GNSS Modernization

04 March 2004
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OVERVIEW

• GPS Modernization
• GPS Augmentation Evolution
• Interoperability of GNSS Components
• Summary
• GPS Augmentation Evolution

GPS Modernization

• Interoperability of GNSS Components

• Summary
Why Modernize?

• For **civil users**, new signals provide:
  – More robustness against interference
  – Compensation for ionospheric delays
  – *Wide-laning/tri-laning* -- Resolves integer ambiguities caused by cycle slips during precise carrier phase measurements

• For **military users**, new spectrally separated signals provide:
  – **Protection** of friendly use
  – **Prevention** of adversary exploitation
  – **Preservation** of civil use outside area of operations

• For both civil/military, **system improvements** in accuracy, availability, integrity, and reliability
L2 Civil (L2C) Signal

• Benefits of L2C versus L2 C/A
  • Overcomes some limitations of L1 C/A
  • Improved Tracking Capability (~ 3dB higher)
  • Better Cross Correlation Protection due to longer codes
    – Two Codes Separated by time (e.g. TDMA)
  • Improved data structure for enhanced data demodulation (5 dB better than C/A)
  • Coherent carrier component favored for high precision applications – longer integration possible
  • Improved protection against continuous wave (CW) interference
Third Civil Signal (L5)

- New signal structure for enhanced performance
  - \(~6\ \text{dB Higher power}\) relative to L1 (-154 dBW)
  - 20 MHz (minimum) broadcast bandwidth
  - Longer code
  - Higher chipping rate

- DME compatibility achieved by frequency reallocation, if required
Summary of Signal Modernization

Block IIRs (8 SV’s)
- Adds L2C
- Adds new military M-Code

Signals in Space

Block IIF (16 SVs)
Add civil L5

Signals in Space

- GPS III Architecture Studies underway to define capabilities
- GPS III satellite launches to begin in 2012 timeframe
Ground Control Modernization

- Upgrade monitor stations and ground antennas with new receivers and computers
- Replace existing Master Control Station mainframe computer with a distributed architecture
- Add **Accuracy Improvement Initiative**
- Build fully mission capable Alternate Master Control Station (AMCS)
- Add IIF command and control functionality
- Add **direct civil code monitoring**
Ground Control Modernization

Current
- Master Control Station - 1
- Ground Antenna - 4
- Monitor Station - 6

Planned
- NIMA All Tracking Station - 6
- Alternate Master Control Station (2004) - 1
• Assure the ability to separate, both spatially and spectrally, military and civil capabilities
  – High power in a focused area
  – Modernized signal architecture
• Re-look at entire GPS Architecture to:
  – Achieve long term GPS performance goals
  – Reduce long term total ownership costs
• Ensure best GPS system for the nation for the next 30 years
GPS III Civil Goals

- Significant increase in **system accuracy**
- Assured and improved level of **unaugmented integrity**
- Improved availability of **accuracy with integrity**
- **Backward compatibility** with existing receivers
- **FOC for new civil signals** in combination with IIR-M & IIF satellites
- Smooth transition from **GPS Block II to Block III**
GPS III Status

• Government & Industry Conducting a Study of Civil & Military Architectures
  – System Architecture and Requirements Definition phase on-going with two follow-on study contracts awarded in January 04
  – Requirements Definition continues in preparation for a System Requirements Review in the 2\textsuperscript{nd} quarter of FY05

• Key Decision to enter Risk Reduction/Design Development phase is currently scheduled for 3\textsuperscript{rd} quarter FY05

• Interagency Forum for Operational Requirements is considering civil GPS III “capabilities” and is reviewing the GPS III Capabilities Definition Document (CDD)
  – Analysis of Alternatives of civil space-based positioning, navigation, and timing requirements is underway

• Joint Requirements Oversight Council (JROC) scheduled to meet in July 04 to approve the CDD
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, MSAS, Gagan, EGNOS, etc) will require less ground infrastructure to provide capability
### GPS Modernization Schedule

<table>
<thead>
<tr>
<th>Activity</th>
<th>Implementation Date</th>
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</thead>
<tbody>
<tr>
<td>SA set to zero</td>
<td>May 2000</td>
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<tr>
<td><strong>GPS IIR-M Enhancements</strong></td>
<td></td>
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<tr>
<td>- New L2 Civil (L2C) Signal</td>
<td></td>
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<tr>
<td>- M-code on L1 &amp; L2</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; launch Feb 2005</td>
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<tr>
<td><strong>GPS IIF Enhancements</strong></td>
<td></td>
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<tr>
<td>- New L2 Civil (L2C) Signal</td>
<td></td>
</tr>
<tr>
<td>- M-code on L1 &amp; L2</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; launch 2006</td>
</tr>
<tr>
<td>- L5</td>
<td></td>
</tr>
<tr>
<td><strong>GPS III Enhancements</strong></td>
<td></td>
</tr>
<tr>
<td>- New L2 Civil (L2C) Signal</td>
<td></td>
</tr>
<tr>
<td>- M-code on L1 &amp; L2 with greater power</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; launch ~ 2012</td>
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<tr>
<td>- L5</td>
<td></td>
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<tr>
<td>- Future Capabilities</td>
<td></td>
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<tr>
<td><strong>OCS Enhancements</strong></td>
<td>On-going</td>
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</tbody>
</table>
GPS Augmentation Evolution

