Global Positioning Systems Wing

GPS Program Update to 49th CGSIC Meeting

21 September 2009

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Technical Director
GPS User Equipment Group
Outline

• Constellation Status
• System Performance
• Recent Successes
• GPS Modernization
• International Cooperation
• Support to Civil Users
• Upcoming Events
GPS Constellation

- Very robust constellation
  - 30 space vehicles currently set healthy
    - 11 GPS IIA
    - 12 GPS IIR
    - 7 GPS IIR-M
    - 1 GPS IIR-M waiting to be set healthy
    - 3 additional satellites in residual status

- Global GPS civil service performance commitment met continuously since December 1993
**Current GPS Accuracy**

- **SPS Signal-in-Space (SIS) User Range error (URE)**
  - One-year RMS through August 2009: 1.04 meters

- **SPS Zero Age-of-Data (AOD) URE**
  - One-year RMS through August 2009: 0.53 meters

Signal-in-Space (SIS) User Range Error (URE) 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.

Selective Availability (SA)
Snapshot: Typical UE

Horizontal Position Error at 2009-03-13 12:00:00
UEE = 2.6 m

Max 4.71 m
95th Percentile 3.02 m
Median 2.37 m
Snapshot: High End UE

Horizontal Position Error at 2009-03-13 12:00:00
UEE = 0.8 m

Max 2.18 m
95th Percentile 1.29 m
Median 0.93 m
Recent Successes

Space Segment

• SVN 49 launched in March 09
  • L5 demo payload secured frequency filing
  • Signal distortion investigation still underway
  • ION panel session Wednesday on SVN-49
• SVN 50 launched in August 09
  • Set healthy
  • Completed GPS Delta II launches
• GPS IIF completed Pathfinder testing
• GPS IIF-1 completed thermal vacuum test & mission assurance review
• GPS IIIA completed Preliminary Design Reviews
Recent Successes (Cont’d)

Ground Segment

- Delivered new version of OCS (AEP 5.5) to final regression testing with SAASM capability
- Completed successful OCX, SDR, Modernized Capability Demo and RFP release
Recent Successes (Cont’d)

System

• Deploying L2C message Type 0 capability for GPS IIRM to support testing of civil UE testing

• Civil Monitoring Performance Specification (CMPS) – 30 Apr 09

• L1C phase relationship configuration established
  • L1C components will be in phase with L1 P(Y)-code
IIF Pathfinder (May – Sep 2009)

• IIF-2 shipped to Cape for risk mitigation
• All transport procedures proven successful
• All mechanical activities performed to plan and facility interfaces verified
• Consolidated System Testing checked all interfaces to OCS AEP and LADO
• Cut IIF-1 critical path to launch by 2 months and reduced schedule risk
• Best Practice for future GPS programs
## GPS IIF Performance

<table>
<thead>
<tr>
<th>Tech Performance Measure</th>
<th>Requirement</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 C/A User Rec. Pwr.</td>
<td>&gt; -158.5 dBW</td>
<td>-156.9</td>
</tr>
<tr>
<td>L1 P(Y) User Rec. Pwr.</td>
<td>&gt; -161.5 dBW</td>
<td>-159.9</td>
</tr>
<tr>
<td>L1 M User Rec. Pwr.</td>
<td>&gt; -158 dBW</td>
<td>-156.3</td>
</tr>
<tr>
<td>L2 C User Rec. Pwr.</td>
<td>&gt; -160 dBW</td>
<td>-159.60</td>
</tr>
<tr>
<td>L2 P(Y) User Rec. Pwr.</td>
<td>&gt; -161.5 dBW</td>
<td>-160.96</td>
</tr>
<tr>
<td>L2 M User Rec. Pwr.</td>
<td>&gt; -161 dBW</td>
<td>-160.56</td>
</tr>
<tr>
<td>L5 User Rec. Pwr.</td>
<td>&gt; -154.9 dBW</td>
<td>-154.1</td>
</tr>
<tr>
<td>Mean Mission Duration</td>
<td>&gt; 9.9 years</td>
<td>10.86</td>
</tr>
<tr>
<td>SV Reliability</td>
<td>&gt; 0.61</td>
<td>0.76090</td>
</tr>
</tbody>
</table>

