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GLOBAL POSITIONING SYSTEM

A Comprehensive Assessment of Potential Options and Related Costs is Needed

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GLOBAL POSITIONING SYSTEM

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GAO Highlights

Highlights of GAO-13-729, a report to congressional committees

Why GAO Did This Study

The GPS—a space-based satellite system that provides positioning, navigation, and timing data to users worldwide—has become an essential U.S. national security asset and component in daily life. The GPS program is being modernized to enhance its performance, accuracy and integrity. In 2013, the House Armed Services Committee directed the Air Force to report on lower-cost GPS solutions. The committee also mandated that GAO review the Air Force report. GAO (1) assessed the extent to which the Air Force GPS report met Committee requirements; and, (2) identified additional information that is important in guiding future GPS investments. GAO reviewed the Air Force report, interviewed officials responsible for preparing it, and consulted subject matter experts from the positioning, navigation, and timing advisory community.

What GAO Recommends

GAO recommends the Air Force: (1) affirm the future size of the GPS constellation it plans to support; (2) ensure future assessments are comprehensive and include cost risk and the impact of options on all three GPS segments; and (3) engage the broader stakeholder community in future assessments of options. DOD concurred with these recommendations.

View GAO-13-729. For more information, contact Marie A. Mak at (202) 512-2527 or makm@gao.gov.

What GAO Found

GAO found the Air Force, the military branch responsible for Global Positioning System (GPS) acquisition, in its report on *Lower Cost Solutions for Providing Global Positioning System Capability*, broadly addressed all four congressional requirements—system capability, implementation approaches, technical and programmatic risks, and estimated costs—for each option presented for the space segment. GPS consists of three segments—space, ground control, and user equipment—but the study only addressed the space segment, which accounts for the largest share of total GPS costs—more than half—in the Air Force's current budget. The Air Force identified and assessed nine options for future GPS space segments, ranging in cost from $13 billion to $25 billion from fiscal year 2013 through 2030. The report assessed each option based on a constellation or collection of 30 total satellites instead of 24, which is the Air Force's baseline GPS requirement for accuracy. This increase in total satellites raises an issue with the constellation size the Air Force intends to support in the future. Air Force officials stated that the cost analyses supporting the nine options were high-level cost estimates. Although this may be expected given the time constraints and other limitations of the study, these estimates are not at a level that would support future GPS investment decisions. Table 1 identifies GAO's evaluation of the Air Force report relating to congressional requirements.

Table 1: Extent Air Force Report Met Congressional Requirements and GAO Observations

Requirement	Requirement met?	GAO observations
System capability	Yes, for the space segment	Each option is assessed on how long it would take the given option to achieve a constellation of 30 satellites; on signal integrity; and on its ability to accomplish its mission in the presence of adverse conditions or hostile actions (resilience).
Implementation approaches	Yes, for the space segment	Each option is assessed on its relative strengths and weaknesses, and potential courses of action are identified.
Technical and programmatic risks	Yes, for the space segment	The level (low, medium, high) of technical and programmatic risks associated with each option are identified.
Estimated costs of any recommended options	Yes, for the space segment	Relative rough cost estimates for each option are identified and comparisons across the options are indicated.

Source: GAO analysis of Air Force information.

Although the Air Force report is a good starting point, more information on key cost drivers and cost estimates, and broader input from stakeholders would help guide future investment decisions. Specifically, the key cost drivers include dual launch capability (launching two satellites on a single launch vehicle), navigation satellites (smaller GPS-type satellites yet to be developed), and a nuclear detection capability. The cost estimates also excluded the ground control and user equipment segments and cost risk. Further, the Air Force did not obtain inputs from some key stakeholders such as those from the GPS positioning, navigation, and timing advisory community. Consequently, without conducting a more comprehensive assessment that addresses each of these concerns, the Air Force is not yet in a position to make sound future GPS investments.

Contents

Abbreviations

DOD	Department of Defense
DOT	Department of Transportation
GPS	Global Positioning System
GPS OCX	GPS Next Generation Operational Ground Control System
NASA	National Aeronautics and Space Administration
NavSats	Navigation Satellites
PNT	Positioning, Navigation, and Timing

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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September 9, 2013

Congressional Committees

The Global Positioning System (GPS)—a space-based satellite system that provides positioning, navigation, and timing (PNT) data to users worldwide—has become an essential U.S. national security asset and a key component in economic growth; transportation safety; homeland security; and critical national infrastructure, supporting power grids and financial institutions, in the United States and abroad. In accordance with national PNT policy,[1] the Department of Defense (DOD) develops and operates GPS, and an intergovernmental committee—co-chaired by DOD and the Department of Transportation (DOT)—manages the U.S. space-based PNT infrastructure, which includes GPS. The Air Force, the military service responsible for GPS acquisition, is in the process of modernizing GPS to enhance its performance, accuracy, and integrity.[2] This modernization effort is divided into three separate programs: the GPS III space segment, which comprises a constellation or collection of PNT satellites orbiting the Earth; a new ground control segment; and a military GPS user equipment segment. GPS III is an acquisition program to develop and field a new generation of satellites to supplement and eventually replace GPS satellites currently in use. The ground control segment, which operates the GPS satellite constellation, is being replaced for all existing and future GPS satellites. The user equipment modernization effort will provide the military services with new GPS receivers with enhanced capabilities to receive GPS signals in hostile jamming or otherwise availability-challenged environments (such as urban areas or mountainous terrain). The user equipment segment is managed by each of the military services for the weapon systems they own and operate.

[1] "U.S. Space-Based Positioning, Navigation, and Timing Policy" (Dec. 15, 2004 Fact Sheet) (available at http://www.gps.gov/policy/docs/2004/).

[2] We have previously reported on the challenges the Air Force faces in this effort. GAO, *Global Positioning System: Significant Challenges in Sustaining and Upgrading Widely Used Capabilities,* GAO-09-325 (Washington, D.C.: April 30, 2009), and GAO, *Global Positioning System: Challenges in Sustaining and Upgrading Capabilities Persist,* GAO-10-636 (Washington, D.C.: September 15, 2010).

In its report accompanying the 2013 national defense authorization bill (H.R. 4310), the House Armed Services Committee directed that the Air Force report to the congressional defense committees on lower-cost solutions for providing GPS capability following the procurement of GPS III satellites.[3] The committee noted that since its inception in the 1970s, the GPS space segment has remained generally the same, and that the evolution of satellite and user equipment technology, combined with today's constrained budget environment, make this the right time to evaluate alternatives for the system. The committee provided that the Air Force report should identify (1) the system capability, (2) possible implementation approaches, (3) technical and programmatic risks, and (4) estimated costs of any recommended solutions. The Air Force submitted its report, *Lower Cost Solutions for Providing Global Positioning System Capability*, to the congressional defense committees on April 19, 2013.[4]

The committee's report also mandated that we review the Air Force's GPS report and provide our recommendations to congressional defense committees. To respond to this mandate, we reviewed the extent to which the Air Force GPS report met the Committee's stated areas for reporting and also identified additional information that is important to guide the Air Force's future investment decisions for GPS.[5] To address the extent to which the Air Force met the Committee's reporting requirements, we reviewed the approach, assumptions, and criteria the Air Force used to conduct its study. We also assessed the completeness of the information collected by reviewing the data collected and the reports that supported the Air Force's report, and discussed the report with GPS program and Aerospace Corporation officials. The Aerospace Corporation is a federally funded research and development center that provides technical and scientific research, development, and advisory services to national security space programs. According to program officials, Aerospace Corporation officials participated extensively in the development of the report, most notably conducting the cost analyses. We did not independently verify the data the Air Force used in conducting its study. To identify additional or clarifying information that is important to guide

[3] H.R. Rep. No. 112-479, at 70-71 (2012).

