIR-M, IIF and III satellites • Service-oriented architecture • Connects to broader networks

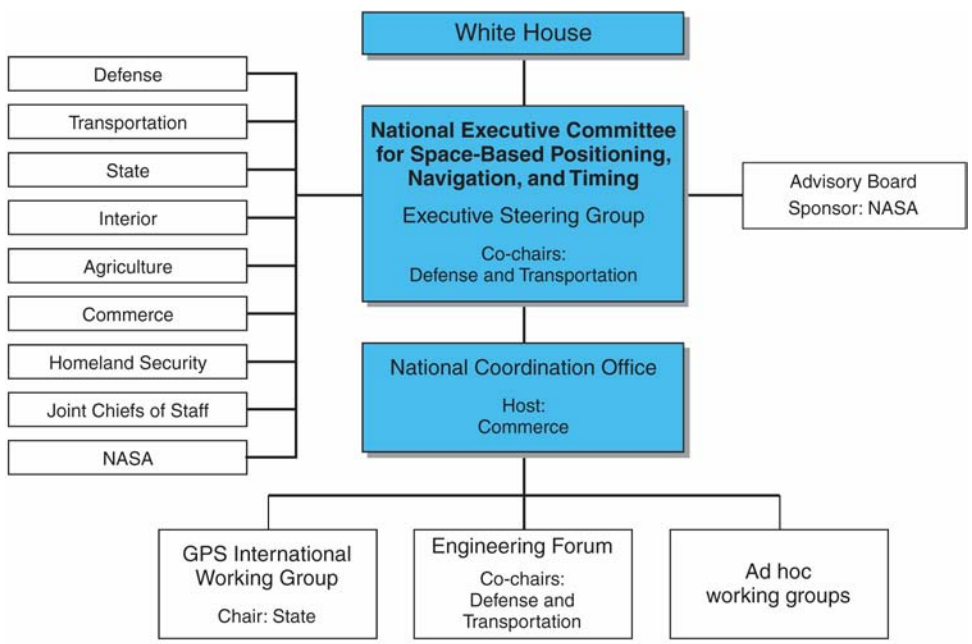
Source: GAO analysis based on DOD program information and discussions with DOD officials.

Full use of 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 netcentric architecture that can support "plug and play" features and can more easily connect to broader networks. To use the modernized military signal from the ground, military users require new user equipment, which will be provided by the military GPS user equipment program.

Broader Coordinating Structure

The 2004 U.S. Space-Based Positioning, Navigation and Timing policy established a coordinating 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 international organizations. As part of the coordinating 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 DOD and DOT, and includes members at the equivalent level from the Departments of State, Commerce, Homeland Security, the Interior, and 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, the Secretary of Defense is responsible for the overall development, acquisition, operation, security, and continued modernization of GPS. The Secretary has delegated acquisition responsibility to the Air Force, though other DOD components and military services are responsible for oversight, for some aspects of user equipment development, and for funding some parts of the program. DOT has the lead responsibility for coordinating civil requirements from all civil departments and agencies. The Department of State leads negotiations with foreign governments and international organizations on GPS PNT matters and regarding the planning, operations, management, and use of GPS.

The Air Force Continues to Face Challenges to Launching Its Satellites as Scheduled, Which Could Affect the Availability of the Baseline GPS Constellation

The Air Force faces challenges to launching its IIF and IIIA satellites as scheduled. The first IIF satellite launched May 27, 2010, almost 3-½ years later than previously planned, and the IIF program appears to have resolved most outstanding technical issues. In addition, the program faces risks that could affect the on-orbit performance of some GPS satellites and subsequent IIF launches. The GPS IIIA program is progressing and the Air Force continues to implement an approach that should prevent the types of problems experienced on the IIF program. However, the IIIA schedule remains ambitious and could be affected by risks such as the program's dependence on a ground system that will not be completed until after the first IIIA launch. Meanwhile, the availability of the baseline GPS constellation has improved, but a delay in the launch of the GPS IIIA satellites could still reduce the size of the constellation to below its 24-satellite baseline, where it might not meet the needs of some GPS users.

After Long Development Delays, the First GPS IIF Satellite Has Been Launched, but the Program Faces Longer-Term Challenges in Launching IIF Satellites as Scheduled

Last year, we reported that under the IIF program, the Air Force had difficulty successfully building GPS satellites within cost and schedule goals, encountered significant technical problems that threatened its delivery schedule, and faced challenges with a different contractor for the IIF program.[3] These problems 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 had overrun its original cost estimate of $729 million by about $870 million and the launch of the first IIF satellite had been delayed to November 2009—almost 3 years late.

[3] GAO-09-325.

Since our last review, launch of the first IIF satellite was postponed an additional 6 months—for an overall delay of almost 3-½ years—to May 2010. The first IIF satellite launched May 27, 2010, and the program appears to have resolved outstanding technical issues. The satellite was delivered to Cape Canaveral Air Force Station, Florida, in February 2010 to undergo final testing and preparations for launch. The GPS Wing[4] attributes recent launch delays to launch vehicle and pad availability issues, but the late discovery of some technical issues also contributed to the launch delay. According to the GPS Wing, the technical issues were a result of inadequate oversight of the contractor earlier in the acquisition. To prevent an even longer launch delay, the program shipped the second IIF satellite to Cape Canaveral Air Force Station and conducted extensive system-level end-to-end tests. This enabled the program to take the time to address some technical issues on the first satellite while reducing risk using the second satellite—GPS Wing officials reported that it saved them approximately 60 days of schedule time.

On-Orbit Performance of IIF Satellites Remains Uncertain

Although the first IIF satellite has launched, it is uncertain how the IIF satellites will perform on orbit and it is unclear how well positioned the program is to address any on-orbit problems without significantly affecting the IIF schedule. Only after the first satellite of a new generation, like IIF, has been launched and months of on-orbit tests have been conducted can a thorough understanding of its performance be obtained. Previously, the GPS Wing had planned to mitigate the risk of potential IIF performance issues by launching some satellites of the prior generation, the IIR-Ms, after the first IIF launch. Space programs in the past have used this practice to reduce risk in case there were on-orbit problems with the new generation of satellites. However, when the delivery of the IIF satellites was continually delayed, the Air Force launched the remaining IIR-M satellites to eliminate the Air Force's dependence on the launch vehicle that was used for previous generations of GPS satellites.

Two GPS Wing officials expressed concern that the GPS program is now in a riskier position than it has been for many years because it does not have any IIR-M satellites in inventory and ready to launch. In fact, the current IIF production and launch schedules indicate that there is little margin to address any potential on-orbit performance issues. Within little

[4] On July 31, 2004, the Air Force 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.

over a year after the first IIF launch, three additional IIF satellites are scheduled to launch and six—half of all IIF satellites—are scheduled to have completed production. If problems are identified during on-orbit testing of the first satellite, the satellites already in production will have to be retrofitted to correct the deficiencies, which could result in delays in launching some IIF satellites.

Competition for Launch Resources Could Affect IIF Launch Schedule

Adding to these challenges, the need to compete for limited launch resources has increased across national security space programs and is likely to affect the Air Force's ability to launch GPS IIF as planned. Until recently, the Air Force made use of four launch facilities on the East Coast and three on the West Coast to launch its national security space satellites. However, the Air Force now plans to launch most national security satellites, including the GPS IIF and IIIA, using one of two Evolved Expendable Launch Vehicle (EELV) rocket types—Delta IV or Atlas V. EELV launches are conducted from two launch facilities on the East Coast and two on the West Coast. With this transition to relying on the EELV, the Air Force has reduced its launch facilities from seven to four. The East Coast launch facilities are in greatest demand, particularly the Atlas V's facility SLC-41. Not only does the Air Force plan to launch several high-priority satellites, including four IIF satellites, from that facility over the next 2 fiscal years, but NASA also plans to use it for the launch of two extremely time-sensitive missions within that same time period. However, historically no more than four satellites have been launched from the SLC-41 facility in a single year, yet eight launches are planned for that facility in fiscal year 2011. Air Force officials stated that they are taking steps to improve their capability to launch more satellites per year on the EELV than in the past.

The Air Force has acknowledged that it will be challenged to achieve its desired launch plans in the near future and is taking some steps to address this challenge. For example, the Air Force designed the GPS IIF satellites to be dual integrated—meaning they can fly on either the Delta IV or Atlas V launch vehicle—which gives the Air Force more flexibility than if it had relied on only one type of launch vehicle. The GPS program in particular plans to request funding to study the possibility of launching GPS satellites on the West Coast, which has the potential of offering a broader array of launch options. However, some of the potential solutions to these launch challenges, such as launching GPS satellites from the West Coast, are long-term solutions. Therefore, despite these efforts, the high demand for limited launch resources will likely affect the GPS program's ability to achieve its planned launches in the near future.

The GPS IIIA Program Has Adopted Several Best Practices but Faces Challenges to Launching Its Satellites on Schedule

Last year, we reported that the Air Force structured the new GPS IIIA program to prevent mistakes made on the IIF program but that the IIIA schedule was optimistic. To avoid repeating past problems, the program was taking measures to maintain stable requirements, use mature technologies, and provide more contractor oversight. However, we also reported that the Air Force would be challenged to deliver IIIA on time because its satellite development schedule was optimistic given the program's late start, past trends in space acquisitions, and challenges facing the new contractor. For example, the GPS IIIA schedule from contract award to first satellite launch is 72 months. We found that that time period was 3 years shorter than the schedule the Air Force had achieved under its IIF program as well as shorter than most other major space programs we have reviewed. Furthermore, we questioned the reliability of the GPS IIIA schedule because we found that it did not fully meet best practices.

Since our prior report, we found that the GPS IIIA program appears to have furthered its implementation of the "back to basics" approach to avoid repeating the mistakes of GPS IIF and that it has passed a key design milestone.[5] More specifically, the program has maintained stable requirements, has used mature technologies, and is providing more oversight than under the IIF program. There have not been any changes to the program to meet increased or accelerated technical specifications, system performance, or requirements. All critical technologies were reported to be mature at program start. The program held multiple levels of preliminary design reviews to ensure that the system was ready to proceed into detailed design. The preliminary design reviews were completed in May 2009, and the program completed its critical design review in August 2010. Furthermore, GPS Wing officials stated that they are requiring that the contractor follow military standards and

[5] The "back to basics" policy was instituted by the Air Force in 2007 to direct space programs to adopt acquisition practices such as incremental introduction of new technologies to constellations of satellites and stabilization of requirements early in the acquisition process.

specifications and that the contractor and subcontractors use earned value management.[6]

Since our last review, the GPS program has also made improvements to its integrated master schedule. The success of any program depends in part on having a reliable schedule and we found the GPS IIIA schedule to be highly integrated and of high quality. In our recent analysis of the IIIA schedule, we found that processes are in place to ensure that all activities are captured, are of reasonable duration, and are assigned resources. Our analysis also shows that in general the program office updates the schedule on a regular basis and logical relationships are used to determine important dates. However, our analysis also revealed instances of unreasonably high total float. Total float represents the amount of time an activity can slip before it affects the project finish date and is directly related to the logical sequencing of activities. High levels of float may interfere with management's ability to properly align resources to ensure that critical activities are not delayed. We also found that schedule risk analysis is performed periodically on the schedule, but some risks may not be captured in the overall risk analysis because of issues at the individual project schedule level. Appendix II discusses our examination of the prime contractor's schedule management process against best practices criteria in more detail.

Despite these efforts to develop a stable and successful program, the GPS IIIA program faces challenges to launching its satellites on schedule. First, the 72-month time period from contract award to first satellite launch is 3-½ years shorter than the schedule achieved for the GPS IIF program. Though the GPS IIIA program has adopted practices that should enable it to deliver in a quicker time frame than the GPS IIF program, the inherent complexities associated with the design and integration phases that have yet to be completed will make it difficult to beat the prior schedule by that order of magnitude. More specifically, the IIIA program is not simply replicating the IIF program in terms of design and production. The program is using a satellite bus, which although it has flown on many

[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.

satellites in the past, has not yet been used in medium-earth orbit, an orbit that requires different control software and production processes, such as a higher level of radiation hardening. The contractor will add a new signal, L1C, to the satellite that has not been included on previous GPS satellites and will also increase the power of the military signal that has been used on previous satellites. These types of changes can increase the time it takes to complete the program because some level of discovery will need to be completed during design and integration and unanticipated technical problems that arise during these phases can have reverberating effects.

Second, the time period from contract award to first satellite launch in the IIIA schedule appears to be compressed compared to what the program had previously estimated. DOD's fiscal year 2004 funding request reported a schedule with 84 months from contract award to first satellite launch, but contract award took place 3 years later than had been planned while the first IIIA launch was only pushed back by 2 years, leaving that time period a year shorter than previously planned—a considerable amount of time given that requirements were not substantially changed to accommodate the schedule change.

Third, according to GPS Wing officials, the program is trying to improve the quality of the satellites by requiring that the contractor follow military standards and specifications. This action is a positive step; however, using this more rigorous approach is likely to pose challenges to meeting the IIIA schedule. GPS Wing officials stated that GPS IIIA is currently the only major space system acquisition that is requiring the use of military standards and specifications and it is shouldering much of the burden of transitioning to these more rigorous standards. Officials report that some of the standards and specifications are out of date and familiarity with these standards has been lost. Updating the standards and specifications along with developing and implementing the necessary training and testing to apply them takes time and creates cost pressure.

