Global Positioning Systems Directorate

GPS Status & Modernization Progress: Service, Satellites, Control Segment, and Military GPS User Equipment

ICG-10, Boulder CO

2 Nov 15

Col Shawn M. Brennan
GPS Transition Director
Global Positioning Systems Directorate
Global Positioning Systems Directorate

"We are... the Green Monsters!"

Mission:
Professionals acquiring, delivering and sustaining reliable GPS capabilities to America's warfighters, our allies, and civil users.

Col Steve Whitney
Director
GPS Overview

Civil Cooperation
- 1+ Billion civil & commercial users worldwide
- Search and Rescue
- Civil Signals
  - L1 C/A (Original Signal)
  - L2C (2nd Civil Signal)
  - L5 (Aviation Safety of Life)
  - L1C (International)

Department of Defense
- Services (Army, Navy, AF, USMC)
- Agencies (NGA & DISA)
- US Naval Observatory
- PNT EXCOMS
- GPS Partnership Council

International Cooperation
- 57 Authorized Allied Users
  - 25+ Years of Cooperation
- GNSS
  - Europe - Galileo
  - China - Beidou
  - Russia - GLONASS
  - Japan - QZSS
  - India - IRNSS

Spectrum
- World Radio Conference
- International Telecommunication Union
- Bilateral Agreements
- Adjacent Band Interference
- International Committee On Global Navigation Satellite Systems (GNSS)

Department of Transportation
- Federal Aviation Administration

Department of Homeland Security
- U.S. Coast Guard

39 Satellites / 31 Set Healthy
Baseline Constellation: 24 Satellites

<table>
<thead>
<tr>
<th>Satellite Block</th>
<th>Quantity</th>
<th>Average Age</th>
<th>Oldest</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS IIA</td>
<td>2</td>
<td>23.4</td>
<td>24.8</td>
</tr>
<tr>
<td>GPS IIR</td>
<td>12</td>
<td>13.7</td>
<td>18.2</td>
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<tr>
<td>GPS IIR-M</td>
<td>7</td>
<td>8.2</td>
<td>10.0</td>
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<tr>
<td>GPS IIF</td>
<td>10</td>
<td>2.1</td>
<td>5.3</td>
</tr>
<tr>
<td>Constellation</td>
<td>31</td>
<td>9.3</td>
<td>24.8</td>
</tr>
</tbody>
</table>

AS OF 1 OCT 15

Satellite Block Quantity Average Age Oldest
GPS IIA 2 23.4 24.8
GPS IIR 12 13.7 18.2
GPS IIR-M 7 8.2 10.0
GPS IIF 10 2.1 5.3
Constellation 31 9.3 24.8

Maintenance/Security
- All Level I and Level II
  - Worldwide Infrastructure
  - NATO Repair Facility
- Develop & Publish ICDs Semi-Annually
  - ICWG: Worldwide Involvement
- Update GPS.gov Webpage
- Load Operational Software on over 970,000 SAASM Receivers
- Distribute PRNs for the World
  - 120 for US and 90 for GNSS

International Cooperation
- 57 Authorized Allied Users
  - 25+ Years of Cooperation
- GNSS
  - Europe - Galileo
  - China - Beidou
  - Russia - GLONASS
  - Japan - QZSS
  - India - IRNSS
• Block IIA satellites, 2 Operational, 7 Spare
• Block IIR satellites, 12 Operational
• Block IIR-M satellites, 7 Operational, 1 Spare
• Block IIF satellites, 10 Operational
• Oldest Satellite is SVN23; will be 25 Yrs Old, Nov 15

• U.S. Government continuously assessing constellation optimization to determine launch need

*Current as of 23 Oct 15
**GPS IIF**

- 10 total GPS IIFs on-orbit
- Mission IIF-11 launch planned for 30 Oct 15
- Mission IIF-12 launch planned for 7 Oct 15

**Most aggressive GPS launch schedule since 1993**
GPS III

- GPS III is the newest block of GPS satellites
  - 4 civil signals: L1 C/A, L1C, L2C, L5
    - First satellites to broadcast common L1C signal
  - 4 military signals: L1/L2 P(Y), L1/L2M

- SV01-SV08 on contract; SV09 & SV10 approved
  - 2 year delay due to technical challenges w/ payload

- SV01 System Module Core Mate completed 7 Apr 15

- Mission Data Unit software qualification complete 6 Aug 15

- SV-level thermal vacuum started Oct 15

- SV01 “available for launch” Aug 2016
• Competing GPS III SV11+ Production
  – Drive down space vehicle costs by promoting effective competition
  – Mitigate reliance on single navigation payload vendor
  – Reduce production cost and schedule risk with minimal design phase