[4] United States Air Force, *Report to Congressional Committees: Lower Cost Solutions for Providing Global Positioning System (GPS) Capability*, April 2013.

[5] For purposes of this report, we term these stated areas for reporting as reporting requirements.

future investment decisions, we reviewed the Air Force report and discussed it with subject matter experts[6] from the PNT advisory community to obtain their insights on the GPS options identified, and information that could provide additional insights. We also assessed the process used to develop the cost estimates in the study to determine the extent to which they followed GAO's 12-Step Reliable Process for Developing Cost Estimates assessment tool.[7]

We conducted this performance audit from April 2013 to September 2013 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. See appendix I for more information on our scope and methodology.

Background

Every satellite has a bus and payload. The bus is the body of the satellite and is managed by the satellite control operations to maintain a desired location. It carries the payload and is composed of a number of subsystems, such as the power supply, antennas, and mechanical and thermal control equipment. The bus also provides electrical power, stability, and propulsion for the entire satellite. The payload includes the devices the satellite needs to perform its mission. This configuration differs for every type of satellite. For example, the payload for a weather satellite could include cameras to take pictures of cloud formations, while the payload for a GPS satellite would include equipment to pass navigation information from the satellites to receivers on Earth. Monitoring and operating of the satellite payload is done to collect data or provide a capability to the warfighter or civilian user.

GPS is a global PNT network consisting of space, ground control, and user equipment segments that support the broadcasts of military and

[6] For purposes of this report, a subject matter expert is either a government employee or a special government employee. A special government employee is an expert from academia or industry who is granted federal employee status when attending to certain government business.

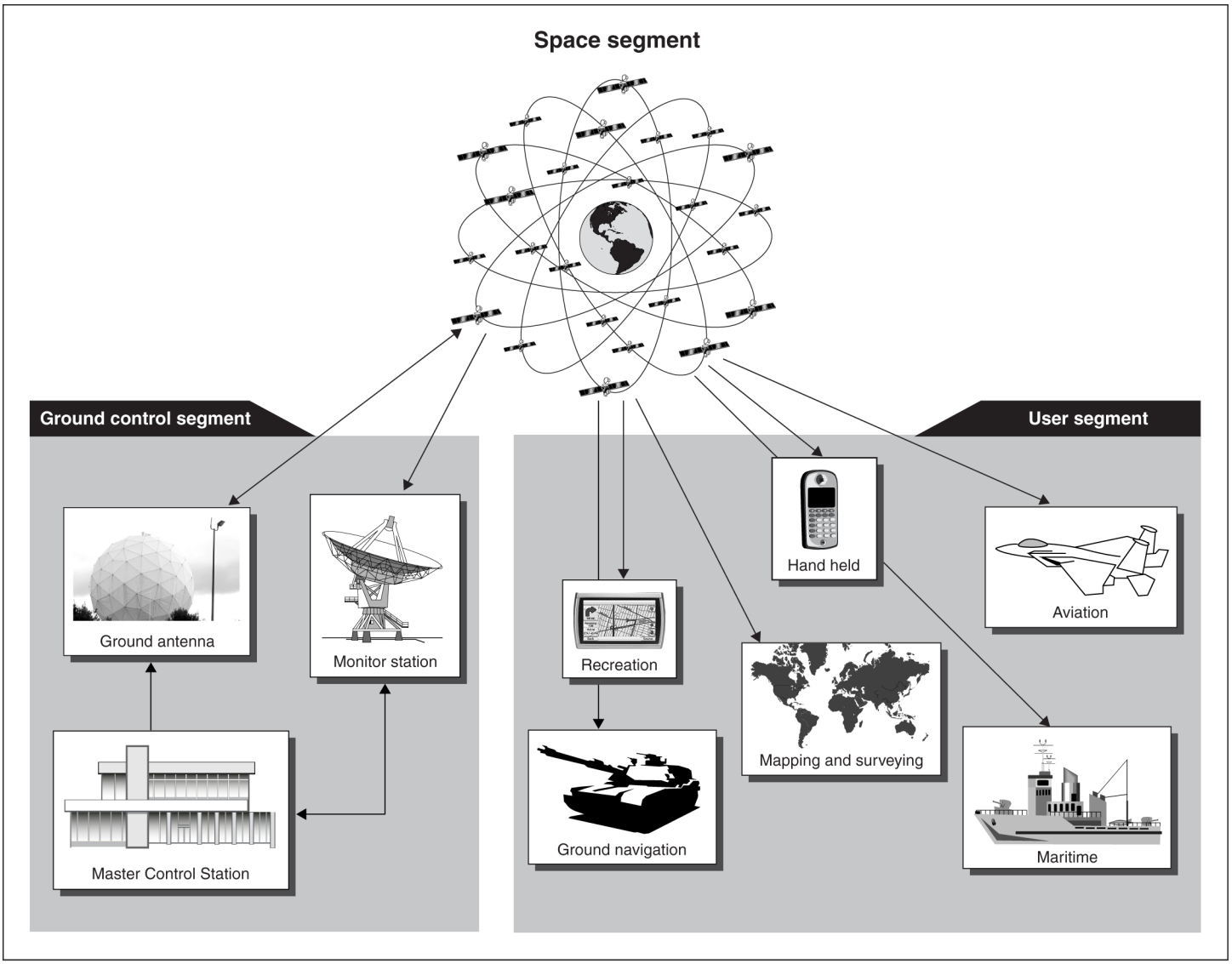
[7] GAO, *GAO Cost Estimating and Assessment Guide Best Practices for Developing and Managing Capital Program Costs*, GAO-06-3SP (Washington, D.C.: March 2009).

civilian 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 has changed the way the world operates, and underpins military operations as well as major sections of the economy, including telecommunications; electrical power distribution; banking and finance; transportation; environmental and natural resource management; agriculture; search and rescue; and other emergency services. GPS is used by all branches of the military to guide troop movements, integrate logistics support, and synchronize communications networks. In addition, many U.S. and allied precision-guided munitions are directed to their targets by GPS signals.

GPS System Description

The space, ground control, and user equipment segments are needed to take full advantage of GPS capabilities. The GPS space segment, which accounts for more than half of the total GPS costs in the Air Force's current budget is a constellation of satellites that orbit approximately 12,500 miles above the earth. According to Air Force officials, current GPS requirements do not specify a number of satellites that are to be in orbit, but rather an accuracy threshold for the system. Based upon the threshold requirement for positioning and timing accuracy, the Air Force derived a constellation size of 24 satellites available 95 percent of the time. Due to the unanticipated longevity of some of the previously launched satellites, the constellation has at times exceeded the derived number of satellites. See figure 1 below for a depiction of the GPS segments.

Figure 1: GPS Operational System and Its Three Segments



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

GPS satellites broadcast encrypted military signals and unencrypted civilian signals that can be processed by GPS receivers to identify their location worldwide. Since the constellation became fully operational in 1995, it has consisted of satellites from various generations of development and production, each introducing improved capabilities and additional signals. The latest generation of satellites in orbit—the GPS

IIF—broadcasts two military and three civilian signals. Additionally, the GPS constellation currently hosts a nuclear detonation detection system payload to monitor nuclear events on Earth.