Lastly, it should be noted that no major satellite program undertaken by DOD in the past decade has met its schedule goals. The GPS IIIA program itself has done more than many programs in the past decade to position itself to meet its dates, but there are still actions that need to be taken across DOD to enable space programs to meet their schedule goals. As we testified in March 2010, these include strengthening the space acquisition workforce, clarifying lines of accountability and authority, and lengthening program manager tenures, among others.[7]

An additional challenge to launching the IIIA satellites on time is the GPS IIIA program's dependence on a ground control system that is currently in development. More specifically, the first block[8] of the ground system, called the Next Generation Control Segment, or OCX, is scheduled to be operational in fourth quarter fiscal year 2015, over 1 year after the launch of the first GPS IIIA satellite. GPS Wing officials stated that a complete system-level test cannot be conducted until OCX is available at which point GPS IIIA can become part of the operational constellation and be set "healthy."[9] They also stated that they would prefer not to launch a second GPS IIIA satellite until the first IIIA satellite is set healthy, meaning until OCX is available, only one GPS IIIA satellite should be launched. Yet the planned launch dates for the GPS IIIA satellites reflect a rapid series of IIIA launches with five launches taking place within 2 years after the first IIIA launch. If OCX is late, as some Air Force satellite ground control systems have been, several IIIA satellites may not be launched as currently scheduled. In October 2009, we reported that three of eight ground control systems were lagging significantly behind their satellite counterparts. Of the five that were not behind, some were still experiencing schedule delays; however, their satellite counterparts were also experiencing delays.[10]

[7] GAO, *Space Acquisitions: DOD Poised to Enhance Space Capabilities, but Persistent Challenges Remain in Developing Space Systems*, GAO-10-447T (Washington, D.C.: Mar. 10, 2010).

[8] A block, or increment, delivers a capability in a discrete, value-added increment. Capability increments are based on a balance of capability, delivery timeline, technology maturity, risk, and budget.

[9] The navigation message broadcast by each GPS satellite contains data that enable GPS receivers to determine whether that satellite should be used to calculate a user's position. If these data indicate that the satellite can be used, then the satellite is considered healthy. During on-orbit checkout and later during routine maintenance, the navigation message is changed to indicate that the satellite is unhealthy and should not be used.

[10] GAO, *Defense Acquisitions: Challenges in Aligning Space System Components*, GAO-10-55 (Washington, D.C.: Oct. 29, 2009).

Current GPS Constellation Availability Improves, but a Delay in GPS III Could Affect GPS Constellation Performance

To ensure that the GPS constellation can provide PNT information to GPS users located anywhere on the earth at almost any time of day, 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. Last year, we reported that the estimated long-term probability of maintaining a constellation of at least 24 operational satellites would fall below 95 percent during fiscal year 2010 and would remain below 95 percent until the end of fiscal year 2014, at times falling to about 80 percent. We also reported that if a 2-year delay were to occur to the launch of the first and subsequent GPS III satellites, the U.S. government would be at a much greater risk of failing to meet this commitment.

The availability of the constellation has shown considerable improvement since last year; the Air Force now predicts that the probability of maintaining a constellation of at least 24 operational satellites will remain above 95 percent for the foreseeable future—through at least 2025, the date that the final GPS III satellite is expected to become operational. However, the long-term impact of a delay to GPS III could still reduce the guaranteed size of the constellation to fewer than 24 satellites, which might not meet the needs of some GPS users. According to the Air Force, the impact of such a delay could be mitigated somewhat by shutting off a second payload on GPS satellites to save power and thereby extend the lives of aging satellites. However, our analysis shows that this approach alone would have a limited impact on enabling the U.S. government to meet its commitment to a 95 percent probability of maintaining a 24-satellite constellation—increasing the predicted size of the constellation (at the 95 percent confidence level) by 1 satellite.

Constellation Availability Analysis and Its Limitations

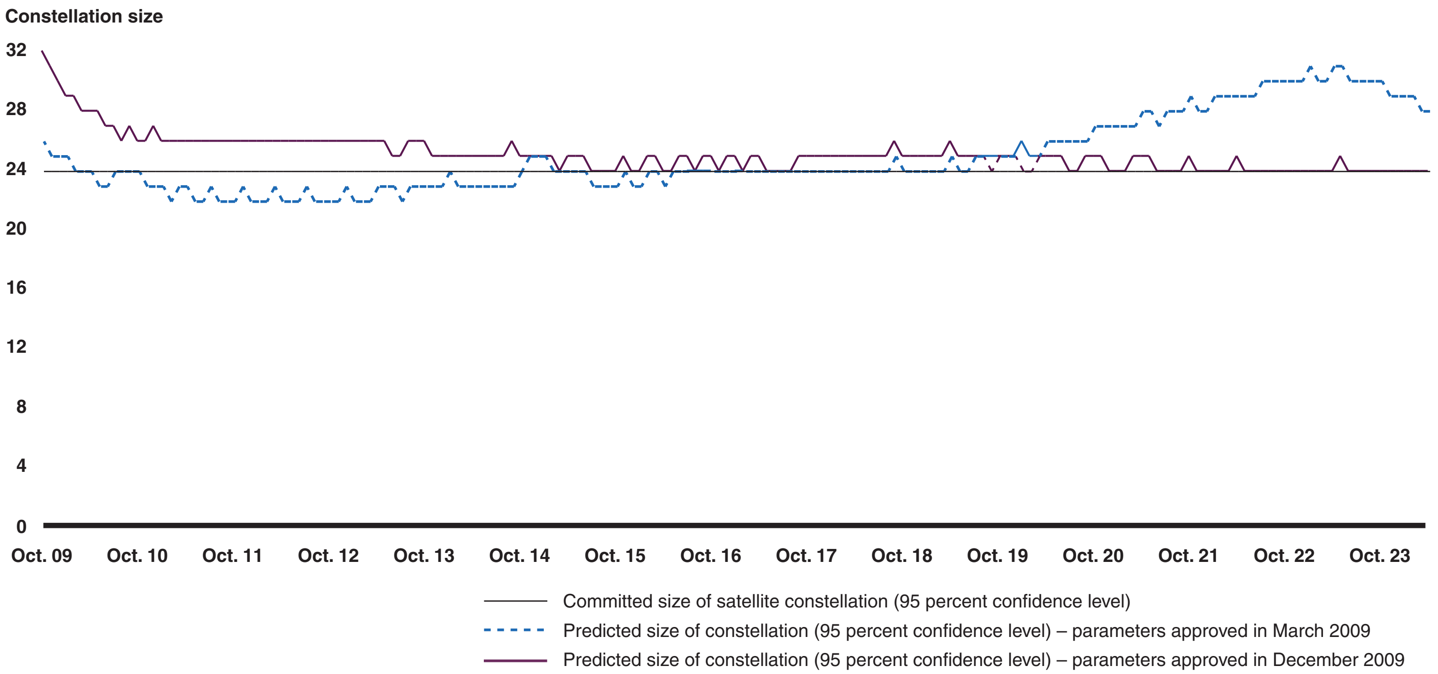
The Air Force, with technical support from the Aerospace Corporation, calculates satellite lifetime estimates for each on-orbit and production (not yet launched) GPS satellite based on detailed reliability analysis of the satellite's primary life-limiting subsystems. We replicated this analysis for this review using parameters provided by the Air Force. The Air Force's analysis is used to generate a reliability function for each satellite—that is, the probability that the satellite will still be operational as a function of its time on orbit. Each satellite's reliability function is modeled as the product of two cumulative probability distributions—one that accounts for the wear out of life-limiting components and one that accounts for random failures. Individual satellite reliability functions can be combined with a launch schedule and launch success probabilities to predict the constellation availability—that is, the predicted size of the constellation as a function of time. (See app. I for a more complete description of the approach used to generate the reliability function for each satellite and to combine these reliability functions into a constellation availability analysis.)

While the mathematical techniques used to combine satellite reliability functions are straightforward, the techniques used to generate the reliability functions themselves have inherent limitations. In particular, because the reliability functions associated with new (unlaunched) generations of GPS satellites are based solely on engineering and design analysis, instead of on-orbit performance data, the actual reliability of these satellites may be very different, and reliability functions may need to be modified once on-orbit performance data become available. For example, while the IIA satellites were designed to last 7.5 years on average, they have actually lasted more than twice as long, and the Aerospace Corporation has had to adjust the reliability functions of these satellites to account for this difference. Moreover, satellite operators work to develop innovative operational tactics to maximize the useful life of each GPS satellite. An official with the 2nd Space Operations Squadron, which operates and maintains the GPS constellation, noted that a healthy tension exists between the acquisitions community, which tends to be conservative in estimating the lifetimes of the things it acquires, and the operations community, which continues to evolve new techniques and procedures for getting more life out of old systems. Nevertheless, the Air Force appears to have a mature process in place to develop, certify, and routinely update satellite reliability functions, and we have found no evidence to suggest that this process is biased toward overly conservative estimates of satellite lifetimes.

Near-Term Constellation Availability Has Shown Considerable Improvement Since Last Year

Last year, we reported that because there were 31 operational GPS satellites of various generations, the near-term probability of maintaining a constellation of at least 24 operational satellites would remain well above 95 percent for a brief period of time, but because older satellites were predicted to fail faster than they were scheduled to be replaced, we reported that the constellation would, in all likelihood, decrease in size. We noted that the probability of maintaining a constellation of 24 operational satellites would fall to below 95 percent in fiscal year 2009, and to as low as 80 percent before recovering near the end of fiscal year 2014. This situation is now much improved. There are still 31 operational satellites, 30 of which are currently working to performance standards and available to GPS users. Our updated analysis, based on the most recent satellite reliability data, indicates that the size of the constellation is still expected to decline somewhat over the next several years. However, if the current launch schedule holds, the probability of maintaining a constellation of 24 satellites will remain above 95 percent for the foreseeable future. Figure 3 compares the predicted size of the GPS constellation over time (at the 95 percent confidence level) that we calculated based on the GPS reliability data and launch schedule we used last year with the predicted size of the constellation over time that we calculated based on the latest available GPS reliability data and launch schedule.[11]

Figure 3: Comparison of Predicted Size of GPS Constellation (at the 95 Percent Confidence Level) Based on Reliability Data and Launch Schedules as of March 2009 and December 2009



Source: GAO analysis of DOD data.

[11] In GAO-09-325, we presented our analysis somewhat differently. We showed the probability of maintaining a constellation of at least 24 GPS satellites as a function of time. For this report, we used the same underlying data to present the predicted size of the constellation—at the 95 percent confidence level—as a function of time. We believe that this presentation of the data better depicts the impact of our constellation availability analysis. In figs. 3 through 6, the analysis shows the guaranteed size of the GPS constellation (at the 95 percent confidence level) under various assumptions, and makes clear that even under worst-case assumptions, there is a high probability that the constellation will remain above about 17 satellites.

The improvement in the near-term predicted size of the constellation is the result of several factors, most notably the Air Force's assumptions regarding an increased life expectancy for some of the on-orbit satellites. Other factors include the successful launches of the last two GPS-IIR-M satellites in March 2009 and August 2009 and some adjustments to the launch schedule.

Our updated analysis does not include the contribution of several residual satellites that have been decommissioned but not yet been permanently disposed of. These satellites could be reactivated if there were an unexpectedly large number of satellite failures in the near future. However, the maximum size of the current constellation is limited to 31 operational satellites because of limitations of the current ground system, and none of these residual satellites is expected to continue operating beyond the end of fiscal year 2013. Consequently, while including these satellites in our analysis would further increase the probability of maintaining a 31-satellite constellation for the next few years, these residual satellites would have little or no impact on the size of the constellation beyond fiscal year 2013.

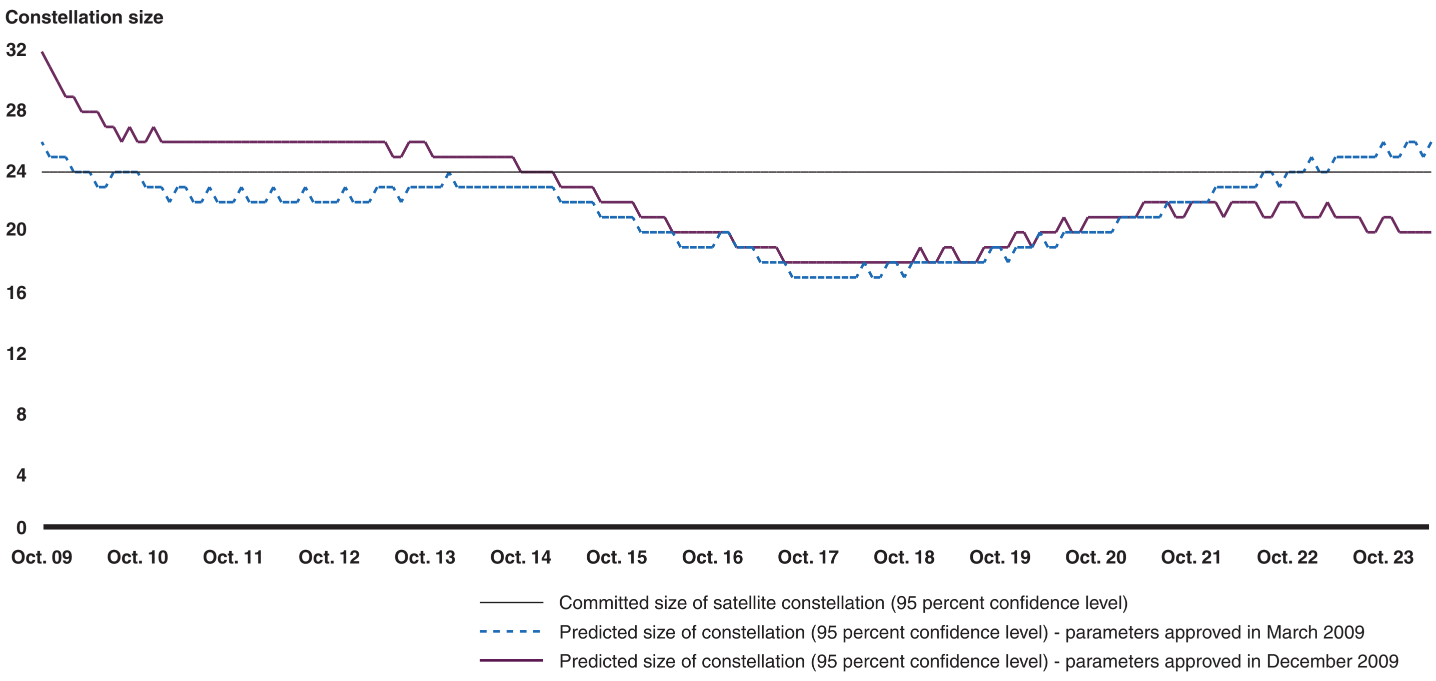
Our updated analysis also assumes that GPS-IIR-M-20—otherwise known as satellite vehicle number 49 (SVN-49)—will remain operational. However, while this satellite is currently operational and broadcasting GPS signals, it has remained in an "unhealthy" status since it was launched in March 2009, and consequently remains unavailable to GPS users. The satellite remains unhealthy because of a small but permanent signal anomaly that could adversely affect GPS user equipment if it were activated without putting mitigation measures in place. This anomaly resulted from unexpected complications following the integration of a demonstration payload onto the satellite—a payload that broadcasts the third civil signal. The Air Force is examining several options to mitigate the impact of this anomaly, but no solution that would work for all GPS users has been identified. On March 26, 2010, DOT published a request seeking public comment on the Air Force's proposed mitigation options in the *Federal Register*.[12] However, a final decision as to whether SVN-49 will be set healthy is not expected to be made until June 2011. If SVN-49 were excluded from our analysis, the impact would be to reduce the predicted size of the constellation by about one satellite until around fiscal year 2020.

