The GPS Modernization Program and Policy Update

National Space-Based PNT Coordination Office

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FIG Congress 2006
Munich, Germany
11 October 2006

OVERVIEW

- Background
- Positioning, Navigation, and Timing Policy
- Constellation Status
- Modernization Program
- Summary

GPS Background

- Active program for over 30 years
  - 1973: development underway from separate programs
  - 1978: begin launch developmental satellites
  - 1989: begin launch operational satellites
  - 1993: Initial Operational Capability (IOC)
  - 1995: Full Operational Capability (FOC)
- Developed 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
  - 1996, March: Presidential Decision Directive; captured by U.S. Public Law- December 1997
  - 2004, December: U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy [http://pnt.gov]

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U.S. Policy History

- 1983: President statement - free civilian access to GPS
- 1996: GPS declared a dual-use system under joint civil/military management
- 1997: Congress passes law requiring civil GPS to be provided free of direct user fees
- 2000: By Presidential Directive, Selective Availability (SA) is turned off in May
- 2004: U.S. Space-Based Positioning, Navigation, & Timing (PNT) Policy recognizes changing international conditions and worldwide growth of GNSS applications based on GPS

U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy

- Released December 2004
- Recognized changes since 1996 policy
- Improved management for PNT issues
- Publicly available information provided at: http://pnt.gov

Policy Objectives

- Provide space-based civil PNT services free of direct user fees on a continuous, worldwide basis
- Commits to continued modernization of GPS and its augmentations - improving global services
  - Ensure civil requirements are met and civil services exceed, or are at least equivalent to, those of other international civil space-based PNT services
  - Improve resistance to interference for civil, commercial, homeland security, and scientific users

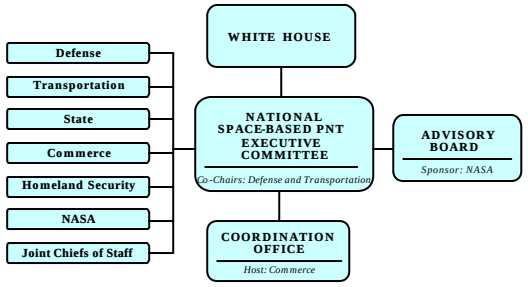
Policy: Objectives (cont'd)

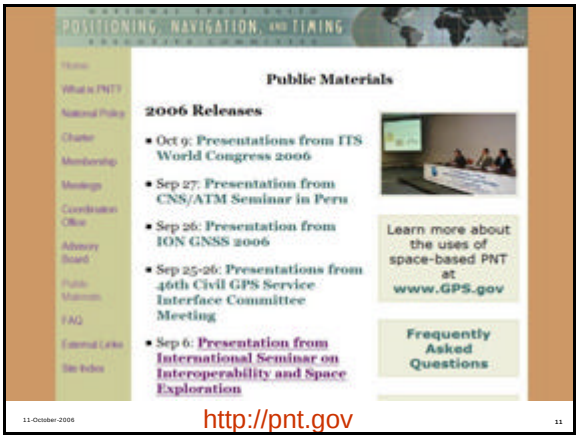
- Open, free access to information needed to use civil GPS and its augmentations
- Improve capabilities to deny hostile use of PNT without unduly disrupting civil and commercial access
- Maintain GPS as component of U.S. Critical Infrastructure (multiple sectors)
  - Plan for backup capabilities and services
- Work to ensure other international PNT systems are interoperable with GPS and its augmentations; at a minimum, are compatible

Policy Implementation

- National Space-Based PNT Executive Committee (PNT ExCom)
  - Chaired by Deputy Secretaries of Defense and Transportation
  - Membership: Deputy Secretaries of State, Commerce, Homeland Security, JCS, and NASA
- National Space-Based PNT Coordination Office (NPCO)
- Space-Based PNT Advisory Board, chartered as a Federal Advisory Committee (non Federal members; national and international representation)

NPNT Organizational Structure





http://pnt.gov

U.S. Policy: Summary

- Commitment to improving GPS and its augmentations for all stakeholders (Domestic and International)
- Framework for public and private decisions
- Coordinated planning and activities
- No intentions to implement "Selective Availability"
- Commitment to preventing hostile use of PNT through regional denial of service
- Promotes common standards for worldwide interoperability
- Creates basis for meaningful dialogue between global service providers and end users

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GPS Constellation Status (1)

30 Operating Satellites

- 16 II/IIA satellites operational
- 12 IIR satellites operational
  - Modernizing up to 8 Block IIR satellites
- 1st IIR-M, launched 25 September 2005
  - Set healthy on 16 December 2005
- 2nd IIR-M launched 25 September 2006
- 3rd IIR-M launch currently scheduled
  - Tentative: 14 November 2006
- 4th IIR-M launch schedule
  - Tentative: September 2007
- 5th through 8th IIR-M: launch by 2009
- 1st IIF: launch ready, tentative May 2008

