SECRETARY OF THE AIR FORCE
WASHINGTON

FEB 25 2015

The Honorable John McCain
Chairman, Committee on Armed Services
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

I am pleased to forward the enclosed report as directed on page 294 of House Report 113-446, accompanying the National Defense Authorization Act for FY15.

This report provides information on the Global Positioning System satellite constellation and replenishment plan. It addresses the current satellite and launch vehicle acquisition schedule, and cost advantages and disadvantages of maintaining the schedule as planned in the FY14 President's budget, as compared to the current schedule. It also provides the age, design life, and technical state of all on-orbit assets, the calculated functional availability as identified with planned launches, a risk assessment of not meeting the required functional availability, options to lower the risk assessment, assessment of the national security impact if the necessary capability is not provided, and the risks of further schedule delays.

A similar letter has been sent to each of the congressional defense committees.

Sincerely,

Deborah Lee James

Attachment:
Global Positioning System Replenishment Report

United States Air Force

Report to Congressional Committees

# Global Positioning System Constellation Replenishment

February 2015

The estimated cost of report or study for the Department of Defense is approximately $6,790 for the 2014 Fiscal Year. This includes $2,500 in expenses and $4,290 in DoD labor.
Generated on 2014 Dec04 RefID: A-911F60B

House Report 113-446, page 319

## 1. Introduction

This report is provided to the congressional defense committees as directed on page 294 of House Report 113-446, accompanying the National Defense Authorization Act for 2015.

***Global Positioning System (GPS) Constellation Replenishment***

*The committee is aware of the Air Force's most recent plan to delay the procurement and launch of Global Positioning System (GPS) III constellation satellites. While the committee is aware that the Air Force may have made some technical changes to enable better power management of on-orbit satellites, this does not affect the overall constellation fragility as characterized by factors such as satellite age and technical state of internal redundancy or lack thereof. The committee is concerned with the revised Air Force plan and has not seen any detailed analysis to support the significant changes to the schedule.*

*Therefore, the committee directs the Secretary of the Air Force to provide a report to the congressional defense committees, by November 1, 2014, on the Global Positioning System satellite constellation and replenishment plan. The GPS plan should address the following: (1) Current satellite and launch vehicle acquisition schedule; (2) Cost advantages and disadvantages of maintaining a satellite and launch vehicle acquisition schedule as planned in the fiscal year 2014 President's budget, as compared to the current schedule; (3) Age, design life, and technical state of all on-orbit assets; (4) Calculated functional availability as identified with planned launches; (5) Risk assessment of not meeting the required functional availability; (6) Options to lower the risk assessment, to include faster replenishment of satellites; (7) National security impact if the necessary capability is not provided; and (8) Risks of further schedule delays to the planned satellite and launch schedule.*

## 2. Executive Summary

The House Armed Services Committee directed the Secretary of the Air Force to provide a report on the GPS satellite constellation replenishment plan by November 1, 2014. The committee report requested detailed information on the delayed schedule for procurement of the Global Positioning System (GPS) satellite III and requested detailed analysis to support changes to the schedule.

Since 1995, the U.S. Air Force (USAF) has provided uninterrupted Positioning, Navigation and Timing (PNT) service at or above the required level of performance (95% availability of 24 operational GPS satellites on-orbit). The Department of Defense is committed to sustaining the PNT mission capability at the required availability level. The USAF assesses the risk as low to maintain the GPS constellation and meet the requirements for PNT capability worldwide. In December 2013, the USAF completed a study on Modified Battery Charging Control and concluded that through its implementation, the GPS IIR and GPS IIR-M satellites would have a predicted increase in life expectancy of at least one to two

years for 18 of the 20 on-orbit satellites. This also allowed schedule relief for GPS III and Next Generation Operational Control System (OCX) readiness dates as well as launch of the four remaining GPS IIF satellites. Detailed modeling and engineering analysis are used to predict thresholds and develop courses of action for launch of GPS satellites and constellation replenishment.

