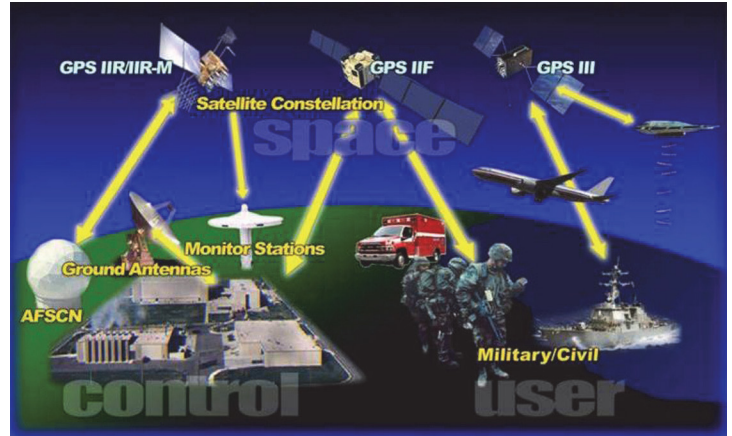


Global Positioning System (GPS) Enterprise

Executive Summary

- The Air Force conducted significant developmental test and evaluation (DT&E) for all three GPS enterprise segments (space, control, and user) in 2016, but did not conduct any operational testing for the GPS enterprise in 2016. DT&E included GPS III thermal vacuum test and post-thermal vacuum system performance and electromagnetic compatibility testing, Next Generation Operational Control System (OCX) Launch Checkout System DT&E, and the second of five phases of DT&E for Military GPS User Equipment (MGUE) Increment 1.
- Expected operational testing dates for all segments have been delayed from dates listed in prior DOT&E Annual Reports and the Enterprise Test and Evaluation Master Plan (ETEMP), approved by DOT&E in March 2012.
- The ETEMP requires an update to reflect test strategy, schedule, and resource changes due to segment delays, acquisition strategy changes, policy and threat changes, and the initiation of the GPS III Contingency Operations (Cops) program. An updated ETEMP is in Military Service coordination with formal OSD review expected early 2017.
- Delays to the OCX have worsened since the FY14 DOT&E Annual Report, and the post-Nunn-McCurdy recertified, restructured OCX program cannot deliver OCX Block 1 in time for operational constellation sustainment. The Air Force has initiated the Cops program to enable employment of GPS III, using a subset of their capabilities, satellites to sustain the operational constellation prior to OCX availability.
- Significant GPS Enterprise risks remain:
 - Ongoing risk that OT&E of GPS III satellites will not occur until after as many as eight of the satellites are built and on-orbit, increasing the risk that deficiencies will not be discovered until it is too late to correct them.
 - Ongoing risk that insufficient platform integration will occur in time for the operational assessment (OA) of MGUE Increment 1, jeopardizing acquisition decisions made on the basis of that OA.
 - Ongoing risk that the DOD has not assessed the degree to which designated Lead Platforms for MGUE Increment 1 cover the range of operational factors and integration challenges for the complete portfolio of DOD programs that will integrate MGUE Increment 1, and that Lead Platform and MGUE Increment 1 limitations will impede the pathfinding value of integration and OT&E on those platforms.
 - Ongoing risk to the integration and fielding of MGUE Increment 1 with the DOD portfolio posed by the lack of a plan for comprehensive risk-reduction integration testing with all platforms, munitions, and platform interfaces expected to integrate MGUE Increment 1.



AFSCN – Air Force Satellite Control Network
 GPS IIR – Global Positioning System (GPS) Block II “Replenishment” Satellites
 GPS IIR-M – GPS Block II “Replenishment – Modernized” Satellites
 GPS IIF – GPS Block II “Follow-On” Satellites
 GPS III – GPS Block III Satellites

- Risk to adequate OT&E of MGUE Increment 1 posed by the apparent gap between the Air Force intent for delivered MGUE Increment 1 functional capabilities and Military Service operational environment-driven performance requirements.
- Risk to sustainment of the operational GPS constellation posed by inadequate resource prioritization and commitment to ensure successful, low-risk execution of the Cops program, and the absence of independent active monitoring of Cops development progress.