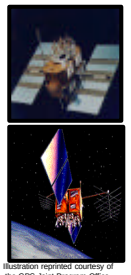


Illustration reprinted courtesy of the GPS Joint Program Office

GPS Constellation Status (2)

30 Operating Satellites

- Continuously assessing constellation health to determine launch need
  - Constellation (operational) average life, as of May 2006: 8.61 years
  - Sustainment issues
    - ✓ Aging satellites – most past design life
    - ✓ 12 SVs launched in 1990-1994 time period
    - ✓ 12 SVs are more than 12 yrs old
      - ➢ 1 SV over 16 yrs old
    - ✓ 3 SVs about 10 years old
    - ✓ Power management requirements
- Since December 1993 (IOC), GPS civil service performance commitment met continuously

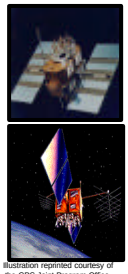


Illustration reprinted courtesy of the GPS Joint Program Office

Constellation Performance

Specification values from the Standard Positioning Service (SPS) Performance Standard, October, 2001

PDOP (Geometry) Availability
- Specification - PDOP of 6 or Less, 98% of the time
- Actual - 99.98798%

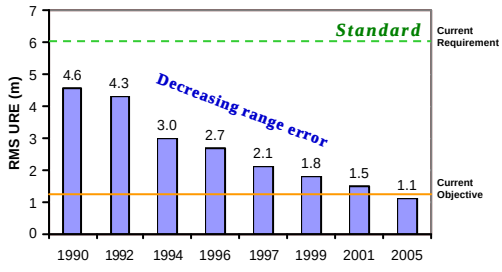
Horizontal Service Availability
- Specification - 95% Threshold of 36 meters, 99% of the Time
- Actual – 2.74 meters

Vertical Service Availability
- Specification - 95% Threshold of 77 meters, 99% of the Time or Better
- Actual – 3.89 meters

User Range Error (URE)
- Specification - 6 meters or Less, Constellation Average
- Actual – see next chart

System accuracy and availability far exceed current specifications

GPS Single Frequency (L1) Performance



Signal in Space RMS URE: Root Mean Square User Range Error

System accuracy far exceeds current standard

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GPS Modernization Program

Increasing System Capabilities • Increasing Defense / Civil Benefit

Block IIA/IIR

Basic GPS
- Standard Service
  - Single frequency (L1)
  - Coarse acquisition (C/A) code navigation
- Precise Service
  - Y-Code (L1Y & L2Y)
  - Y-Code navigation

Block IIR-M, IIF

IIR-M: IIA/IIR capabilities plus
- 2nd civil signal (L2C)
- M-Code (L1M & L2M)

IIF: IIR-M capability plus
- 3rd civil signal (L5)
- Anti-jam flex power

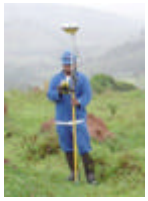
Block III

- Backward compatibility
- 4th civil signal (L1C)
- Increased accuracy
- Increased anti-jam power
- Assured availability
- Navigation surety
- Controlled integrity
- Increased security
- System survivability

Why Modernize?

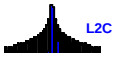
- For civil users, new signals provide:
  - More robustness against interference
  - Improved compensation for ionospheric delays
  - Wide-laning/tri-laning – more precision
  - Interoperability between constellations increases capability to users with reduced satellite visibility (urban canyon, forest canopy, etc.)
- For military, new spectrally separated signals provide:
  - Protection of friendly use; Prevention of exploitation
  - Preservation of civil use outside area of operations
- For both civil and military, system improvements:
  - More accuracy, availability, integrity, and reliability

Second Civil Signal (L2C)



Benefits existing professional receivers

- Designed to meet civil user needs for enhanced capabilities
  - Dual civil code signals – higher accuracy in combination with L1 C/A code phase data
  - Less susceptible to interference
- Available since Dec 2005
  - Currently on 2 satellites
  - Will be on all future satellites
- Expected to generate substantial user productivity benefits

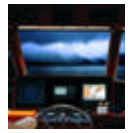


Increases accuracy for consumers

Supports miniaturization, possible indoor use

Third Civil Signal (L5)

- Higher power than other GPS civil signals
- Designed to meet demanding requirements for transport safety
  - In Aeronautical Radionavigation Service Band
- Wider bandwidth improves resistance to interference
- New signal structure for enhanced performance
- May also enable global, centimeter-level accuracy using new techniques
- Opportunity for international interoperability
  - Interoperable with Galileo's E5a