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; and various monitoring stations and ground antennas. Information from the monitoring stations is processed at the Master Control Station to determine the accuracy of the satellites' clocks (for signal timing) and the precision of their orbits. The Master Control Station operates the satellites and regularly updates their navigation messages, transmitting information 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 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 based on the time it takes each of the signals to reach the receiver. Military GPS receivers are designed to utilize the encrypted military GPS signals that are only accessible to authorized users; commercial receivers use the civilian GPS signal, which is publicly available worldwide.

Current Modernization Efforts

The Air Force is in the process of modernizing the space segment under the GPS III program, which will incorporate advances over the GPS IIF satellites it is replacing, including a higher power military navigation signal to improve jamming resistance[8] and a new civilian signal to allow users to receive GPS signals in combination with foreign satellite navigation systems. The acquisition strategy is to purchase up to 34[9] satellites following an incremental approach to replenish the current satellites in the constellation as they reach the end of their operational life. The original strategy was to purchase up to eight satellites in each of the first two increments and up to 18 satellites in the last increment. However, the

[8] A higher power signal increases resistance to jamming or confusion of military GPS receivers. This increases the likelihood the jammers will be identified by military forces and prevent obscuring of the GPS signal.

[9] The first two satellites are developmental units, and the remaining 32 are expected to be production units.

GPS program is drafting a modified acquisition strategy to streamline the last two increments into one to allow larger buying quantities to take advantage of economies of scale, making this an appropriate time to examine future GPS options. The Air Force has purchased four GPS III satellites to date, the first of which is expected to launch in 2015. The Air Force plans to incrementally increase the capabilities of the GPS III satellites as technology maturation occurs and funding allows.

The ground control segment is being modernized under the Air Force's Global Positioning System Next Generation Operational Ground Control System (GPS OCX) program. GPS OCX is also being developed in three increments and will eventually allow DOD to take full advantage of the capabilities offered by the various satellites. The first increment is to deliver a capability to launch and initiate on-orbit testing of GPS III satellites; the next increment is to deliver a capability to command and control GPS II and GPS III satellites; and the final increment is to deliver a capability to make military and international signals operational.[10] Software challenges have delayed availability of the command and control capability, which was previously planned for 2015 and is currently expected to be operational in late 2016 (final block is planned for 2017).

Each of the military services is managing modernization of its user equipment through the joint Military GPS User Equipment program, which is to develop modernized military GPS receivers that deliver improved capabilities for accurate, reliable, and available PNT service where current receiver performance might be compromised (e.g., jammed) or unavailable.

Broader Coordinating Structure

The 2004 U.S. Space-based PNT policy established a coordinating structure to integrate input from, and delineate the respective roles of the military and civilian departments and agencies for program planning (including identification of system requirements), resource allocation, system development, and operations. As part of the coordinating structure, an executive committee advises and coordinates among U.S. government agencies on maintaining and improving U.S. space-based PNT infrastructures, including GPS and related systems. The executive

[10] The original GPS satellites have been modernized in various generations of upgrades beginning with GPS IIA followed by GPS IIR, GPS IIR-M, GPS IIF, and GPS III, which is in development.

committee is co-chaired by the deputy secretaries of the DOD and the 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). The National Coordination Office for Space-based PNT provides day-to-day support for the executive committee.

Committee Requirements Broadly Addressed but Constellation Size Remains a Key Issue

The Air Force broadly addressed all committee reporting requirements in its assessment of future GPS options for the space segment. These requirements include evaluation of system capabilities, implementation approaches, technical and programmatic risks, and estimated costs. However, each of the options presented and evaluated is based on a GPS constellation of 30 satellites, whereas the Air Force's requirement is for a 24-satellite constellation. The 30-satellite constellation assumption has a significant effect on the cost of the options studied. It also raises questions about what constellation size the Air Force is committed to fielding and maintaining in the future.

Air Force GPS Report Met Committee Requirements for the Space Segment

The Air Force GPS report identified and assessed nine options for the space segment of a future GPS which were developed as part of a six-step process the Air Force used to conduct the study, to include:

- Define the purpose, scope, and decision criteria.
- Assess the user requirement or capability in operational context.
- Develop a broad trade space of all available options.
- Review the trade space with GPS Senior Advisory Group to select a small set of promising options and to develop criteria for assessing the down-selected options.
- Analyze the options and assess them against the criteria using modeling and analysis tools, and conduct a risk assessment for each option.
- Integrate all the findings and develop recommendations.

According to program officials, they focused the report on options for the space segment because it is the most costly part of the GPS. The space segment accounts for more than half of all GPS program costs in the current budget. For the space segment, we found that the Air Force's report addressed all four Committee requirements for each of these nine options. Specifically, the report identified system capability, implementation approaches, technical and programmatic risks, and estimated costs, as provided for by the Committee. Each of the options

for the space segment is assessed to determine how quickly it could be fielded, implementation approaches, technical and programmatic risks, and space segment costs (to include the cost of launch). GPS program officials stated that the cost analyses that support the nine space segment options were not high fidelity estimates but instead estimated at a high level. Although this may be expected given the limited time provided to complete the study and prepare the report, the high-level cost estimates are not at a level that would support programmatic decisions. Table 1 below identifies our evaluation relating to the Committee requirements as well as our observations.

Table 1: Extent Air Force Report Met Committee Report Requirements and GAO Observations

Requirement	Requirement met?	GAO observations
System capability	Yes, for the space segment	Each option is assessed on how long it would take the given option to achieve a constellation of 30 satellites; on signal integrity; and on its ability to accomplish its mission in the presence of adverse conditions or hostile actions (resilience).
Implementation approaches	Yes, for the space segment	Each option is assessed on its relative strengths and weaknesses, and potential courses of action are identified.
Technical and programmatic risks	Yes, for the space segment	The level (low, medium, high) of technical and programmatic risks associated with each option are identified.
Estimated costs of any recommended options	Yes, for the space segment	Relative rough cost estimates for each option are identified and comparisons across the options are indicated.

Source: GAO analysis of Air Force information.

Of the nine options the Air Force identified for the space segment, several relied on a core constellation of 18 to 24 GPS III satellites that would be augmented with other satellites to reach a total of 30. The last two options do not rely on a core GPS III constellation but would also consist of 30 satellites. See table 2 for a description of each option as well as information on the results of the Air Force's risk and cost assessments. Technical risk, for some of the options, includes the incorporation of technologies that are new to GPS. Programmatic risk includes areas such as establishing requirements, budgeting for funds, and obtaining approval of the acquisition strategy. The options are not presented in any particular order of significance.

