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

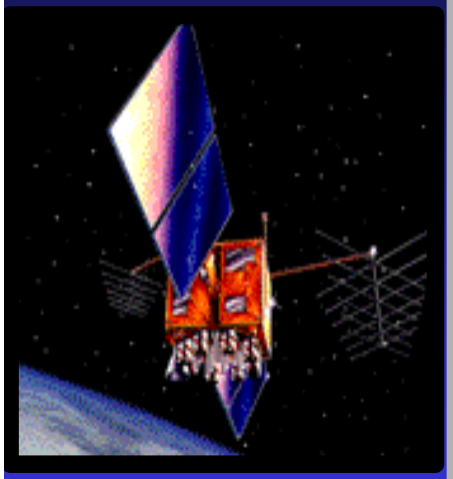
L2 Civil (L2C) Signal

- **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)

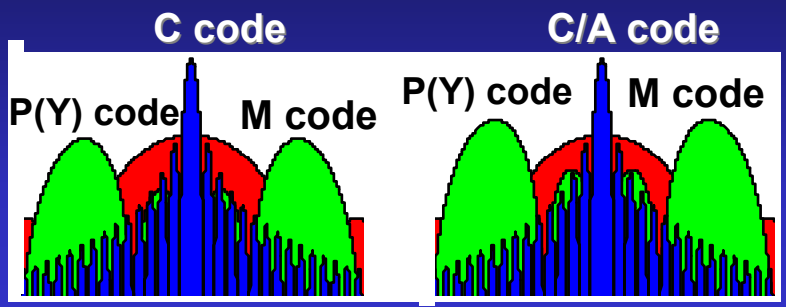
- **New signal structure for enhanced performance**
  - **~ 6 dB Higher power relative to L1 (-154 dBW)**
  - **20 MHz (minimum) broadcast bandwidth**
  - **Longer code**
  - **Higher chipping rate**
- **DME compatibility achieved by frequency reallocation, if required**

Summary of Signal Modernization



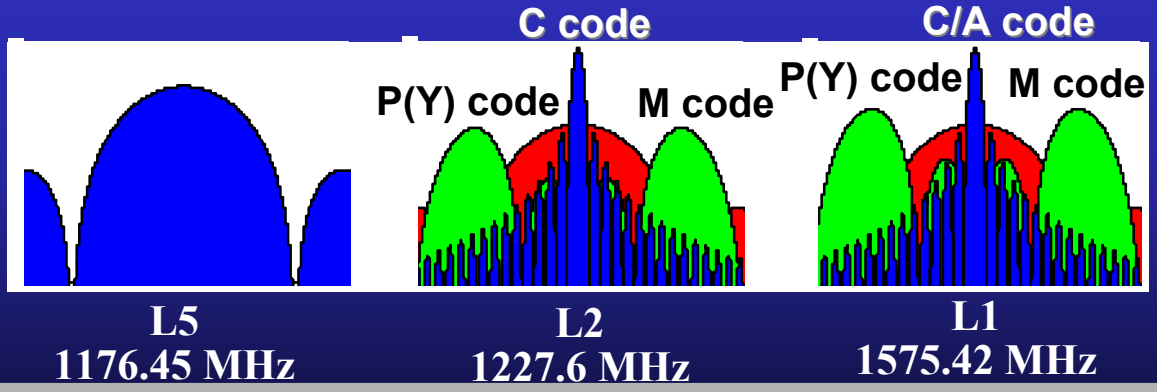
Block IIRs (8 SV's)
- Adds L2C
- Adds new military M-Code

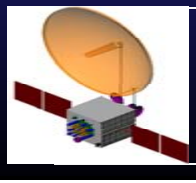
Signals in Space



Block IIF (16 SVs)
Adds 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

GPS III Overview

- **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 2nd quarter of FY05
- Key Decision to enter Risk Reduction/Design Development phase is currently scheduled for 3rd 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

Activity	Implementation Date FY05 PB
SA set to zero	May 2000
GPS IIR-M Enhancements - New L2 Civil (L2C) Signal - M-code on L1 & L2	1st launch Feb 2005
GPS IIF Enhancements - New L2 Civil (L2C) Signal - M-code on L1 & L2 - L5	1st launch 2006
GPS III Enhancements - New L2 Civil (L2C) Signal - M-code on L1 & L2 with greater power - L5 - Future Capabilities	1st launch ~ 2012
OCS Enhancements	On-going

- GPS Modernization

GPS Augmentation Evolution

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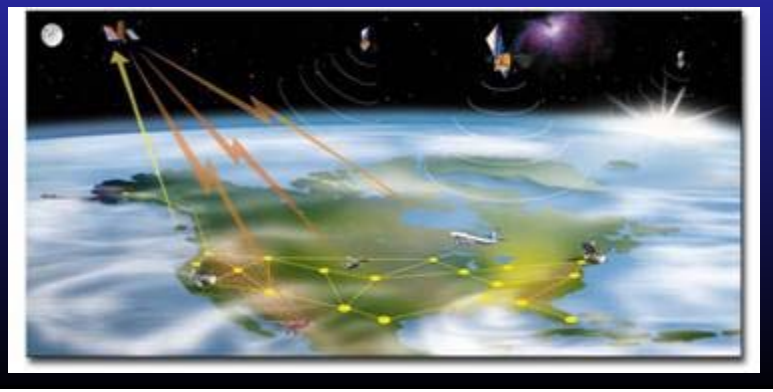
GNSS EVOLUTION IN U.S.

