

Global Positioning System (GPS) Enterprise

Executive Summary

- The Air Force conducted significant development for all three enterprise segments in 2014, including component testing for GPS III and prototype risk-reduction testing for Military GPS User Equipment (MGUE) Increment 1, but did not conduct any operational testing for the GPS enterprise in 2014.
- Expected operational testing dates for all three segments have changed from those listed in the current Enterprise Test and Evaluation Master Plan (ETEMP) approved in March 2012.
- Significant delays to the Next Generation Operational Control System (OCX) pose risks to the Air Force’s ability to sustain the operational GPS constellation, as the Air Force may require operational use of GPS III satellites before OCX Block 1 is available to control those satellites. The Air Force is developing plans for a contingency operations capability.
- Other concerns include:
 - OCX delays add risk that OT&E will not discover GPS III satellite deficiencies until it is too late to correct them.
 - The Air Force’s current plan for operational assessment of the MGUE Increment 1 will not provide sufficient data to support an informed Milestone C decision by USD(AT&L), adding risk to that decision.
 - Air Force and Army-requested MGUE Increment 1 Lead Platform changes will reduce the pathfinding value of Lead Platform testing, and the Air Force’s proposed MGUE Increment 1 source selection approach may reduce post IOT&E competition and delay fielding of MGUE to non-Lead Platforms.
 - The Air Force is not mitigating several significant risks to the GPS enterprise, including the potential loss of a critical industrial production capability, the unfunded need for overseas monitoring stations, indications of receiver-host platform integration and compatibility problems, and sustainment of the de facto 27-satellite operational constellation.
 - Air Force GPS enterprise schedules provided to DOT&E and other OSD components are not accurate, current, or consistent with GPS segment schedules.
 - The Air Force has requested that USD(AT&L) waive the requirement for the MGUE Increment 1 operational assessment (OA). Failure to conduct an OA prior to the Milestone C decision for MGUE Increment 1 would add significant risk to the program.

System

- The GPS enterprise is an Air Force-managed, satellite-based radio navigation system-of-systems that provides worldwide military and civil users accurate position, velocity, and time.



- 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 over 65 GPS satellites and currently operates over 30 healthy GPS satellites, comprised of Block IIA (launched 1990-1996), 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, the Operational Control System (OCS) supports (1) operation of GPS Block IIF and legacy satellites, (2) Selective Availability/Anti-Spoof Module capabilities in GPS User Equipment, and (3) Launch/Early Orbit, Anomaly Resolution, and Disposal Operations.
 - **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 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

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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 that far exceeds that of all earlier blocks. GPS III will 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, replaces the current OCS/Architecture Evolution Plan control segment and is backward compatible with Block IIR and later satellites. OCX will provide (1) control of GPS III satellites and legacy signals, (2) full control of modernized civil and M-code signals, and (3) significant cybersecurity improvements over OCS.
- User Segment – MGUE Increments 1 and 2 are pre-Major Defense Acquisition Programs expected to be ACAT 1D. MGUE Increment 1 includes the Ground-Based GPS Receiver Application Module-Modernized (GB-GRAM-M) form factor for ground and low-dynamic platforms such as small unmanned aircraft systems, and the GPS Receiver Application Module-Standard Electronic Module-E/Modernized (GRAM-S/M) for maritime and aviation applications. MGUE Increment 2 requirements are 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.

Mission

- GPS is a global utility, integral to U.S. national security, economic growth, transportation safety, homeland security,

and the world's economic infrastructure. It is U.S. national policy to provide continuous worldwide access to GPS, for peaceful civil uses, and to employ GPS to satisfy U.S. civil and national security needs.

- Combatant Commanders, U.S. military forces, allied nations, and various civilian agencies rely on GPS to provide highly-accurate, real-time, all-weather, 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.
- Properly 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 Space and Intelligence Systems – Seal Beach, California
- Control Segment
 - OCS: Lockheed Martin – Colorado Springs, Colorado
 - OCX: Raytheon Company, Intelligence, Information and Services – Aurora, Colorado
- User Segment (MGUE Inc 1)
 - L-3 Communications/Interstate Electronics Corporation– Anaheim, California
 - Rockwell Collins – Cedar Rapids, Iowa
 - Raytheon Company – El Segundo, California

