GPS Civil Service Update & U.S. International GNSS Activities

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International GNSS (IGNSS) Conference
Sydney, Australia

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Overview

➢ **Policy and Service Provision**

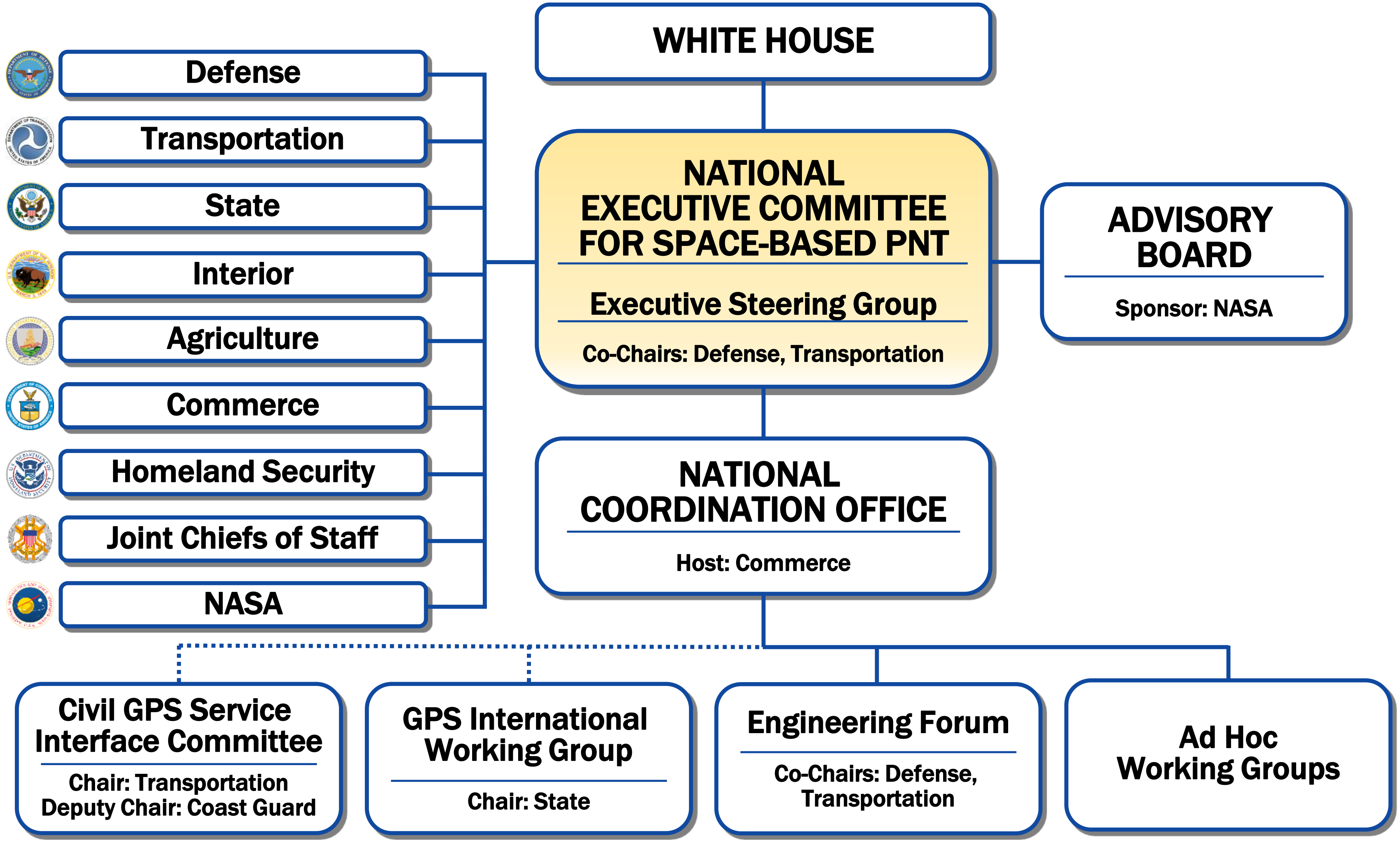
- Constellation Status and Modernization
- International Cooperation

U.S. National Space Policy

Space-Based PNT Guideline: Maintain leadership in the service, provision, and use of GNSS

- Provide civil GPS services, free of direct user charges
  - Available on a continuous, worldwide basis
  - Maintain constellation consistent with published performance standards and interface specifications
  - Foreign PNT services may be used to complement services from GPS
- Encourage global *compatibility* and *interoperability* with GPS
- Promote *transparency* in civil service provision
- Enable market access to industry
- Support international activities to detect and mitigate harmful interference