Table 2: GPS Space Segment Options and Key Assessment Information Identified by the Air Force

Option	Description	Risk assessment (technical/programmatic)	Rough order cost estimate for fiscal years 2013-2130 (fiscal year 2012 dollars in billions)
1	GPS III satellites with minimal changes (current baseline GPS program)	Low / Low	$23
2	GPS III satellites with all possible upgrades previously planned for the program[a]	Low / Low-medium	$25
3	GPS III satellites modified to launch two per launch vehicle	Low-medium / Low-medium	$22
4	GPS III satellites modified to launch two per launch vehicle and augmented by navigational satellites (NavSats)[b] with all civilian and military signals[c]	Medium / Medium-high	$20
5	GPS III satellites modified to launch two per launch vehicle and augmented by NavSats with limited civilian and military signals[d]	Medium / Medium-high	$18
6	GPS III satellites modified to launch two per launch vehicle and augmented by PNT payloads hosted on other satellites in a more distant orbit[e]	Medium / High	$21
7	GPS III satellites modified to launch two per launch vehicle and augmented by dedicated PNT satellites in a more distant orbit[f]	Medium / Medium-high	$22
8	Constellation evolves into all NavSats	High / High	$13
9	NavSat constellation augmented by 3 PNT satellites in a more distant orbit	High / High	$14

Source: GAO presentation of Air Force data

[a]Includes enhanced command and control (i.e., sending "crosslinked" signals between satellites for improved signal integrity monitoring) and regional protection (i.e., high-power signals that can be transmitted over a combat zone for localized jam resistance).

[b]The Air Force is conceptualizing NavSats as smaller, lower-cost PNT satellites that in options 4 and 5 would be launched into orbit to augment an existing core constellation of 18 to 24 GPS III satellites.

[c]Refers to PNT payloads that transmit the full complement of signals on GPS III satellites.

[d]Refers to PNT payloads that only transmit selected GPS signals (two military and two civilian signals).

[e]Hosted payloads in this case would involve navigation signal transmitters attached to commercial or other government satellites in geosynchronous-Earth orbit. Current GPS satellites are in medium-Earth orbit, at a distance of approximately 12,500 miles above the earth. Geosynchronous-Earth orbit is further still, where the Earth's gravitational pull is such that objects orbiting at that distance circle the Earth once a day, with their position relatively fixed to the same spot on Earth.

[f]According to program officials, GPS satellites in geosynchronous-Earth orbit have the advantage of broader regional coverage, but require more fuel on launch to reach their orbit, as well as more power to transmit signals over a farther distance.

GPS program officials noted that none of the options presented in the report represent a radical departure from the GPS III program, which they characterized as an essential investment for the health of the constellation. The GPS III program plans to eventually replace the

existing constellation with upgraded satellites that carry the nuclear detonation detection system payload. The first seven options presented in the Air Force report involve GPS III or some modification of it. Specifically, five options (numbers 3, 4, 5, 6, and 7) involve launching two GPS III satellites on a single launch vehicle (referred to as dual launch), and according to the Air Force report, are expected to substantially reduce costs by eliminating the need to buy launch vehicles for each satellite, as is currently practiced. Further, four options (numbers 4, 5, 8, and 9) entail fielding smaller, lower-cost PNT satellites—referred to as navigation satellites (NavSats)—yet to be developed satellites that would complement the core constellation of GPS III satellites in various configurations, or to replace GPS III satellites entirely. The NavSat concept is comparable to GPS III except that it is comprised of dedicated PNT satellites (without the secondary nuclear detonation detection system); and according the Air Force report, is expected to be significantly less costly than GPS III satellites due to the development and use of mass-reducing technologies.

Future Supported Constellation Size is Unclear

According to Air Force officials, the baseline GPS requirement for accuracy drives a requirement for a 24 satellite constellation at 95 percent availability.[11] However, each of the GPS space segment options the Air Force assessed is based on a constellation of 30 satellites. Therefore, it is unclear whether investment costs for these options will in fact be lower than the baseline cost of the current GPS III program. Moreover, based on the estimated costs presented in the report, basing all options on a 30-satellite constellation may actually increase the overall GPS investment because the limited differences between the options assessed narrows the range of costs across the seven options that rely on a core of GPS III satellites.

Program officials noted that although the requirement is for 24 satellites, for the last seven years the Air Force has operated at least 27 satellites in the GPS constellation and, more recently, as many as 31 satellites due to the existing satellites outlasting the useful life originally estimated. We reported in 2010 that DOD predicted many of the older satellites in the constellation will reach the end of their operational life faster than they will

[11] The Air Force GPS report cites the same requirement—a 24-satellite constellation at 95 percent availability.

be replenished over the next several years, decreasing the size of the constellation from its current level. Since the magnitude of error calculated by GPS receivers dramatically decreases as the constellation reaches 30 satellites, and program officials stated that users have come to rely on this increased accuracy over the last several years, the Air Force determined it was appropriate to assess options for providing this same level of service into the future. As a result, the report establishes a constellation of 30 satellites—an increase over the Air Force's requirement for accuracy—as a baseline for each of the GPS options assessed. Program officials, however, acknowledged that there is reluctance to formally require the GPS constellation to be larger than the 24-satellite requirement supported by the Air Force without the certainty of a corresponding growth in program funding. While a 30-satellite constellation may be justifiable, using that as a baseline in the study may have eliminated some lower cost options that may exist with 24 satellites. Additionally, given the uncertainty regarding the magnitude of future GPS investments, the DOD and civilian agency community would benefit from knowing which constellation size the Air Force is committed to supporting.

More Information on Key Cost Drivers and Cost Estimates, and Broader Input from Stakeholders are Important for Future Investment Decisions

The Air Force GPS report identifies key drivers of cost and capability across the assessed options, but more information on each of these drivers is needed to fully assess their potential effect on the future GPS program. Similarly, additional information is needed on inputs for the cost estimates presented. This information includes analysis of costs and other potential options associated with the ground and user equipment segments, which were excluded from the study, as well as costs associated with the various technical and programmatic risks identified in the report. Assurance that best practices are followed for subsequent cost estimates would also benefit future investment decisions. Additionally, the Air Force was not required by the Committee to consult representatives from the broader PNT advisory community, but several of these individuals provided us with useful information relating to the options assessed. Future investment decisions would benefit from a broader outreach to gain the input and perspectives of other GPS stakeholders.

Information on Key Cost Drivers is Incomplete

Development of dual launch capability for GPS III satellites, development of the NavSat concept, and the inclusion or exclusion of the nuclear detonation detection system payload, are key drivers of cost and capability between the GPS options assessed by the Air Force. For example, both the dual launch capability and the NavSat concept require use of technologies new to GPS with associated developmental risks, and

as key drivers of cost, they are factors that differ significantly enough to have a material impact on the analysis and the resulting findings, including estimated costs. Additionally, two of the NavSat options are based on the possibility that the nuclear detonation detection mission could eventually be transferred to another space-based system, but the effect of such a change on overall system capability was not fully considered in the report. To assess the options as a basis for making future GPS investment decisions, more information on each of these drivers is important to understand the full impact they could have on the future integrity, capability, and cost of the system.

Dual Launch Capability

For options 3 through 7, development of a dual launch capability for GPS III satellites is necessary, but a lack of detail in the Air Force's report on the maturity of key technologies and cost considerations make it difficult to conduct a fully informed assessment of the viability of these options. Program officials indicated that this ongoing effort will require reductions in the size, weight, and power of the GPS III satellites, as well as development of equipment (adaptors) that will allow two satellites to fly on a single launch vehicle. According to program officials, these adaptors are nearing a high level of technology maturity. However, the report names various other components and technologies under development for this effort, such as lithium ion batteries and more efficient signal amplifiers, but does not indicate where they stand in terms of technology maturity. Instead, the report assumes that dual launch capability is fully developed and that demonstration of the capability will be ready in time to launch the seventh and eighth GPS III satellites (of potentially 32 production satellites). Consequently, it is difficult to assess the near- to medium-term feasibility and timeframes of all options that are based on dual launching GPS III satellites.