Activity

- The Air Force conducted significant development for all three enterprise segments in 2014, including component testing for GPS III and prototype risk-reduction testing for MGUE Increment 1, but did not conduct any operational testing for the GPS enterprise in 2014.
- Expected operational testing dates for all three segments have changed from those listed in the current ETEMP approved in March 2012, as indicated below. Those schedule changes result from development and delivery delays to GPS III and OCX, and from Air Force-proposed changes to the MGUE Increment 1 Acquisition Strategy, as well as from Air Force and Army-proposed changes to their Service-nominated Lead Platforms for MGUE Increment 1.
- The Air Force currently expects to conduct operational tests for each GPS segment as follows:
 - OA of MGUE Increment 1 accelerated from late 2016 to late 2015, to support USD(AT&L)'s combined Milestone B/C decision for MGUE Increment 1, under an accelerated Air Force-proposed schedule.
 - IOT&E of MGUE Increment 1 accelerated from 2021 to 2017, to support USD(AT&L)'s Beyond Low-Rate Initial Production decision for MGUE Increment 1, leading to procurement and fielding of MGUE Increment 1 components by the Services, for their respective platforms.
 - The Operational Utility Evaluation of OCX Block I and GPS III satellite vehicle (SV) 01 slipped from early 2016 to early 2019, supporting an Air Force fielding decision for OCX Block 1 and operational acceptance of GPS III SV01.
 - Multi-service OT&E of the modernized GPS enterprise in 2020, including OCX Block II and all associated navigation warfare and modernized signal and messaging functions testing, supporting an Air Force fielding decision for OCX Block II.
- The next revision of the GPS ETEMP is in coordination within the Air Force and with Service Operational Test Agencies; DOT&E expects to receive the revised ETEMP in early 2015 for OSD approval, and it should describe developmental T&E (DT&E) and OT&E to take place in 2015 and beyond. The

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ETEMP will require further revision to incorporate updated development and test planning assumptions entailed by changes to all three GPS enterprise segment schedules, and to describe OT&E for any contingency capability developed to operate GPS III satellites prior to the availability of OCX Block I.

Assessment

- No OT&E test data are available at this point.
- DOT&E's November 2014 memorandum to USD(AT&L) identified several significant concerns regarding sustainment of the GPS enterprise and execution of GPS enterprise modernization.
 - Impact of OCX delays on GPS III OT&E. OCX delays add risk that OT&E will not discover GPS III deficiencies until it is too late to correct them. OCX Block 1 is needed to operate and support OT&E of GPS III satellites. The schedule delays for OCX Block I delivery will delay OT&E of GPS III until after at least six, and as many as eight, GPS III satellites have been built and launched. This introduces significant risk that effectiveness and suitability deficiencies in GPS III satellites will not be discovered until it is too late to prevent their introduction to the operational constellation.
 - Risk to the MGUE Increment 1 OA. The Air Force's current plan for the MGUE Increment 1 OA will not provide sufficient data to support an informed Milestone C decision by USD(AT&L), adding risk to that decision.
 - The Air Force has proposed an accelerated acquisition strategy for MGUE Increment 1, which combines Milestones B and C, and eliminates the engineering, manufacturing, and development phase, requiring earlier execution of the OA for MGUE Increment 1. The Air Force does not currently intend to integrate MGUE Increment 1 onto any Lead Platforms prior to the scheduled OA in 2015. DOT&E informed the Air Force in December 2013 that an adequate OA for MGUE Increment 1 should encompass integration and developmental test of at least one Lead Platform per MGUE form factor being evaluated. This shortfall will significantly reduce the OA's utility in informing the Milestone C decision.
 - The Air Force MGUE risk-reduction activities to-date with the RQ-11B Raven small unmanned aircraft system have had mixed results, which underscore substantial remaining challenges for MGUE integration on other platforms, and reinforce the need for an adequate OA.
 - Lead Platform Changes and Source Selection. Air Force and Army-requested Lead Platform changes will reduce the pathfinding value of Lead Platform testing, and the Air Force's proposed MGUE Increment 1 source selection approach may reduce post IOT&E competition and delay fielding of MGUE to non-Lead Platforms.
 - MGUE Increment 1 Lead Platforms are pathfinders, intended to represent the operational environment and integration challenges for all DOD platforms using those respective form factors. The four Service-nominated Lead Platforms identified in the MGUE Increment 1 Capabilities Development Document are:
 - The RQ-11B Raven (Army) and Joint Light Tactical Vehicle (Marine Corps) for the GB-GRAM-M form factor
 - The F-15E (Air Force) and DDG-51, *Arleigh Burke* class destroyer (Navy) for the GRAM-S/M form factor.
 - The U.S. Army and Air Force recently requested to replace their designated Lead Platforms with the Defense Advanced GPS Receiver Distributed Device-equipped Stryker family of vehicles and the B-2 Spirit, respectively. This changes the range of integration challenges and operational factors that can be evaluated prior to a Beyond Low-Rate Initial Production decision, and may reduce the degree to which the Lead Platforms are able to "pathfind" for non-Lead Platforms. In turn, this may increase the integration challenges and OT&E requirements for non-Lead Platforms and ultimately delay fielding of MGUE Increment 1 receivers for the rest of the DOD.
 - The Air Force-proposed MGUE Increment 1 Acquisition Strategy source selection approach entails each Service selecting only a single vendor solution, from among the multiple vendor solutions that may be certified and available, to integrate with their Lead Platforms and undergo OT&E. There are two possible, undesirable outcomes to this strategy.
 - The two lead platforms for each MGUE form factor choose the same vendor. This leads to adequate operational testing of the single vendor chosen but inadequate operational testing of any other MGUE vendor solutions, reducing post-IOT&E competition.
 - The two lead platforms for each MGUE form factor choose different vendors. This leads to inadequate operational testing for each MGUE vendor solution because the IOT&E will not have tested any solution across the widest possible range of operational environments and integration challenges for that form factor. This could result in higher integration costs and will drive expanded OT&E for non-Lead Platforms that subsequently integrate MGUE Increment 1.
 - Inadequate Articulation of Risks. The Air Force is not mitigating several significant problems as risks to the GPS enterprise. Examples include:
 - The potential sale to foreign ownership of the only U.S. trusted foundry producing the application-specific integrated circuits for MGUE Increment 1, which would impede development and production of MGUE Increment 1.
 - The descoped and unprogrammed provision of M-code monitoring stations outside the continental U.S., which would impede M-code anomaly detection and resolution.