National Space-Based PNT Organization



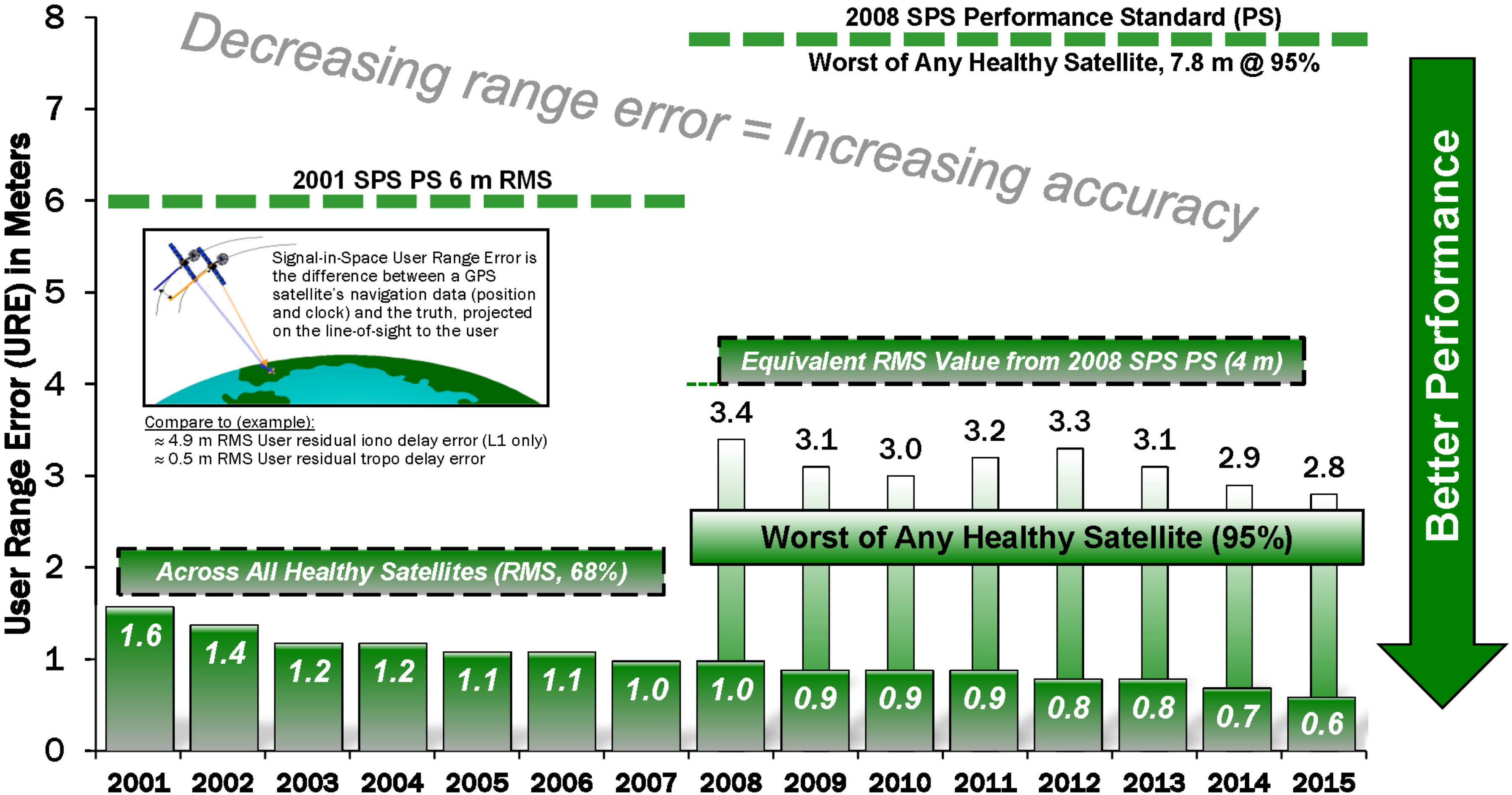
GPS Civil Service Provision

- Global GPS civil service performance commitment continuously met/exceeded since 1993
- Open, public signal structures with public domain documentation necessary to develop receivers
  - Promotes open competition and market growth for commercial GNSS
- A critical component of the global information infrastructure
  - Compatible with other satellite navigation systems and interoperable at the user level
  - Guided at a national level as multi-use asset
  - Acquired and operated by Air Force on behalf of the USG