Nonetheless, risk is inherent in complex systems. The USAF maintains a mature enterprise risk program and manages several top-level risks that have the potential for schedule delays and degradation of PNT performance for military and civil users if the mitigation plans fail. The major risks to falling below the required constellation performance include delayed delivery of the first GPS III satellite (SV01), delays to the GPS III space operator crew mission readiness, and delayed implementation of OCX for control of legacy and GPS III satellites. In respective order, first, the USAF is mitigating remaining risks to the GPS III satellite development and delivery by managing the integrated baseline schedule and adjusting resources to address technical issues. Second, the USAF has revised the Mission Readiness Campaign to account for program perturbations and is confident in achieving on-time space operator crew mission readiness for launch and checkout. Third, the USAF has conducted engineering studies to identify alternative solutions for operations and sustainment of both legacy and next generation GPS satellites. In the event that OCX is not ready, the USAF identified critical milestones in the enterprise schedule that will trigger alternative plans to modify existing architecture to support operations until the OCX is fully operational.

In summary, risk is assessed as low to the GPS satellite constellation and the replenishment plan, based in part on implementation of Modified Battery Charging Control procedures and launch of the four remaining GPS IIF satellites. In addition, multiple independent teams of engineers, operators and technical managers use on-orbit data, detailed analyses and rigorous modeling to predict constellation sustainment and replenishment needs. These predictions are historically, and by design, conservative. Thus the USAF and broader GPS community are confident in the current predictions for functional availability and related launch schedule.

## 3. Report

The report is organized into eight sections (3.1-3.8) corresponding to the questions detailed in the congressional language on page 294 of House Report 113-446 (*Also included in the Introduction Section of this report).*

### *3.1. Current satellite and launch vehicle acquisition schedule*

With eight of twelve GPS IIF satellites now on-orbit, there are four GPS IIF satellites ready to launch into the operational constellation. The first GPS III satellite vehicle is expected to be available for launch in Calendar Year (CY) 2016, with Space Vehicles (SV) 02-08 on contract for delivery between CY2016 and CY2020. GPS III SV09 and beyond are not yet on contract. The GPS III SV09 is part of the FY15 President's budget requirement. The launch vehicle acquisition schedule is another key factor that determines the ability to

meet constellation replenishment needs. The acquisition schedule for GPS launch vehicles is approximately 24 months. Space and launch vehicle acquirers, planners and operators meet on a quarterly basis to coordinate space and launch vehicle integration.

**Table 1.** Space vehicle Initial Launch Capability (ILC) dates for GPS IIF and GPS III (as of 19 November 2014). Space vehicle ILC is the date that the space vehicle could be ready for launch, not the actual scheduled launch date according to the official launch manifest.

| Mission | Space Vehicle Initial Launch Capability |
|---|---|
| GPS IIF-9 | January 2015 |
| GPS IIF-10 | February 2015 |
| GPS IIF-11 | March 2015 |
| GPS IIF-12 | February 2015 |
| GPS III SV01 | September 2016 |
| GPS III SV02 | June 2017 |
| GPS III SV03 | December 2017 |
| GPS III SV04 | June 2018 |
| GPS III SV05 | December 2018 |
| GPS III SV06 | June 2019 |
| GPS III SV07 | December 2019 |
| GPS III SV08 | June 2020 |

*3.2. Cost advantages and disadvantages of maintaining a satellite and launch vehicle acquisition schedule as planned in the fiscal year 2014 President's budget (PB), as compared to the current schedule*

Maintaining an affordable constellation requires a fine balance of aligning replenishment requirements with an affordable, stable satellite production line. Maintaining the GPS constellation requires persistent satellite procurements while also preserving the ability to adjust production rates based on constellation need. The GPS reliability planning provides the necessary data to inform satellite production buy profiles ensuring an efficient production line that is aligned to meet constellation replenishment needs. Production rate adjustments seek to maximize production line savings and minimize storage costs from early-to-need satellites. While maintaining the FY14 PB schedule could result in decreased satellite cost in the near term, aligning production with replenishment needs may yield a more affordable constellation in the long term.