[12] 75 Fed. Reg. 14,658 (Mar. 26, 2010).

A Delay in GPS III Could Still Affect GPS Constellation Availability

Last year, we reported that a delay in the production and launch of GPS III satellites could have a big impact on the U.S. government's ability to meet its commitment to maintain a 24-satellite GPS constellation. We noted that the severity of the impact would depend on the length of the delay, and that, for example, a 2-year delay (which is less than the average delay experienced by major space programs over the past decade) 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. Put another way, we predicted that the guaranteed size of the constellation (at the 95 percent confidence level) would fall to about 17 satellites by that time. Our updated analysis based on the latest reliability data and launch schedule indicate that a 2-year delay in the production and launch of the GPS III satellites would still lead to a drop in the guaranteed size of the constellation (at the 95 percent confidence level) to about 18 satellites by fiscal year 2018. See figure 4 for details.

Figure 4: Predicted Size of GPS Constellation (at the 95 Percent Confidence Level) Based on a 2-Year GPS III Launch Delay and Reliability Data and Launch Schedules as of March 2009 and December 2009



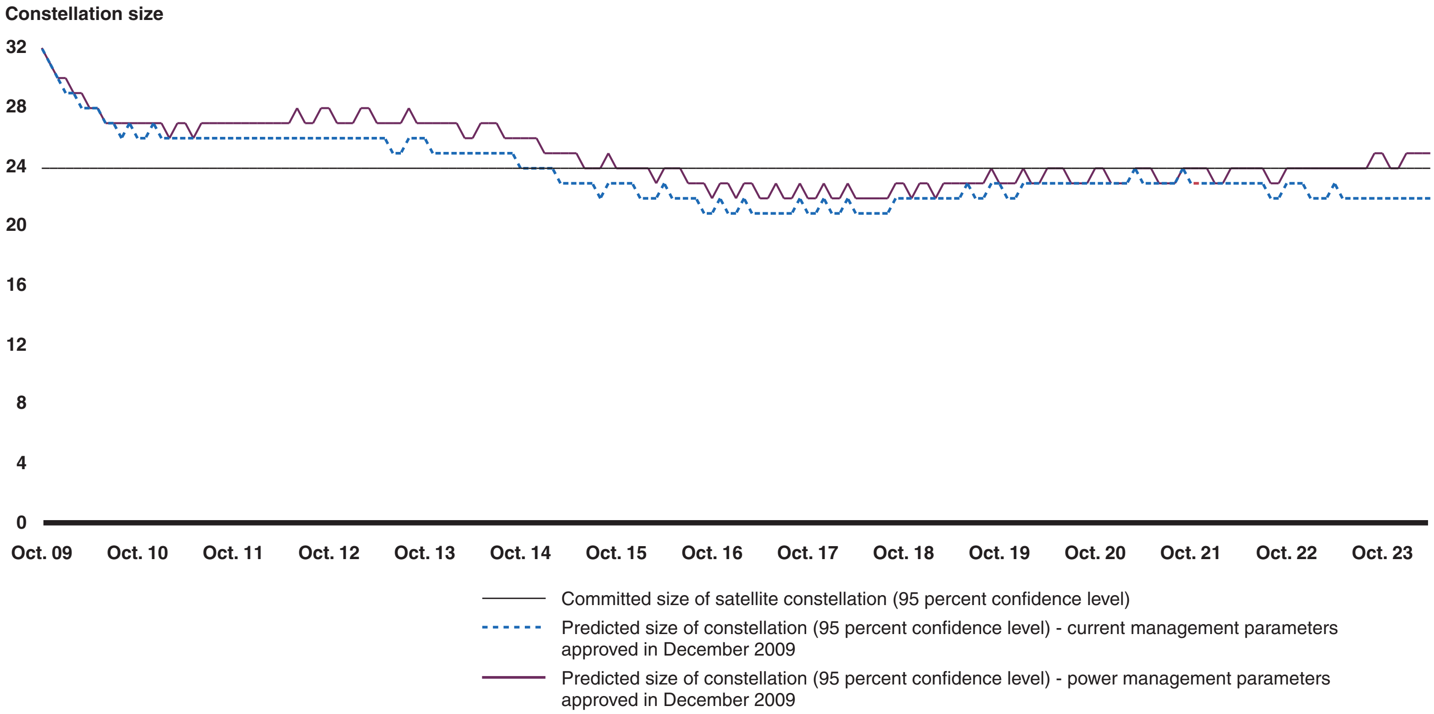
Source: GAO analysis of DOD data.

This analysis assumes that the Air Force will be able to launch all 12 IIF satellites on schedule; a slower IIF launch rate would change the shape of the availability curve—reducing the amount of time that the guaranteed size of the constellation would remain above 24 satellites—but would not reduce the depth of the decline in the constellation's guaranteed size. Moreover, while the performance of several of the on-orbit satellites has been somewhat better than was expected last year, there has been no change to the expected lifetimes of any of the IIF, IIIA, IIIB or IIIC satellites. Consequently, the predicted size of the constellation around fiscal year 2018—at a time when the constellation will be predominantly made up of IIF, IIIA, and IIIB satellites—is about the same as last year's analysis had predicted. The drop-off in the predicted size of the constellation in fiscal year 2022 is the result of changes to the approved launch schedule for the IIIC satellites since last year. While the Air Force still plans to launch the first IIIC satellite in June 2019, the scheduled launch dates for the rest of the IIIC satellites have been pushed back from 5 months (for the second IIIC launch) to 28 months (for the 16th and final IIIC launch).

Employment of Power Management Would Mitigate the Impact of a Delay in GPS III, but the Effect Would Be Small

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. The effects of this power loss can be mitigated somewhat by actively managing satellite subsystems—shutting them down when they are not needed—thereby reducing the satellite's overall consumption of power. The Air Force currently employs this approach—referred to as current management—to extend the life of GPS satellites. According to the Air Force, it would also be possible to significantly reduce a satellite's consumption of power and further extend the life of its PNT mission by shutting off a second payload on a GPS satellite once the satellite could not generate enough power to support both the missions. Shutting off the second payload once the satellite cannot support both missions—known as power management—would further mitigate the impact of a delay in GPS III. However, the impact is limited to increasing the predicted size of the constellation by about 1 satellite. For example, if the GPS III program were delayed by 1 year, the guaranteed size of the constellation (at the 95 percent confidence level) would decline to about 21 satellites by fiscal year 2017 if current management were employed and to about 22 satellites if power management were employed. See figure 5 for details.

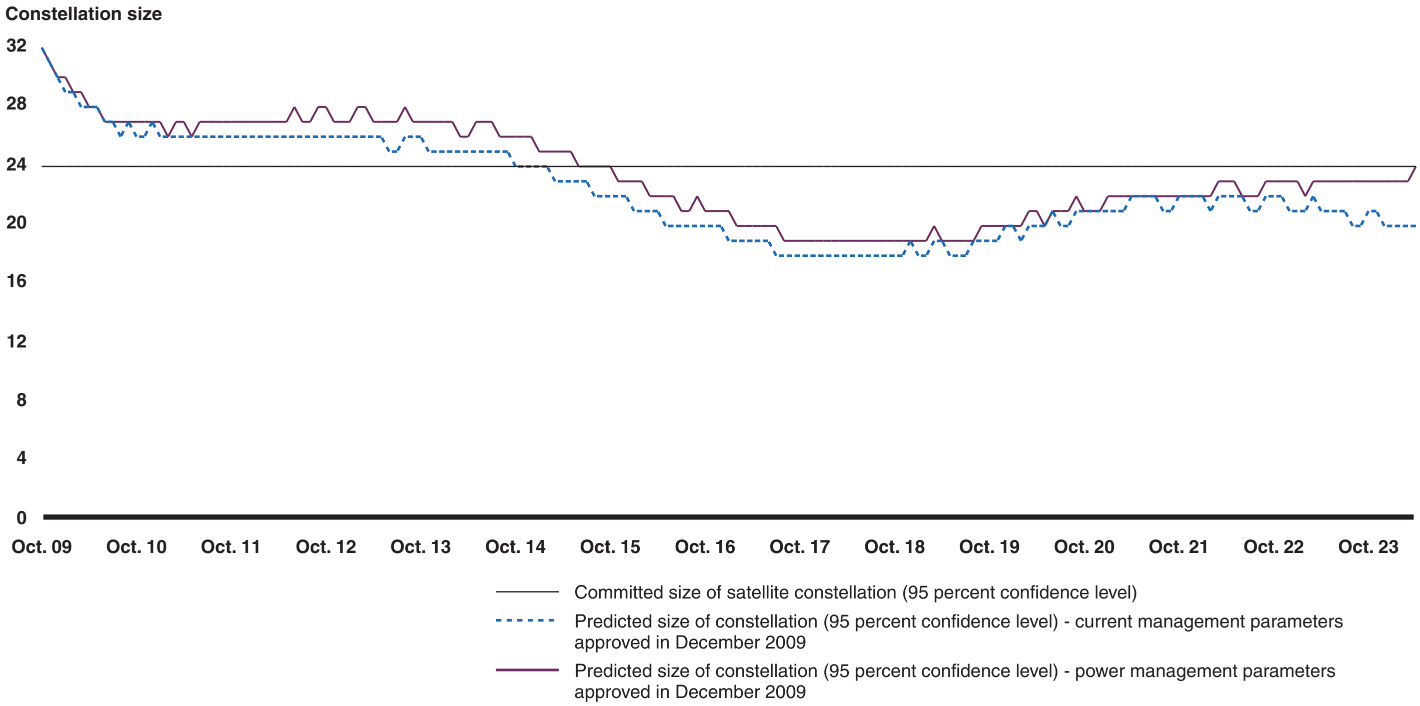
Figure 5: Predicted Size of GPS Constellation (at the 95 Percent Confidence Level) Based on a 1-Year GPS III Launch Delay and Current Management and Power Management Reliability Data and Launch Schedules as of December 2009



Source: GAO analysis of DOD data.

If the GPS III program were delayed by 2 years, the guaranteed size of the constellation (at the 95 percent confidence level) would decline to about 18 satellites by fiscal year 2018 if current management were employed and to about 19 satellites if power management were employed. See figure 6 for details.

Figure 6: Predicted Size of GPS Constellation (at the 95 Percent Confidence Level) Based on a 2-Year GPS III Launch Delay and Current Management and Power Management Reliability Data and Launch Schedules as of December 2009



Source: GAO analysis of DOD data.

Because the second payload relies on the PNT payload, there would be no operational benefit to retaining the second payload and shutting off the PNT payload at the point where a satellite cannot support both missions. However, the constellation availability analysis that employs power management does not address whether the constellation is satisfying the missions supported by the second payload. Moreover, according to Air Force Space Command officials, power management should not be used as the basis for official constellation availability analysis, given the uncertainties associated with predicting a satellite's actual power usage. We agree, given the criticality of GPS to military and civilian users.

Potential Effects of a Decline in the Availability of the GPS Constellation Appear to Be Poorly Understood but Vary Significantly Depending on Circumstances

If GPS constellation performance were to fall below the baseline constellation of 24 satellites, the constellation would continue to provide a high level of service to most users most of the time, although accuracy and availability could diminish in some locations for brief periods. Military users of GPS understand that a diminished constellation of fewer than 24 satellites will affect their operations. However, it is unclear whether military users of GPS understand the potential specific effects. The Army, Marine Corps, and Navy user representatives reported that their services had not conducted any studies to assess how their operations would be affected if the constellation were to drop below 24 satellites. Furthermore, while some user representatives pointed out that the effects of diminished constellation availability would vary depending on which satellites continued to be available, most did not provide very specific explanations of the potential effects of a decline below performance standards on their services' operations. For example, the services reported the following:

- Air Force. The Air Force user representative stated that the Air Force has "a healthy concern for the ready viability, integrity, and availability of this system. Specific data points, analysis, and vulnerabilities would be classified." Any system that would possibly function without its full designed or optimized capability would naturally have some operational degradation.
- Army. The Army user representative stated that effects largely depend on which satellites would remain available. If there is a decline just below 24 satellites, the effect would probably be minimal, but with each additional space vehicle lost the operational impact would increase.
- Marine Corps. The Marine Corps user representative stated that Marines are accustomed to using GPS for PNT; therefore the loss of GPS would severely affect Marines' ability to navigate. Effects would vary depending on the situation in which a user operates. The most severely affected Marines would be those who use GPS in marginal but currently acceptable conditions, such as under foliage, in mountains, and in urban settings, where a smaller constellation is more likely to result in diminished or no service.
- Navy. The Navy user representative stated that there is no "one-size-fits-all" answer, that information regarding the effects would be classified, and that the Navy would continue to operate even if it could not use GPS, although missions might take longer to accomplish and require additional assets.