GPS provides continuously improving, predictable, and dependable Global Public Service

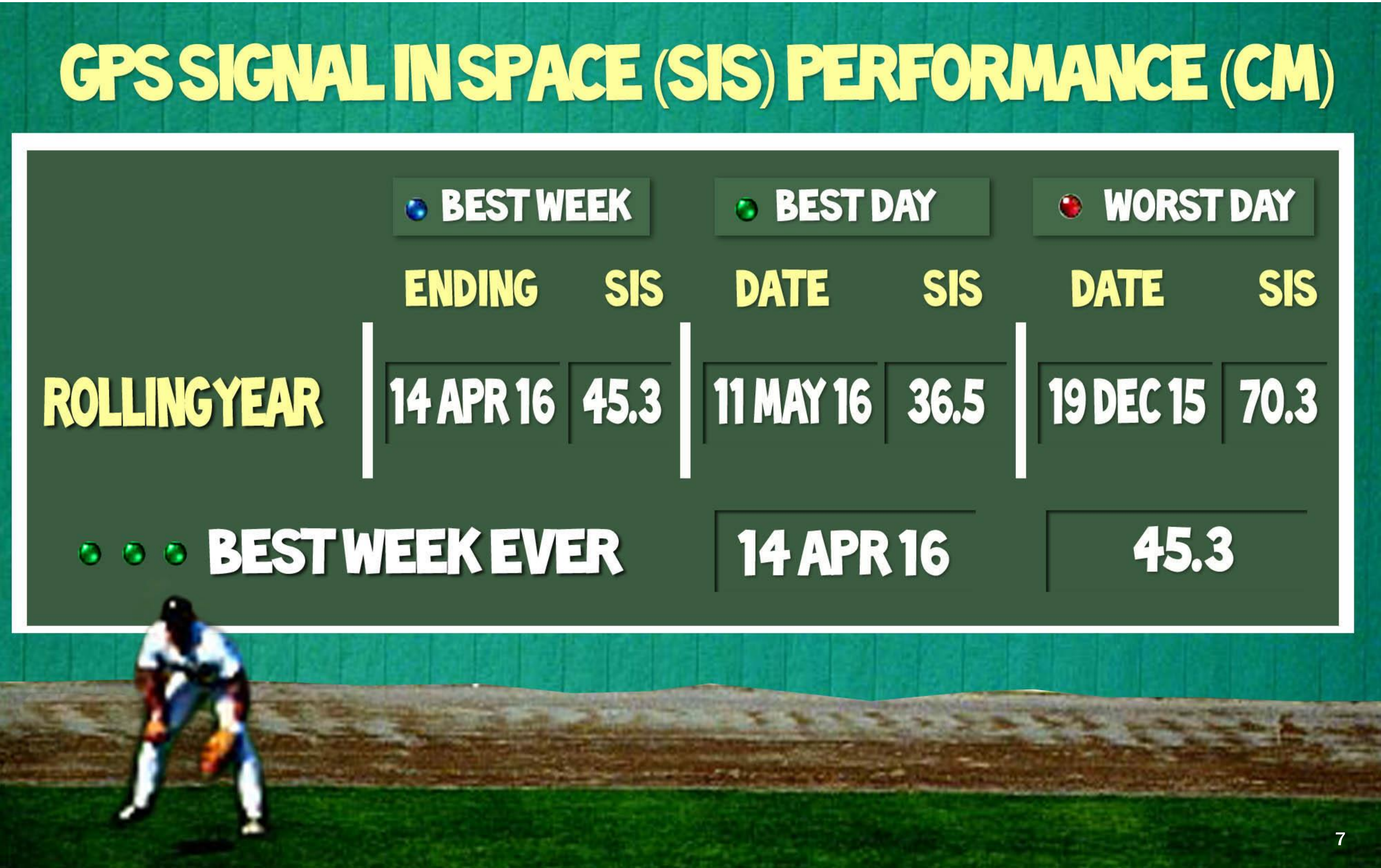
Accuracy: Civil Commitments
Standard Positioning Service (SPS) Performance Standard

Standard Positioning Service (SPS) Signal-in-Space Performance



System accuracy better than published standard

GPS Signal in Space Performance Scoreboard



GPS SIGNAL IN SPACE (SIS) PERFORMANCE (CM)

	BEST WEEK		BEST DAY		WORST DAY	
	ENDING	SIS	DATE	SIS	DATE	SIS
ROLLING YEAR	14 APR 16	45.3	11 MAY 16	36.5	19 DEC 15	70.3

BEST WEEK EVER	14 APR 16	45.3

GPS Performance Report Card

- 2013 report now available on gps.gov
  http://www.gps.gov/systems/gps/performance/
- This report measures GPS performance against GPS SPS Performance Standard