GPS III SV01-08 are currently on contract. In the FY14 PB, the buy profile for space vehicles (starting with GPS III SV09) was two vehicles in FY15, two vehicles in FY16, three in FY17, and three in FY18. In the FY15 PB, that space vehicle buy profile was changed to one vehicle in FY15, one in FY16, three in FY17, and three in FY18. The U.S. Air Force (USAF) is conducting market research to review the industrial base for GPS SVs to determine whether alternate sources exist for future GPS III SV production and to explore the possibility of competition. Fostering a competitive environment may reduce taxpayer burden by potentially encouraging production efficiency.

*3.3 Age, design life, and technical state of all on-orbit assets*

The USAF asserts that the GPS constellation is robust. The nominal GPS constellation consists of 24 satellites including GPS Blocks IIA, IIR, IIR-M and IIF. More than 24 satellites are on orbit to maintain the required 95% probability that 24 satellites are available for operations. To support this, the launch replenishment schedule is calculated using models and operational data of on-orbit satellites to predict end-of-life. Due to acquisition and replenishment planning and because several satellites have exceeded predicted end-of-life forecasts, there are currently 30 operational satellites that are "healthy," one satellite (SVN 69) in on-orbit checkout, and eight more in "residual/test" status (as of 19 November 2014). "Healthy" is defined as a technical state where the satellite is transmitting a navigation signal and is used to compute the PNT solution. "Unhealthy" is defined as a technical state where the satellite is not transmitting a navigation signal and is set off to all users. The term "residual/test" status is defined as a satellite that is partially functional but the signals are not part of the PNT solution. On-orbit GPS satellite vehicle age, design life, and current health are detailed in Table 2.

**Table 2.** GPS Satellite Vehicle Age, Design Life, and Technical State (as of 19 November 2014).

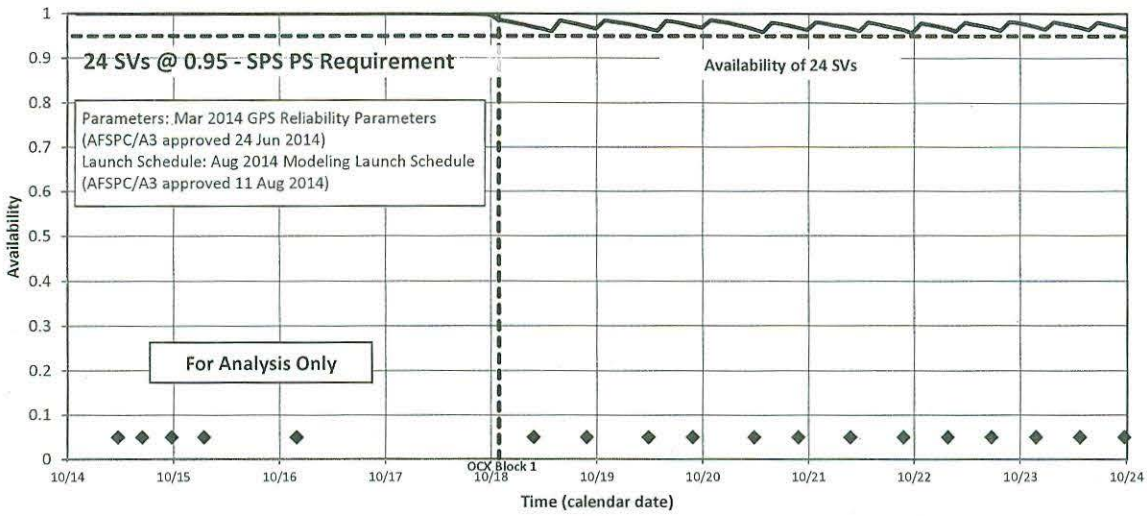
| GPS Block | GPS Space Vehicle | Vehicle Age (in years) | Vehicle Design Life (in years) | Technical State |
|---|---|---|---|---|
| GPS IIA | SVN23 | 24.0 | 7.5 | Healthy |
| GPS IIA | SVN26 | 22.4 | 7.5 | Healthy |
| GPS IIA | SVN27 | 22.2 | 7.5 | Unhealthy |
| GPS IIA | SVN32 | 22.0 | 7.5 | Unhealthy |
| GPS IIA | SVN34 | 21.5 | 7.5 | Healthy |
| GPS IIA | SVN35 | 20.7 | 7.5 | Unhealthy |
| GPS IIA | SVN36 | 17.0 | 7.5 | Unhealthy |
| GPS IIA | SVN37 | 21.1 | 7.5 | Unhealthy |
| GPS IIA | SVN38 | 17.3 | 7.5 | Unhealthy |
| GPS IIA | SVN39 | 21.2 | 7.5 | Unhealthy |
| GPS IIA | SVN40 | 21.4 | 7.5 | Healthy |
| GPS IIR | SVN41 | 18.3 | 7.5 | Healthy |
| GPS IIR | SVN43 | 15.1 | 7.5 | Healthy |
| GPS IIR | SVN44 | 11.6 | 7.5 | Healthy |
| GPS IIR | SVN45 | 13.8 | 7.5 | Healthy |
| GPS IIR | SVN46 | 14.0 | 7.5 | Healthy |
| GPS IIR | SVN47 | 11.8 | 7.5 | Healthy |
| GPS IIR | SVN51 | 14.3 | 7.5 | Healthy |
| GPS IIR | SVN54 | 10.9 | 7.5 | Healthy |
| GPS IIR | SVN56 | 14.5 | 7.5 | Healthy |