System

- The GPS enterprise is an Air Force-managed, satellite-based radio navigation system of systems that provides military and civil users accurate position, velocity, and time within the multi-trillion cubic kilometer volume of near-earth space, earth atmosphere, and worldwide earth surface areas.
- The current GPS enterprise consists of three operational segments:
 - Space Segment – The GPS spacecraft constellation consists of a minimum of 24 operational satellites in semi-synchronous orbit. The Air Force has successfully launched 70 GPS satellites and currently operates 31 healthy GPS satellites, comprising Block IIR (1997-2004), Block IIR-M (2005-2009), and Block IIF (2010-present).
 - Control Segment – The GPS control segment consists of primary and backup GPS master control stations, satellite control antennas, a pre-launch satellite compatibility station, and geographically-distributed operational monitoring stations. The current GPS control segment includes the Operational Control System

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(OCS)/Architecture Evolution Plan (AEP) supporting (1) operation of GPS Block IIR, IIR-M, and IIF satellites, (2) Selective Availability/Anti-Spoof Module capabilities in U.S. military and authorized Federal and allied military GPS User Equipment, the Launch/Early Orbit, Anomaly Resolution, and Disposal Operations (LADO) system, and the Selective Availability Anti-Spoofing Module (SAASM) Mission Planning System (SMPS).

- User Segment – There are many versions of military GPS mission receivers fielded on a multitude of operational systems and combat platforms, including the most common Defense Advanced GPS Receivers and embedded Ground-Based GPS Receiver Application Modules (GB-GRAM), numbering in the hundreds of thousands.
- In 2000, the DOD approved initiation of a GPS enterprise modernization effort to include upgrades to all three segments, along with new civil and military signals (M-code). In addition to replenishment of the satellite constellation, this modernization is intended to improve both military and civil signal integrity and service quality in terrain- and geography-impeded environments, as well as in the presence of unintentional and deliberate interference. Modernized GPS enterprise improvements include:
 - Space Segment – GPS III satellites, an Acquisition Category (ACAT) 1D program, have a design life exceeding that of earlier blocks. GPS III satellites are intended to be capable of transmitting a fourth civil signal and higher-powered M-code, as well as all legacy military and civil navigation signals of previous satellite blocks.
 - Control Segment – OCX, an ACAT 1D program to be delivered in three blocks, replaces the current OCS/AEP control segment and LADO, is backward compatible with Block IIR and later satellites, and will interface with modified SMPS versions. OCX is intended to provide significant cybersecurity improvements over OCS, and through OCX Block 0 the ability to launch and check out GPS III satellites, through OCX Block 1 the ability to control GPS Block II and III satellites, and through OCX Block 2 the full control of modernized civil and M-code signals and navigation warfare functions.
 - User Segment – MGUE Increment 1 is an ACAT 1D program and Increment 2 is a pre-Major Defense Acquisition Program, expected to be ACAT 1D. MGUE Increment 1 includes the GB-GRAM-Modernized form factor for ground and low-dynamic platforms such as small unmanned aircraft systems, and the GRAM-Standard

Electronic Module-E/Modernized for maritime and aviation applications. The MGUE Increment 2 Capability Development Document is in development and presumed to address requirements and applications not addressed by MGUE Increment 1, including handheld, precision-guided munition, and standard space receiver applications.

- Delays in OCX Block I delivery led the Air Force in 2015 to initiate the COps program as a “bridge capability” to enable employment of GPS III satellites, using only legacy signals, for operational constellation sustainment until OCX Block 1 is available.

Mission

- Combatant Commanders, U.S. military forces, allied nations, and various civilian agencies rely on GPS to provide highly accurate, real-time, all-weather, position, navigation, and time information to operational users worldwide. GPS provides force enhancement for combat operations and military forces in the field on a daily basis throughout a wide variety of global strategic, operational, and tactical missions.
- Appropriately equipped military forces will employ modernized GPS capabilities to (1) determine or contribute to their determination of their location and velocity, (2) support precision munitions targeting and employment, and (3) synchronize operations and secure communications in all environments.