Civil agency officials stated that if the constellation performance fell below the committed level of service, their operations would be affected; however, the effects vary by agency. For instance, Federal Aviation Administration (FAA) officials stated that a constellation smaller than the committed 24 satellites could result in flight delays and increased reliance on legacy ground-based navigation and surveillance systems. Likewise, U.S. Coast Guard officials stated that they could revert back to older methods of navigation if GPS service were diminished, but there would be a loss of efficiency. On the other hand, the National Institute of Standards and Technology, within the Department of Commerce, relies on GPS for timing data rather than navigation data and may be less sensitive to decreases in the number of GPS satellites. Furthermore, some civil agencies rely on both GPS and augmentation systems. For example, FAA augmentation systems increase the integrity of GPS for aviation purposes. However, officials from a few civil agencies explained that the augmentation systems cannot compensate for a drop in the size of the GPS constellation below the committed level.

Exploitation of New Satellite Capabilities Delayed Further Because of Ground Control and User Equipment Delays and Acquisition Challenges

GPS modernization efforts across the space, ground control, and user equipment segments introduce new capabilities, such as improved resistance to jamming and greater accuracy. For most of these new capabilities, all three segments need to be in place in order for users to benefit from the new capability. However, the development of GPS ground control systems has experienced years of delay and in some cases will delay the delivery of new capabilities to users. In addition, although the Air Force has taken steps to enable quicker procurement of military GPS user equipment, there are significant challenges to these systems' implementation.

Ground Control Challenges

We previously reported that the Air Force had not been fully successful in synchronizing the acquisition and development of the next generation of GPS satellites with the ground control system, thereby delaying the ability of military and civil users to utilize new GPS satellite capabilities.[13] The delay was due to funding shifts that were made to resolve GPS IIF satellite development problems. Since our last report, we found that the Air Force has faced technical problems and continued to experience delays in upgrading the capabilities of the current ground control system and that the delivery date of the follow-on ground system has further slipped.

[13] GAO-09-325.

Table 2 highlights specific new capabilities for which there have been significant delays in the ground segments and additional delays that have occurred since last year's review.

Table 2: Delays in Delivery of New GPS Ground Segment Capabilities

Capability enabled	Originally planned delivery date	Delivery date reported by GAO in 2009	Delay in months	Current delivery date	Delay in months
Selective Availability Anti-Spoofing Module	September 2005	September 2009	48	January 2010	52
Second civil signal	September 2007	September 2012 or 2013	60-72	August 2015	95
Military Code	September 2007	September 2012 or 2013	60-72	September 2016	108
Third civil signal	September 2007	September 2012 or 2013	60-72	September 2016	108
Fourth civil signal	May 2013	Not previously reported on	N/A	September 2016	40

Source: GAO analysis of GPS Wing data.

Since our 2009 report, the contract for the newest ground system development effort—known as OCX—was awarded in February 2010, about 10 months later than the original contract award date was to occur. To account for the delay and increase confidence in the schedule, the Air Force extended the OCX delivery schedule by adding 16 months of development time. As a result, key OCX capabilities associated with the IIIA satellites will not be operational until September 2016[14]—over 2 years after the first IIIA satellite launch. The Air Force is working on a mitigation strategy that calls for development of a separate effort to launch and control the first IIIA satellite. However, GPS Wing officials indicated that the effort will not enable new capabilities offered by IIIA, including a signal known as Military Code (M-code), which is designed to enable resistance to jamming, and three civil signals: the second civil signal (L2C), to improve the accuracy of the other signals; the third civil signal (L5), to be used for aviation; and the fourth civil signal (L1C), to offer interoperability with international global space-based PNT systems.

[14] The Air Force plans to develop OCX in blocks. Block I, to be delivered in August 2015, will command and control the IIIA satellites and enable the second civil signal. Block II, to be delivered in September 2016, will enable the third civil signal, the Military Code, and the fourth civil signal.

The other delayed capability identified in table 2 is the Selective Availability Anti-Spoofing Module (SAASM),[15] which will provide military users with improved security and information assurance. The ground control system software that precedes OCX deploys the SAASM functionality, which is a critical enabler of DOD's navigation warfare strategy. Although new user equipment capable of exploiting SAASM was delivered to the warfighters in 2004, they were not able to take full advantage of this capability until January 2010—when the SAASM module was delivered as part of the ground control system.

User Equipment Challenges

GPS has become an essential element in conducting military operations. GPS user equipment is incorporated into nearly every type of system used by DOD, including aircraft, spacecraft, ground vehicles, ships, and munitions. A key component of the GPS modernization is a new military signal—known as M-code—that will increase the jam resistance of the GPS military service. For military users to benefit from this new capability, they need to be provided with new military user equipment capable of receiving and processing the new military signal.

In 2009, we found that the Air Force was not fully successful in synchronizing the acquisition and development of the next generation of GPS satellites with the user equipment, thereby delaying users' ability to benefit from M-code. While the signal was to be made operational by the GPS satellites and ground control system in about 2013 (now 2016), we found that the warfighters would not be able to take full advantage of this new signal until about 2025—when the modernized user equipment is completely fielded. We also found that diffuse leadership was a contributing factor, given that there was no single authority responsible for synchronizing procurements and fielding of user equipment. More specifically, while the Air Force was responsible for developing the satellite and ground segments for GPS, the military services were individually responsible for procuring user equipment for the weapon systems they owned and operated. As such, there were separate budget, management, oversight, and leadership structures over the space, ground control, and user equipment segments. While there were valid reasons to segment procurement responsibility, DOD and GAO studies have

[15] 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.

consistently found that DOD has lacked the tools necessary to coordinate these procurements and ensure that they are synchronized to the extent that warfighters can take advantage of M-code and other new capabilities available to them through GPS satellites.

Since our 2009 report, the Air Force has taken steps to enable quicker procurements of user equipment, but there are still significant challenges to its implementation. First, the Air Force intends to follow an acquisition approach that will enable the military services to contract separately with commercial GPS providers rather than develop entirely new, customized user equipment systems. To support this approach, the Air Force plans to develop a common module, which commercial providers could use, along with interface control documents, to produce their equipment. The Air Force's current expectation is that it will issue requests for proposals in February 2011, formally initiate the military user equipment acquisition program in fiscal year 2012, and begin production in fiscal year 2015. At this time, however, the Air Force does not have approved requirements or an approved military user equipment acquisition strategy.

Second, as a pathway to its new approach, the Air Force is working with three contractors to develop GPS receiver cards capable of receiving and processing legacy GPS signals and the new military signal, while incorporating a new security architecture into the design. However, the delivery of receiver cards from two contractors has slipped by about a year because of unforeseen challenges with software and hardware integration and antispoofing software development and integration. The third contractor is facing technical problems, the cause of which has not yet been identified, and the Air Force is uncertain as to when this contractor will deliver its receiver card. Even after the cards are developed and delivered, they still need to go through independent security and technology testing to demonstrate that the technologies are mature, which can take 9 months to a year. Moreover, since there is still no program of record for the military GPS user equipment, it is difficult to forecast when enough military GPS user equipment will be in place to utilize the M-code capabilities operationally.

Third, some steps have been taken to better coordinate procurements of user equipment. Specifically, in January 2010, the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics held its first annual GPS enterprise review. The purpose of this review, which will be held again in the fall of 2010, is to review the status of the GPS acquisition programs at one time and provide more visibility into how the GPS acquisitions and capabilities fit together. In addition, DOD recently created the Space and Intelligence Office within the Office of the Under Secretary for Acquisition, Technology and Logistics to ensure that all three segments of GPS stay synchronized in the development and acquisition processes. DOD has also documented GPS synchronization as one of its goals for the next 15 years in its March 2010 Net-Centric Portfolio Strategic Plan, used in part to identify areas requiring additional focus. More specifically, DOD plans to ensure synchronized development and fielding of GPS space, ground control, and user equipment segments to support delivery of advanced capabilities. This includes fielding user equipment to all designated users starting in 2014 and almost completing fielding by full operational capability of the GPS III satellite constellation. In DOD's netcentric plan, M-code initial operational capability is defined as having 18 M-code satellites on orbit, having the control segment able to command and upload M-code capabilities to the satellites, and having enough military GPS user equipment in place across DOD to utilize M-code capabilities operationally. Furthermore, the Air Force has made significant changes to the definition of initial operational capability, which now takes into account all three GPS segments rather than only the satellite segment.

DOD has taken some steps to coordinate GPS segments, but it is not likely that these will be sufficient to ensure that all GPS segments are synchronized to the maximum extent practicable, which we recommended last year. Specifically, we recommended that the Secretary of Defense appoint a single authority to oversee the development of GPS, 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 creation of the Space and Intelligence Office is a positive development; however, the office does not have authority over all user equipment. In addition, we recently reported that DOD program officials believe that the primary reason that user equipment is not optimally synchronized is a lack of coordination and effective oversight of the many military organizations that either develop user equipment or have some hand in the development.[16]

[16] GAO-10-55.

The GPS Interagency Requirements Process Is Relatively Untested and Lacks Detailed Guidance

The GPS interagency requirements process remains relatively untested and civil agencies continue to find the process confusing. The lack of detailed guidance on the process is a key source of confusion and has also contributed to other problems, such as disagreement and inconsistent implementation of the process. In addition, we found that the interagency requirements process relies on individual agencies to identify their own requirements but does not identify PNT needs across civil agencies.

We previously reported that DOD and civil agencies considered the process for approving civil GPS requirements rigorous but relatively untested, and that civil agencies found the process confusing.[17] We stated that prudent steps had been taken to manage requirements and coordinate among the many organizations involved with GPS. However, we reported that civil agencies had not submitted many requirements proposals to date. We focused on two proposals: those for the Distress Alerting Satellite System (DASS) and the geodetic requirement implemented by Satellite Laser Ranging (SLR). These proposals had yet to complete the initial steps in the interagency requirements process. In addition, we reported that civil agencies that had proposed GPS requirements found the requirements approval process confusing and time-consuming. We recommended that if weaknesses are found the Secretaries of Defense and Transportation should address civil agency concerns for developing requirements, improve collaboration and decision making, and strengthen civil agency participation. Both DOD and DOT concurred with this recommendation. DOD noted that it would seek ways to improve civil agency understanding of the DOD requirements process and would work to strengthen civil agency participation. DOT indicated that it would work with DOD to review the process and improve civil agency participation.

GPS Interagency Requirements Process Remains Relatively Untested

In our current work, we found that the requirements process continues to be relatively untested and the lack of documentation of the various stages of the process makes it difficult to determine the extent to which requirements followed the GPS interagency requirements process. No new civil requirements have been requested since our prior report; while DASS and SLR have made some progress, no final decision on whether these requirements will be included on GPS has been made. In addition, there are some civil requirements that have already been included in the DOD

[17] GAO-09-325.

requirements document for GPS III, but the extent to which they were evaluated via the interagency requirements process is unclear.

The Interagency Forum for Operational Requirements (IFOR), which is co-chaired by officials from DOD and DOT and includes members from several agencies, serves as the entry point into the process and is responsible for receiving and processing new operational requirements and for clarifying existing requirements. DOT has the lead responsibility for the coordination of civil requirements from all civil departments and agencies. Although guidance on the steps in the interagency requirements process describes a more complex process, descriptions by officials involved with the process indicate that there are three key steps in the requirements process with the final determination of whether a requirement is approved being made by DOD's Joint Requirements Oversight Council (JROC) in coordination with the DOT's Extended Positioning/Navigation Executive Committee:

1. Civil agencies are to internally identify and validate their requirements and conduct cost, risk, and performance analyses.
2. Civil requirements proposals are submitted to IFOR, which is composed of military and civil working groups. IFOR is then to assist with preparing civil requirements proposals for a GPS satellite capability development document.
3. Upon IFOR recommendation, civil requirements enter the Joint Capabilities Integration Development System (JCIDS), the DOD process to validate warfighter requirements. DOD's JROC will make the final determination of whether a requirement will be approved for inclusion on GPS, which is documented in the JROC-approved capability development document.

Additional details in the guidance provide more specificity regarding how these steps are to be implemented and describe additional steps that may be necessary if there are disagreements or other issues that require adjudication. In addition, there may be a considerable amount of communication with the requesting agency and revision during this process if IFOR or DOD determines that improvements to the requirements packages are necessary.

As shown below, two requirements, DASS and SLR, formally entered the interagency requirements process but have not yet completed the review process. Two other civil requirements were included in the GPS III capability development document, but as is reflected in table 3, the lack of documentation of their review makes it difficult to determine the extent to which the GPS interagency requirements process was applied for those submissions.

Table 3: Status of Completion of Interagency Requirements Process Key Steps for Requirements Initiated after the Development of the GPS Interagency Requirements Process

Civil requirement	Step 1: Civil agency identification, validation, and analysis	Step 2: IFOR reviews and approves for submission to DOD requirements process	Step 3: Requirement is reviewed and approved or rejected by JROC
L1C	No. Generated via international agreement and sponsored by the White House.	No. No formal proposal submitted to IFOR, and IFOR did not conduct a formal review.	Yes. Reviewed and approved by JROC, as reflected in GPS III capability development document.
Aviation/navigation integrity	Yes. Sponsored by DOT/FAA.	No. Submitted to IFOR for review; no formal documentation of IFOR approval prior to JCIDS review.	Yes. Reviewed and approved by JROC, as reflected in GPS III capability development document.
DASS	Yes. Sponsored by the Coast Guard.	Yes. IFOR has reviewed requirement.	No. Not yet submitted to JCIDS.
Geodetic requirement/SLR	Yes. Sponsored by NASA and endorsed by other agencies.	No. Pending review.	No. Not yet submitted to JCIDS.

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

Lack of Detailed Guidance Contributes to Confusion and Disagreement

Guidance for the interagency requirements process lacks sufficient detail in areas such as explanations of key terms, documentation standards, steps in the process, and funding. This lack of detail has contributed to a number of problems, such as confusion, disagreement among the agencies involved, and inconsistent implementation of the process.

Three documents provide guidance specific to the interagency requirements process. National Security Presidential Directive No. 39 (NSPD-39)[18] provides high-level guidance and the GPS Interagency

[18] White House, *U.S. Space-Based Positioning, Navigation, and Timing Policy*, NSPD-39 (Dec. 8, 2004). NSPD-39 is the national space-based positioning, navigation, and timing policy.

