

Global Positioning System (GPS) Enterprise

Executive Summary

- The Air Force conducted developmental test and evaluation (DT&E) for all three GPS enterprise segments (space, control, and user) in 2018. DT&E included the GPS III Satellite Vehicle (SV) 01 Mission Readiness Test, Next Generation Operational Control System (OCX) Launch and Control/Checkout System (or Block 0) testing, and Military GPS User Equipment (MGUE) Increment 1 circuit card testing.
- The Lead Developmental Test and Evaluation Organization (LDTO) has done commendable work managing the breadth of developmental testing activities, emerging test requirements (such as the OCX Block 0 cyber test), and significant changes to test plans.
- The Program Office conducted a cybersecurity test, including developmental and operational test objectives, of the OCX Block 0 baseline with a National Security Agency-certified Red Team.
- Schedule slips have caused operational testing delays for all GPS segments from dates listed in prior DOT&E Annual Reports.
- The Program Office updated the Enterprise Test and Evaluation Master Plan (ETEMP) Revision B to reflect acquisition strategy changes, capture schedule and resource changes due to segment delays, and define the initial strategy for contested space testing. DOT&E approved the ETEMP in September 2018.
- While the Air Force has made progress across the segments, significant GPS Enterprise operational risks remain:
 - Ground control delays will limit adequate and timely operational testing for the full capabilities of GPS III satellites prior to extensive procurement and incorporation of the satellites into the operational constellation.
 - GPS III lacks sufficient test resources for realistic operational space segment threat testing.
 - The MGUE program continues to face challenges implementing the new technology, resulting in repeated delays to development of final software and hardware builds by all three MGUE vendors.
 - Ongoing MGUE Lead Platform test schedule slips increase integration risks for platforms seeking to implement MGUE before Lead Platform testing is complete.

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 near-Earth space, Earth atmosphere, and worldwide Earth surface areas.
- The current GPS enterprise consists of three operational segments:



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

- **Space Segment** – The GPS spacecraft constellation consists of satellites in semi-synchronous orbit. The Air Force has successfully launched 70 GPS satellites and currently operates 31 operational GPS satellites. The operational constellation is comprised of Block IIA (1990-1997), Block IIR (1997-2004), Block IIR-M (2005-2009), and Block IIF (2010-2016).
- **Control Segment** – The GPS control segment consists of primary and backup GPS master control stations, satellite ground antennas, a pre-launch satellite compatibility station, and geographically distributed monitoring/tracking stations. The GPS control segment includes: the Operational Control System (OCS)/Architecture Evolution Plan (AEP), which supports operations of the current satellite constellation; the Launch/Early Orbit, Anomaly Resolution and Disposal Operations (LADO) system; the Selective Availability/Anti-Spoof Module (SAASM) Mission Planning System (SMPS); and OCX Block 0, which will launch and initialize GPS III satellites.
- **User Segment** – There are many versions of military GPS mission receivers fielded on a multitude of operational systems and combat platforms, including the Defense Advanced GPS Receivers and embedded Ground-Based GPS Receiver Application Modules (GB GRAM), numbering in the hundreds of thousands.
- In 2000, the Air Force initiated 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 will improve both military and civil signal

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integrity and service quality. Modernized GPS enterprise improvements include:

- Space Segment – The Air Force intends for the GPS III satellites, an Acquisition Category (ACAT) 1C program, 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. The Air Force plans for 10 GPS III satellites and subsequently 22 GPS III Follow-On Production (GPS IIIF) satellites, which will have enhancements such as regional military protection, laser retro-reflector arrays for better on-orbit position determination, and a redesigned nuclear detonation detection system.
- Control Segment – The Air Force plans to deliver OCX, an ACAT 1D program, in three blocks. OCX will replace OCS and LADO, be backward compatible with legacy/modernized satellites, and interface with updated SMPS versions. OCX Block 0 will launch and initialize GPS III satellites, while OCX Block 1 will command and control GPS Block II and III satellites. OCX Block 2 (now merged and scheduled concurrently with the OCX Block 1 delivery) will provide full control of modernized civil and M-code signals and navigation warfare functions. OCX is intended to provide significant cybersecurity improvements over OCS.
- User Segment – MGUE Increment 1 is an ACAT IC program and, currently, Increment 2 is a pre-Major Defense Acquisition Program. MGUE Increment 1 includes the GB-GRAM-Modernized form factor for ground and low-dynamic platforms and the GRAM Standard Electronic Module-E/Modernized for maritime and aviation applications.
- Due to delays in OCX Block 1 delivery, the Air Force initiated the GPS III Contingency Operations (COps) program as