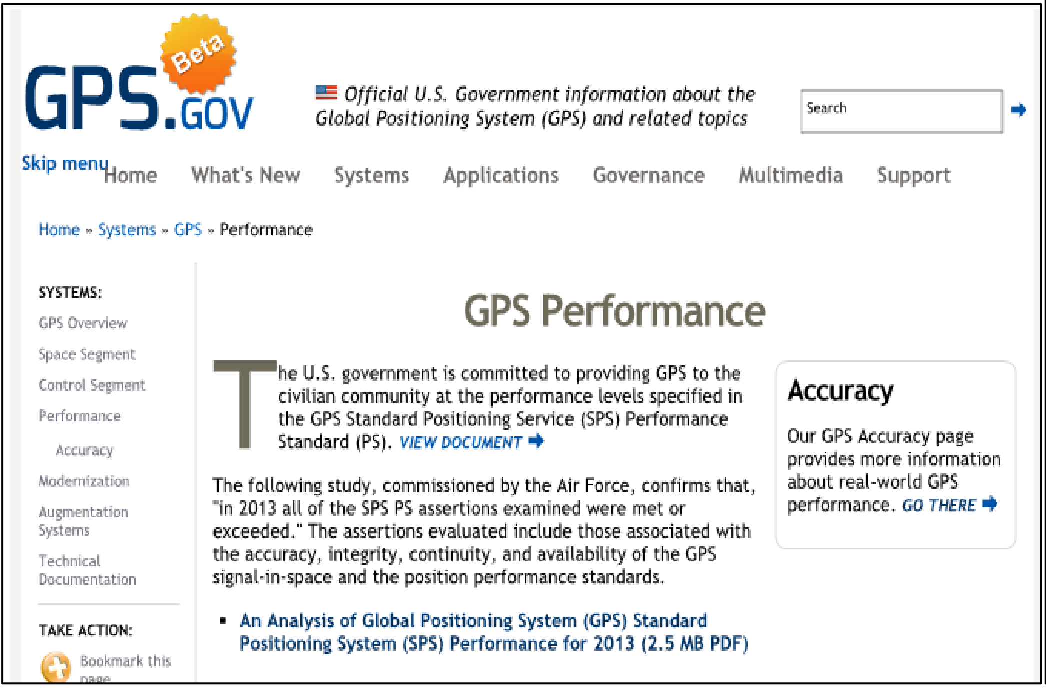


Table 2.1: Summary of SPS PS Metrics Examined for 2013

SPSPS08 Section	SPS PS Metric	2013 Status
3.4.1 SIS URE Accuracy	≤ 7.8 m 95% Global average URE during normal operations over all AODs	✔✚
	≤ 6.0 m 95% Global average URE during normal operations at zero AOD	✔✚
	≤ 12.8 m 95% Global average URE during normal operations at any AOD	✔✚
	≤ 30 m 99.94% Global average URE during normal operations	✔✚
	≤ 30 m 99.79% Worst case single point average URE during normal operations	✔✚
3.5.1 SIS Instantaneous URE Integrity	≤ $1X10^{-5}$ Probability over any hour of exceeding the NTE tolerance without a timely alert	✔✚
3.6.1 SIS Continuity - Unscheduled Failure Interruptions	≥ 0.9998 Probability over any hour of not losing the SPS SIS availability from the slot due to unscheduled interruption	✔✚
3.7.1 SIS Per-Slot Availability	≥ 0.957 Probability that (a.) a slot in the baseline 24-slot will be occupied by a satellite broadcasting a healthy SPS SIS, or (b.) a slot in the expanded configuration will be occupied by a pair of satellites each broadcasting a healthy SIS	✔✚
3.7.2 SIS Constellation Availability	≥ 0.98 Probability that at least 21 slots out of the 24 slots will be occupied by a satellite (or pair of satellites for expanded slots) broadcasting a healthy SIS	✔✚
	≥ 0.99999 Probability that at least 20 slots out of the 24 slots will be occupied by a satellite (or pair of satellites for expanded slots) broadcasting a healthy SIS	✔✚
3.7.3 Operational Satellite Counts	≥ 0.95 Probability that the constellation will have at least 24 operational satellites regardless of whether those operational satellites are located in slots or not	✔✚
3.8.1 PDOP Availability	≥ 98% Global PDOP of 6 or less	✔✚
	≥ 88% Worst site PDOP of 6 or less	✔✚
3.8.2 Position Service Availability	≥ 99% Horizontal, average location ≥ 99% Vertical, average location ≥ 90% Horizontal, worst-case location ≥ 90% Vertical, worst-case location	✔✚
3.8.3 Position Accuracy	≤ 9 m 95% Horizontal, global average ≤ 15 m 95% Vertical, global average ≤ 17 m 95% Horizontal, worst site ≤ 37 m 95% Vertical, worst site	✔✚

