

Global Positioning System (GPS) Enterprise

Executive Summary

- The GPS Enterprise continues to experience program delays in two of its three segments (the user terminal and satellite control segments). The Military GPS User Equipment (MGUE) Increment 1 program – the user segment – will re-baseline the Air and Maritime cards to incorporate delays by the end of 2020. The control segment continues to experience delays to the Next Generation Operational Control System (OCX) due to hardware and software problems and the coronavirus (COVID-19) pandemic.
- The Space Force conducted operational testing on the current Operational Control Segment (OCS), which included Contingency Operations (Cops) and M-code Early Use (MCEU). Cops and MCEU were necessary software upgrades to the OCS required by the delay in the delivery of OCX. Cops and MCEU performed well during operational testing.
- DOT&E has identified the following significant GPS Enterprise operational risks:
 - More work is needed to comprehensively replicate cybersecurity threats to determine their effects on the Enterprise to include mitigation efforts and a comprehensive strategy to counter those threats.
 - The MGUE Increment 1 program continues to experience delays integrating the new technology into the lead platforms and in developing final software and hardware builds by MGUE vendors.
 - Ongoing schedule slips to OCX, to include a 10-month delay for the hardware replacement effort and up to a 2-month delay for COVID-19, increases the probability of conflicts between the baseline OCX program and the OCX 3F program necessary to operate the GPS IIRF satellites.

System

- The GPS Enterprise is a satellite-based global radio navigation system of systems that provides military and civil users accurate position, velocity, and time.
- The GPS Enterprise consists of three operational segments:
 - Space Segment – The GPS spacecraft constellation consists of satellites in medium Earth orbit. The current constellation consists of 31 operational satellites comprised of Block IIR (launched from 1997-2004), Block IIR-M (2005-2009), Block IIF (2010-2016), and GPS III (first launched in 2018) satellites.
 - Control Segment – The GPS control segment consists of primary and alternate GPS master control stations, satellite ground antennas, a pre-launch satellite compatibility station, and geographically distributed monitoring/tracking stations. The GPS control segment includes:



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

- The OCS/Architecture Evolution Plan, which the U.S. Space Force’s 2nd Space Operations Squadron uses to operate the GPS satellite constellation
- The Launch, Anomaly, and Disposal Operations (LADO), which previously launched the IIF satellites and currently supports anomaly resolution and disposal operations for the legacy Block II satellites
- The Launch and Checkout Capability (LCC)/Launch and Checkout System (LCS), which launches and initializes GPS III satellites
- The Selective Availability/Anti-Spoof Module (SAASM) Mission Planning System (SMPS), which provides U.S. Space Command the capability to task navigation warfare effects in support of the Combatant Commanders
- User Segment – Various models of military GPS mission receivers are fielded on a multitude of operational systems and combat platforms.
- Modernized GPS Enterprise improvements include:
 - Space Segment – The current operational constellation includes three GPS III satellites. The GPS III Space vehicles deliver better accuracy, provide improved anti-jamming capabilities, and transmit a fourth civil signal to enable interoperability with other international global navigation satellite systems. The satellites also use a higher powered M-code signal for military use, as well as all legacy military and civil navigation signals of previous satellite blocks. The Space Force plans to acquire 10 GPS III satellites and subsequently 22 GPS III Follow-On Production (GPS IIRF) satellites. GPS IIRF will have enhancements such as regional military protection signals, support for search and rescue services, laser retro-reflector

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arrays for better on-orbit position determination, and a dual band commanding capability to further command flexibility via Unified S-band.

- Control Segment – The Space Force plans to deliver OCX, which is the command and control component of the next generation GPS, in several increments, starting with Block 0 installed at the LCC/LCS in 2017. OCX will replace OCS and command all modernized and legacy satellites, and interface with updated SMPS versions. OCX Block 1 will command and control GPS Block II and III satellites. OCX Block 2 (now merged and scheduled concurrently with OCX Block 1 delivery) will provide full control of modernized civil and M-code signals and navigation warfare functions. OCX is intended to provide cybersecurity improvements over OCS. OCX Block 3F will fly the GPS IIF spacecraft once available. Due to delays with OCX, the Space Force delivered two software upgrades to OCS: COps and MCEU. COps allows the OCS to command and control the new GPS III satellites and MCEU allows OCS to task, upload, and monitor M-code on the GPS constellation.
- User Segment – MGUE is a joint Service program developed to modernize military GPS receivers. The MGUE program is split into two increments. MGUE Increment 1 includes the GB-GRAM-Modernized form factor for the ground and low dynamic platform domains and the GRAM-Standard Electronic Module-E/Modernized (GRAM-S/M) for the maritime and aviation domains. MGUE Increment 1 performs the same core functions (signal acquisition and tracking, position, time, velocity determination, and host interfaces) as legacy GPS user equipment, but it delivers the M-code capability to the user equipment, which will improve GPS signal availability in degraded threat environments. The Air Force approved MGUE Increment 2 in November 2018 as two separate Middle Tier of Acquisition/Section 804 programs of record. Under MGUE Increment 2, the Space Force will develop (1) the Miniaturized Serial Interface form factor with a smaller Next Generation Application-Specific Integrated