Requirements Plan (IRP)[19] and the IFOR charter[20] provide more process-specific guidance. The documents do not define key terms, such as secondary mission requirement, civil use, and dual use, nor do they outline how these types of requirements should be treated in the interagency requirements process. As a result, distinctions based on informal verbal instructions appear to have affected how requirements have been treated in the process and could affect future funding decisions.

- Secondary mission requirements. A secondary mission requirement, sometimes called a secondary payload, is a requirement that does not directly support the primary GPS mission to provide PNT information. The guidance does not define the term nor does it indicate whether or how a secondary mission requirement should be evaluated via the interagency requirements process. DASS is considered to be a secondary mission requirement, and Coast Guard officials involved with the DASS program report that its review was delayed for several years because of uncertainty regarding how secondary mission requirements should be treated in the interagency process. According to those officials, when the DASS requirement was submitted to IFOR in 2003, the Coast Guard was told that DASS should not be reviewed via this process because it was a secondary mission requirement and that it should instead be submitted directly to DOD's JCIDS requirements process. After several years of delay, the Coast Guard was informed that DASS should be reviewed by IFOR after all. IFOR ultimately accepted the requirement for review in 2008.
- Civil and dual use. According to officials involved with the interagency requirements process, requirements that are identified by the civil community are considered initially to be "civil unique" and may later be determined to have military utility and identified as "dual use." However, the guidance does not define the terms, nor does it state how civil unique or dual-use requirements are to be treated in the process. Even though the guidance does not distinguish between these two terms, some agencies involved in the process have indicated that whether a requirement is considered to be civil unique or dual use should determine how the requirement is funded. For example, NASA contends that SLR should be

[19] Department of Defense, Joint Staff, *Interagency Requirements Plan* (Revised June 2007). The IRP outlines the 2001 interagency requirements process. The process was revised and approved in 2007 by JROC as requested by the National Executive Committee for Space-Based Positioning, Navigation, and Timing.

[20] Air Force Space Command and Department of Transportation, *The Interagency Forum for Operational Requirements (IFOR) Charter* (June 11, 2001). The IFOR charter was approved in 2001 to outline roles, responsibilities, and relationships. The IFOR charter was approved by both DOD and DOT.

considered dual use and that DOD should therefore partially cover the costs of SLR. According to NASA, both the civil community and the military would benefit from SLR because it would improve GPS accuracy. However, some DOD officials disagree. They stated that there are no military requirements for SLR and that it is therefore not a dual-use requirement, implying that it should be funded solely by NASA.

In addition, the guidance provides some information regarding what types of documents should be submitted, but it lacks specificity, resulting in confusion and disagreement among the military and civil agencies involved. The IRP states that cost, risks and performance trades, and other information will be submitted in order to defend requirements' feasibility, affordability, and best value for the government. However, the guidance documents do not specify the type, level of detail, or formatting requirements for submissions to IFOR.

- There has been a disconnect between the Coast Guard's understanding of documentation needs and DOD's documentation expectations. To remedy this, some Coast Guard officials involved with submitting the DASS requirement stated that a list of required reports and their format should be provided to civil agencies. These officials said that they provided IFOR with assessments of six alternatives, but they were told by DOD officials that the analyses were not adequate. In addition, although guidance does not indicate that documents should be submitted using the JCIDS format, Coast Guard officials indicated that some of the studies they provided in support of the DASS requirement submission were not accepted because they did not use that format.
- Similarly, NASA officials have expressed frustration with the lack of clear and consistent guidance on documentation standards. While NASA officials stated that since 2007 they have provided all the documentation and analyses on SLR requested by IFOR, DOD officials stated that SLR has not been fully developed as a requirement.

The guidance also does not explain in detail the steps in the interagency requirements process. For example, the guidance lacks detail about formal approvals needed to proceed to the next step in the process and about standards regarding what is to take place during each phase of the process. This has resulted in confusion about next steps for agencies that have submitted requirements and it may also have contributed to inconsistent implementation of the process.

- Approval requirements. There is limited information in the guidance on what formal approvals are required, how they are to be documented, and few details as to when and how these approvals relate to one another. As a result, civil agency officials have indicated that they find it difficult to know when a requirement has been approved to move to the next step in the process or whether it has received final approval. In the case of SLR, in 2007, IFOR released a memo recommending that SLR be included in the GPS III capability development document. However, after some concerns about SLR were identified within DOD that approval was de facto rescinded. SLR is again pending IFOR review and approval. Similarly, there appears to be some confusion about the ultimate fate of some requirements that have already been included in a capability development document. For example, some of the aviation-related requirements were included in the GPS III capability development document for later increments of GPS III, which are important to meeting the needs of FAA's Next Generation Air Transportation System program, a satellite-based air traffic management system that is under development and is expected to increase the safety and enhance the capacity of the air transport system. However, some DOD officials report that this capability development document will be treated as the one for GPS IIIA and that requirements not included on GPS IIIA will have to be submitted through JCIDS again on the capability development documents for either the GPS IIIB or GPS IIIC.

- Phases of the process. The guidance lacks details about specific phases of the interagency requirements process, which may have contributed to inconsistent implementation. For example, the guidance regarding the initial step in the interagency requirements process states, among other things, that civil agencies are to internally identify and validate their requirements. However, the requirement for L1C never went through this phase of the process. Instead, the request resulted from an international agreement and was submitted by the White House. In addition, expertise and experience with requirements and their identification and validation processes vary greatly across government agencies. DOT and DOD officials report that some agencies have documented, disciplined requirements processes. However, while other agencies represent vital GPS applications and users, they have limited experience with requirements processes because they do not typically acquire systems to fulfill their missions. Although it may not be realistic to expect civil agencies to have requirements processes that are as rigorous as DOD's, more detailed guidance on expectations regarding standards for identification and validation of requirements could help ensure that there is more consistency in the first stage of the process.

Lastly, the guidance does not include criteria for funding decisions beyond indicating that sponsoring agencies must pay for their requirements. More specifically, the lack of details in guidance regarding the required timing of funding commitments has caused confusion. The process for considering civil GPS requirements is intended to maintain fiscal discipline by ensuring that only critical needs are funded and developed. Our past work has shown that requirement add-ons cause cost and schedule growth.[21] Guidance requires that the agency proposing the requirement pay the costs associated with adding it to the GPS satellites, thereby forcing agencies to separate their wants from needs. IFOR has requested that sponsoring agencies commit to fund a requirement when the requirement proposal is submitted. For example, IFOR requested that the Coast Guard provide a funding commitment for DASS before the requirement enters the JCIDS process. However, information regarding when a funding commitment is required is not included in guidance on the interagency requirements process.

Approach to Identify Civil Requirements Does Not Identify PNT Needs Across Agencies

The interagency requirements process relies on individual agencies to identify their own requirements but does not identify PNT needs across civil agencies. For example, the DASS requirement is a secondary mission requirement to support a search and rescue system rather than a performance requirement specific to PNT. While such requirements may fulfill important needs, they do not reflect civil community requirements for PNT capabilities. Yet there are considerable challenges to identifying needs across agencies. For example, civil agencies have different roles, missions, and priorities ranging from providing leadership related to food, agriculture, and natural resources to providing the safest, most efficient aerospace system in the world. The civil PNT Executive Committee Co-chair pointed out that most civil agencies have not identified PNT requirements for their agencies, which poses a considerable challenge to identifying these requirements across agencies. These challenges have resulted in an approach that is agency specific and not coordinated rather than a coordinated national approach to identifying PNT needs.

While there is no standardized process for identifying requirements across civil agencies, we found that two efforts under way are attempting to contribute to the development of a coordinated national approach to identifying PNT requirements. First, DOT officials stated that they are working with civil agencies to identify PNT requirements that represent their stakeholder needs with respect to accuracy, availability, coverage, and integrity. This information would serve as input for the 2010 Federal Radionavigation Plan, a document that reflects official U.S. radionavigation policy, which covers radionavigation systems, including

[21] GAO, *Military Space Operations: Common Problems and Their Effects on Satellite and Related Acquisitions*, GAO-03-825R (Washington, D.C.: June 2, 2003).

GPS. Second, DOD's National Security Space Office has been working with civil agencies to develop a national PNT architecture to address capability gaps and provide a framework for evaluating and recommending new requirements.

Coordination of GPS Activities with the International Community Continues, and Some Challenges Have Been Addressed

Last year, we reported that the State Department has engaged other planned global navigation satellite system providers bilaterally and multilaterally in pursuit of compatibility with GPS signals and services and interoperability with civil GPS signals and service. The United States has made joint statements of cooperation with several countries and an executive agreement with the European Community, although according to State Department officials, this agreement has not yet been ratified by all European Union members.[22] Additionally, State Department officials reported that they believe they lack dedicated technical expertise to monitor international activities. State Department officials stated that they 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. Furthermore, U.S. firms had raised a concern to the Department of Commerce about the lack of information from the European Commission relating to the process for obtaining licenses to sell equipment that is compatible with Galileo, a space-based global navigation satellite system being developed by the European Union. However, according to the executive agreement with the European Community, subject to applicable export controls, the United States and the European Community are to make sufficient information publicly available to ensure equal opportunity for persons who seek to use these signals, manufacture equipment to use these signals, or provide value-added services that use these signals.

State Department officials said that they had no new issues or concerns to add to what we reported in April 2009. State Department officials also stated that they continue to engage other planned global navigation satellite system providers bilaterally and multilaterally in pursuit of interoperability with civil GPS signals and compatibility with GPS military

[22] Agreement on the Promotion, Provision and Use of Galileo and GPS Satellite-Based Navigation Systems and Related Applications, U.S.-E.C., June 2004. The European Union replaced and succeeded the European Community on December 1, 2009. Treaty of Lisbon amending the Treaty on European Union and the Treaty Establishing the European Community, December 17, 2007, O.J. (C 306) 1 (2007).

signals. According to the officials we spoke with, there have been no changes in the number or status of cooperative agreements between the United States and other countries since April 2009. Furthermore, the State Department reported that the current number of DOD technical experts needed for international discussions about foreign global navigation satellite systems is now sufficient.

Additionally, U.S. GPS industry representatives we met with remain concerned about the lack of information from the European Commission. In July 2009, the Office of the U.S. Trade Representative reported to Congress that industry representatives were concerned about (1) the lack of information on how to secure licenses to sell products, protect intellectual property rights, or both; (2) access to signal test equipment for Galileo's publicly available service; and (3) the lack of information on the three other Galileo PNT services—service for safety-of-life applications, an encrypted signal for government users, and an encrypted service intended for commercial users.[23] However, according to State Department officials, in spring 2010, the European Commission helped address the first two of these concerns when it published an updated technical document that includes information on the process for licensing intellectual property rights related to Galileo. State Department officials said that the U.S. government is seeking additional clarification on Galileo's newly established intellectual property licensing scheme, which if it is obtained, should address the first concern. State Department officials explained that the updated technical document addresses the second concern, regarding access to signal test equipment for Galileo's publicly available service, and that the U.S. government will no longer need to pursue the issue.

Conclusions

Conditions have improved for the near-term size and availability of the GPS constellation. While DOD has strengthened acquisition practices for GPS and made concerted efforts to maximize the life of GPS satellites, it still faces many of the same challenges we identified last year, as well as new ones we identified this year. For example, the GPS IIIA program has complex and difficult work ahead as it undertakes assembly, integration, and test efforts, and its schedule may leave little margin to address challenges that may arise. Such issues could affect the Air Force's ability

[23] Office of the U.S. Trade Representative, "USTR Report to Congress on U.S. Equipment Industry Access to the Galileo Program and Markets" (statement before Congress, July 2009).

to launch satellites on time, which in turn may affect future GPS constellation availability. Furthermore, because of continued delays with ground control systems and the challenges the Air Force is encountering with enabling quicker procurement of military GPS user equipment, new capabilities may not be delivered to the warfighters when DOD needs them. To better align key decisions and capability deliveries, DOD is now looking more broadly across the GPS enterprise. However, it remains to be seen whether these actions go far enough to synchronize all GPS segments to the maximum extent practicable. For example, while DOD's new Space and Intelligence Office will help ensure that the development and acquisition of all GPS segments are synchronized, this office does not have authority over all military user equipment development. Consequently, we reiterate our recommendation from our April 2009 report that the Secretary of Defense appoint a single authority to oversee the development of GPS, 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. Furthermore, we specified that the appointee should have the authority to ensure that all GPS segments are synchronized to the maximum extent practicable, and should coordinate with the existing PNT infrastructure to assess and minimize potential service disruptions should the satellite constellation decrease in size for an extended period of time. Regarding the GPS interagency requirements process, there is still a great deal of confusion about how civil agencies should submit and pay for their requirements. Moreover, this year we found that a lack of comprehensive guidance on the GPS interagency requirements process is a key source of this confusion. Taking steps to clarify the process, documentation requirements, and definitions of key terms would help alleviate this confusion.

Recommendation for Executive Action

We recommend that the Secretaries of Defense and Transportation, whose departments co-chair the National Executive Committee for Space-Based Positioning, Navigation, and Timing, develop more comprehensive guidance for the GPS interagency requirements process, including an explanation of key terms, documentation expectations, process steps, requirements approval, and funding commitments.

Agency Comments and Our Evaluation

We provided a draft of this report to the Secretaries of Defense, Commerce, Energy, Homeland Security, State, and Transportation and the Administrator of the National Aeronautics and Space Administration for comment. DOD provided written comments on a draft of this report that are reprinted in appendix III. DOT provided oral comments on a draft of this report.

In written comments, DOD did not concur with our recommendation that the Secretary of Defense and the Secretary of Transportation develop comprehensive guidance for the GPS interagency requirements process, including an explanation of key terms, documentation expectations, process steps, requirements approval, and funding commitments. DOD stated that the actions being taken by IFOR to clarify existing guidance, ranging from the new IFOR charter (signed in May 2010) to a directed review of the IRP, meet the needs being recommended by the report. DOT generally agreed to consider our recommendation.