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- Observed MGUE Increment 1 thermal, power, and interface implementation, which may adversely affect integration with host platforms.
- Risk to the probability of sustaining availability of a 27-satellite operational constellation, which has become the de facto expected standard of service for military GPS users due to its benefit for terrain-impeded users.
- Inaccurate, Implausible, and Incoherent Schedules. Air Force schedules for the GPS enterprise, provided in support of OSD acquisition decisions, reflect timelines for integration and test of MGUE Increment 1 that have not been endorsed by the responsible Lead Platform program offices or operational test agencies. Independent and OSD reviews have identified a lack of accuracy, currency, and coherence in GPS enterprise schedules, which negatively affects effective program management and oversight.
- Overstatement of MGUE Development Maturity. The Air Force requested in November 2014 that USD(AT&L) waive the requirements for Critical Design Review and OA of MGUE Increment 1, on the premise of technical maturity in the MGUE Increment 1 program. Based on the results of risk-reduction activities to date, and historical experience with complex and challenging host platform integration, MGUE Increment 1 has not demonstrated technical maturity that would warrant waiver of these critical assessment functions.

Recommendations

- Status of Previous Recommendations. The Air Force has partially addressed the five previous recommendations listed in the 2011 Annual Report:
 1. There has been no opportunity thus far for end-to-end testing of OCX with MGUE receivers, but the ETEMP incorporates planning for the Multi-service OT&E of the modernized GPS enterprise, which will address end-to-end testing. The Air Force is not yet planning for adequate integration on representative platforms to enable timely OT&E in representative environments in support of well-informed 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 DT&E and OT&E in realistic operational environments, in time to support acquisition decisions.
 2. Synchronization of the development of the Space, Control, and User segments has only marginally improved. Descriptions of the impact of delays in each segment upon the GPS enterprise and other segment schedules are often not clearly articulated. 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 now in Service coordination reflects clear 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 2013 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 Services have made progress in emphasizing/enforcing the use of crypto-keyed GPS receivers, but should redouble their efforts.
- 5. The 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.
- FY14 Recommendations. The Air Force should:
 1. Mitigate the risks to the GPS enterprise associated with delays to OCX delivery and the inability to conduct OT&E of GPS III SV01 prior to the launch of as many as eight GPS III satellites.
 2. Integrate and conduct DT&E of MGUE Increment 1 on at least one Lead Platform per form factor in time to support an OA informing MGUE Increment 1 Milestone C.
 3. Continue the engineering, manufacturing, and development of MGUE Increment 1 until it has demonstrated maturity in both functional performance and integration with host platforms.
 4. 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.
 5. 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.
 6. Identify and articulate a mitigation plan of action and milestones for all significant risks to the GPS enterprise.
 7. Maintain and disseminate coherent, accurate, and timely schedule information for all segments of the GPS enterprise, ensuring that each segment schedule and the enterprise master schedule reflect interdependencies between segments. Ensure these segment and enterprise schedules reflect the most current government estimates and are caveated to reflect any un-validated assumptions.