| | | | | |
|---|---|---|---|---|
| GPS IIR | SVN59 | 10.7 | 7.5 | Healthy |
| GPS IIR | SVN60 | 10.4 | 7.5 | Healthy |
| GPS IIR | SVN61 | 10.0 | 7.5 | Healthy |
| GPS IIR-M | SVN48 | 7.1 | 7.5 | Healthy |
| GPS IIR-M | SVN49 | 6.9 | 7.5 | Test |
| GPS IIR-M | SVN50 | 8.0 | 7.5 | Healthy |
| GPS IIR-M | SVN52 | 5.7 | 7.5 | Healthy |
| GPS IIR-M | SVN53 | 6.7 | 7.5 | Healthy |
| GPS IIR-M | SVN55 | 8.2 | 7.5 | Healthy |
| GPS IIR-M | SVN57 | 9.1 | 7.5 | Healthy |
| GPS IIR-M | SVN58 | 5.3 | 7.5 | Healthy |
| GPS IIF | SVN62 | 4.5 | 12 | Healthy |
| GPS IIF | SVN63 | 3.3 | 12 | Healthy |
| GPS IIF | SVN64 | 2.1 | 12 | Healthy |
| GPS IIF | SVN65 | 1.5 | 12 | Healthy |
| GPS IIF | SVN66 | 0.7 | 12 | Healthy |
| GPS IIF | SVN67 | 0.5 | 12 | Healthy |
| GPS IIF | SVN68 | 0.3 | 12 | Healthy |
| GPS IIF | SVN69 | 0.1 | 12 | Check Out |

### *3.4. Calculated functional availability as identified with planned launches*

The Department of Defense (DoD), USAF, Air Force Space Command (AFSPC), and the GPS Directorate remain committed to sustaining the Positioning, Navigation and Timing (PNT) mission capability at the required availability level. AFSPC produces an annual PNT Functional Availability Report (FAR) to inform future launch and budget planning and constellation sustainment considerations. Referring to Figure 1, the initial estimates indicate likely increases in the GPS IIR/IIR-M mean-life-estimate; however, these estimates have not yet been included in the AFSPC FAR update. The GPS constellation will maintain 95% probability of 24 operational satellites by launching approximately two GPS III satellites per year, starting no later than FY19 (not including the first GPS III satellite scheduled launch) and continuing through FY33.