✔✚ - Met or Exceeded

Overview

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- **Constellation Status and Modernization**
- International Cooperation

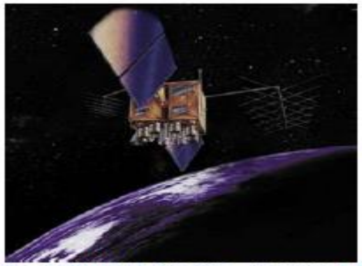
GPS Constellation Status

36 Total Satellites / 31 Operational
(Baseline Constellation: 24)

Four Generations of Operational Satellites

- Block IIA - 5 Residual
  - 7.5 year design life
  - Launched 1990 to 1997
- Block IIR - 12 Operational
  - 7.5 year design life (oldest operational satellite is 19 years old)
  - Launched 1997 to 2004
- Block IIR-M - 7 Operational, 1 Residual
  - 7.5 year design life
  - Launched 2005 to 2009
  - Added 2nd civil navigation signal (L2C)
- Block IIF - 12 Operational
  - 12 year design life
  - Launched 2010 to 2016
  - Added 3rd civil navigation signal (L5)


Block IIA Satellite – Designed & Built by Rockwell International


Block IIR/IIR-M Satellite – Designed & Built by Lockheed Martin


Block IIF Satellite – Designed & Built by Boeing

GPS III

- GPS III is the newest block of GPS satellites
  - 4 civil signals: L1 C/A, L1C, L2C, L5
    - First satellites to broadcast common L1C signal
  - 4 military signals: L1/L2 P(Y), L1/L2M
  - 3 improved Rubidium atomic clocks

- SV01-SV10 on contract
  - Resolved technical challenges with payload
  - SV9-10 same requirements baseline as SV01-08
- Current Status
  - SV01 In Testing Flow
    - -- Baseline thermal vacuum testing completed 23 Dec 15
    - -- Electromagnetic Interference (EMI) test completed 14 May 16
  - SV02/03 In Assembly and Integration
  - SV04 thru 08 in box level assembly

GPS III SV01 Available For Launch December 2016

GPS Ground Segment Status

- Current system Operational Control Segment (OCS)
  - Flying GPS constellation using Architecture Evolution Plan (AEP) and Launch and Early Orbit, Anomaly, and Disposal Operations (LADO) software capabilities
  - Increasing Cyber security enhancements
- Next Generation Operational Control System (OCX)
  - Modernized command and control system
  - Modern civil signal monitoring and improved PNT performance
  - Robust cyber security infrastructure
  - OCX currently in integration and test
  - Block 0 supports launch and checkout for GPS III
  - Block 1 supports transition from current control segment
  - Block 2 to enable new capabilities including civil signal performance monitoring capability

Monitor Station

Ground Antenna

Modernized Civil Signals

- The U.S. initiated continuous CNAV message broadcast (L2C & L5) on 28 Apr 14
- CNAV uploads transmitted on a daily basis beginning on December 31, 2014
- **19 GPS satellites currently broadcast L2C and 12 broadcast L5**
  - These signals should continue to be considered pre-operational and should be employed at the user's own risk
    - Position accuracy not guaranteed during pre-operational deployment
    - L2C message currently set "healthy"
    - L5 message set "unhealthy" until sufficient monitoring capability established

