Global Positioning Systems Directorate

GPS Program Update to ION GNSS+ 2014

10 Sep 2014

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Deputy Director, GPS Directorate
Mission: Acquire, deliver and sustain reliable GPS capabilities to America’s warfighters, our allies, and civil users.

Col Bill Cooley
GPS Overview

**Civil Cooperation**
- 1+ Billion civil & commercial users
- Search and Rescue
- Civil Signals
  - L2C (2nd Civil Signal)
  - L5 (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
  - Russia - GLONASS
  - Europe - Galileo
  - China - BeiDou
  - Japan - QZSS
  - India - IRNSS

**Maintenance/Security**
- All Level I and Level II
  - Worldwide Infrastructure
  - NATO Repair Facility
- Develop & Publish ICDs Annually
  - ICWG: Worldwide Involvement
- Update www.GPS.gov Webpage
- Load Operational Software on over 1 million SAASM Receivers
- Distribute PRNs for the World
  - Including 90 for GNSS

**Spectrum**
- World Radio Conference
- International Telecommunication Union
- Bilateral Agreements
- Adjacent Band Interference

**Department of Transportation**
- Federal Aviation Administration

**Department of Homeland Security**
- U.S. Coast Guard

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<table>
<thead>
<tr>
<th>Satellite</th>
<th>Quantity</th>
<th>Avg Life</th>
<th>Oldest</th>
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<tbody>
<tr>
<td>GPS IIA</td>
<td>5</td>
<td>20.1</td>
<td>23.8</td>
</tr>
<tr>
<td>GPS IIR</td>
<td>12</td>
<td>12.7</td>
<td>17.1</td>
</tr>
<tr>
<td>GPS IIR-M</td>
<td>7</td>
<td>7.9</td>
<td>8.9</td>
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<tr>
<td>GPS IIF</td>
<td>7</td>
<td>1.63</td>
<td>4.3</td>
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<tr>
<td><strong>Constellation</strong></td>
<td>31</td>
<td>10.4</td>
<td>23.8</td>
</tr>
</tbody>
</table>

AS OF: 27 AUG 14
**GPS Constellation**

- **Robust constellation**
  - 31 space vehicles currently in operation
    - 5 GPS IIA, 12 GPS IIR, 7 GPS IIR-M, 7 GPS IIF
    - 7 additional satellites in residual status, 1 in test status

- **Extensive International and Civil Cooperation**
  - Agreements with 57 international customers
  - 1 billion+ civil/commercial users
  - Countless applications…and growing

- **Global GPS civil service performance commitment met continuously since Dec 1993**
  - Best performance 46.6 cm User Range Error (URE) 8 Jun 2013; best weekly average 58.7 cm URE 18 Aug 14
  - Performance improving as new satellites replace older satellites
GPS Signal in Space Performance

System accuracy exceeds published standard
GPS Performance – Past 12 Months

As-Broadcast SIS vs JPL Real Time

SIS RMS URE (m)
GPS IIA/IIR/IIR-M Status

• 19 GPS IIR and GPS IIR-M satellites are on orbit
  – Current backbone of the GPS constellation
  – SIS URE of 0.53 meters (1-yr performance Aug 2014); (1.04m for GPS IIA and 0.64m for GPS IIF)

• Excellent life expectancy
  – GPS IIA performing well past design life (2.5x on avg)
  – GPS IIR/IIR-M solar array capacity far exceeds specified Mean Mission Duration
  – No GPS IIR/IIR-M clock failures to date
  – GPS IIR/IIR-M battery life extension implemented, yielding avg 1-2 years additional life per satellite
What a year!
• Launched GPS IIF-5 on 21 Feb 14
  – Satellite Vehicle Number 64, PRN 30
• Launched GPS IIF-6 on 15 May 14
  – Satellite Vehicle Number 67, PRN 6
• Launched GPS IIF-7 on 1 Aug 14
  – Satellite Vehicle Number 68, PRN 9
• 7 total GPS IIFs on orbit
  – Continued demonstration of Flex Power capability
• 5 more GPS IIFs in the pipeline
  – SV-8 scheduled for launch in Oct 2014
  – SVs 10, 11, and 12 are in storage
  – SV-9 is in production testing
  – Improved Rubidium clocks on SVs 3 and 5-12
• Newest block of GPS satellites
  – 4 civil and 4 military signals:
    L1 C/A, L1C, L2C, L5; L1/L2 P(Y), L1/L2M
  – First satellites to broadcast common L1C signal
  – Three improved Rubidium atomic clocks
• SV07/08 contract awarded 31 Mar 14
• Navigation Payload Panel in acceptance testing
• GPS III Non-Flight Satellite Testbed accomplished launch processing at Cape Canaveral; reduced risk for integration & test and launch processing
• GPS III SV01 available for launch starting Jan 2016
Ground Segment Status