**Figure 1.** GPS Constellation Functional Availability with planned launches as of 19 November 2014




*3.5. Risk assessment of not meeting the required functional availability*

The PNT FAR uses an annually AFSPC-approved set of quantitative measures for estimating functional success; these success criteria are derived from program requirement documents. To support constellation sustainment (both on-orbit re-positioning and launch of new satellites) and satellite procurement decisions, analysts use AFSPC-approved modeling software to probabilistically determine when satellites should be acquired. The software model is based on historical launch reliability, satellite reliability, and satellite operational data; the model generates statistics to estimate and quantify procurement risk in the form of system effectiveness parameters such as availability, outage, and probability of launch need. The software model has proven to be a reliable tool used for predicting constellation needs.

Specifically, the risk of not meeting the required functional availability is low due to replacement of GPS IIAs with GPS IIFs. The risk is estimated as low based on the utilization of modeling tools and forums to predict and monitor constellation risk. Further risk reduction is achieved by employing a strategy to nominally have at least one SV available to replenish the constellation in the event of a catastrophic failure. GPS IIAs are the highest risk satellites due to their age and normal satellite degradation. The acquisition and subsequent launch of GPS III satellites will address the mid-term risk of the aging GPS IIR and IIR-M satellites by replenishing the constellation and maintaining the minimum requirement of 95% availability of 24 on-orbit satellites.

*3.6. Options to lower the risk assessment, to include faster replenishment of satellites*

To maintain this service, the DoD and USAF employ a wide range of measures to ensure comprehensive risk management. These measures include semi-annual reviews and reports, on-orbit power management, use of auxiliary (broadcast GPS signals but not in one of the 24 primary slots) and residual satellites (refer to section 3.3), and launch schedule adjustments. Additionally, AFSPC manages a precise launch manifest management process to ensure high confidence on upcoming launches and to avoid launch schedule slips and

satellite availability gaps that could result in the delay of replenishment satellites and bringing new capabilities to users.

To mitigate the consequences of a potential launch or on-orbit failure, the USAF normally preserves a rapid replenishment capability by maintaining at least one additional satellite available for launch. Additionally, the constellation can be supplemented with auxiliary and residual satellites that may be re-positioned for operational use. Adjusting the launch schedule to accommodate earlier than planned launches is also an option. In addition, on-orbit implementation of the GPS IIR/IIR-M modified battery charging methodology is expected to extend the lifetime of 18 GPS satellites by at least one to two years each, effectively overcoming a drop in projected constellation availability.

Comprised of technical experts, operators, acquirers, and leaders from the Fourteenth Air Force (14 AF), AFSPC, Air Force Technical Applications Center (Nuclear Detonation Detection System), and the Federal Aviation Administration, among other stakeholders, the GPS Constellation Sustainment Assessment Team (CSAT) meets semi-annually to review the space launch manifest and current launch schedule (refer to Table 1), examine the health of the operational constellation (refer to Table 2), ensure user requirements are satisfied, and forecast GPS launch requirements. To meet requirements, the GPS CSAT members develop short-to-medium-range (up to 36 months) courses of action (routine and contingency) for the sustainment and replenishment of the GPS constellation for 14 AF. These courses of action consider on-orbit reliability and redundancy of individual satellite components and subsystems; the reliability models are updated with satellite performance data for each "tail number."

To increase overall constellation robustness and user accuracy, most of the auxiliary satellites are available for users full-time but are "paired" with other satellites with known failed components to minimize the user impact if one satellite in the pair fails unexpectedly. Essentially, two partially degraded satellites that are operationally capable are paired in close proximity so in the event one satellite becomes non-operational the other satellite can be inserted into the constellation and assume the role of the failed satellite. A satellite is maintained as an on-orbit auxiliary only if it can still provide users the expected level of performance, does not degrade the overall constellation, and is not in danger of failing in such a manner as to prevent proper disposal.