Additionally, the Air Force did not fully consider the cost impact of its dual launch approach. While cost savings may eventually be accrued from dual launches, the report does not address the acquisition and operations strategy—what is necessary to buy and conduct dual launches up front. For example, one of the subject matter experts we consulted identified a number of factors which would result in cost increases that offset some of the expected savings from not procuring a second launch vehicle. These include (1) taking the steps to ensure the constellation's integrity would remain intact in the event of a launch failure, as two satellites would be lost in such an instance rather than one (e.g., Air Force officials would have to decide whether to orbit more spares to overcome the effects of a possible launch failure); (2) making changes at the manufacturing level to accommodate two satellites, such as the additional storage costs to hold

the first satellite until the second satellite is ready to launch; (3) ensuring launch site facilities are capable of processing two satellites essentially simultaneously, noting that discovery of an anomaly during launch site testing of one satellite could affect the other satellite; and (4) ensuring the additional support equipment and personnel necessary to support preparing two satellites for launch. This expert further acknowledged that none of these factors were "showstoppers" but suggested that they should be taken into consideration. Program officials noted that in developing the notional launch schedule for the options, they factored in a two percent probability of launch failure which is an industry standard for mature launch vehicle designs. However, they acknowledged that modifications needed on the launch vehicle to dual launch GPS satellites have not been demonstrated.

NavSat Development

Some of the identified technical risks for the notional NavSat options may be understated given that they involve undertaking new acquisition programs with technologies not previously used on GPS satellites. For example, many of the initiatives to reduce satellite size, weight, and power underway for developing dual launch capability are also being explored for application on NavSats. We have found in our prior work relating to best practices for weapon system acquisition that programs employing technologies that are not fully mature tend to face challenges staying on budget and on schedule, which increases risk to the overall program.[12] The Air Force report indicates that maturation of the NavSat concept is a prerequisite for many options assessed, including development of new satellite buses and payloads. These development efforts are assigned medium and medium-high technical and programmatic risk. While the report acknowledges that there are technical risks involved with developing higher efficiency signal amplifiers and other space, weight, and power reducing technologies, it concludes that none of these technologies is high risk. However, officials from the Air Force Research Laboratory, which is helping to develop some of these technologies for potential application on NavSats, noted that some of the new technologies are currently at a relatively low level of maturity (i.e., only tested in a laboratory environment), and will not likely be feasible for the GPS program until at least 2018. Moreover, one of the subject matter experts we consulted noted that there are other potential risks associated

[12] GAO, *Defense Acquisitions: Assessments of Selected Weapon Programs,* GAO-13-294SP (Washington, D.C.: March 28, 2013.

with the NavSat options, such as not having a proven track record. This expert noted problems in the NavSat programs could result in the loss of user confidence in GPS that has been built up over decades of delivering a reliable satellite navigation service.

Details regarding technology maturity are also needed to better understand the cost impact of these options on the overall GPS program. For example, program officials acknowledged that savings from dual launching GPS III satellites could help offset some of the additional costs associated with development of NavSats. However, they noted that there would likely be significant initial development costs for the NavSats that would result in the need for a net budget increase in the near-term.

Additionally, a key aspect of NavSat capability relevant to civilian GPS users is not addressed in the Air Force report and without additional clarification, it is difficult to determine the impacts to these users. The report notes that one approach for reducing the size, weight, power, and cost of proposed NavSats, would be to reduce the total number of navigation signals they transmit. Specifically, under option 5 in the report, NavSats would broadcast two of four civilian signals and two military signals. Three of the subject matter experts we consulted noted concerns in part because determining which civilian signals to exclude would likely result in the prioritization of one user group over another, as the civilian signals have different applications. Air Force officials indicated that, option 5 is based on a larger core of GPS III satellites—which are required to carry all civilian signals—and augmented by a smaller number of NavSats. However, it is unclear how a core of GPS III satellites would compare with a combined constellation of GPS III satellites and NavSats, both required to broadcast all civilian signals.

Nuclear Detonation Detection System

Two of the NavSat options included in the Air Force report would require the eventual elimination of the nuclear detonation detection system payload from GPS satellites, and the report notes that as long as this mission is a priority and is planned to be hosted on GPS satellites, these options—and the low relative costs—would therefore not be viable. Elimination of the nuclear detonation detection system could have other effects on the overall capability of the GPS system not recognized or addressed in the Air Force report. For example, one of the subject matter experts we consulted mentioned that the GPS search and rescue function, a requirement for GPS III satellites, shares an antenna with the

nuclear detonation detection system payload.[13] Thus, the two options (numbers 8 and 9) that drop the nuclear detonation detection system completely would potentially forgo the search and rescue function as well. However, program officials said the search and rescue payload is relatively small and could be adapted to the NavSats without the nuclear detonation detection system, and also noted that in a mixed constellation of GPS III satellites and NavSats, there would likely be sufficient coverage for the search and rescue mission even if the search and rescue sensors were only on the GPS III satellites. Given the differing views of these officials and subject matter experts, this issue will need to be resolved as the Air Force pursues future assessments of GPS options.

Cost Estimates are Not Comprehensive

The Air Force's high-level cost estimates appear consistent across the options for the space segment, but the estimates do not include the other two key GPS segments. For its study, the Air Force defined affordability as the reduction in total ownership cost of sustaining GPS throughout its life cycle. However, without inclusion of the other two key segments of the system, the methodology used does not reflect true life cycle costs. Additionally, Air Force officials noted that the cost estimates developed for the report do not include cost risk. This leaves some question as to the ultimate usefulness of the cost estimates, risk rankings, or both. In addition, the Air Force did not apply all aspects of best practices in developing its cost estimates, which further reduces the usefulness of these estimates in decisionmaking. Finally, the Air Force did not obtain input from the PNT advisory community which may have helped inform its assessment.

Estimated Overall Costs for Options Exclude Key Segments

For a defense acquisition program, DOD defines life cycle costs as the total cost to the government of acquisition and ownership for a program over its full life.[14] This includes the cost of development, acquisition, operations, and support (to include personnel), and where applicable, disposal. While the Air Force report indicates that the estimates are based upon life cycle costs, it does not include key elements necessary to

[13] According to Air Force officials, each group of GPS III satellites it procured can be contracted for additional capabilities. The search and rescue function will be available on GPS III satellites beginning with deployment of the ninth satellite.

[14] Defense Acquisition Guidebook. (June 28, 2013) (available at https://acc.dau.mil/CommunityBrowser.aspx?id=654219).

meet the definition of life cycle cost, thereby underestimating the total costs of the options and limiting their usefulness. The Air Force's cost estimates for each option only included the space segment—satellite and launch vehicles—which it determined to be the only segment to have significant impact on overall costs. As mentioned previously, the space segment accounts for the largest share—more than half—of total GPS costs in the Air Force's current budget. Under this methodology, program officials said options dealing with the ground control system were not included in the cost estimates because costs associated with adding capability to control new satellites were estimated to be a small percentage of the total GPS system cost, and would not provide a significant distinction between the options. However, this estimation, without the ground control segment, may not be valid given that there could be unknown cost and schedule risks for the ground control segment associated with modifications to accommodate new and different satellite vehicles. More specifically, while changes to the ground segment may not be a major cost differentiator between the options, they have presented significant challenges. For example, program officials said the costs of adding ground control capability for a new generation of satellites are known, but this is based on updates to the current ground control system. However, in our prior work, we also reported that modernization of the current ground control segment has been challenging, and has only enabled limited capability to control the new satellites, rather than facilitating full access to their new capabilities.[15] Additionally, the ground control segment is being completely replaced as part of the GPS OCX program, which according to Air Force officials, will eventually enable users to take full advantage of the capability offered by the GPS constellation, and is expected to cost nearly $3.7 billion through fiscal year 2017. This cost is significantly higher than initial planning estimates due to software and other challenges experienced thus far, and the extent and cost of this effort were not recognized in the Air Force report.