Circuit (ASIC) as core GPS receiver technology to support low-power applications, such as guided munitions, and address the MGUE Increment 1 ASIC obsolescence; and (2) the joint modernized handheld receiver end-item, which improves anti-jam and anti-spoof capabilities during acquisition and tracking, as well as provides longer battery life.

- Due to delays in OCX Blocks 1 and 2 delivery, the Air Force delivered and operationally accepted the COps upgrade in March 2020, as a “bridge capability”/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, OCS MCEU will deliver operational use of core M-code, with full M-code functionality delivered in OCX Blocks 1 and 2. Space Force is expected to operationally accept MCEU in November 2020.

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 a myriad of non-military users worldwide.

Major Contractors

- Space Segment
 - Block IIR/IIR-M/III/IIF satellites: Lockheed Martin Space Systems – Denver, Colorado
 - Block IIF satellites: Boeing, Network and Space Systems – El Segundo, California
- Control Segment
 - OCS, COps, and MCEU: Lockheed Martin Space Systems Division – Denver, Colorado
 - OCX: Raytheon Technologies, Intelligence, Information, and Services – Aurora, Colorado
- User Segment (MGUE Increment 1)
 - L3Harris Technologies, Inc. – Anaheim, California
 - Raytheon Technologies, Space and Airborne Systems – El Segundo, California
 - BAE Systems – Cedar Rapids, Iowa

Activity

- All operational testing is in accordance with the GPS Enterprise Test and Evaluation Master Plan (E-TEMP) approved by DOT&E on September 13, 2018.
- Schedule slips in development of the ground and control GPS segments have caused operational testing delays from dates listed in prior DOT&E Annual Reports. Operational testing was completed in 2020 on two software upgrades to OCS: COps and MCEU. These are stop-gap capabilities due to delays in delivery of OCX. MGUE Increment 1 card delays have pushed operational testing to FY21.
 - In FY20, the Space Force conducted developmental test and evaluation (DT&E) for the space, control, and user

segments. Testing included the Mission Readiness and On-Orbit Checkout Tests for GPS III satellites 02 and 03, integrated system of tests for GPS III/COps and MCEU, early OCX Block 1 testing, and MGUE Increment 1 card-level testing in the labs and also integrated into two lead platform vehicles.

- The Program Office is revising the GPS E-TEMP to address an updated space threat test strategy, cyber testing, concurrent delivery of OCX Blocks 1 and 2, MGUE Increment 2, an upgraded Nuclear Detonation Detection System control system, GPS IIF satellites, and OCX Block 3F.

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COVID-19

- The GPS Enterprise was affected by COVID-19 during FY20, which resulted in testing delays and development schedule slips.
 - The OCX program reported a 4 to 10-week schedule slip due to constraints within work spaces and self-isolation. OCX worldwide monitoring station deployments and testing have been affected by travel restrictions imposed by other countries resulting in a 3-month delay.
 - The MGUE Increment 1 program experienced delays to DT&E activities in spring 2020 due to travel restrictions and quarantine requirements. Temporary closures of the labs and personnel constraints have contributed to schedule slips of ongoing card-level testing and development and delivery.

Control Segment

- The U.S. Space Force Star Delta Provisional Detachment 4 currently plans to conduct OT&E of OCX in FY23 during the GPS Enterprise Multi-Service OT&E (MOT&E) that will include OCX and GPS III satellites. Operational testing will be conducted to support OCX Operational Acceptance following transition of constellation control from OCS to OCX, followed by full M-code MOT&E to include M-code user segment systems. The MOT&E will inform both the Positioning, Navigation, and Timing Initial Operating Capability (IOC) as well as the Constellation Management IOC.
- Detachment 4 completed operational testing of COps in February 2020, concurrent with GPS III SV01 operational testing. The Space Force operationally accepted COps in March 2020.
- MCEU operational testing began in August 2020 and completed in October 2020. MCEU testing was conducted to verify the OCS could task, upload, and monitor M-code within the GPS constellation. Control Segment testing will include the six worldwide distributed GPS M-code capable monitoring stations. MCEU results were not completed at the time of the annual report.