Coordinated Universal Time Offset (UTCO) Anomaly

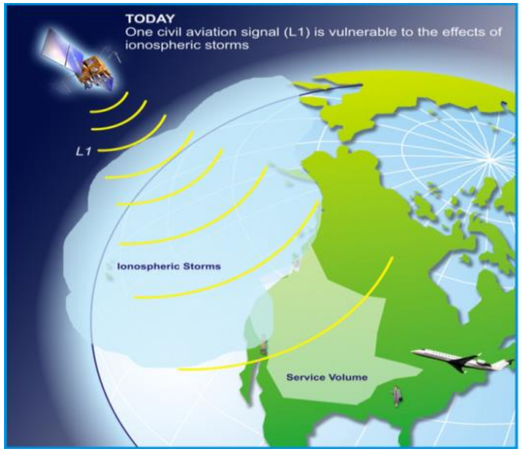
- GPS Mission Control Segment uploaded incorrect UTCO parameters to a portion of the GPS constellation
  – Occurred 25 - 26 January for ~14 hour window; 15 SVs affected
  – Once identified and confirmed, fix was uploaded to all affected satellites within 1.5 hours
- GPS Program Office and Ops Squadron implemented software update to resolve core upload issue
- GPS Program Office also exploring:
  – Potential addition of "resilience considerations for handling GPS data" to SPS PS
  – Increased UTCO parameter monitoring and additional options
  – Follow-on software update to provide additional protections against UTCO issues
- ION paper on UCTO Anomaly impacts to receivers posted at gps.gov (http://www.gps.gov/systems/gps/performance/)

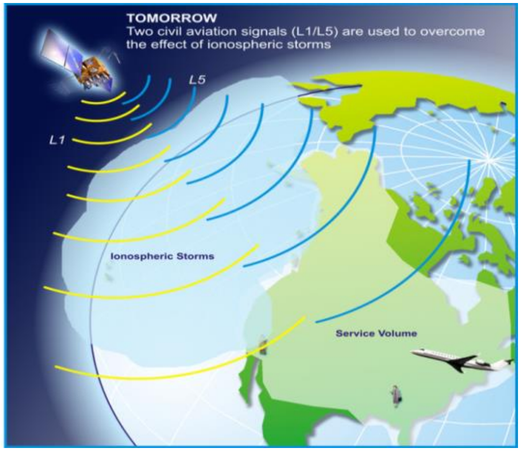
WAAS Phase IV Dual Frequency Operations

Objective: Obtain Dual-Frequency Multi-Constellation (DFMC) Service

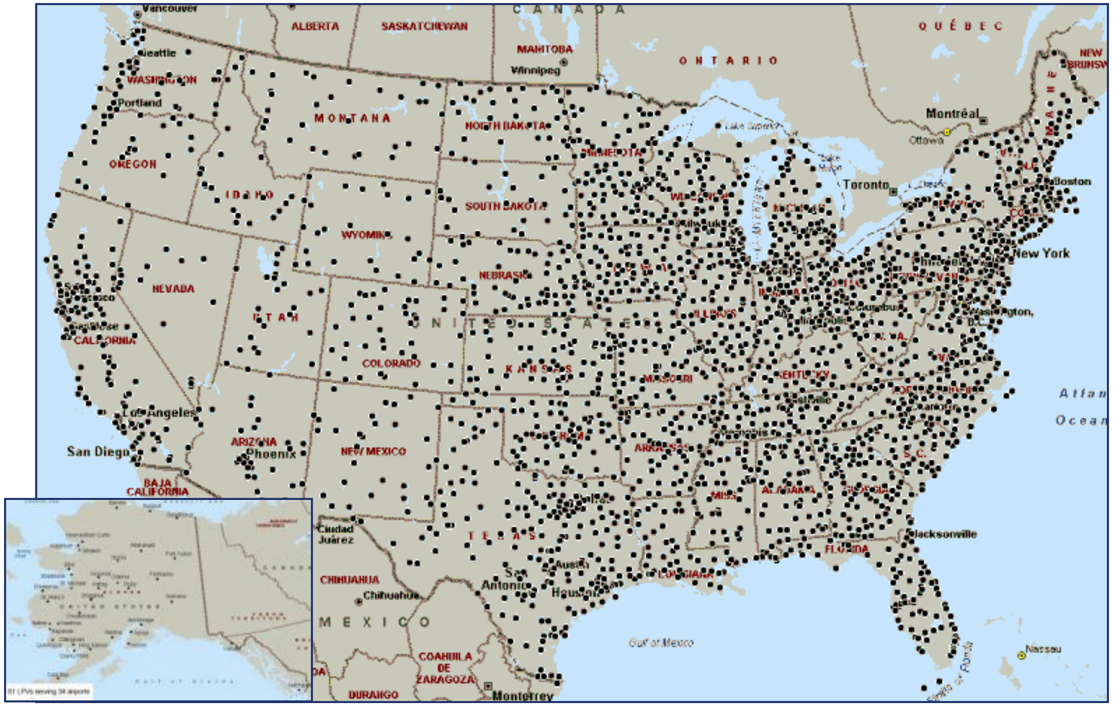
Phase IV Segment 1: Infrastructure improvements and technical refresh to support current system and enable future DF operations

