Global Positioning System Status

Joint Meeting of Action Team on GNS and GNSS Experts of UN/USA Regional Workshops and International Meeting 2001 - 2002

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U.S. Department of Transportation
Overview

• Background

• Performance Standards

• GPS Modernization

• Spectrum
GPS Background

• Active program for over 25 years
  – Created from separate programs in 1973
  – Developmental satellites began launch in 1978; operational satellites in 1989
  – Initial Operational Capability in 1993; Full Operational Capability in 1995

• Designed as a dual-use system
  – Military applications for US and Allied use
  – Civilian applications for worldwide use

• Consistent U.S. National Policy from both Executive and Legislative branches
  – U.S. Public Law - December 1997
GPS Satellites

Block II/IIA
- All have been launched
- Rockwell (now Boeing)
- First launch Feb 1989
- 20 operational
- Mean Mission Duration (MMD) 9.88/10.64 yrs

Block IIR/IIR-M
- In production
- Lockheed/Martin
- 21 procured
- 8 operational
- 1 Destroyed on launch
- MMD 10.62/8.57 yrs

Block IIF
- In development
- Boeing
- 6 already procured
- Options for 10 more
- MMD 11.0 yrs
Improve Civil GPS Services

- Given current GPS system, civil performance improvements are needed
  - Early 1990’s began developing GPS augmentation systems
  - 2000 – Selective Availability set zero
  - Mid-2000s will begin launch of GPS IIR/IIF satellites with new civil signals
  - 2010 and beyond: System architecture for GPS III and Galileo being considered
GPS Open Market

- Civil service is **free of user charges**
  - Now and in the future
- **Publicly published GPS specifications** allow anyone to build receivers (no licensing fees)
- Equipment is becoming a **common commodity**
- Great potential in **value-added services**
  - Software development
  - Embedded applications
  - Localized geographic info systems (GIS) databases
  - Internet integration
  - Wireless markets
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GPS Constellation Status

28 Operating Satellites
(to ensure 24)

- 20 Block II/IIA satellites operational
- 8 Block IIR satellites operational
  - 12 of 21 Block IIR satellites available
  - Modernizing up to 8 Block IIR satellites
  - Last launch: 31 Mar 03
- Next Launch: 20 Dec 03 (GPS IIR-10)
- Continuously assessing constellation health to determine launch need
- Global civil service performance commitment has been met continuously since Dec 93
GPS SPS Performance Standard

• Defines the **levels of performance** the U.S. Government commits to provide to domestic and international civil GPS users

• **Not a requirements** document

• Current edition published **October 2001**
  – Updated performance as a result of discontinuing Selective Availability (SA)

Commitment of Service
• **Main body** -- The performance standards
  – Constellation management
  – Service availability
  – Service reliability
  – Accuracy
  – Status and problem reporting

• **Appendix A** -- Documented historical performance and supporting analysis
  – For information only
### SPS Performance Standard (cont’d)

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>Global Accuracy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All-in-View Horizontal 95%</td>
<td>100 meters</td>
<td>13 meters</td>
<td>4 meters</td>
</tr>
<tr>
<td>All-in-View Vertical 95%</td>
<td>156 meters</td>
<td>22 meters</td>
<td>6 meters</td>
</tr>
<tr>
<td><strong>Worst Site Accuracy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All-in-View Horizontal 95%</td>
<td>100 meters</td>
<td>36 meters</td>
<td>6 meters</td>
</tr>
<tr>
<td>All-in-View Vertical 95%</td>
<td>156 meters</td>
<td>77 meters</td>
<td>10 meters</td>
</tr>
<tr>
<td><strong>Time Transfer Accuracy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All-in-View Time Transfer</td>
<td>340 nanoseconds</td>
<td>40 nanoseconds</td>
<td>7-10 nanoseconds</td>
</tr>
<tr>
<td>User Solution 95%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Constellation RMS User Range Error</strong></td>
<td>NONE</td>
<td>6 meters</td>
<td>1.6 meters</td>
</tr>
<tr>
<td><strong>Geometry (PDOP ≤ 6)</strong></td>
<td>95.87% global</td>
<td>98% global</td>
<td></td>
</tr>
<tr>
<td></td>
<td>83.92% site</td>
<td>88% site</td>
<td></td>
</tr>
<tr>
<td><strong>Constellation Availability</strong></td>
<td>NONE</td>
<td>95% Probability of 24 Operational Satellites</td>
<td>25-28 Healthy Satellites</td>
</tr>
<tr>
<td><strong>Service Reliability</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Failure Threshold</td>
<td>99.97% global</td>
<td>99.94% global</td>
<td>100% global</td>
</tr>
<tr>
<td>Service Failure Rate</td>
<td>99.79% worst site</td>
<td>99.79% worst site</td>
<td>100% worst site (28 July 2001 PRN22 Failure)</td>
</tr>
<tr>
<td>Service Failure Duration</td>
<td>500 m Horizontal Error</td>
<td>30 m SIS URE</td>
<td>almost 2 hours of URE &gt; 30 m</td>
</tr>
<tr>
<td></td>
<td>Up to 6 Hours/Failure</td>
<td>Up to 6 Hours/Failure</td>
<td></td>
</tr>
</tbody>
</table>
The U.S. Government, DoD, and U.S. Air Force are committed to being good stewards of GPS.