- GPS Modernization
- Interoperability of GNSS Components
- Summary
Additional civil GPS signals
- L2C civil signal: First launch 2005
- L5 civil signal: First launch 2006
- Enhanced capabilities with GPS III

- Wide Area Augmentation System (WAAS)
  - Commissioned in July 2003
  - Service available for aviation use

- Nationwide Differential GPS System (NDGPS)
  - Single station coverage in 2005
  - Dual station coverage in 2008
Wide Area Augmentation System (WAAS)

- WAAS consists of:
  - 25 Reference Stations
  - 2 Master Stations
  - 2 Geosynchronous Satellites
  - 3 Uplink Stations

- WAAS augments GPS to meet the necessary integrity, availability, accuracy, and continuity for use in most phases of flight
WAAS Status

- WAAS service is available now in the U.S.
  - Commissioned in July 2003
- GPS/WAAS is a primary navigation system in US national airspace
  - En-route through approach
  - Currently 3800 GPS approaches
    - Includes 500 approaches with vertical guidance
- Allows reduction in ground-based navigation aids (e.g. VOR, etc.)
- Working toward interoperability with Japanese MSAS, Indian Gagan, and European EGNOS
Nationwide DGPS System (NDGPS)

- Began as a **Maritime DGPS** (MDGPS) service
  - For coastal and inland waterways
  - Operational in March 1999

- **Nationwide DGPS System** (NDGPS) is an expansion of MDGPS to cover continental U.S. and Alaska
  - Frequencies optimum for surface transportation

- **40 countries** currently operate DGPS services that are compatible with NDGPS
Nationwide DGPS
Current Coverage
Current NDGPS Status

• **NDGPS expansion is progressing**
  – Currently 82 sites are operational
  – Continue to fill coverage gaps

• **Single-station** coverage now at 85% of the CONUS

• **Dual-station** coverage currently 45%

• Single nationwide coverage projected by the **end of 2005** with the addition of 9 more sites

• **Full Operational Capability** projected for **2008**
• GPS Modernization

**Interoperability of GNSS Components**

• GPS Augmentation Evolution

• Summary
What is Compatibility and Interoperability?

- **Compatibility** (e.g.) -- the assurance that one GNSS will 'do no harm' to another GNSS by degrading the stand alone services that it provides.

- **Interoperability** (e.g.) – the ability to improve the level of service provided to users by any single system through the use of a combined system receiver.

- The US Government considers the assurance of **Compatibility** as the primary requirement for the GPS user community.

**Existing and future GPS users must be protected from harmful service degradation.**
Interoperability
Augmentation Systems

• Benefits of common standards
  – Aircraft and ships can use same equipment around the world

• Critical for safety-of-life services
  – Satellite-based systems (WAAS, MSAS, EGNOS) for aviation
  – Land-based DGPS technology for maritime and terrestrial uses: already adopted by 40 countries
  – Pseudolites for high accuracy or low visibility areas
  – Global, non-proprietary standards

• Goal – Seamless worldwide service
Compatibility
GPS and GLONASS

• Two fully independent systems
• Compatible but not truly interoperable
  – Different geodesy, timing, and signal standards
• However, users can still gain some improved performance using combined receivers
Compatibility/Interoperability
GPS and QZSS

• Common standards
  – System plans to use GPS L1, L2, and L5 civil signal structures (but probably not L1 C/A-code)
  – Control segment linkages to be discussed

• QZSS will improve performance in urban canyons and mountainous regions

• Joint Japan-U.S. Technical Working Group has been established
Compatibility/Interoperability
GPS and Galileo

• Two independent systems
  – Compatibility is essential
  – Interoperability is achievable at the user level
    • Different coordinate reference systems – but within ~ 2 cm
    • Different system times – but with broadcast corrections
    • Different signal structures – but with two shared frequencies

• U.S. Goal is to provide the greatest possible benefit to the largest number of users
  – Simplified, inexpensive receivers
  – Increased availability (greater number of satellites in view)

U.S. & Europe have agreed to a common baseline L1 open civil signal that can become a global standard and is compatible with national/allied/NATO security
• GPS Modernization

Summary

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• Interoperability of GNSS Components
The GNSS Road Ahead

- **Ever expanding use** of satellite navigation in transportation safety and other civil applications

- New civil GPS signals **begin next year** with enhancements continuing through GPS III
  - Augmentations continue to be **an integral component**

- The total number of systems contributing to an overall GNSS architecture is growing

- Encouraged that GPS/Galileo should be **compatible and interoperable**
  - Greater satnav capabilities for civil users worldwide
  - **Spectral separation** of civil and military GNSS signals facilitates preservation of peaceful civil use