*3.7. National security impact if the necessary capability is not provided*

If the threshold for the availability requirement of 95% probability of 24 satellites is breached, then civil and military users will experience degraded PNT performance. The impacts increase corresponding to the severity of the loss in capability and the duration of time required to replenish the constellation. Many factors contribute to the successful delivery of PNT solutions and the application to civil and military users including the number of satellites, the quality and accuracy of their timing, the ability to command and control the satellites, and the capability of the civil and military receivers. Specific to the GPS satellite constellation, a reduction in the number of satellites from 24 to 18 would have significant impacts. The ability to meet the 95% probability of four satellites in view would still be met,

pending orbital maneuvering to ensure requisite coverage; nonetheless, fewer satellites would degrade GPS accuracy worldwide. Accounting for the time required to procure satellites, a failure to maintain a 24 satellite constellation could result in years of degraded PNT before recovering to normal PNT performance. This would incur additional military, commercial, and civil infrastructure costs to compensate for the loss of reliable GPS PNT service. One of the greatest impacts to military operators would be navigation accuracy and degraded geo-location accuracy for air, land, sea and space operations. The degraded accuracy would extend beyond military application and would affect civilian technologies that rely on GPS, such as precision navigation, civil aviation, maritime and water-way navigation, precision agriculture and fishing, financial transactions, cell phones, surveying and mapping, wild-life research, mining and construction, land-based public transportation, U.S. border management, time-stamping, and approximately two billion users worldwide that rely on the U.S. for PNT which directly supports national prestige.

*3.8. Risks of further schedule delays to the planned satellite and launch schedule*

The USAF assesses the overall risk of further schedule delays to the planned satellite and launch schedule as low. The USAF maintains a mature enterprise risk program and manages several top-level risks that have the potential for schedule delays and degradation of PNT performance for military and civil users if the mitigation plans fail. The major risks to falling below the required constellation performance include delayed delivery of the first GPS III satellite (SV01), delays to the GPS III space operator crew mission readiness, and delayed implementation of OCX for control of legacy and GPS III satellites. In respective order, the USAF is mitigating remaining risks to the GPS III satellite development and delivery by managing the integrated baseline schedule and adjusting resources to address technical issues. Second, the USAF has revised the Mission Readiness Campaign to account for program perturbations and is confident in achieving on-time space operator crew mission readiness for launch and checkout. Third, the USAF has conducted engineering studies to identify alternative solutions for operations and sustainment of both legacy and next generation GPS satellites. In the event the OCX is not ready, the USAF identified critical milestones in the enterprise schedule that will trigger alternative plans to modify existing architecture to support operations until the OCX is fully operational.

The risk assessment of not meeting required functional availability is low to meet the commitment to maintain a 95% probability that the GPS constellation will have at least 24 operational satellites as specified in the GPS Standard Positioning Service Performance Specification (2008). The most significant risks remaining are those common to all space systems, including catastrophic failure of on-orbit satellites, catastrophic launch failure, and legacy ground system vulnerabilities. To mitigate this risk and keep it low, the CSAT process is used to recommend updates to the schedule as needed. The implementation of Modified Battery Charging Control procedures on IIR and IIR-M satellites, the launch out of remaining GPS IIF satellites by FY16, and the extensive expert assessment of constellation sustainment needs provides prudent margin to accommodate schedule slips to GPS III while also maintaining the 95% probability of 24 satellites well into the future.

## 4. Conclusion

The DoD is committed to sustaining the PNT mission capability at the required availability level. The USAF has provided uninterrupted PNT service at or above the required level of performance through continuance of the 95% availability of 24 operational GPS satellites on-orbit. To maintain the GPS services at the required availability, the DoD and USAF employ a wide range of measures to ensure comprehensive risk management. In order to assure GPS coverage for civil and military users, the U.S. must continue to commit the necessary resources. Overall risk is assessed as low to the GPS constellation and replenishment plan. Thus the USAF is confident in the current predictions for functional availability and the related launch schedule.

# Distribution

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