GPS SPS Performance Standard available on US Coast Guard Navigation Center website:

http://www.navcen.uscg.gov/
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GPS Modernization Plan

**Block IIA/IIR**
- Basic GPS
- Std Service (16-24m SEP)
  - Single frequency (L1)
  - C/A code navigation
- Precise Service (16m SEP)
  - Two frequencies (L1&L2)
  - P-code navigation

**IIR-M**: IIA/IIR capabilities plus
- 2nd Civil Signal on L2 (L2C)
- Earth coverage M-Code on L1 & L2

**IIF**: IIR-M capability plus
- 3rd Civil Signal on L5

Flex Power upgrade adds ability to increase power on both P and M-Code signals to defeat low level enemy jamming

**Block III**
- GPS III
- Navigation Surety
- Increased Accuracy
- Assured Availability
- Controlled Integrity
- System Survivability
- Continuation of Legacy Signals

**Increasing System Capabilities** • **Increasing Defense/Civil Benefit**
GPS Modernization

• **Additional civil GPS signals**
  – L2C civil signal: First launch 2004
  – L5 civil signal: First launch 2006
  – Further capability with GPS III

• **More robust satnav service**
  – Reduces vulnerability to interference

• **Dual frequency** for worldwide safety-of-life transportation applications

• **Centimeter-level** accuracy for scientific and survey applications
Second Civil Signal (L2C)

- **More robust** civil signal service
  - Civil users currently only have codeless/semi-codeless access to P(Y) on L2
- **Increased accuracy**
  - Coded dual-frequency ionospheric corrections at the receiver
- **Advanced signal structure**
  - Working Group defined signal characteristics
  - Better cross-correlation properties than C/A
  - Data-free component for robust tracking
  - Designated primary L2 civil code versus C/A
Third Civil Signal (L5)

- Improved **signal structure** for enhanced performance
  - 6 dB Higher power relative to L1 (-154 dBW)
  - 20 MHz (minimum) broadcast bandwidth
  - Improved data message
- **ARNS allocation** to support civil aviation
- **DME compatibility** achieved by frequency reallocation, if required
- **L5 signal definition**
  - RTCA SC 159, WG #1, developed L5 Specification
  - GPS JPO originated/coordinated ICD-GPS-705
GPS L5 for Safety-of-Life

• **Domestic** operations
  – Improves reliability and availability
  – Significantly reduces possibility of unintentional interference
  – Some improvement in anti-jam capability

• **International** operations
  – Improves safety
  – Provides precision guidance throughout the world without costly infrastructure
Civil Benefits of GPS Modernization

• **More robust** GPS service worldwide
  – Reduces vulnerability to **unintentional interference**

• **Centimeter-level** accuracy for scientific and survey applications

• Reduced **data rate** for Differential GPS (DGPS) corrections

• **Worldwide dual frequency** for safety-of-life applications
  – Satellite-based augmentation systems (e.g., WAAS, EGNOS, Gagan, MSAS) will require less ground infrastructure to provide capability
GPS III Civil Goals

- Significant increase in **system accuracy**
- **Improve robustness** to interference
- Improve level of **integrity for all users**
- Improve availability of **accuracy with integrity**
- **Backward compatibility** with existing receivers
- **Initial Operating Capability** for L5
  - In combination with GPS IIF satellites
- **Flexibility to respond** to evolving requirements with limited programmatic impacts
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Spectrum: The Great Enabler

- Critical for **modernizing** transportation systems
  - Increasingly dependent on spectrum
- All **radio bands under scrutiny** for commercial use
- Support **technological innovation/creativity while** jointly shaping a safe operating environment
- Presidential **Spectrum Policy Initiative**
  - U.S. National Spectrum Management Reform
  - Equitable spectrum management and coordination
Spectrum Challenge

• **Protect spectrum** for GNSS/GPS and other current/future critical systems from interference (e.g., Ultra Wideband (UWB), Mobile Satellite Service (MSS))
  – GPS degradation harms strategic military and civil plans
  – Goal is to enable new GPS applications (e.g. ITS, E911)

• **Compatibility/interoperability** with other global satellite navigation systems (Galileo, QZSS, etc.)

• **Spectral separation** of civil/military GNSS/GPS signals
  – Facilitates preservation of peaceful civil use outside an area of conflict
The Road Ahead

• Launch of satellites with **new civil/military GPS signals** starts next year with enhancements through GPS III
  – Augmentations are **an integral component** of current civil GPS service provision

• Hopeful that Galileo will be **compatible as well as interoperable** with GPS
  – Greater satnav capabilities for civil users worldwide
  – **Spectral separation** of civil and military GNSS signals facilitates preservation of peaceful civil use

• **Spectrum protection** requires vigilance and early action on emerging issues
Summary

• Stable, consistent GPS policy and service
• Expanding use in transportation safety and other civil uses
• GPS Modernization is a multiple step process
  – Selective Availability set to zero
  – Second civil signal (L2C): First launch in 2004
  – Third civil signal (L5): First launch in 2006
  – GPS III addressing future dual-use requirements
• Continuing international outreach to be responsive to global user needs

Future GPS performance will dramatically improve as a result of modernization