- Five Releases
  - Release 1: Processor Upgrades by 2nd quarter 2017
  - Release 2: Cutover to GEO 5 by 2nd quarter 2018
  - Release 3: GIII Multicast Structure (including monitoring): cutover to complete by 2nd quarter 2018
  - Release 4: Corrections & Verification Safety Computer: validation and deployment cutover by end of 2018
  - Release 5: GEO Uplink System Safety Computer upgrade kits for GEO 5 summer 2017; GEO 6 cutover Sept 2019
- Dual-Frequency Multi-constellation Capability (DFMC)
  - Avionics and Infrastructure development underway
  - Assisting with SBAS provider perspective on DFMC capabilities
- Advanced RAIM (ARAIM): developing avionics centric approach for use of multi-constellation GNSS
  - Focus on requirements for horizontal navigation (H-ARAIM)
- Phase IV Segments 2 & 3 Tasks & Activities in definition phase



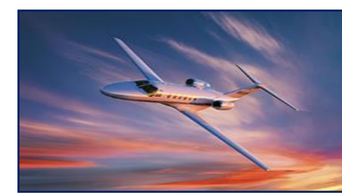


Procedures and Users Depending on WAAS



Approach Procedures

- 4,343 WAAS Procedures published (as of Oct 2016)
  - 3,722 Localizer Precision V procedures
  - 621 LP procedures



Users

- Over 91,000 WAAS/SBAS equipped aircraft
- All aircraft classes served in all phases of flight
- WAAS/SBAS is enabling technology for FAA NextGen
  - Automatic Dependent Surveillance Broadcast (ADS-B)
  - Performance Based Navigation (PBN)

Overview

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- Constellation Status and Modernization

➢ **International Cooperation**

U.S. Objectives in Working with Other GNSS Service Providers

- Ensure **compatibility** — ability of U.S. and non-U.S. space-based PNT services to be used separately or together without interfering with each individual service or signal
  - Radio frequency compatibility
  - Spectral separation between M-code and other signals
- Achieve **interoperability** – ability of civil U.S. and non-U.S. space-based PNT services to be used together to provide the user better capabilities than would be achieved by relying solely on one service or signal
- Promote fair competition in the global marketplace

Pursue through Bilateral and Multilateral Cooperation

Bilateral GNSS Cooperation

- *Europe:* GPS-Galileo Cooperation Agreement signed 2004
  - Working Group on Next Generation GPS/Galileo Civil Services meets twice per year – most recent meeting Oct. 2016
  - Working Group on Trade & Civil Applications met Mar. 2016
  - PRS access negotiations are under way
- *China:* Most recent civil GNSS Plenary – Jun. 2015
  - Sub-group on compatibility and interoperability met Sep. 2016 in Portland, OR
  - GNSS discussed at U.S.-China Civil Space Dialogue – Oct. 2016
- *Japan:* Civil Space Dialogue held in Tokyo – Sep. 2015
  - U.S. hosts QZSS monitoring stations in Hawaii and Guam
- *India:* Civil Space Joint Working Group Meeting in Bangalore – Sep. 2015
  - ITU compatibility coordination completed

Additional Bilateral Dialogues

- *Australia:* Joint Delegation Statement on Cooperation in the Civil Use of GPS in 2007
  - Last formal space bilateral meeting held in Oct. 2010
  - Periodic informal discussions held
- *Canada:* Civil GNSS meeting held in Ottawa – May 2015
  - U.S. participated in Federal GNSS Coordination Board Workshop on GNSS policy, vulnerabilities and mitigation – Oct 2016 in Ottawa
- *Republic of Korea:* 2nd bilateral Civil Space Dialogue held in Seoul – Apr. 2016
  - Discussion about Korea's development of their SBAS
- *Ukraine:* U.S.-Ukraine Civil Space Dialogue held in Washington – May 2016

International Committee on Global Navigation Satellite Systems (ICG)

- Emerged from 3rd UN Conference on the Exploration and Peaceful Uses of Outer Space July 1999
  - Promote the use of GNSS and its integration into infrastructures, particularly in developing countries
  - Encourage compatibility and interoperability among global and regional systems
- Members include:
  - **GNSS Providers:** (U.S., EU, Russia, China, India, Japan)
  - Other Member States of the United Nations
  - International organizations/associations

ICG International Committee on Global Navigation Satellite Systems

http://www.unoosa.org/oosa/en/ourwork/icg/icg.html

11th Meeting of the International Committee on GNSS (ICG-11)