The IFOR charter, which was updated on May 26, 2010, includes some notable improvements compared to previous guidance, but it does not address all of the shortcomings we identified. In particular, the revised guidance provides more clarity regarding what documentation should be provided with requirements proposal submissions; IFOR's role in approving or rejecting proposed new requirements; and expectations regarding funding commitments, including the timing of commitments. In addition, the guidance states that requirements will be classified as operational requirements or additional payloads; however, it does not explain what the implications of those classifications are in terms of how the requirements will be treated in the interagency requirements process. The guidance also does not include definitions of civil unique and dual-use requirements, yet there are ongoing deliberations regarding whether SLR is a dual-use requirement. The revised guidance also lacks information on the type of detail, level of detail, and formatting structure for documentation required with requirements proposal submissions. Lastly, the guidance does not specify how IFOR approvals are to be documented and lacks specificity regarding at what stage a requirement is officially approved for inclusion on GPS satellites. Given that there is still confusion about how civil agencies should submit and pay for their requirements, we believe our recommendation remains valid that the Secretaries of Defense and Transportation, who are responsible for leading interagency coordination, should provide more comprehensive guidance.

DOD's written comments noted that DOD concurred with a "For Official Use Only" (FOUO) designation for our report, which was its status while in draft. We subsequently worked with DOD to identify and revise specific areas of the report containing FOUO information, and DOD has confirmed that this version of the report is acceptable for public release.

We received technical comments from the Departments of Commerce, Energy, State, and Transportation and the National Aeronautics and Space Administration, which have been incorporated where appropriate.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 7 days from the report date. At that time, we will send copies of this report to the appropriate congressional committees; the Secretaries of Defense, Commerce, Energy, Homeland Security, State, and Transportation; the Administrator of the National Aeronautics and Space Administration; and other interested parties. The report also will 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 to this report are listed in appendix IV.

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Director
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Appendix I: Scope and Methodology

In order to assess the status of the U.S. Air Force's efforts to develop and deliver new Global Positioning System (GPS) satellites, the availability of the GPS constellation, and the potential impacts on users if the constellation availability diminishes below its committed level of performance, we performed several tasks. Our work is based on the most current information available as of April 16, 2010.

To assess the status of the Department of Defense's (DOD) efforts to develop and deliver new GPS satellites, we reviewed and analyzed current program plans and documentation related to cost, requirements, program direction, and acquisition and launch schedules. We also interviewed officials from the Office of the Assistant Secretary of Defense, Networks and Information Integration; the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics; the Office of the Joint Chiefs of Staff; U.S. Strategic Command; the Air Force Space Command; the Air Force Space and Missile Systems Center's GPS Wing; the Air Force's 2nd Space Operations Squadron; and the Air Staff. In addition, to assess the reliability of the GPS IIIA space vehicle integrated master schedule, we reviewed 5 of 20 supporting project schedules and compared those schedules with relevant best practices as identified in our *Cost Estimating and Assessment Guide*.[1] The review period for the 5 schedules was from May 2008 to July 2009. These 5 schedules were selected because they make up the bulk of the work and they are most critical to the production of the GPS IIIA space vehicle. This analysis revealed the extent to which the schedules reflected key estimating practices that are fundamental to having a reliable schedule. In conducting this analysis, we interviewed GPS Wing officials and contractor representatives to discuss their use of best practices in creating the program's current schedules.

To assess the availability of the GPS constellation, we did the following:

- Interviewed officials from the Air Force Space and Missile Systems Center GPS Wing, the Air Force Space Command, the Air Force's 2nd Space Operations Squadron, and the Department of Energy's National Nuclear Security Administration. To assess the risks that a delay in the acquisition and fielding of GPS III satellites could result in the U.S. government failing to meet its commitment to a 95 percent probability of maintaining a constellation of 24 operational GPS satellites, we obtained information

[1] GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: March 2009).

from the Air Force predicting the reliability of 79 GPS satellites—each of the 32 operational (on-orbit) satellites, 44 future GPS satellites, and 3 residual satellites—as a function of their time on orbit. Each satellite's total reliability function defines the probability that the satellite will still be operational (or in sufficient working order to be made operational) at a given time in the future. This reliability function is generated from the product of two cumulative reliability functions—a wear out reliability function governed by the cumulative normal distribution and a random reliability function governed by the cumulative Weibull distribution.[2] The reliability function for a specific satellite is defined by a set of four parameters—two that define the cumulative normal distribution and two that define the cumulative Weibull distribution.

- Obtained two sets of reliability parameters for each of the 79 satellites. One set of parameters describes the reliability of the satellites based on the "current management" approach—the Air Force's efforts to actively manage satellite subsystems to reduce a satellite's overall consumption of power. The second set of parameters assumed use of a power management approach—shutting off the satellite's second payload once the satellite is not expected to be capable of generating enough power to support both the positioning, navigation, and timing (PNT) mission and the set of missions supported by the second payload. For each of the 44 unlaunched satellites, we also obtained a parameter defining its probability of successful launch and its scheduled launch date. The 44 unlaunched satellites include 12 IIF satellites, 8 IIIA satellites, 8 IIIB satellites, and 16 IIIC satellites; launch of the final IIIC satellite is scheduled for July 2025. Using this information, we generated overall reliability functions for each of the 32 operational, 44 unlaunched, and 3 residual satellites 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.
- Developed a Monte Carlo simulation[3] using the reliability function for each of the 32 operational and 44 unlaunched GPS satellites to predict the probability that at least a given number of satellites would be operational

[2] The Weibull distribution is a common two-parameter continuous probability distribution; it is used to model the random failures of GPS satellites.

[3] 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.

as a function of time, based on the GPS launch schedule approved in December 2009.[4] We conducted several runs of our simulation—each run consisting of 10,000 trials—and generated curves depicting the predicted size of the GPS constellation at the 95 percent confidence level as a function of time. During last year's review, we compared the results for a 24-satellite constellation with a similar Monte Carlo simulation that the Aerospace Corporation had performed for the Air Force, and confirmed that our simulation produced results that are very similar.[5] We compared our results with the results for the predicted size of the GPS constellation over time (at the 95 percent confidence level) that we had calculated last year using the GPS reliability data and launch schedule approved in March 2009. 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 a new curve for the size of the operational constellation as a function of time.

To assess the military services' understanding of the potential impacts on users if the constellation availability diminishes below its committed level of performance, we asked Air Force, Army, Marine Corps, and Navy military service user representatives to provide formal studies and analyses regarding this issue. However, because most military service representatives stated that their services had not conducted formal studies and analyses on this issue, we also obtained written responses to questions regarding this issue from the military service representatives. In addition, to describe civil departments' and agencies' understanding of the potential impacts on users if the constellation availability diminishes below its committed level of performance, we obtained written responses to questions regarding this issue from civil departments and agencies involved with the GPS interagency requirements process, including the National Aeronautics and Space Administration; the Department of Transportation, including the Federal Aviation Administration; the Department of Commerce, including the National Oceanic and Atmospheric Administration and the National Institute of Standards and

[4] Our Monte Carlo simulation also included the reliability functions for each of the three residual satellites; however, we excluded these satellites from our primary analysis. We did, however, run an excursion to demonstrate what the effect of including these residual satellites would be on the predicted size of the constellation.

[5] Last year we reported our results differently—as the probability of maintaining a constellation of at least 24 satellites—instead of the size of the constellation at the 95 percent confidence level. However, the underlying data generated by our Monte Carlo simulation can present the information in either way.

Technology; and the Department of Homeland Security, including the U.S. Coast Guard.

To assess the progress of efforts to acquire the GPS ground control and user equipment, we interviewed officials who manage and oversee these acquisitions, including officials from the Office of the Assistant Secretary of Defense, Networks and Information Integration; the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics; the Office of the Joint Chiefs of Staff; U.S. Strategic Command; the Air Force Space Command; the Air Force Space and Missile Systems Center's GPS Wing; the Air Force's 2nd Space Operations Squadron; and the Air Staff. We reviewed recent documentation regarding the delivery of capabilities and equipment and assessed the level of synchronization among satellites, ground systems, and user equipment. Our work is based on the most current information available as of April 16, 2010.

To assess the GPS interagency requirements process, we (1) reviewed and analyzed guidance on the process and documents related to the status of civil requirements and (2) interviewed officials from the National Aeronautics and Space Administration; the Department of Transportation, including the Federal Aviation Administration; the Department of Commerce, including the National Oceanic and Atmospheric Administration and the National Institute of Standards and Technology; the Coast Guard; the Office of the Assistant Secretary of Defense, Networks and Information Integration; the National Security Space Office; the Air Force Space Command; the Interagency Forum for Operational Requirements; and the National Coordination Office for Space-Based Positioning, Navigation, and Timing. Our work is based on the most current information available as of March 10, 2010.

To assess GPS coordination efforts with the international global PNT community, we interviewed officials at the Department of State and the Air Force Space and Missile Systems Center's GPS Wing and some industry representatives. We also reviewed a July 2009 report to Congress from the Office of the U.S. Trade Representative. Our work is based on the most current information available as of March 2, 2010.

We conducted this performance audit from July 2009 to September 2010 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: GAO Assessment of GPS IIIA Prime Contractor Schedule Management Processes

Our research has identified nine practices associated with effective schedule estimating[1]: (1) capturing all activities, (2) sequencing all activities, (3) assigning resources to all activities, (4) establishing the duration of all activities, (5) integrating schedule activities horizontally and vertically, (6) establishing the critical path for all activities, (7) identifying float[2] between activities, (8) conducting a schedule risk analysis, and (9) updating the schedule using logic and durations to determine the dates.

The GPS IIIA space vehicle integrated master schedule consists of a master schedule with 20 embedded project schedules representing individual integrated product teams. We selected 5 of these project schedules for review because they make up the bulk of the work and they are most critical to the production of the GPS IIIA space vehicle. Specifically, we selected the Antenna Element, Bus, General Dynamics, Navigation Unit Panel, and Launch Operations project schedules and assessed them against the nine best practices for schedule development (see table 4). The review period for the 5 schedules was from May 2008 to July 2009.

Table 4: Schedules and Their Descriptions

Schedule name	Description
Antenna Element	Represents the subcontractor integration effort for the antenna element program that ensures the development, testing, and qualification of the following antennas: navigation L-band (long-frequency wave used in civil signals) antennas; the legacy ultra high-frequency crosslink antenna; and telemetry, tracking, and control antennas.
Bus	Represents the Lockheed Martin integration effort for the design, development, fabrication, assembly, testing, and qualification of the space vehicle bus and subsystems and units.
General Dynamics	Represents General Dynamic's effort as a subcontractor on the communications portion.
Launch Operations	Represents the Lockheed Martin integration effort to assess all facilities, communications, timelines, transportation, test equipment, plans, and other capabilities for a successful launch campaign.
Navigation Unit Panel	Represents the Lockheed Martin integration effort of International Telephone and Telegraph subcontractor work (Mission Data Unit time keeping, panel, program engineering, test equipment, and transmitter subschedules).

Source: GAO analysis of Air Force GPS IIIA schedule data.

[1] GAO-09-3SP.

[2] Float is the amount of time an activity can slip before affecting the critical path, which is the longest duration path through the sequenced list of activities.

A well-defined schedule helps to identify the amount of human capital and fiscal resources that are needed to execute the program, and thus is an important contribution to a reliable cost estimate. Our research has identified a range of best practices associated with effective schedule estimating.[3] These practices are as follows:

- Capturing all activities: The schedule should reflect all activities (steps, events, outcomes, etc.) as defined in the program's work breakdown structure, including activities to be performed by both the government and its contractors.
- Sequencing all activities: The schedule should be planned so that it can meet the program's critical dates. To meet this objective, activities need to be logically sequenced in the order that they are to be carried out. In particular, activities that must finish prior to the start of other activities (i.e., predecessor activities) and activities that cannot begin until other activities are completed (i.e., successor activities) should be identified. By doing so, interdependencies among activities that collectively lead to the accomplishment of events or milestones can be established and used as a basis for guiding work and measuring progress.
- Assigning resources to all activities: The schedule should realistically reflect what resources (i.e., labor, material, and overhead) are needed to do the work, whether all required resources will be available when they are needed, and whether any funding or time constraints exist.
- Establishing the duration of all activities: The schedule should reflect how long each activity will take to execute. In determining the duration of each activity, the same rationale, data, and assumptions used for cost estimating should be used for schedule estimating. Further, these durations should be as short as possible and they should have specific start and end dates. Excessively long periods needed to execute an activity should prompt further decomposition of the activity so that shorter execution durations will result.
- Integrating schedule activities horizontally and vertically: The schedule should be horizontally integrated, meaning that it should link the products and outcomes associated with already sequenced activities. These links are commonly referred to as handoffs and serve to verify that activities are arranged in the right order to achieve aggregated products or outcomes. The schedule should also be vertically integrated, meaning that traceability exists among varying levels of activities and supporting tasks and subtasks. Such mapping or alignment among levels enables different groups to work to the same master schedule.

[3] GAO-09-3SP.

- Establishing the critical path for all activities: Using scheduling software the critical path—the longest duration path through the sequenced list of activities—should be identified. The establishment of a program's critical path is necessary for examining the effects of any activity slipping along this path. Potential problems that may occur on or near the critical path should also be identified and reflected in the scheduling of time for high-risk activities.
- Identifying float between activities: The schedule should identify float—the time that a predecessor activity can slip before the delay affects successor activities—so that schedule flexibility can be determined. As a general rule, activities along the critical path have the least amount of float.
- Conducting a schedule risk analysis: A schedule risk analysis uses a good critical path method schedule and data about project schedule risks as well as Monte Carlo simulation (statistical) techniques to predict the level of confidence in meeting a program's completion date, the amount of time needed for a level of confidence, and the identification of high-priority risks. This analysis focuses not only on critical path activities but also on other schedule paths that may become critical. A schedule/cost risk assessment recognizes the interrelationship between schedule and cost and captures the risk that schedule durations and cost estimates may vary because of, among other things, limited data, optimistic estimating, technical challenges, lack of qualified personnel, and other external factors. As a result, the baseline schedule should include a buffer or a reserve of extra time. Schedule reserve for contingencies should be calculated by performing a schedule risk analysis. As a general rule, the reserve should be held by the project manager and applied as needed to those activities that take longer than scheduled because of the identified risks. Reserves of time should not be apportioned in advance to any specific activity since the risks that will actually occur and the magnitude of their impact is not known.
- Updating the schedule using logic and durations to determine the dates: The schedule should use logic and durations in order to reflect realistic start and completion dates for program activities. The schedule should be continually monitored to determine when forecasted completion dates differ from the planned dates, which can be used to determine whether schedule variances will affect downstream work. Maintaining the integrity of the schedule logic is not only necessary to reflect true status, but is also required before conducting a schedule risk analysis. The schedule should avoid logic overrides and artificial constraint dates that are chosen to create a certain result on paper. To ensure that the schedule is properly updated, individuals trained in critical path method scheduling should be responsible for updating the schedule.