- ✓ **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 augments GPS to meet the necessary integrity, availability, accuracy, and continuity for use in most phases of flight**
- **WAAS consists of:**
  - **25 Reference Stations**
  - **2 Master Stations**
  - **2 Geosynchronous Satellites**
  - **3 Uplink Stations**



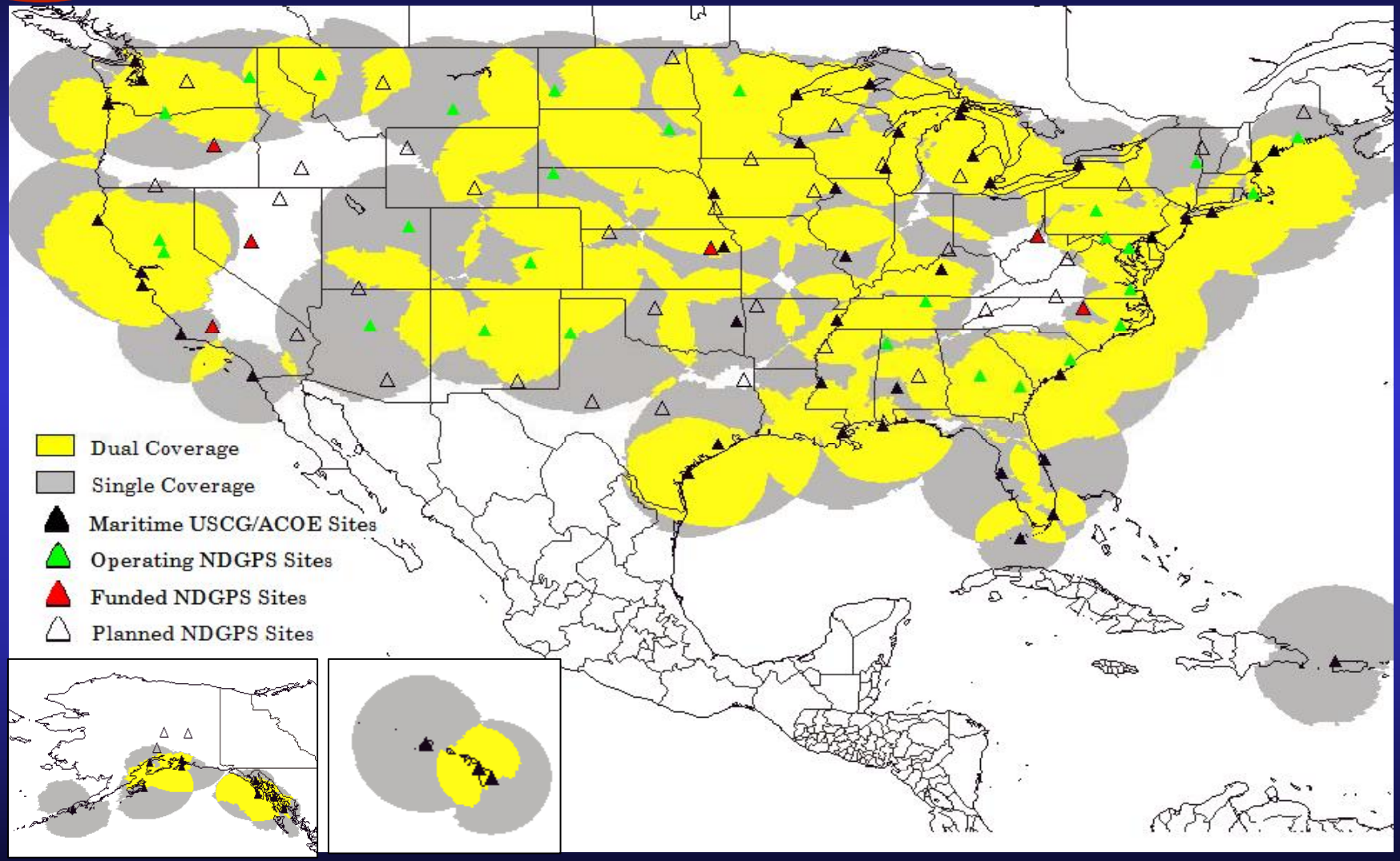
WAAS Status

- 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

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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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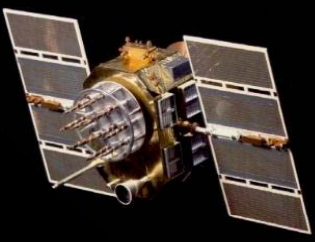
The GNSS Road Ahead

- **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



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