Additionally, two of the subject matter experts we consulted indicated that inclusion of user equipment could have benefited the study. The Air Force report did not assess any options that would require hardware changes to user equipment beyond what is already planned for user equipment modernization because of the large number of civilian receivers currently

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

in use. One subject matter expert noted that although the report cites this as the primary reason user equipment was not examined; civilian user equipment will continue to evolve by integrating GPS signals with signals from other global navigation systems, as well as with non-space-based PNT capabilities such as inertial navigation sensors, chip scale atomic clocks, and terrestrial radiolocation technologies. The expert noted that this could reduce some of the capability that the space segment needs to provide in the future. Based on our discussions with officials from the Air Force Research Laboratory, this could in turn potentially reduce the size and power requirements for the space vehicle and thereby the overall cost.

Estimated Overall Costs for Options Exclude Cost Risk

According to Air Force officials involved in the study, the overall cost estimates do not include cost risk,[16] which is defined as the risk associated with the ability of the program to achieve its acquisition strategy cost objectives. Similarly, identified technical and programmatic risks and their relative rankings do not generally appear to have a basis in cost. The options involving a constellation of all NavSats or at least a core of NavSats (numbers 8 and 9 respectively) both reflect high technical and programmatic risks. At the same time, the cost estimates for these options reflect the lowest development and procurement costs (excluding operations and sustainment costs) over the fiscal year 2013 to fiscal year 2030 timeframe. We have found in our prior work relating to key practices for weapon system acquisition that programs employing technologies that are not fully mature tend to require more time in development or production and more funding than is initially anticipated.[17] Without additional details as to how cost factors into the risk determination, it is difficult to know the relative utility of the Air Force's cost estimates for making further GPS decisions.

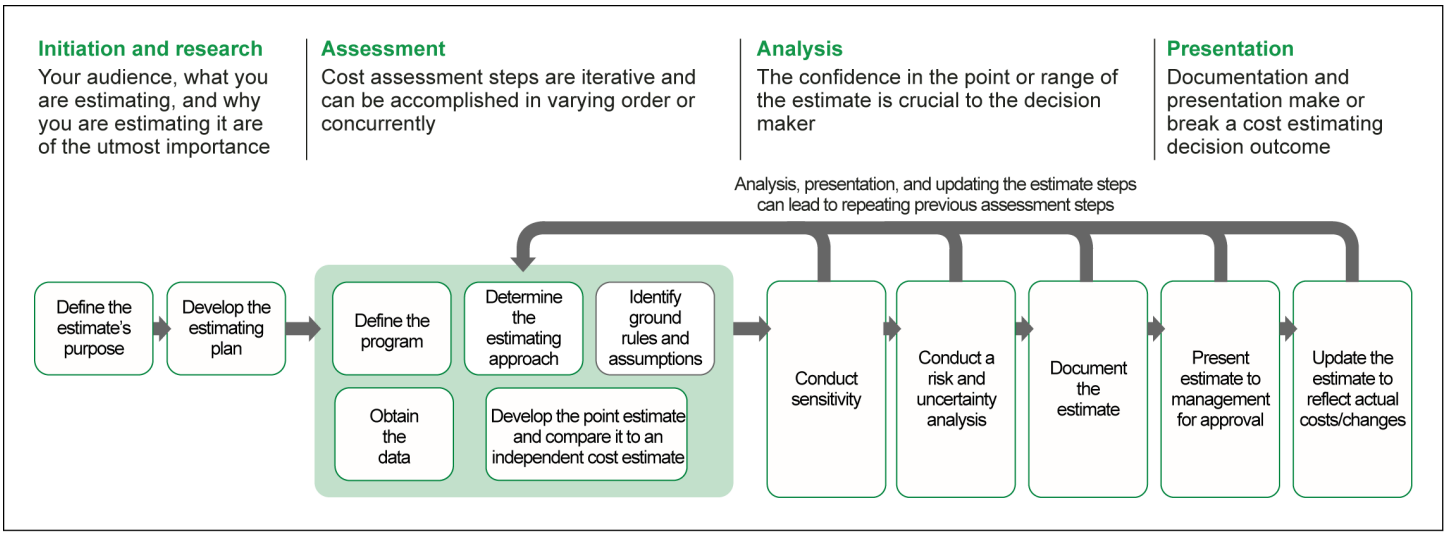
Best Practices for Cost Estimating Could Improve Future Estimates

Best practices in cost estimating result in accurate and credible cost estimates that management can use for making informed decisions. The methodology consists of 12 steps that we present in figure 2.

[16] Although the Air Force report states that cost estimates include cost risk, program officials told us this was in error and that, in fact, cost risk was not included in the cost estimates.

[17] GAO-13-294SP.

Figure 2: GAO's 12-Step Cost Estimating Process



Source: GAO.

These best practices represent an overall process of established, repeatable methods that result in high-quality cost estimates that are comprehensive and accurate, and that can be easily and clearly traced, replicated, and updated. We found that the Air Force followed some aspects of the 12-step process in developing its estimates for GPS architecture options, but did not follow others. For example, the Air Force defined the estimate's purpose and identified some ground rules and assumptions, but did not perform sensitivity analysis and conducted minimal analysis of cost-related risks. This would be expected given the time constraints and other limitations of the study; however, to further assess its GPS options, more fully-developed cost estimates would be important in facilitating more rigorous comparisons across the options.

Consultation with Key Stakeholders Could Provide Additional Insights

GPS has grown into a global utility whose multi-use services are integral to U.S. national security and transportation safety, and are an essential element of the worldwide economic infrastructure. As a result, any decision regarding GPS has far reaching consequences for many beyond DOD. This fact was clearly addressed in the national PNT policy which formalized the membership of the PNT executive committee to include other government departments and agencies that have a stake in the stewardship of GPS. This committee ensures that the national security, homeland security, and civil requirements receive full and appropriate consideration in the PNT decision process and facilitates the integration

and reduction of conflicts of these requirements for PNT, as required. However, the Air Force did not seek input from those departments and agencies that are represented on the committee, including the Department of Transportation, which co-chairs the committee with DOD. These key stakeholders could have provided valuable insight on potential impacts of the options presented, as well as future needs arising from any changes to the GPS.

Several of the subject matter experts we consulted directly represent the stakeholders identified in the PNT policy. While these individuals largely believe the Air Force report is a good starting point for future GPS decisions, they provided additional, meaningful insights relating to potential risks and costs associated with the individual options as well as with ground control and satellite launch; user equipment capabilities; and the concerns and needs of various GPS users. According to Air Force officials, they did receive input from individuals who advocated for the needs of non-DOD users, but acknowledged that these individuals did not directly represent those users or other stakeholders identified in PNT policy. While not specifically required by the House Armed Services Committee to seek input from others, obtaining input from key stakeholders, such as was provided by the subject matter experts we consulted, the Air Force may have been able to obtain additional insights as it developed and weighed the various GPS options. This was a sentiment shared by some of our subject matter experts who expressed concern over the lack of input from the civilian community.