Major Contractors

- Space Segment
 - Block IIR/IIR-M/III satellites: Lockheed Martin Space Systems – Denver, Colorado
 - Block IIF satellites: Boeing, Network and Space Systems – El Segundo, California
- Control Segment
 - OCS: Lockheed Martin, Space Systems Division – Colorado Springs, Colorado
 - OCX: Raytheon Company, Intelligence, Information, and Services – Aurora, Colorado
 - COps: Lockheed Martin, Space Systems Division – Colorado Springs, Colorado
- User Segment (MGUE Increment 1)
 - L-3 Communications/Interstate Electronics Corporation – Anaheim, California
 - Raytheon Company, Space and Airborne Systems – El Segundo, California
 - Rockwell Collins – Cedar Rapids, Iowa

Activity

- The Air Force conducted significant DT&E for all three enterprise segments in 2016, including GPS III thermal vacuum test and post-thermal vacuum system performance and electromagnetic compatibility testing, OCX Launch Checkout System DT&E, and the second of five phases of DT&E for

MGUE Increment 1. It did not conduct any operational testing for the GPS enterprise in 2016.

- Expected operational testing dates for all three segments have been delayed from dates listed in the current ETEMP approved in March 2012, and in prior DOT&E Annual Reports. Those

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schedule changes resulted from development and delivery delays for all segments, as well as from Lead Platform integration-related delays caused or exacerbated by MGUE Increment 1 development delays and management decisions.

- OCX cost and schedule exceedance led to a Nunn-McCurdy Act program review and recertification.
- The Air Force currently expects to conduct operational tests for each GPS segment as follows:
 - The planned OA of MGUE Increment 1 has slipped to late 2017, primarily due to the immaturity of MGUE Increment 1 initial test articles and delayed delivery of follow-on test articles. That planned OA was previously accelerated from late 2016 to late 2015 to support a planned USD(AT&L) combined Milestone B/C decision under an accelerated schedule approved in the MGUE Increment 1 Acquisition Strategy Document (ASD). USD(AT&L) now plans to conduct a Milestone B-only Defense Acquisition Board for MGUE Increment 1 in early 2017, and it is unclear what post-Milestone B or Beyond Low-Rate Initial Production (BLRIP) decisions will occur for MGUE.
 - The planned IOT&E of MGUE Increment 1 has slipped to 2019 through 2020. This IOT&E will involve data gathered during testing in four separate operational utility evaluations (OUEs) of MGUE Increment 1 on the four designated Lead Platforms. The Air Force had previously accelerated the IOT&E from 2021 to 2017, to support the USD(AT&L) planned BLRIP decision for MGUE Increment 1, based on the schedule approved in the MGUE Increment 1 ASD.
 - The planned OUE of OCX Block I has slipped from early 2016, to early 2019, and now to no sooner than mid-2022, with low confidence in that schedule. This OUE was to combine with an OUE of GPS III satellite vehicle (SV)01 to support an Air Force fielding decision for OCX Block 1 and operational acceptance of GPS III SV01.
 - A December 2015 USD(AT&L) Acquisition Decision Memorandum directed a restructure and 24-month extension for OCX Block 1 delivery, to between mid-2021 and mid-2022. Indications of critical cost and schedule breaches led to a June 2016 Secretary of the Air Force Nunn-McCurdy notification for OCX to Congress.
 - In October 2016, USD(AT&L) recertified a restructured OCX program, rescinded the OCX Milestone B, and directed the Air Force to return for a Milestone B Defense Acquisition Board no later than June 30, 2017. The Air Force plans to propose an Acquisition Program Baseline with a mid-2022 delivery of OCX Block 1.
 - The OCX Block 1 delivery and GPS III SV01 delivery and launch are no longer aligned. The initial GPS III OUE, excluding test of modernized signals, will now occur concurrently with the OUE of COps, which must be developed and fielded to allow employment of GPS III satellites with legacy-only capability to sustain the operational constellation of 24 GPS satellites.
 - The Cops OUE is currently planned for mid-2019, concurrent with the OUE of GPS III SV01, in support of a Program Executive Officer Space (Commander, Air Force Space and Missile Systems Center) limited fielding decision for COps and a Commander, Air Force Space Command operational acceptance decision for COps.
- An initial GPS III OUE is currently planned for mid-2019, concurrent with the OUE of COps, in support of a USD(AT&L) limited fielding decision for GPS III SV01 excluding use of modernized GPS signals, and a Commander, Air Force Space Command operational acceptance decision for GPS III SV01, using legacy-only signals. Post-thermal vacuum chamber defect discovery on GPS III SV01 delayed the satellite's availability-for-launch, but it will still likely be ready for launch before the OCX Block 0 control segment will be ready to support GPS III launch and checkout.
- Multi-Service OT&E (MOT&E) of the modernized GPS enterprise has slipped to an indeterminate date beyond 2022, and will be required after delivery of OCX Block 2-associated navigation warfare and modernized signal and messaging functions, supporting a fielding decision for OCX Block 2 and/or operational acceptance decisions for those capabilities. GPS Enterprise MOT&E was previously planned for 2020, but can occur no earlier than the delivery of OCX Block 2-associated functions.
- Although the GPS Program Office continues to support Service platform program office efforts to incorporate keyed military GPS receivers in their weapons, and the Services have made progress increasing integration of, training with, and reliance on keyed military receivers, the Joint Navigation Warfare Center-compiled data show many DOD weapon systems continue to use non-military receivers and some forces fail to routinely key and train with keyed military receivers.
- The next revision of the GPS ETEMP remains in coordination within the Air Force and Service Operational Test Agencies, and the Air Force plans to submit it for formal OSD review in early 2017. The approved GPS ETEMP is over 4 years old, and is outdated, but revision has been delayed by significant fluctuation in all enterprise segment delivery and availability schedules, as well as the OCX and MGUE acquisition strategies, and initiation of COps.