• Current system Operational Control Segment (OCS)
  – Flying GPS constellation on Architecture Evolution Plan (AEP) and Launch & Early Orbit, Anomaly, and Disposal Operations (LADO) software systems
  – Cyber security enhancements in progress

• Next Generation Operational Control System (OCX)
  – Modernized command & control system with M-Code, modern civil, signal monitoring, info assurance infrastructure and improved PNT performance
  – OCX Block 0 supports launch & checkout for GPS III and is in integration & test; Raytheon (Aurora, CO) - Prime
  – OCX Block 1 supports transition from OCS in 2018
  – Successfully completed 3 GPS III launch exercises
GPS Modernization – New Civil Signals

- Second civil signal “L2C”
  - Designed to meet commercial needs
  - Available since 2005 without data message
  - Phased roll-out of CNAV message
  - Currently 14 SVs broadcasting L2C

- Third civil signal “L5”
  - Designed to meet transportation safety-of-life requirements
  - Uses Aeronautical Radio Navigation Service band
  - Currently 7 SVs broadcasting L5

- Fourth civil signal “L1C”
  - Designed for GNSS interoperability
  - Specification developed in cooperation with industry
  - Launches with GPS III in 2016
  - Improved tracking performance

Early CNAV test conducted in Jun 2013
CNAV Pre-Operational Deployment

- Initiated continuous CNAV message broadcast (L2C & L5) on 28 Apr 14
- CNAV Data message uploaded twice a week initially; with daily uploads expected by Dec 2014
- Position accuracy not guaranteed during pre-operational deployment of CNAV signals; “use at own risk”
  - L2C message currently set “healthy”
  - L5 message set “unhealthy” until sufficient monitoring capability established (signal verification)
- Expected Performance for users:
  - During first 24 hours after upload, CNAV performs as LNAV
  - Expect divergence between CNAV & LNAV as CNAV data ages until next CNAV upload
CNAV & LNAV Performance from Modernized SVs (IIRM & IIF)

<table>
<thead>
<tr>
<th>SIS Type</th>
<th>RMS URE (m)</th>
<th>Avg AOD (hr)</th>
<th>1wk RMS URE (m)</th>
<th>1wk Avg AOD (hr)</th>
<th>24hr RMS URE (m)</th>
<th>24hr Avg AOD (hr)</th>
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<tr>
<td>LNAV</td>
<td>0.513</td>
<td>12:27</td>
<td>0.485</td>
<td>11:53</td>
<td>0.390</td>
<td>12.07</td>
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<tr>
<td>CNAV</td>
<td>1.414</td>
<td>34:06</td>
<td>0.748</td>
<td>23.59</td>
<td>0.408</td>
<td>14.24</td>
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CNAV Performance Within Expectations
Effect of Upload Frequency on CNAV User Range Error

- Improved tools reduce age of data & CNAV User Ranging Error (URE)
- Initial, twice-a-week upload (Apr 2014) drives high CNAV URE

RMS URE Driven by Upload Latency & Integration with AEP

Integrated Solutions Will Broadcast CNAV URE Comparable to Legacy in Dec 2014
• Modernized signal development in progress
  – 12 L2C, 5 L5 and 12 M-Code capable SVs on orbit
  – OCX will implement full C2 of L1/L2M, L2C, L5
  – Continuous L2C, L5 CNAV message broadcast began Apr 2014
  – Expect the first L1C SV launch in 2016
  – Continued progress to M-Code early use ~2018
• Modernization of all GPS Segments making progress but still with technical challenges commensurate with the advanced tech
• Working domestically, internationally and with Industry to simultaneously protect GNSS services and release spectrum for mobile services

Maintaining the world’s “Gold Standard” PNT service is Job #1
The PNT EXCOM drives civil signal implementation.