a “bridge capability” or risk mitigation effort to enable employment of GPS III satellites using legacy (pre-M-Code) signals for operational constellation sustainment until OCX is delivered. Additionally, M-Code Early Use (MCEU) will deliver early operational use of core M-Code, with full M-Code functionality delivered in OCX Block 1 and 2.

Mission

Combatant Commanders of U.S. and allied military forces use GPS to provide accurate, position, navigation, and time information to operational users worldwide. GPS also supports myriad non-military users worldwide.

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
 - Block IIIF satellites: Lockheed Martin – Denver, Colorado
- Control Segment
 - OCS, COps, and MCEU: Lockheed Martin, Space Systems Division – Colorado Springs, Colorado
 - OCX: Raytheon Company, Intelligence, Information, and Services – Aurora, Colorado
- User Segment (MGUE Increment 1)
 - L3 Technologies/Interstate Electronics Corporation – Anaheim, California
 - Raytheon Company, Space and Airborne Systems – El Segundo, California
 - Rockwell Collins – Cedar Rapids, Iowa

Activity

- The Air Force conducted DT&E for all three GPS enterprise segments (space, control, and user), but did not conduct operational testing in 2018. Testing included the GPS III SV01 Mission Readiness Test, OCX Block 0 testing, and MGUE Increment 1 card testing.
- Schedule slips have caused operational testing delays for all GPS segments from dates listed in prior DOT&E Annual Reports. The Air Force plans to begin operational testing of the space, ground, and user segments in 2019.
- The Program Office updated the ETEMP Revision B to reflect acquisition strategy changes, incorporate the GPS III COps and MCEU test strategies, capture schedule and resource changes due to segment delays, and define the initial strategy for contested space testing. DOT&E approved ETEMP Revision B in September 2018.
- GPS Enterprise segment activity includes:

OCX

- The Program Office conducted a cybersecurity test, including DOT&E-approved operational cyber test objectives, of the OCX Block 0 baseline with a National Security Agency-certified Red Team. The cybersecurity test combined elements of developmental and operational cybersecurity test objectives.
- The Milestone Decision Authority approved the OCX Milestone B in September 2018.
- The Air Force Operational Test and Evaluation Center (AFOTEC) will conduct OT&E of OCX in 2023 as part of a GPS Enterprise Multi-Service OT&E (MOT&E) that will include OCX, GPS III, and MGUE. This will inform both the Positioning, Navigation, and Timing (PNT) Initial Operating Capability (IOC) as well as the Constellation Management IOC.

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GPS III COps

- AFOTEC is planning operational testing of COps in October 2019, concurrent with GPS III SV01 operational tests.

MCEU

- Shortly after contract approval, the Air Force modified the contract to address M-Code “hot start” requirements for GPS receivers. Hot start is the capability of M-Code receivers to initialize legacy GPS receivers with data derived from a modernized navigation signal. Initial hot start capability only requires changes to the MGUE cards. The Program Office intends to implement an enterprise hot start capability with a more enduring, coded solution in the ground, space, and user segments.
- AFOTEC plans to conduct operational testing of MCEU in 2020.

GPS III and GPS III Follow-On Production

- The first of 10 GPS III satellites is scheduled to launch in December 2018. In August 2018, the Air Force declared the second GPS III satellite fully tested and available for launch.
- In February 2018, the Air Force released its request for proposals to acquire 22 GPS IIIIF satellites. The contract was awarded to Lockheed Martin in September 2018.