Assessment

- No OT&E test data are available at this point.
- In the FY14 Annual Report, DOT&E cited concerns identified in DOT&E's November 2014 memorandum to USD(AT&L) regarding sustainment and modernization of GPS capabilities. Those concerns remain valid, with some mitigation:
 1. OCX delays limit adequate, timely OT&E for GPS III satellites prior to extensive procurement and incorporation of the GPS III satellites into the operational constellation.
 2. Deferred platform integration jeopardizes adequate MGUE Increment 1 OA and risks late deficiency discovery.
 3. There is limited pathfinding value to Lead Platform testing compared to the represented portfolio of platforms.
 4. Limiting MGUE integration funding for each Lead Platform to the first available MGUE Increment 1 vendor card risks

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limiting post-IOT&E competition and delays to MGUE Increment 1 fielding throughout the DOD portfolio.

5. There is inadequate articulation of program risks. This is being addressed. The Air Force has acknowledged the numerous schedule and performance risks to GPS outlined in this report; mitigation of those risks is incomplete.
 6. The program schedules are inaccurate, implausible, and incoherent. This is being addressed. The Air Force has established a plausible schedule for MGUE Increment 1, with the exception of undefined Milestone Decision Authority (MDA) decisions for BLRIP activities on Lead Platforms and non-Lead Platforms. The GPS enterprise schedule appears to better reflect facts-in-being for each segment modernization effort.
 7. The Air Force has overstated MGUE development maturity. This point has been demonstrated by the poor performance of initial MGUE Increment 1 test articles during the first phase of government DT&E in late 2015. MGUE Increment 1 has demonstrated marginal technical maturity and platform interoperability improvements to-date.
- In a January 2016 memorandum to the SECDEF, DOT&E identified concerns with the risk to U.S. GPS capability posed by delays to OCX and inadequate prioritization and resource allocation for COps development. DOT&E recommended that the SECDEF direct the Air Force to prioritize resources to ensure successful COps execution and require COps progress reporting in quarterly OCX reports to the Comptroller General, to facilitate active monitoring. The Air Force included cursory information but no detailed COps status in its first two quarterly OCX reports.
 - In a January 2016 memorandum to USD(AT&L), DOT&E recommended against approving a combined Milestone B and C for MGUE Increment 1, stated that MGUE Increment 1 testing to-date did not indicate that current designs could be produced and would work, and that MGUE interoperability risk remained substantial and unmitigated. DOT&E further recommended expanded risk-reduction integration testing with all platforms, munitions, and platform interfaces expected to integrate MGUE Increment 1, and completion of DT&E and an adequate OA prior to USD(AT&L)'s Milestone C decision. USD(AT&L) has not approved MGUE Increment 1 Milestones B or C and has postponed until January 2017 the Milestone B Defense Acquisition Board previously scheduled for October 2016. USD(AT&L) has not directed, and the Air Force has not elected to conduct the DOT&E-recommended expanded risk-reduction testing.
 - In a July 2016 memorandum to the SECDEF, DOT&E reiterated the urgent need for greater focus on COps, to ensure its availability to sustain GPS operations, and recommended the Air Force prioritize and commit resources to ensure successful, low-risk execution of the COps program and active monitoring of COps development progress. COps remains on DOT&E oversight and has not been placed on USD(AT&L) oversight.