• Two-phase acquisition approach allows contractors time to mature designs
  – GPS III SV11+ Production Readiness Feasibility Assessment (Phase 1)
    • Gain insight into contractor-funded space vehicle and navigation payload production design maturity and risk
    • Full and open competition
    • Up to 3 Firm-Fixed Price contracts, $6M per source (incl/ options)
    • Request For Proposal release 1QFY16 with contract awards in 3QFY16
  – GPS III SV11+ Follow-on Production Competition (Phase 2)
    • Acquisition strategy to be informed by Feasibility Assessment performance and results
    • Notional full and open competition for up to 22 satellites
    • Projected award in FY18
Ground Segment

• **Architecture Evolution Plan (AEP)**
  – Day-to-day command and control of up to 31 satellites
  – 4 dedicated Ground Antennas and AFSCN capability
  – 6 dedicated and 10 NGA Monitor Stations

• **Launch, Anomaly Resolution, and Disposal Operations (LADO)**
  – Day-to-day command and control residual satellites using AFSCN
  – State-of-health monitoring
  – Leverage for some vehicle emergencies
  – Launch prep and initial post-launch operations
  – Satellite end of life disposal operations
• **Modernized command & control system**
  – GPS III command & control
  – M-Code
  – Robust cyber security infrastructure
  – Modern civil signals & monitoring
  – Improved PNT performance

• **Prime: Raytheon (Aurora, CO)**

• **OCX Block 0: launch & checkout for GPS III**
  – Currently in test
  – Successfully completed seven launch exercises/simulations

• **OCX Block 1: replaces AEP, adds modern features**
  – Currently in design and risk reduction testing prior to restart of coding

• **OCX Block 2: adds advanced NAVWAR and Civil Signal Performance Monitoring capabilities**
Accuracy: Civil Commitments
Standard Positioning Service (SPS) Performance Standard

Standard Positioning Service (SPS) Signal-in-Space Performance

- **User Range Error (URE) in Meters**
  - **Signal-in-Space User Range Error** is the difference between a GPS satellite’s navigation data (position and clock) and the truth, projected on the line-of-sight to the user.
  - **Compare to (example):**
    - ≈ 4.9 m RMS User residual iono delay error (L1 only)
    - ≈ 0.5 m RMS User residual tropo delay error

- **2001 SPS PS 6 m RMS**
- **2008 SPS Performance Standard (PS)**
  - Worst of Any Healthy Satellite, 7.8 m @ 95%
- **Equivalent RMS Value from 2008 SPS PS (4 m)**
  - 3.4 3.1 3.0 3.2 3.3 3.1 2.9
- **Across All Healthy Satellites (RMS, 68%)**
  - 1.6 1.4 1.2 1.2 1.1 1.1 1.0 1.0 0.9 0.9 0.9 0.8 0.8 0.7

**System accuracy better than published standard**
CNAV Broadcast is performing as expected.

- **CNAV is being broadcast today!**
  - L2C CNAV set Healthy, 18 SVs by the end of the year
  - L5 CNAV set Unhealthy, available for test
  - Intended to support modernized civil receiver development

<table>
<thead>
<tr>
<th>CNAV message types currently being broadcast</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>33</td>
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</table>

- Collaborating on GPS/GNSS Time Offset (GGTO) test plan with Civil community

CNAV Broadcast is performing as expected.
Civil Signal Coverage

Current Constellation – L2C – 4 Fold Visibility Gaps

1 October 2015 - No Failures

Tuesday, October 20, 2015 5:04:51 AM
Civil Signal Coverage

Current Constellation – L5 – 4 Fold Visibility Gaps

1 October 2015 - No Failures

Latitude

Longitude

-180.0 -150.0 -120.0 -90.0 -60.0 0.0 30.0 60.0 90.0

0 hrs

0 hrs to 2 hrs

2 hrs to 4 hrs

4 hrs to 8 hrs

8 hrs to 16 hrs

Greater than 16 hrs

Tuesday, October 20, 2015 5:32:42 AM
The GPS Directorate is actively supporting ARAIM development activities as part of EU-US WG-C.

- ARAIM
  - Residuals test
  - \{URA, P_{sat}, P_{const}\}
  - \{URA, P_{sat}, P_{const}\}
  - \{URA, P_{sat}, P_{const}\}
  - Lateral + vertical

**Reference Stations**
- Global network
- e.g. SBAS reuse or
- e.g. NASA's GDGPS

**Offline monitors check GNSS commitments**
- on \(P_{sat}\) & \(P_{const}\)

**ISM updates:**
- new constellations
- \{URA, P_{sat} & P_{const}\}
- broadcast using databases or GNSS

**ARAIM May Enable Multi-GNSS Use by Safety-of-Life Applications!**