Overview

- SVN-62
- SVN-49
- Recent Lessons Learned
- Performance Standards
IIF-1 is SVN 62 and PRN-25
  – Launched May 2010, set healthy August 2010

Three SVN-62 signals characteristics have generated interest recently
  – Clock performance
  – L5 phase variation
  – L5 digital distortion

L1 C/A, L1 P(Y), L2 P(Y) signals meet specs
  – Comply with the ISs/ICDs and the Performance Standards (PSs)

L2C, L5, M-Code will meet specs with OCX
  – OCX required for CNAV or MNAV data messages
  – Modernized signal PSs will be published as signal IOCs approach
  – No SVN-62/PRN-25 technical problems to prevent meeting specs
IIF-1 SVN-62/PRN-25 Clock

- Rubidium clock is among best ever seen
  - Stability of “apparent clock” affected by orbit-period harmonic errors
    - Similar effect seen with other high-stability satellite clocks
  - Expect clock stability to gradually improve
    - Further clock settling and updates to solar pressure model

![Graph from Ken Senior at Naval Research Laboratory](Plot from Ken Senior at Naval Research Laboratory)
SVN-62/PRN-25 L5 Carrier

- L5 carrier not as coherent as L1 and L2
  - L1/L2 carriers & all PRN codes are coherent with each other
  - L5 carrier is coherent with other signals within ±0.06 m worst case
- Well within related GPS III specification value of ±6.1 m worst case (FAA)

Plot from Montenbruck, Hauschild, Steigenberger, and Langley; “Three’s the Challenge”; published by GPS World, 20 July 2010
SVN-62/PRN-25 L5 Codes

- L5 codes are slightly more distorted than usual
  - The benchmark for “usual” is L1 C/A-code
  - L5 codes have a slight $\Delta$ values (+1 vs -1 chip duration mismatch)
- Well within related GPS III specification value of 10 nsec worst case (FAA)

Plot from Phelts, Gao, Wong, Heng, Walter, Enge, Erker, Thoelert, and Meurer; “Aviation Grade”; published by Inside GNSS, July/August 2010
• GPS IIR-20(M) (SVN 49) was launched 24 Mar 09
  – Navigation payload was modified to include an L5 demonstration payload
• Signal distortion observed during On-orbit check-out
  – At higher elevations, the user sees a 4m+ error from the navigation signal
• Improper installation of L5 payload determined as root cause of the anomaly
  – A small amount of L1/L2 energy is reflected from the L5 filter back into the antenna, creating a multi-path effect as the delayed signal gets rebroadcast
  – SVN-49 does not meet spec with distortion (IS-GPS-200 3.3.1.4, “Spurious Transmissions”)
• Vehicle currently “UNHEALTHY” to all users
  – GPSW and 50 SW are working to develop a way ahead that may allow setting SVN 49 “HEALTHY”
SVN 49 Investigation

- Mitigation techniques and response of stakeholders

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<tr>
<th>Mitigation Technique</th>
<th>SPS</th>
<th>HIGH ACCURACY</th>
<th>PPS</th>
<th>MCODE</th>
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<tbody>
<tr>
<td>1) 152m APC &amp; Clock Offset</td>
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<td>2) Factory APC + AEP 5.5.4</td>
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<td>3) Multipath Resistant Rcvr</td>
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<td>4) SW Updates for UE</td>
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<td>5) Increase URA to 3+</td>
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<td>6) No Data on L2P(Y)</td>
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<td>7) Change L2C PRN</td>
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<td>8) Unhealthy but Usable*</td>
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<td>9) Other PPS Mitigation</td>
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- DOT Request for Feedback

- SPS:
  - Significantly increased PNT errors in some SPS solutions

- HIGH ACCURACY:
  - Increased errors in PPS UE solutions

- PPS:
  - Too expensive to swap out every receiver
  - Too expensive/difficult to upgrade all UE software
  - Not sufficient for Codeless UE, may harm DoD UE
  - Not sufficient for L2C users
  - Keep unhealthy while users implement their own options
  - Should provide error correction ONLY for PPS users

- MCODE:
  - No negative impacts
  - Not sufficient for L2C users

*Requires unique ID

GPSW is pursuing mitigations 2, 5, and 9
Receiver vendors are encouraged to pursue 3 and 4
SVN 49 Summary

- SVN 49 accomplished L5 demo successfully but caused signal distortion
- Distortion can be mitigated sufficiently to make SVN 49 useful
  - Some mitigations feasible from Space and Ground Segments
  - Others needed from User Segment
- **Cannot make SVN 49 compliant with ICD-200**
  - Should not be included in availability predictions
- **Provide 3-4 years to prepare for setting SVN 49 healthy**
  - Kalman Filter upgrade in AEP 5.5.4 & eventually for OCX
  - URA increase to 3+
  - PPS user mitigation
  - Other user mitigations
  - Updates to performance standards for SVN 49 (IS-GPS-200, 700, 705)
- **Set SVN 49 healthy after mitigations have been implemented and affected users have had time to prepare for it**
  - Set it healthy sooner if total # of SVs drops to <24 or if constellation needs demand it

**Striving to Maximize Usefulness of SVN 49**
Recent Lessons Learned

• GPS receiver anomalies were reported several times this year coinciding with testing activities
  – Almanac problem in Nov 2009, SAASM issue in Jan 2010, etc.

• Problems were traced to non-compliant UE
  – Unauthorized use of reserved bits, incorrect assumption on almanac time, incorrect implementation/interpretation of SAAM function

• Problems mitigated by working extensively with UE vendors to fix non-compliance issues

• Resulted in delays to fielding of SAASM capabilities

• Improvements in compliance verification are being put in place

ICD Compliance is Critical for GNSS Success
**SPS Signal in Space Performance**

Signal-in-Space 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.

- **2001 SPS Performance Standard (RMS over all SPS SIS URE)**
  - 1990: N/A
  - 1992: N/A
  - 1994: N/A
  - 1996: N/A
  - 1997: N/A
  - 2001: 1.6
- **2008 SPS Performance Standard (Worst of any SPS SIS URE)**
  - 2004: 1.2
  - 2006: 1.1
  - 2008: 1.0
  - 2009: 0.9

Selective Availability (SA)

System accuracy exceeds published standard.
**PPS Signal in Space Performance**

**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.

System accuracy exceeds published standard.
Coming Up: SPS PS Update

• Planning a draft update of the SPS PS by Q1FY11
  – Name change to "Open Service Performance Standard" (OS PS)
  – Addition of L2C signal to current L1 C/A signal
  – Same performance values
  – Draft update will be circulated for review & comment within U.S. Government
  – SPS PS update approval before Initial Operational Capability (IOC) declaration for L2C

• Planning subsequent draft updates for L5 signal and for L1C signal
  – Prior to each subsequent IOC declaration

• Exploring new performance metrics
  – Different users and applications
  – Different environments