 - At the time of this report, the MGUE Increment 1 program is preparing for a Milestone B Defense Acquisition Board review with USD(AT&L). DOT&E concerns include:
 1. The mismatch between the approved MGUE Increment 1 ASD, actual program execution, and the ETEMP-described acquisition and test strategies as well as the need for clarification on planned acquisition decisions. Specifically, DOT&E requires clarity on the criteria and timing of acquisition milestone decisions which will allow MGUE Increment 1 and derived components to be fielded on Lead Platforms and non-Lead Platforms. This is needed in order to recommend an appropriate OT&E strategy to provide assessment in support of fielding decisions.
 2. The absence of a plan to assess MGUE Increment 1 performance across the wide variety of intended interfaces and platforms leaves significant unmitigated integration risk, and therefore fielding cost and schedule risk for the DOD.
 3. An apparent gap between MGUE Increment 1 functional capabilities and Military Service operational requirements. For example, Army requirements for the D3/Stryker's operational environment exceed Air Force-planned MGUE Increment 1 functional capabilities. This jeopardizes the adequacy of MGUE Increment 1 OT&E on the D3/Stryker Lead Platform.
 - When the Air Force returns in mid-2017 for the post-Nunn-McCurdy Milestone B Defense Acquisition Board, it plans to propose a mid-2022 delivery of OCX Block 1. The program's ability to deliver OCX Block 1 on that schedule, if possible, will be dependent on the successful execution of several test strategy and test resource changes. These changes include implementation of planned automated software testing, increases in contractor and Program Office skilled software subject matter expertise, and procurement of additional software development and testing environments to address resource constraints within and between GPS segments.
 - Additional OT&E of MGUE will be required for non-Lead Platforms integrating MGUE and covering operational and environmental conditions for MGUE not evaluated during planned Lead Platform testing.
 - Additional OT&E of all M-code-capable satellite blocks will be required once an M-code-capable control segment and user equipment are available, prior to the operational employment of M-code signals from those satellites. The M-code capabilities of GPS Block IIR, IIR-M, and IIF satellites have not previously been operationally tested, and should be included in OT&E, along with GPS Block III M-code capabilities, once OCX is available to support testing.
- ### Recommendations
- Status of Previous Recommendations. The Air Force has partially addressed the five previous recommendations listed in the FY11 Annual Report:
 1. There has been no opportunity thus far for end-to-end testing of OCX with MGUE receivers, and the ETEMP requires revision to reflect updated planning for the MOT&E of the modernized GPS enterprise, which will address end-to-end testing. The Air Force does not have a plan for adequate integration on representative platforms

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to enable timely OT&E in representative environments in support of acquisition and fielding decisions. The Air Force should continue to plan for end-to-end testing of the GPS enterprise, including integration on Lead Platforms and non-Lead Platforms, and DT&E and OT&E in realistic operational environments, in time to support acquisition decisions.