GPS IIF is meeting or exceeding all specified requirements.
GPS IIF Summary

- GPS IIF available for launch in November 2009
- New/improved capabilities for civil and military users
- Reliable sustainment of GPS constellation over the coming years
- Partnership between GPSW and Boeing continues to focus on mission success
Modernization

Satellites

Legacy (Block IIA/IIR)
- Basic GPS
- C/A civil signal (L1C/A)
- Std Pos. Service
- Precise Pos. Service
- L1 & L2 monitoring
- NDS

(Block IIR-M)
- 2nd civil signal (L2C)
- M-Code signals (L1M, L2M)
- Flex AJJ power (+7dB)

(Block IIF)
- 3rd civil signal (L5)

GPS III (Block III)
- Increased accuracy
- Increased AJJ power (up to 20 dB)
- Signal integrity
- Search and Rescue
- Common Galileo
  OS & GPS (L1C)

Control Systems

Legacy
- TT&C
- L1 & L2 monitoring

Upgraded (AEP)
- GPS IIF TT&C
- SAASM

OCX Blk 1 (Modernized)
- Flexible Architecture
- Mission Ops for all SVs
- Control 1 new signal (L2C, L5, or M-Code)
- Control Flex Power
- Signal Integrity Monitoring

OCX Blk 2
- LADO ops for all SVs
- All new signals (including L1C)

OCX Blk 3&4 (GPS III B/C)
- Manage Spot Beam
- NAVWAR, GNOC
- Mission Planning
- Effects-Based Ops

User Equipment

Legacy
- Man Pack
- MAGR, PLGR
- RCVR-3A, 3S
- OH, UH
- FRPA, CRPA

Upgraded
- DAGR
- GAS-1
- CSEL
- MAGR2K
- GB-GRAM

MGUE (Modernized)
- Anti-Jam, Anti-Spoof
- Military exclusivity
- Handheld / Anti-Tamper
- Gnd & Avionics embed
- Auto OTA Rekeying

Cornerstones to the Future GPS are GPS III, OCX, & MGUE
GPS Modernization – New Civil Signals

- **Second civil signal “L2C”**
  - Designed to meet commercial needs
  - Higher accuracy through ionospheric correction

- **Third civil signal “L5”**
  - Designed to meet demanding requirements for transportation safety-of-life
  - 1st launch: ~ 2009 (GPS IIF); 24 satellites: ~2018

- **Fourth civil signal “L1C”**
  - Designed with international partners for GNSS interoperability
  - Begins with GPS Block III
  - 1st launch: ~2014; 24 satellites: ~2021
International GNSS Coordination

Signal Modernization

GLONASS

4. Planned Signals

<table>
<thead>
<tr>
<th>Generic Signal Name</th>
<th>Center Frequency</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1/C/A</td>
<td>1575.42MHz</td>
<td></td>
</tr>
<tr>
<td>L1C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2C</td>
<td>1227.6MHz</td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td>1176.45MHz</td>
<td></td>
</tr>
<tr>
<td>L1-SAIT†</td>
<td>1575.42MHz</td>
<td>Compatibility with GPS-SBA</td>
</tr>
<tr>
<td>LEX</td>
<td>1278.75MHz</td>
<td>Experimental Signal with high-rate message (2Kbps)</td>
</tr>
</tbody>
</table>

QZSS

IRNSS SERVICES & CENTRE FREQUENCIES

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Signals</th>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td>Standard Positioning</td>
<td>1 MHz</td>
<td>L5 (1176.45 MHz) (2492.08 MHz)</td>
</tr>
<tr>
<td>Service</td>
<td>BPSK</td>
<td></td>
</tr>
<tr>
<td>Precision Service</td>
<td>BOC(5,2)</td>
<td>L5 (1176.45 MHz) (2492.08 MHz)</td>
</tr>
</tbody>
</table>