Conclusions

The Air Force's GPS report met the committee's reporting requirements and serves as a good starting point from which to assess potential lower cost GPS options. The study focused on the space segment and as such, the options consist of various configurations of satellites and launch options—whether to launch satellites individually or in multiples. The less risky options appear to be relatively minor deviations from the department's current approach in fielding GPS III, with the key decision being whether to launch one or two satellites at a time. Pursuing any options would likely require a near term increase in the overall GPS budget to achieve future savings—a challenge in the current fiscally constrained environment. Yet, the study used a larger constellation size than the Air Force's current derived requirements and lacked the comprehensiveness that would allow the study to be used for future decision making. Based on acquisition best practices, there are actions the Air Force could take to improve the study results to include: identifying the constellation size to be supported; expanding the areas of

consideration to include ground control and user equipment; more thoroughly defining and analyzing key capabilities and implementation approaches; and using a higher fidelity approach in assessing risk and estimating cost going forward. The Air Force could also benefit from greater consultation from the broader PNT stakeholder and advisory community, which could offer valuable perspectives relating to the overall approach for investigating future GPS options, as well as the relative merits and unknowns associated with each option analyzed. While there are a number of limitations in the study, it is valuable as a basis for substantive discussion of long-term GPS investments. Going forward, it is important for the Air Force to take a more comprehensive approach in assessing options for making sound future GPS investments.

Recommendations for Executive Action

To better position the DOD as it continues pursuing more affordable GPS options, and to have the information necessary to make decisions on how best to improve the GPS constellation, we recommend that the Secretary of Defense direct the Secretary of the Air Force to take the following three actions:

1. Affirm the future GPS constellation size that the Air Force plans to support, given the differences in the derived requirement of the 24-satellite constellation and the 30-satellite constellations called for in each of the space segment options in the Air Force's report.
2. Ensure that future assessments of options include full consideration of the space, ground control, and user equipment segments, and are comprehensive with regard to their assessment of costs, technical and programmatic risks, and schedule.
3. Engage stakeholders from the broader civilian community identified in PNT policy in future assessments of options. This input should include civilian GPS signals, signal quality and integrity, which signals should be included or excluded from options, as well as issues pertaining to other technical and programmatic matters.

Agency Comments and Our Evaluation

In written comments on a draft of this report, DOD concurred with all three of our recommendations to better position the DOD as it continues pursuing more affordable GPS options, and to have the information necessary to make decisions on how best to improve the GPS constellation. DOD's written comments are reprinted in appendix II.

DOD concurred with our first recommendation that the Secretary of the Air Force affirm the future GPS constellation size the Air Force plans to

support. In its response, the department stated the numbers of satellites are affirmed annually in the President's Budget request. However, the budget shows satellite procurements over time and does not specify the target constellation size to meet current or future accuracy requirements, which has a direct impact on annual procurement costs. Additionally, as our report indicates, the Air Force report based all options on a 30-satellite constellation while reporting a GPS requirement for accuracy of a 24 satellite constellation at 95 percent availability. Therefore, the need remains for the department to more clearly and transparently identify the target GPS constellation size the department intends to pursue.

DOD also concurred with our second recommendation to ensure future assessments of options include full consideration of the space, ground control, and user equipment segments, and are comprehensive with regard to their assessment of costs, technical and programmatic risks, and schedule. In its response, the department stated that while consideration of the space and ground control segments should be comprehensive in these areas, the user equipment segment should be included in future assessments when those assessments include the fielding of new user equipment capability. As one of the subject matter experts we consulted noted, user equipment continues to evolve and could potentially embrace PNT technologies and capabilities that would reduce required capabilities for GPS satellites. As our report indicates, a comprehensive look at user equipment is warranted, especially given that the user equipment modernization program is in a pre-development phase.

Finally, DOD concurred with our third recommendation to engage stakeholders from the broader civilian community identified in PNT policy in future assessments of options. In its response, the department said stakeholders from the broader civilian community identified in PNT policy should be engaged in future assessment of options that include changes to the Standard Positioning System performance standard or to agreements or commitments the DOD has already made with civil stakeholders. However, as we noted in our report, considering the unknown effect on the civilian user community of some of the options presented, as well as potential future application of new technology for user equipment, comprehensive assessment of future GPS options should involve the broader PNT community, particularly those stakeholders identified in PNT policy.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Defense, and the Secretary of the Air Force. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-2527 or makm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are listed in appendix III.

Marie A. Mak
Acting Director
Acquisition and Sourcing Management

List of Committees

The Honorable Carl Levin
Chairman,
The Honorable James Inhofe
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Dick Durbin
Chairman,
The Honorable Thad Cochran
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Howard P. “Buck” McKeon
Chairman,
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable C.W. Bill Young
Chairman,
The Honorable Paul Visclosky
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Scope and Methodology

House Report No. 112-479 accompanying H.R. 4310, the National Defense Authorization Act for Fiscal Year 2013 directed the Commander of the Space and Missile Systems Center, U.S. Air Force, to provide a report to the congressional defense committees on lower-cost solutions for providing GPS capability following the procurement of the GPS III satellites.[1] The Committee provided that the report should identify the system capability, possible implementation approaches, technical and programmatic risks, and the estimated costs of any solutions it recommends. The committee also mandated GAO to review the report provided by the Commander of the Space and Missile Systems Center, and to provide its recommendations to the congressional defense committees within 90 days after the Air Force report is received.

To determine the extent to which the Air Force's report, *Lower Cost Solutions for Providing Global Positioning System (GPS) Capability*, met the requirements, and to identify additional information that could guide future investment decisions, we assessed the report and the approach, assumptions, and criteria the Air Force used to conduct the study. To accomplish this, we obtained and reviewed documents that supported the Air Force's report. We then discussed the report and our preliminary analysis of the report with GPS program and Aerospace Corporation officials responsible for the report to obtain their perspectives and clarify aspects of the report. We also reviewed other relevant high-level space strategic documents including the National Space Policy[2] and the *2008 Biennial GPS Report to Congress*.[3] To identify the technological advances available to the Air Force and the readiness of those technologies, we interviewed officials from Defense Advanced Research Projects Agency and the Air Force Research Laboratory. To identify additional or clarifying information that could help guide future investment decisions, we sent data collection instruments to ten subject matter experts from the Positioning, Navigation and Timing stakeholder and advisory community to obtain their insights on GPS options the Air Force identified, as well as information that could provide additional insights, and received responses from seven of them. These subject matter

[1] H.R. Rep. No. 112-479, at 70-71 (2012).

[2] *National Space Policy of the United States of America* (June 28, 2010) (available at http://www.whitehouse.gov/the-press-office/fact-sheet-national-space-policy).