2. The Air Force has improved synchronization of the development of the Space, Control, and User segments, in that descriptions of the effect of delays in each segment upon the GPS enterprise and other segment schedules are more often clearly articulated. Delays in MGUE Increment 1 and OCX Block 1 will result in their delivery after most of the first block of GPS III satellites are built and launched. The Air Force should ensure that status and critical interdependencies of each enterprise segment are well understood, and should promptly assess and disseminate to all stakeholders those predicted enterprise impacts resulting from forecast changes in segment schedules.
3. The revised ETEMP still in Service coordination reflects improvements in planning for comprehensive and realistic cybersecurity testing of the GPS enterprise, although additional revisions will be necessary to reflect GPS segment changes and DOT&E's August 2014 guidance, Procedures for Operational Test and Evaluation of Cybersecurity in Acquisition Programs. The Air Force should continue to refine its cybersecurity testing approach to GPS.
4. The Military Services have made progress in emphasizing/enforcing the use of crypto-keyed GPS receivers, but should redouble their efforts, in accordance with Joint Navigation Warfare Center and United States Strategic Command recommendations.
5. The Military Services have made progress in developing concepts of operations and tactics, techniques, and procedures for keying GPS receivers, but that has not translated into use of encrypted receivers for all military operations.
- The Air Force has partially addressed the seven recommendations listed in the FY14 Annual Report:
 1. If COps is delivered as planned, it will support a partial OT&E of the first GPS III satellite, but substantial risk of undiscovered deficiencies will remain until completion of GPS III OT&E when OCX Block 2 is available. The Air Force should still mitigate this risk.
 2. The Air Force now intends to include data from integration and DT&E of MGUE Increment 1 on at least some Lead Platforms in an OA informing as-yet-undetermined MGUE Increment 1 acquisition decisions. The Air Force plans to propose at the next MGUE Defense Acquisition Board adoption of multiple "Technical Requirements Verification" decisions in lieu of a Milestone C decision for the program. The Air Force should still plan for an adequate OA encompassing integration and DT&E on at least one Lead Platform per form factor to inform these acquisition decisions.
3. The Air Force is continuing the engineering, manufacturing, and development of MGUE Increment 1, and resumed government DT&E in mid-2016, but has no plan or direction to conduct comprehensive integration and interoperability testing on non-Lead Platforms to determine MGUE Increment 1 integration maturity. The Air Force should still plan for and conduct comprehensive risk-reduction integration testing with all platforms, munitions, and platform interfaces expected to integrate MGUE Increment 1.
4. The Air Force has no plan to assess the degree to which designated Lead Platforms for MGUE Increment 1 cover the range of operational factors and integration challenges for the complete portfolio of DOD platforms each MGUE form factor is intended to support. The Air Force believes the DOD should conduct this assessment, but that it is out of scope for the MGUE program. USD(AT&L) should direct the Air Force or another organization to conduct this assessment.
5. The Air Force does not plan to ensure each available MGUE Increment 1 vendor solution for a given form factor is integrated with all Lead Platforms for that respective form factor to support adequate MGUE IOT&E. The Air Force has recommended a "first card" strategy, in which each Lead Platform will integrate and complete DT&E and OT&E with the first vendor card available, with no provision for the follow-on integration and testing of the other vendor cards as each becomes available. The Air Force should still pursue an "each card" strategy, integrating and testing each MGUE Increment 1 vendor solution on applicable Lead Platforms as soon as those vendor solutions are available.
6. The Air Force has identified risks to the GPS enterprise and has articulated plans of action and milestones for the mitigation of some risks, but not all. The Air Force should still identify and articulate mitigation plans for all significant risks to the GPS enterprise, in particular, for the risk that COps will not be delivered in time to support constellation sustainment.
7. The Air Force has improved the coherence of its GPS enterprise schedule information, but these schedules are not always updated to reflect the most current government estimates, nor caveated to reflect un-validated assumptions. The Air Force should maintain and disseminate coherent, accurate, and timely schedule information for all segments, ensuring the schedules reflect segment interdependencies, most current government estimates, and caveats for un-validated assumptions.
- FY16 Recommendation.
 1. The Air Force should prioritize and commit resources to ensure successful, low-risk execution of the COps program, and ensure active independent monitoring of COps development progress.

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