IRNSS

Compass

1.3 Signals

<table>
<thead>
<tr>
<th>Signal</th>
<th>Carrier frequency (MHz)</th>
<th>Bandwidth (MHz)</th>
<th>PRN code chip rate (Mgps)</th>
<th>Signal modulation</th>
<th>Navigation data bit rate (bps)</th>
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</thead>
<tbody>
<tr>
<td>B1</td>
<td>1561.098</td>
<td>4.097</td>
<td>2.048</td>
<td>QPSK</td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>1561.098</td>
<td>4.097</td>
<td>2.048</td>
<td>QPSK</td>
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</tr>
<tr>
<td>B5</td>
<td>1561.098</td>
<td>5.14</td>
<td>10.22</td>
<td>QPSK</td>
<td></td>
</tr>
<tr>
<td>B6</td>
<td>1561.098</td>
<td>5.14</td>
<td>10.22</td>
<td>QPSK</td>
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<tr>
<td>B1-BOC</td>
<td>1579.42</td>
<td>16.008</td>
<td>1.022</td>
<td>MBOC (15, 1, 2, 11)</td>
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<tr>
<td>B2-BOC</td>
<td>1579.42</td>
<td>30.69</td>
<td>5.131</td>
<td>BOC (10, 2)</td>
<td></td>
</tr>
<tr>
<td>B4-BOC</td>
<td>1579.42</td>
<td>55.065</td>
<td>2.0575</td>
<td>BOC (15, 1, 2)</td>
<td></td>
</tr>
</tbody>
</table>
Support to Civil Users

- Resident Program Manager for Civil Applications
  - DOT representative located within GPSW

- Freely available, accurate, and stable documentation
  - Standard Positioning Service Performance Standard (SPS PS)
  - Interface Control Documents (ICDs) / Interface Specifications (ISs)
    - Technical definitions for L1 C/A, L2C, L5, and L1C signals

- Public Interface Control Working Groups (ICWGs)
  - Insight, access, and influence to ICDs/Iss

- Special manufacturer/user outreach
  - Developing resolution plans for SVN-49 anomaly
Upcoming Events

• Wednesday, 23 Sep 09
  • ION panel session dedicated to SVN-49 anomaly

• Public Interface Control Working Groups (ICWGs)
  • Tuesday, 29 Sep 09
    • ICWG for IS-GPS-200
  • Wednesday, 30 Sep 09
    • ICWG for IS-GPS-800
  • Thursday, 1 Oct 09
    • ICWG for IS-GPS-705

• Early 2010
  • Launch of first IIF satellite

In Los Angeles
The Military GPS Challenge

• Bring advantages of commercial market to the joint and allied warfighter,

\textit{and}

• Maintain the advantages of military exclusivity and resistance to electronic attack

\begin{align*}
\text{COTS features} & + \quad \text{MIL advantages} \\
& = \quad \text{Warfighter effectiveness}
\end{align*}
Solutions

- Previous approach (2003): Study commercial devices and levy their benefits as requirements in a traditional military acquisition

DAGR – Defense Advanced GPS Receiver: All-in-view, Second Generation Security, under 1 lb

- Pro: Strong military receiver performance
- Con: Interface and features are quickly outdated

Current approach (2012): Develop military components for insertion into COTS or non-COTS systems

GPSW Builds Enabling “Engines” + Integrators Build Applications = Global Military GPS Use
keys to the global success of gps

- program stability and performance
  - civil service performance commitment met continuously since 1993
  - continuous improvements in accuracy, availability, etc.
  - continuity of constellation and signals ensured through Air Force operation and acquisition
  - funding through U.S. taxpayers

- policy stability and transparency
  - open access to civil GPS signals, free of direct user fees
  - open, free, and stable technical documentation
  - market-based competition worldwide
  - national-level policy coordination including civil and military leaders

- commercial entrepreneurship and investment
Summary

- GPS has continuously met its commitments to all users since FOC
- GPS has had multiple operational and acquisition successes in the past year
- Modernization of all GPS Segments is on track

Maintaining And Improving GPS Services For All Users Is Job #1