Space Segment

- The Air Force, and subsequently the Space Force, successfully launched the first 3 of 10 GPS III satellites into orbit in 2018, 2019, and 2020, respectively. The satellites have undergone successful checkout and have now operationally joined the GPS constellation.
- In 2018, the Air Force contracted Lockheed Martin to build 22 GPS IIIIF satellites. The first GPS IIIIF satellite will be available for launch no later than 2028, but current estimates forecast 2026.

User Segment

- In 2018, the Air Force Service Acquisition Executive approved the MGUE Increment 2 acquisition strategy. This approval resulted in the release of a draft Request for Proposal announcement for the MGUE Increment 2 receiver card in 2019 and expected contract award in FY21.

- The Program Office completed system-level developmental testing with MGUE Increment 1 cards integrated into the two ground lead platforms.
- MGUE OT&E will be followed by the two-phase GPS Enterprise MOT&E in FY23, with the second phase incorporating user equipment, using both lead and non-lead platforms.

Assessment

- The Space Force has improved the GPS Enterprise planning by addressing schedule and performance risks; however, articulation of program risks with OSD stakeholders continues to be incomplete, increasing the probability of unmitigated risks causing further program delays.
- The Lead Developmental Test Organization is effectively managing the breadth of developmental testing activities, emerging test requirements, and significant changes to test plans; however, due to the Space and Missile Systems Center reorganization, the staff has taken on more responsibilities and activities leading to delays in planned revisions to the E-TEMP.

Control Segment

- OCX had delays in Product Test completion and increased discrepancy reports within Segment Integration, along with delays in contractor equipment deliveries have driven increasingly tight and compressed developmental testing schedules.
- Operational Acceptance expected by the Space Force occurred in November 2020.

Space Segment

- GPS space vehicles lack requirements to address cybersecurity survivability threats; however, that does not preclude the need for operational testing against the full characterization of adversary threats against the system.
- The Program Office continues to develop a space threat plan to address adversary threats against the system as directed in DOT&E's "Guidance on Threat Representation in Operational Testing and Evaluation of Space Systems" memorandum, dated September 24, 2019.
- The Air Force made the GPS IIIIF Milestone C decision in July 2020 based on completion of Critical Design Review, prior to development or testing of any GPS IIIIF satellites. The first launch is expected in 2026 due to the high level of commonality of GPS III and GPS IIIIF satellites. Acquiring sufficient test articles is imperative to test the satellites prior to launch.
- With the advice and assistance of DOT&E, Detachment 4 conducted cybersecurity testing on the GPS III satellite simulator in October 2020.

User Segment

- The MGUE Increment 1 program continues to face challenges meeting the aviation and maritime technical requirements.

- Ongoing delays of final software and hardware builds by MGUE Increment 1 vendors continue to cause delays to MGUE Increment 1 lead platform test schedules, which increases the risk for platforms seeking to implement MGUE before lead platform testing is complete. Due to imminent closure of the production line, final purchases of MGUE Increment 1 ASIC technologies from the trusted foundry production lines have been completed, prior to full completion of testing to verify the ASIC's operational performance.

Recommendations

The Space Force should:

1. Continue to plan to conduct operational testing of the GPS Enterprise against current and emerging space threats to assess the ability of the system and its operators to support DOD missions in a contested space environment.
2. Improve the process to inform users of GPS across the DOD of GPS Enterprise test results and schedule delays, to enable users to plan for integration of new GPS capabilities.
3. Conduct regular Enterprise-wide testing events to gauge GPS ability to support the warfighter using the new M-code capabilities. This will provide insight into the status of each segment relative to the others and the M-code capabilities the overall system will provide to the warfighter.
4. Provide the expected availability of the M-code capabilities to the warfighter, including the availability of MGUE cards for operational use.
5. Conduct a threat specific test or MOT&E-like event involving a no-notice transfer to the Alternate Master Control Station to verify system survivability.
6. Include cyber survivability requirements into all future acquisition programs to ensure systems can address and respond to adversarial threats.