- Multilateral meeting hosted by the Russian Federation in Sochi
- More than 100 participants
  - Representatives from 21 countries/organizations
  - Representation from all 6 GNSS Providers
- Agenda included:
  - Meeting of the Providers' Forum
  - System Provider Updates
  - Applications and Experts Session
  - Meeting of all four Working Groups

ICG-11: Significant Accomplishments and Recommendations

- Interference Detection and Mitigation (IDM) & Spectrum Protection
  - Recommendation for Providers to promote the implementation of protection measures of GNSS operations around the world
  - Proposal for ICG Secretariat to deliver a communication to select members of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) - Focused on National Efforts to protect RNSS Spectrum, with a request for member states to report their regulations and report on efforts to mitigate interference
  - 6th IDM workshop to take place in May 2016 in Croatia
- International Multi-GNSS monitoring (IGMA)
  - Recommendation for an ICG workshop to be held in May 2017 to discuss the multi-GNSS monitoring trial project established in 2016 between the ICG and IGS, and discuss the need for GNSS signal quality monitoring
- Interoperability – Timing
  - Recommendation for ICG expert level workshop to be held in 2017 to further discuss GNSS system time offsets among the systems

ICG-11: Significant Accomplishments and Recommendations (continued)

- Space Service Volume (SSV)
  - SSV Booklet to be released in early 2017 – results of completed simulations used to develop definitions and assumptions for an interoperable SSV
  - Outreach activities scheduled in 2017 to highlight the importance of the ICG work taking place and the benefits of an interoperable SSV
- Signal Patents
  - Recommendation for nations to ensure that open signal structure patents are discouraged and not used for the collection of royalties
- Search and Rescue (SAR)
  - Presentations from 3 GNSS providers on SAR implementation status – recognition by providers of the importance of having interoperable SAR services
- Space Weather
  - Discussion about ionospheric models – will be further discussed at future ICG meetings

Summary

- U.S. policy encourages the worldwide use of civil GPS services and cooperation with other GNSS providers
  - Compatibility, interoperability, and transparency in civil service provision are priorities
- GPS performance continues to improve beyond published commitments
- Ongoing GPS modernization is adding new capabilities for user benefits
- The ICG, with strong U.S. participation, is working to provide civil GNSS services that benefit users worldwide

THANK YOU !

Headlines: Space Bill Addresses PNT; DHS Demonstrates Precision Timing Technology at NYSE

GPS B·U·L·L·E·T·I·N

Information for Policymakers from the National Coordination Office for Space-Based Positioning, Navigation, and Timing (PNT)

May 3, 2016

Space Bill Addresses PNT

On April 14, Rep. Jim Bridenstine (R-OK) introduced the American Space Renaissance Act.

Section 103 of the bill is titled "Positioning, Navigation, and Timing." According to the Congressman, the provision "Expresses a sense of Congress on the importance of positioning, navigation, and timing (PNT) for national security and economic prosperity. Requires the Secretary of Defense to provide a strategy to ensure DOD PNT leverages the best available signals from alternative PNT systems. The strategy will address issues associated with monitoring and verifying accuracy, integrity, availability, security, and reliability of foreign PNT signals."

Section 104 cites the National Executive Committee for Space-Based PNT as a model for establishing a new National Executive Committee on Weather.

Learn more at GPS.gov

DHS Demonstrates Precision Timing Technology at NYSE

On April 20, DHS announced the successful demonstration of Enhanced LORAN (eLoran), a precision timing technology, for financial transactions at the New York Stock Exchange (NYSE). Recognizing the challenges of space-based signals and the importance of having multiple timing sources, eLoran is one technology being considered to provide a complementary timing solution to existing GPS technology.

Precise and synchronized timing of financial transactions is critical to markets worldwide and is mandated by regulation in the European Union and is increasingly required in the United States. Today, precision timing capabilities are provided primarily by GPS. However, GPS's space-based signals are low-power and susceptible to possible disruptions. GPS signals are also difficult to receive indoors and in urban canyons.

The live demonstration at the NYSE was hosted by Juniper Networks, Harris Corporation, and UrsaNav, under a cooperative agreement with DHS. Over 60 industry and government representatives attended, including senior officials from DHS, DOT, DOD, Treasury, and DOE. The ensuing discussion highlighted the over-reliance upon GPS for precise timing, the threat of a loss of civil GPS services, possible impacts to the U.S. critical infrastructure and the economy, and a common interest in developing resilient timing solutions for our nation's critical infrastructure.

View press release at DHS.gov

Jeffrey Auerbach

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