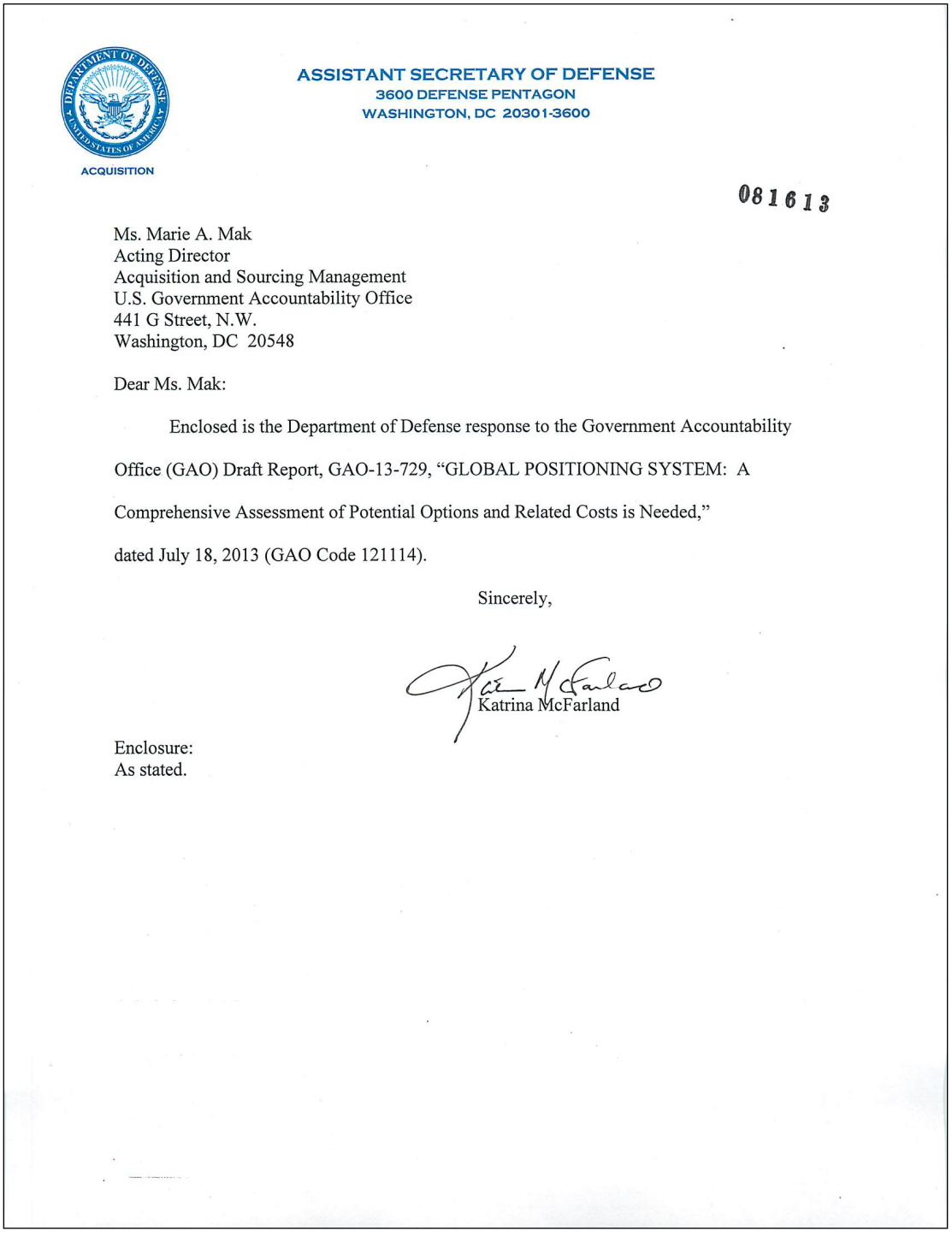
[3] Available at http://www.gps.gov/congress/reports/. This was the last report available, as the biennial GPS reports were discontinued thereafter.

experts were advisors to the National Space-Based Positioning, Navigation, and Timing Executive Committee or were identified by the National Coordination Office for Space-Based Positioning, Navigation, and Timing as experts in the field, and who were also government officials. To assess the completeness of cost estimates cited in the report, we assessed the process used to develop the cost estimates in the study to determine the extent to which they followed GAO's *12-Step Reliable Process for Developing Cost Estimates* assessment tool.[4]

We conducted this performance audit from April 2013 to September 2013 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.

[4] GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-06-3SP (Washington, D.C.: March 2, 2009).

Appendix II: Comments from the Department of Defense



ASSISTANT SECRETARY OF DEFENSE
3600 DEFENSE PENTAGON
WASHINGTON, DC 20301-3600

ACQUISITION

081613

Ms. Marie A. Mak
Acting Director
Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Ms. Mak:

Enclosed is the Department of Defense response to the Government Accountability Office (GAO) Draft Report, GAO-13-729, "GLOBAL POSITIONING SYSTEM: A Comprehensive Assessment of Potential Options and Related Costs is Needed," dated July 18, 2013 (GAO Code 121114).

Sincerely,

Katrina McFarland

Enclosure:
As stated.

GAO Draft Report Dated July 18, 2013
GAO-13-729 (GAO CODE 121114)

"GLOBAL POSITIONING SYSTEM: A COMPREHENSIVE ASSESSMENT OF POTENTIAL OPTIONS AND RELATED COSTS IS NEEDED"

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: To better position the DoD as it continues pursuing more affordable GPS options, and to have the information necessary to make decisions on how best to improve the GPS constellation, GAO recommends that the Secretary of Defense direct the Secretary of the Air Force to affirm the future GPS constellation size that the Air Force plans to support, given the differences in the derived requirement of the 24-satellite constellation and the 3D-satellite constellations called for in each of the space segment options in the Air Force's report.

DoD RESPONSE: Concur. The Department affirms the numbers of satellites annually in the President's Budget request. The GPS IIIA Capability Development Document captures and documents the position and time accuracies and the availability requirements of the system. The number of satellites required to meet the system performance is driven by a number of factors, such as receiver sensitivity, spectrum interference and clock errors both in the receiver and on satellites.

RECOMMENDATION 2: To better position the DoD as it continues pursuing more affordable GPS options, and to have the information necessary to make decisions on how best to improve the GPS constellation, GAO recommends that the Secretary of Defense direct the Secretary of the Air Force to ensure that future assessments of options include full consideration of the space, ground control, and user equipment segments, and are comprehensive with regard to their assessment of costs, technical and programmatic risks, and schedule.

DoD RESPONSE: Concur. Future assessments of GPS options should include full consideration of the space and ground control segments and be comprehensive with regard to assessment of costs, technical and programmatic risk, and schedule. The user equipment segment should be included in future assessments when those assessments include the fielding of new user equipment capability. The backwards compatibility requirement should remove consideration of future changes to user equipment in all other types of assessments.

RECOMMENDATION 3: To better position the DoD as it continues pursuing more affordable GPS options, and to have the information necessary to make decisions on how best to improve the GPS constellation, GAO recommends that the Secretary of Defense direct the Secretary of the Air Force to engage stakeholders from the broader civilian community identified in PNT policy in future assessments of options. This input should include civilian GPS signals, signal quality and integrity, which signals should be included or excluded from options, as well as issues pertaining to other technical and programmatic matters.

DoD RESPONSE: Concur. Stakeholders from the broader civilian community identified in PNT policy should be engaged in future assessment of options when those assessments include changes to the Standard Positioning System (SPS) performance standard or to agreements or commitments the DoD has already made with civil stakeholders.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Marie A. Mak, (202) 512-2527 or makm@gao.gov.

Staff Acknowledgments

In addition to the contact named above, Art Gallegos, Assistant Director; Andrew Redd; Emile Ettedgui; Jean Lee; Marie Ahearn; Karen Richey; Roxanna Sun; and Robert Swierczek made key contributions to this report.