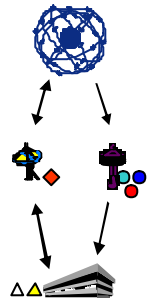


Ground Control Modernization

- Upgraded Master Control Station (MCS) with:
  - Improved operator interfaces
  - IIR-M and IIF capabilities
    - ✓ Monitoring all civil signals – L2C & L5 – full control
  - Launch and Early Orbit Anomaly Resolution and Disposal Operations
- Fully mission capable Alternate MCS
- Legacy Accuracy Improvement Initiative (L-AII)
  - Additional data from National Geospatial-Intelligence Agency (NGA) GPS Monitor Station Network, yielding improvement in:
    - ✓ Monitoring signal integrity and constellation performance
    - ✓ Accuracy of Kalman filter state estimates
    - ✓ Amount of data used for satellite time and position estimation, resulting in more accurate predicted satellite orbital position and clock data in the satellite broadcast message

Reference: GPS World, March 2006 – "New, Improved GPS – Legacy Accuracy Improvement Initiative"

Ground Control System Expansion
Accuracy Improvement Initiative (AII)



△ △ Master / Backup Control Stations: Provide navigation estimation (ephemeris and clock), control the satellites, control the operations network, and schedule missions

GPS (6) / NGA monitor stations (6) / upcoming NGA monitor stations (5) : Monitor navigation messages to collect system performance metrics, collect environment data, send data to OCS to calculate accurate satellite uploads

Ground antennas: Transmit navigation data / commands and collect telemetry

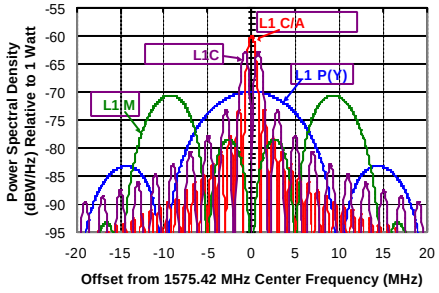
GPS III Goals

- Increased system accuracy
- Assured and improved level of unaugmented integrity
- Improved availability of accuracy with integrity
- Backward compatibility with existing receivers
- Support for new signals in combination with IIR-M & IIF satellites
  - L2C, L5, M-code (existing with IIR-M, IIF)
  - L1C and future options for new navigation messages, flexible power levels
- Smooth transition from GPS Block II to Block III

Fourth Civil Signal (L1C)

- Modernized civil signal at L1 frequency
  - Original signal (L1 C/A) retained for backward compatibility
- Improved code and carrier tracking
- New message structure
- More robust navigation across a broad range of user applications
- Improved performance in challenged tracking environments
- Internationally defined civil signal
  - Common use with Japan's QZSS
  - Interoperable with Galileo's Open Service
  - Possibility for use in modernized GLONASS?

L1 GPS Spectrum



IS-GPS-800: L1C Signal Design Initial Review Stage


DRAFT

NAVSTAR GLOBAL POSITIONING SYSTEM

INTERFACE SPECIFICATION

Draft IS-GPS-800

Navstar GPS Space Segment/User Segment L1C Interfaces

IS-GPS-800 Initial Review & Process

- US-Galileo WG 'A' distribution for signal design review (Oct. 2005)
- US-Japan EWG distribution for signal design review as mutually agreed (Jan. 2006)
- US internal government pre-review (1 March 2006)
- IS-GPS-800 publicly released for review (20 April 2006)
- Document available at GPS JPO Public website:

http://gps.losangeles.af.mil/engineering/icwg/

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GPS Legacy and Modernized Signals

- **Legacy Signals (no cost for access & use)**
  - L1 C/A-code (1st Civil Signal) – foundation for today's global GNSS industry
  - L1/L2 P(Y)-code – global military use
- **Modernized Signals (no cost for access & use)**
  - L2C (2 satellites) – 2nd civil signal
  - L1/L2 M-code (2 satellites) – new military signals
  - L5 (first launch 2008) – 3rd civil signal
  - L1C (first launch 2013) – 4th civil signal
    - ✓ International design – U.S., Europe and Japan

GPS Modernization Program Status

Activity	Implementation Date
SA set to zero	May 2000
GPS IIR-M Enhancements - New L2 civil (L2C) signal - M-code on L1 & L2	1st satellite operational on December 16, 2005 2nd Launched 25 Sept. 2006
GPS IIF Enhancements - L2 civil (L2C) signal - M-code on L1 & L2 - New L5 civil signal	1st launch currently scheduled for May 2008
GPS III Enhancements - L2 civil (L2C) signal - M-code with greater power - L5 - New L1C civil signal	1st launch ~ 2013
Control Segment Enhancements	On-going

Summary

- GPS continues to evolve as a key part of the global space-based PNT infrastructure
- Civil service continues to exceed performance standards
- Modernization is underway
  - IIR-M launch with L2C and M-code
  - IIF satellites with L2C, L5 and M-code
- Modernization - future
  - GPS III - enhancements will continue
    - ✓ L1C
- Sustainment of constellation is number one priority
- Civil users are engaged in defining the way-ahead for GPS sustainment and modernization

POSITIONING, NAVIGATION, AND TIMING

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