Table 5 presents the findings for the five project schedules for each best practice, along with an overall score for the integrated master schedule on each best practice. Tables 6 through 10 provide details on the individual project schedule assessments. All durations are given in working time, that is, there are 5 working days per week, 22 working days per month, and 260 working days per year.

Table 5: Extent to Which Each Project Schedule Met Best Practices

Best practice	Overall assessment (met, substantially met, partially met, minimally met, not met)[a]	Antenna	Bus	General Dynamics	Navigation unit panel	Launch operations
1. Capturing all activities	Met	Met	Met	Met	Substantially met	Met
2. Sequencing all activities	Substantially met	Substantially met	Substantially met	Partially met	Partially met	Substantially met
3. Assigning resources to all activities	Met	Met	Met	Met	Met	Substantially met
4. Establishing the duration of all activities	Substantially met	Substantially met	Substantially met	Substantially met	Substantially met	Substantially met
5. Integrating schedule activities horizontally and vertically	Substantially met	Substantially met	Substantially met	Substantially met	Substantially met	Substantially met
6. Establishing the critical path for all activities	Substantially met	Substantially met	Met	Substantially met	Substantially met	Met
7. Identifying float between activities	Partially met	Partially met	Partially met	Partially met	Partially met	Partially met
8. Conducting a schedule risk analysis	Met	Met	Met	Met	Partially met	Substantially met
9. Updating the schedule using logic and durations to determine dates	Met	Substantially met	Substantially met	Met	Met	Met

Source: GAO analysis of Air Force GPS IIIA schedule data.

[a]Based on our analysis of the schedules and discussions with the GPS IIIA contractor, we rated each schedule against our five-point criteria and assigned a corresponding score using the evidence provided to support our ratings: met = 5, substantially met = 4, partially met =3, minimally met = 2, and not met = 1. Met—DOD provided complete evidence that satisfies the entire criterion. Substantially met—DOD provided evidence that satisfies more than half of the criterion. Partially met—DOD provided evidence that satisfies about half of the criterion. Minimally met—DOD provided evidence that satisfies less than half of the criterion. Not met—DOD provided no evidence that satisfies any part of the criterion.

Table 6: Antenna Element Schedule Analysis Details

Best practice	Criterion met?	GAO analysis
1.Capturing all activities	Met	Activities in the GPS IIIA integrated master schedule are mapped to Integrated Master Plan (IMP), Statement of Work (SOW), Contractor Work Breakdown Structure (CWBS), and Control Account Manager (CAM) custom fields. The activities in the Antenna schedule are mapped to 18 different SOW numbers. CAMs are involved in developing the schedule and revising activities within the schedule as necessary.
2. Sequencing all activities	Substantially met	Our analysis shows that none of the 554 remaining activities have missing logic. Of those remaining activities that have predecessor and successor logic, only 3 activities are "open-ended," that is, 3 activities are missing logic that would determine their start dates. Because their start dates are not determined by logic, these 3 open-ended activities may inhibit the power of the schedule to calculate a critical path and important downstream dates. We found that the schedule uses many constraints, particularly Start No Earlier Than (SNET) constraints. There are 71 remaining activities (13 percent) with SNET constraints. Program schedule officials stated that the SNET constraints are used to manage resources and to schedule procurement tasks to start once funding is available. However, constraining an activity's start date prevents managers from accomplishing work as soon as possible and consumes flexibility early in the project. Moreover, scheduling a procurement activity with a constrained date does not guarantee that the item will arrive on that date in reality. Of the remaining activities, 35 activities (6 percent) are linked to their successor activities with lags. Lags are often used to put activities on a specific date or to insert a buffer for risk; however, these lags persist even when predecessor activities are delayed (that is, when the buffer should be consumed).
3. Assigning resources to all activities	Met	We found the schedule to be sufficiently resource loaded. There are 53 resources listed in the schedule; two are specifically applied to the Antenna schedule activities with no evidence of overallocation. GPS Wing officials also indicated that the CAMs use the schedule along with other tools to review and plan for resource usage.
4. Establishing the duration of all activities	Substantially met	The durations of the majority of remaining activities meet best practices. However, several activities have longer-than-expected[a] durations. For example, 28 remaining activities have durations over 200 days. Several of these activities are long-lead item procurement activities that may need alternative ways to monitor their progress. GPS Wing officials stated that CAMs review and monitor activity durations.
5. Integrating schedule activities horizontally and vertically	Substantially met	Our analysis of the schedule concludes that vertical traceability—that is, the ability to consistently trace Work Breakdown Structure (WBS) elements between detailed, intermediate, and master schedules—is demonstrated because the overall GPS IIIA integrated master schedule is made up of individual subschedules like the Antenna schedule. However, issues with reliance on date constraints and the use of lags keep this detailed schedule from being fully compliant with the requirement of horizontal traceability—that is, the overall ability of the schedule to depict relationships between different program elements and product handoffs.
6. Establishing the critical path for all activities	Substantially met	We discussed with GPS Wing officials how the critical path is calculated in the Antenna schedule. The Antenna critical path contains a 20-day margin for risk, which is considered a good practice as this represents an acknowledgment of inherent risk within the schedule. However, our analysis also shows that there are lags of 130 days and 40 days in the critical path, and the first activity of the path starts with an unjustified SNET constraint. The critical path should determine the project completion date by computation using the logical relations between predecessor activities and their durations rather than artificial constraints.

Best practice	Criterion met?	GAO analysis
7. Identifying realistic total float	Partially met	There are 31 activities with over 400 days of total float, and 211 activities with from 200 to 399 days of total float. In other words, according to the schedule, 242 activities could be delayed by 9 to 18 months and not delay the final activity in the Antenna schedule. Activities with such large float values indicate some lack of completeness in the schedule logic.
8. Conducting a schedule risk analysis	Met	GPS Wing officials provided evidence of a risk analysis being done on the entire integrated master schedule. The program uses traditional risk ranges of minimum, most likely, and high, which are applied to activity durations. The ranges are applied to triangular distributions before Monte Carlo simulations. In the Antenna schedule, we found 421 activities that have reasonable risk ranges for their durations that follow the guidance provided by the program. Note that there is no need to put risk ranges on every detail task to have a successful risk analysis. GPS Wing officials told us that risk analysis is run on the schedule monthly.
9. Updating the schedule using logic and durations to determine the dates	Substantially met	There are only seven instances of out-of-sequence logic—that is, actual progress being recorded on successor activities even though the predecessor activities are not complete. This is a common occurrence in scheduling, as reality often overrides planned logic. However, some of the schedule logic appears to have been initially incorrect as some of the successor activities have started almost 2 years early. Some of these successors are in other detailed schedules and cannot be moved by the Antenna schedule.

Source: GAO analysis of Air Force GPS IIIA Antenna element schedule data.

[a]The Defense Contract Management Agency recommends keeping individual task durations to less than 2 calendar months (or 44 working days). The shorter the duration of the tasks in the schedule, the more often the CAMs are compelled to update completed work, which more accurately reflects the actual status of the tasks. When task durations are very long, management insight into the actual status is decreased.

Table 7: Bus Schedule Analysis Details

Best practice	Criterion met?	GAO analysis
1. Capturing all activities	Met	Activities in the GPS IIIA integrated master schedule are mapped to IMP, SOW, CWBS, and CAM custom fields. There are 100 out of the remaining 2,082 activities that do not have SOW numbers, but these are mostly zero-duration milestones, and one is a general delay task. CAMs are involved in developing the schedule and revise activities within the schedule as necessary.
2. Sequencing all activities	Substantially met	Our analysis shows that none of the 2,082 remaining activities have missing logic. Of those remaining activities that have predecessor and successor logic, only 5 activities are “open-ended”—that is, 5 activities are missing logic from their finish dates that would determine the start dates of their successors. Because their finish dates do not link to the start dates of successor activities, these 5 open-ended activities will not affect the start dates of any successors if they are delayed. In addition, these open-ended activities can create artificially large total float values, which may affect management’s ability to effectively allocate resources. We found that the schedule uses many constraints, particularly SNET constraints. There are 270 remaining activities (13 percent) with constraints, 269 of which are SNET constraints. Program schedule officials stated that the SNET constraints are used to manage resources and to schedule procurement tasks to start once funding is available. However, constraining an activity’s start date prevents managers from accomplishing work as soon as possible and consumes flexibility early in the project. Moreover, scheduling a procurement activity with a constrained date does not guarantee that the item will arrive on that date in reality. Of the remaining activities, 63 activities (3 percent) are linked to their successor activities with lags. Lags are often used to put activities on a specific date or to insert a buffer for risk; however, these lags persist even when predecessor activities are delayed (that is, when the buffer should be consumed).
3. Assigning resources to all activities	Met	We found the schedule to be sufficiently resource loaded. There are 14 main resources listed in the Bus schedule that have been used in over 2,000 activity assignments. There is no evidence of overallocation. GPS Wing officials also indicated that the CAMs use the schedule along with other tools to review and plan for resource usage.
4. Establishing the duration of all activities	Substantially met	The durations of the majority of remaining activities meet best practices. However, several activities have longer-than-expected durations. For example, 7 remaining activities have durations over 400 days, and 106 have durations from 200 to 400 days. The longest duration is that of the battery cell life test, which takes 7-½ years. It will be difficult to update such an activity unless the activity is split up into more manageable parts. GPS Wing officials stated that CAMs review and monitor activity durations.
5. Integrating schedule activities horizontally and vertically	Substantially met	Our analysis of the schedule concludes that vertical traceability—that is, the ability to consistently trace WBS elements between detailed, intermediate, and master schedules—is demonstrated because the overall GPS IIIA integrated master schedule is made up of individual subschedules like the Bus schedule. However, issues with reliance on date constraints and the use of lags keep this detailed schedule from being fully compliant with the requirement of horizontal traceability—that is, the overall ability of the schedule to depict relationships between different program elements and product handoffs.
6. Establishing the critical path for all activities	Met	We discussed with GPS Wing officials how the critical path is calculated in the Bus schedule. Only six activities in the Bus schedule are on the critical path and hence determine the date for SV01 Satellite Delivery. This is a consequence of a highly integrated master schedule with 20 component schedules.

Best practice	Criterion met?	GAO analysis
7. Identifying realistic total float	Partially met	There are 50 activities with over 600 days of total float, and 303 activities with from 300 to 600 days of total float. In other words, according to the schedule, 353 activities could be delayed by 14 to 27 months and not delay the final activity in the Bus schedule. These high float values are due to incomplete logic and reliance on constraints instead of logic and durations to drive this schedule. Activities with such large float values indicate some lack of completeness in the schedule logic.
8. Conducting a schedule risk analysis	Met	GPS Wing officials provided evidence of a risk analysis being done on the entire integrated master schedule. In the Bus schedule, we found 1,109 activities that have reasonable risk ranges about their durations. Note that there is no need to put risk ranges on every detail task to have a successful risk analysis. These ranges are mostly percentages around the durations and are right-skewed to convey a higher probability of running longer than running shorter—a common technique in risk analysis. GPS Wing officials told us that risk analysis is run on the schedule monthly.
9. Updating the schedule using logic and durations to determine the dates	Substantially met	There are 13 instances of out-of-sequence logic—that is, actual progress being recorded on successor activities even though the predecessor activities are not complete. This is a common occurrence in scheduling, as reality often overrides planned logic. However, some of the schedule logic shows successors that were completed in earlier years, which should be corrected. Without complete, up-to-date logic, the critical path and important dates downstream may be incorrect.

Source: GAO analysis of Air Force GPS IIIA Bus schedule data.

Table 8: General Dynamics Schedule Analysis Details

Best practice	Criterion met?	GAO analysis
1. Capturing all activities	Met	Activities in the GPS IIIA integrated master schedule are mapped to IMP, SOW, CWBS, and CAM custom fields. There are 15 out of the remaining 1,922 activities that do not have SOW numbers. CAMs are involved in developing the schedule and revise activities within the schedule as necessary.
2. Sequencing all activities	Partially met	Our analysis shows that 43 of the 1,922 remaining activities (2 percent) are "open-ended." Of these, 42 activities are missing logic from their finish dates that would determine the start dates of their successors. Because their finish dates do not link to the start dates of successor activities, these 42 open-ended activities will not affect the start dates of any successors if they are delayed. In addition, these open-ended activities can create artificially large total float values, which may affect management's ability to effectively allocate resources. We found that the schedule uses many constraints, particularly SNET constraints. There are 416 remaining 1,922 activities (22 percent) with constraints, 382 of which are SNET constraints. Program schedule officials stated that the SNET constraints are used to manage resources and to schedule procurement tasks to start once funding is available. However, constraining an activity's start date prevents managers from accomplishing work as soon as possible and consumes flexibility early in the project. Moreover, scheduling a procurement activity with a constrained date does not guarantee that the item will arrive on that date in reality. The 416 constraints within the schedule include 27 Finish No Earlier Than (FNET) constraints. Each FNET constraint needs to be examined and justified, as such constraints prevent an activity from finishing earlier if predecessor activities allow it. Of the remaining activities, 167 activities (9 percent) are linked to their successor activities with lags. Lags are often used to put activities on a specific date or to insert a buffer for risk; however, these lags persist even when predecessor activities are delayed (that is, when the buffer should be consumed).
3. Assigning resources to all activities	Met	We found the schedule to be sufficiently resource loaded. There are 92 resources listed in the General Dynamics schedule that are named, costed, and assigned to activities. GPS Wing officials also indicated that the CAMs use the schedule along with other tools to review and plan for resource usage.
4. Establishing the duration of all activities	Substantially met	The durations of the majority of remaining activities meet best practices. However, several activities have longer-than-expected durations (i.e., durations of no more than 2 months). For example, 26 remaining activities have durations from 300 to 780 days, and 102 have durations from 100 to 300 days. There are 10 activities with durations greater than 700 days, all of which appear to be level-of-effort activities. However, these durations are fixed, so that if the activities that they support take more or less time, the level of effort does not change durations as it should.
5. Integrating schedule activities horizontally and vertically	Substantially met	Our analysis of the schedule concludes that vertical traceability—that is, the ability to consistently trace WBS elements between detailed, intermediate, and master schedules—is demonstrated because the overall GPS IIIA integrated master schedule is made up of individual subschedules like the General Dynamics schedule. However, issues with reliance on date constraints and the use of lags keep this detailed schedule from being fully compliant with the requirement of horizontal traceability—that is, the overall ability of the schedule to depict relationships between different program elements and product handoffs.