MGUE

- In order to begin platform integration testing with the MGUE receiver cards, the Services have been conducting bench and chamber developmental testing activities to understand how the host applications perform under various environmental and electromagnetic conditions.
- The Program Office conducted a developmental field test of MGUE card maturity in July 2018. Test findings will inform MGUE card development and support preparations for MGUE Lead Platform developmental field testing scheduled to begin in 2019.
- MGUE Lead Platform OT&E will include data collection from separate MGUE Increment 1 Operational Utility Evaluations on the four designated Service Lead Platforms. MGUE OT&E will be followed by the GPS Enterprise MOT&E in 2023 and will include OCX, GPS III, and MGUE.
- The MGUE Increment 1 Acquisition Decision Memorandum directed the Air Force to provide the MGUE Increment 2 Acquisition Strategy, and the Air Force submitted the Increment 2 Acquisition Strategy to the Milestone Decision Authority in November 2018.

Assessment

- The Air Force has improved the GPS enterprise schedule by addressing schedule and performance risks; however, articulation of program risks with stakeholders continues to be incomplete, increasing the probability of unmitigated risks causing further program problems and delays.
- The Air Force made efforts to integrate the GPS space, ground, and user segments; however, there are still major disconnects in the synchronization of the enterprise segments

due to technical problems, development delays, and a lack of integrated strategies.

- The LDTO developed an initial outline of the test strategy for contested space in the recently signed ETEMP Revision B; however, significant work needs to take place to identify specific strategies to address space threats. AFOTEC needs to develop test methodologies, operational threat scenarios, and measures for operational testing of threats against the GPS space segment.
- The LDTO managed the breadth of developmental testing activities, emerging test requirements (such as the OCX Block 0 cyber test), and significant changes to test plans.
- Assessment of the GPS Enterprise segments follows:

OCX and COps/MCEU

- Ground control delays will limit adequate and timely operational testing for the full capabilities of GPS III satellites prior to extensive procurement and incorporation of the GPS III satellites into the operational constellation.
- The OCX Program Office and LDTO leaned forward to conduct cybersecurity testing of the OCX Block 0 system. Additionally, the combined effort between developmental and operational testers provided beneficial lessons on agile, efficient testing. The testing suggested areas for needed cybersecurity hardening and the necessity to better characterize the defense posture of the full system.
- Since the 2016 Nunn-McCurdy OCX review, the Program Office has attempted to reduce future schedule risk by increasing manpower, improving system engineering and configuration management processes, and evolving its testing approach. While there has been improvement, it is unclear the Air Force has enough satellite simulator test resources to conduct developmental testing on GPS III COps and OCX in parallel, which is required to keep these programs on the current schedule.

GPS III and GPS IIIIF

- GPS III lacks sufficient test resources for realistic operational space segment threat testing.
- The Program Office is planning for the GPS IIIIF Non-flight Satellite Testbed (GNST+) in the GPS IIIIF program; however, GNST+ will not provide full capability for realistic threat testing. The program plans to conduct environmental testing; but, it is not currently planning for sufficient test articles to support full characterization of adversary threats against the system.
- The Air Force has proposed a Milestone C decision in 2020, before any GPS IIIIF satellites will be developed or tested. Additionally, the delay in publishing an enterprise strategy makes it difficult to plan for upgrades of GPS capability.

MGUE

- The MGUE program continues to face challenges implementing the new technology, resulting in repeated delays to development of final software and hardware builds by all three MGUE vendors.
- Development of “hot start” capabilities will add to MGUE cost and schedule, with each Service having differing

operational requirements that could result in varying implementation needs across the DOD.

- Due to thermal performance problems with one MGUE vendor circuit card, the Army and Marines are not planning to test that vendor card in their respective MGUE GPS Lead Platforms. This leaves only two vendor cards for testing in the ground lead weapons platforms, reducing the available comparison data from vendor card performance that the LDTO and AFOTEC will be able to provide for other DOD weapons platform integration decisions.
- Ongoing MGUE Lead Platform test schedule slips increase integration risks for platforms seeking to implement MGUE before Lead Platform testing is complete. The utility of the Lead Platforms to act as pathfinders will also diminish due to these delays. The U.S. Strategic Command

(USSTRATCOM) Joint Navigation Warfare Center's expertise and assessments are an important resource for navigation warfare testing and to more broadly assess MGUE integration across the DOD operational envelope.

Recommendations

The Air Force should:

1. Comprehensively test the GPS III satellite against on-orbit threats with operationally representative test articles and simulators.
2. Leverage the USSTRATCOM Joint Navigation Warfare Center's expertise and assessments to more broadly assess MGUE integration across the DOD operational envelope.