Best practice	Criterion met?	GAO analysis
6. Establishing the critical path for all activities	Substantially met	We discussed with GPS Wing officials how the critical path is calculated in the General Dynamics schedule. Our analysis of the critical path shows that while it is determined by predecessor logic and durations rather than constraints, it includes two unexplained lags of 77 total days. It is not clear why the program should choose to delay the start of the lagged activities that occur on the critical path by a total of 15 weeks.
7. Identifying realistic total float	Partially met	There are 1,079 remaining activities (56 percent) with 100 or more days of total float, 25 of which have from 700 to 771 days of total float. In other words, according to the schedule, 25 activities could be delayed by almost 32 months and not delay the final activity in the General Dynamics schedule. These high float values are due to incomplete logic and reliance on constraints instead of logic and durations to drive this schedule. Activities with such large float values indicate some lack of completeness in the schedule logic.
8. Conducting a schedule risk analysis	Met	GPS Wing officials provided evidence of a risk analysis being done on the entire integrated master schedule. The program uses traditional risk ranges of minimum, most likely, and high, which are applied to activity durations. The ranges are applied to triangular distributions before Monte Carlo simulations are run. In the General Dynamics schedule, we found 1,758 activities that have reasonable risk ranges about their durations. These ranges are mostly percentages around the durations and are right-skewed to convey a higher probability of running longer than running shorter—a common technique in risk analysis. GPS Wing officials told us that risk analysis is run on the schedule monthly.
9. Updating the schedule using logic and durations to determine the dates	Met	Our analysis shows that there are no instances of out-of-sequence logic—that is, actual progress being recorded on successor activities even though the predecessor activities are not complete. Our analysis found no instances of actual dates in the future or dates in the past that are not marked as "actual."

Source: GAO analysis of Air Force GPS IIIA General Dynamics schedule data.

Table 9: Navigation Unit Panel Schedule Analysis Details

Best practice	Criterion met?	GAO analysis
1. Capturing all activities	Substantially met	Activities in the GPS IIIA integrated master schedule are designed to be mapped to IMP, SOW, CWBS, and CAM information. CAMs are involved in developing the schedule and revise activities within the schedule as necessary. However, officials stated that while the Panel schedule was verified by the prime contractor to fully support the SOW, the SOW data were inadvertently overwritten with other data. Senior schedulers are currently in the process of repopulating the SOW information in the Panel schedule.
2. Sequencing all activities	Partially met	Our analysis shows that 9 of the 126 remaining activities (7 percent) are "open-ended." These 9 open-ended activities are missing logic from their finish dates that would determine the start dates of their successors. Because their finish dates do not link to the start dates of successor activities, these 9 open-ended activities will not affect the start dates of any successors if they are delayed. In addition, these open-ended activities can create artificially large total float values, which may affect management's ability to effectively allocate resources. Considering that there are only 95 remaining detail activities (the other 31 remaining activities are milestones), this means that nearly 10 percent of the remaining work activities are not properly linked. We found the schedule uses many constraints, particularly SNET constraints. There are 12 SNET constraints placed on activities within the schedule, of which 11 activities are imported from other schedules within the integrated master schedule. These 11 activities would presumably have their dates established in their own schedules by logic and duration, and therefore should not need constraining in the Panel schedule. There are 15 activities with lags to their successor activities. Lags are often used to put activities on a specific date or to insert a buffer for risk; however, these lags persist even when predecessor activities are delayed (that is, when the buffer should be consumed).
3. Assigning resources to all activities	Met	We found the schedule to be sufficiently resource loaded. There are 18 resources listed in the Panel schedule, several of which have been applied extensively to the schedule. GPS Wing officials also indicated that the CAMs use the schedule along with other tools to review and plan for resource usage.
4. Establishing the duration of all activities	Substantially met	The durations of the majority of remaining activities meet best practices. However, several activities have longer-than-expected durations (i.e., durations of no more than 2 months). For example, 13 remaining activities have durations from 200 to 540 days, and 13 have durations from 45 to 199 days. It will be difficult to update long, non-level-of-effort activities unless the activities are split up into more manageable parts. GPS Wing officials stated that CAMs review and monitor activity durations.
5. Integrating schedule activities horizontally and vertically	Substantially met	Our analysis of the schedule concludes that vertical traceability—that is, the ability to consistently trace WBS elements between detailed, intermediate, and master schedules—is demonstrated because the overall GPS IIIA integrated master schedule is made up of individual subschedules like the Panel schedule. However, issues with reliance on date constraints and the use of lags keep this detailed schedule from being fully compliant with the requirement of horizontal traceability—that is, the overall ability of the schedule to depict relationships between different program elements and product handoffs.
6. Establishing the critical path for all activities	Substantially met	We discussed with GPS Wing officials how the critical path is calculated in the Panel schedule. Our analysis of the critical path shows that while it is determined by predecessor logic and durations rather than constraints, it includes two unexplained lags of 26 total days. While these are not large lags, it is not clear why the program should choose to delay the start of events on the critical path by over 5 weeks.

Best practice	Criterion met?	GAO analysis
7. Identifying realistic total float	Partially met	There are 31 activities within the schedule with 400 or more days of total float, 18 of which have more than 1,000 days of total float. In other words, according to the schedule, 31 activities could be delayed by more than 1-½ years and not delay the final activity in the Panel schedule. These high float values are due to incomplete logic and reliance on constraints instead of logic and durations to drive this schedule.
8. Conducting a schedule risk analysis	Partially met	GPS Wing officials provided evidence of a risk analysis being done on the entire integrated master schedule. However, our analysis of the Panel schedule reveals that only two short tasks have meaningful risk ranges. No other tasks within the schedule have risk ranges. Therefore, the Panel schedule is not fully contributing to the overall integrated master schedule risk analysis. Our analysis indicates that some activities, by their descriptive names alone, seem probable candidates for risk analysis. These include activities such as “Test Flight . . . ,” “Test on . . . ,” “Verify . . . ,” “Assembly . . . ,” and “Final Functional Test . . . .” Without conducting a comprehensive schedule risk analysis, decision makers will not know in advance which risks might delay the project, what a safe completion date might be for the current plan, and how much contingency reserve of time may be needed to achieve a successful completion date.
9. Updating the schedule using logic and durations to determine the dates	Met	Our analysis shows that there is only one instance of out-of-sequence logic—that is, actual progress being recorded on successor activities even though the predecessor is not complete. This is a common occurrence in scheduling, as reality often overrides planned logic. Our analysis found no instances of actual dates in the future or dates in the past that are not marked as “actual.”

Source: GAO analysis of Air Force GPS IIIA Navigation Unit Panel schedule data.

Table 10: Launch Operations Schedule Analysis Details

Best practice	Criterion met?	GAO analysis
1. Capturing all activities	Met	Activities in the GPS IIIA integrated master schedule are designed to be mapped to IMP, SOW, CWBS, and CAM information. CAMs are involved in developing the schedule and revise activities within the schedule as necessary. All 382 remaining detail activities are assigned to one of nine SOW numbers within the schedule.
2. Sequencing all activities	Partially met	Our analysis shows that only 1 of the 497 remaining activities is "open-ended." This open-ended activity is missing logic that would determine its start date. Because its start date is not determined by logic, this open-ended activity may inhibit the power of the schedule to calculate a critical path and important downstream dates. We found that the schedule uses many constraints, particularly SNET constraints. There are 57 SNET constraints placed on activities within the schedule. Program schedule officials stated that the SNET constraints are used to manage resources and to schedule procurement tasks to start once funding is available. However, constraining an activity's start date prevents managers from accomplishing work as soon as possible and consumes flexibility early in the project. Moreover, scheduling a procurement activity with a constrained date does not guarantee that the item will arrive on that date in reality. There are 14 activities with lags to their successor activities. Some lags are extremely long, ranging from 540 to 850 days. Lags are often used to put activities on a specific date or to insert a buffer for risk; however, these lags persist even when predecessor activities are delayed (that is, when the buffer should be consumed). Extremely long lags are usually used to force successor tasks to occur on specific dates.
3. Assigning resources to all activities	Substantially met	We found only one resource in the schedule, which was assigned to 272 of 382 detail activities. GPS Wing officials indicated that the CAMs use the schedule along with other tools to review and plan for resource usage.
4. Establishing the duration of all activities	Substantially met	The durations of the majority of remaining activities meet best practices. However, several activities have longer-than-expected durations (i.e., durations of no more than 2 months). For example, 34 remaining activities have durations from 45 to 99 days, and 5 have durations from 200 to 281 days. It will be difficult to update long, non-level-of-effort activities unless the activities are split up into more manageable parts. GPS Wing officials stated that CAMs review and monitor activity durations.
5. Integrating schedule activities horizontally and vertically	Substantially met	Our analysis of the schedule concludes that vertical traceability—that is, the ability to consistently trace WBS elements between detailed, intermediate, and master schedules—is demonstrated because the overall GPS IIIA integrated master schedule is made up of individual subschedules like the Launch operations schedule. However, issues with reliance on date constraints and the use of lags keep this detailed schedule from being fully compliant with the requirement of horizontal traceability—that is, the overall ability of the schedule to depict relationships between different program elements and product handoffs.
6. Establishing the critical path for all activities	Met	We discussed with GPS Wing officials how the critical path is calculated in the Launch schedule. The critical path in the Launch schedule is less than 90 days. It begins with an external activity, which is the result of extensive linkage between schedules in the GPS IIIA integrated master schedule.
7. Identifying realistic total float	Partially met	There are 111 activities within the schedule with 200 or more days of total float, 33 of which have from 500 to 900 days of total float. In other words, according to the schedule, 33 activities could be delayed by over 22 months and not delay the final activity in the Launch schedule. These high float values are due to incomplete logic and reliance on constraints instead of logic and durations to drive this schedule.

Best practice	Criterion met?	GAO analysis
8. Conducting a schedule risk analysis	Substantially met	GPS Wing officials provided evidence of a risk analysis being done on the entire integrated master schedule. Our analysis of the Launch schedule shows that 271 of 382 detail activities have risk applied to them. However, all 271 activities have the same risk applied to their durations. Therefore, it is difficult to determine whether the Launch schedule is fully or meaningfully contributing to the overall integrated master schedule risk analysis. Without conducting a comprehensive schedule risk analysis, decision makers will not know in advance which risks might delay the project, what a safe completion date might be for the current plan, and how much contingency reserve of time may be needed to achieve a successful completion date.
9. Updating the schedule using logic and durations to determine the dates	Met	Our analysis shows that there are only two instances of out-of-sequence logic—that is, actual progress being recorded on successor activities even though the predecessor activities are not complete. This is a common occurrence in scheduling, as reality often overrides planned logic. Our analysis found no instances of actual dates in the future or dates in the past that are not marked as “actual.”

Source: GAO analysis of Air Force GPS IIIA Launch Operations schedule data.

Appendix III: Comments from the Department of Defense

FOUO designation was removed during subsequent review and discussion (see p. 40).

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

JUL 26 2010

NETWORKS AND
INFORMATION INTEGRATION

Ms. Christina Chaplain
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office (GAO)
441 G Street, NW
Washington, DC 20548

Dear Ms. Chaplain:

This is the Department of Defense (DoD) response to the GAO draft report, GAO-10-636, "GLOBAL POSITIONING SYSTEM: Challenges in Sustaining and Upgrading Capabilities Persist," dated May 28, 2010 (GAO Code 120847).

The Department non-concurs with the recommendation that the Secretary of Defense and Secretary of Transportation develop comprehensive guidance for the GPS interagency requirements process. The actions being taken by the Interagency Forum for Operational Requirements (IFOR) to clarify existing guidance, ranging from the new IFOR Charter (signed May 2010) to a directed review of the GPS Interagency Requirements Plan (IRP), meet the needs being recommended by the report. The Department also concurs with the "For Official Use Only" designation of the subject report, with limited public release.

Since its inception over 30 years ago, 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. GPS enables national security and economic infrastructures, which enhances efficiency and improves safety and effectiveness of virtually all operations. GPS is the cornerstone of our National PNT Architecture, around which future PNT services will evolve. The DoD accepts its responsibility with respect to GPS and is committed to maintaining and improving the services it provides. In that regard, the Department seeks support from Congress to maintain stability of GPS funding, enabling synchronized modernization of GPS space, ground control, and user equipment that is now underway.

The staff point of contact for this review is Mr. Raymond Swider. He can be reached at raymond.swider@osd.mil or (703) 607-1122.

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

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the contact named above, key contributors to this report were Art Gallegos, Assistant Director; Greg Campbell; Tisha Derricotte; Steven Hernandez; Laura Holliday; Jason Lee; Sigrid McGinty; Karen Richey; Jay Tallon; Hai Tran; Alyssa Weir; and Rebecca Wilson.

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