



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



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# *Overview*

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## ➤ **Policy and Service Provision**

- Constellation Status and Modernization
- International Cooperation



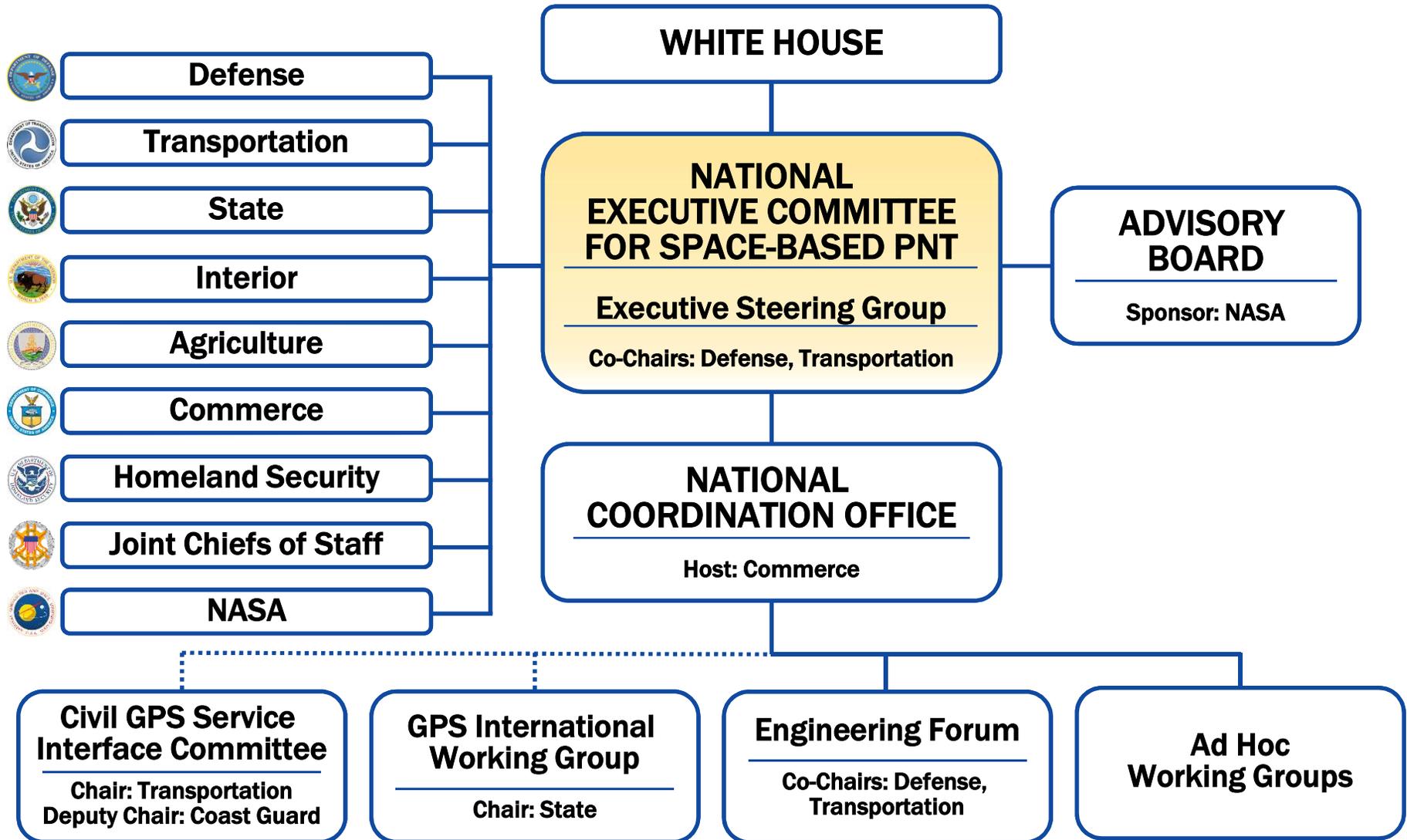
# ***U.S. National Space Policy***

## ***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

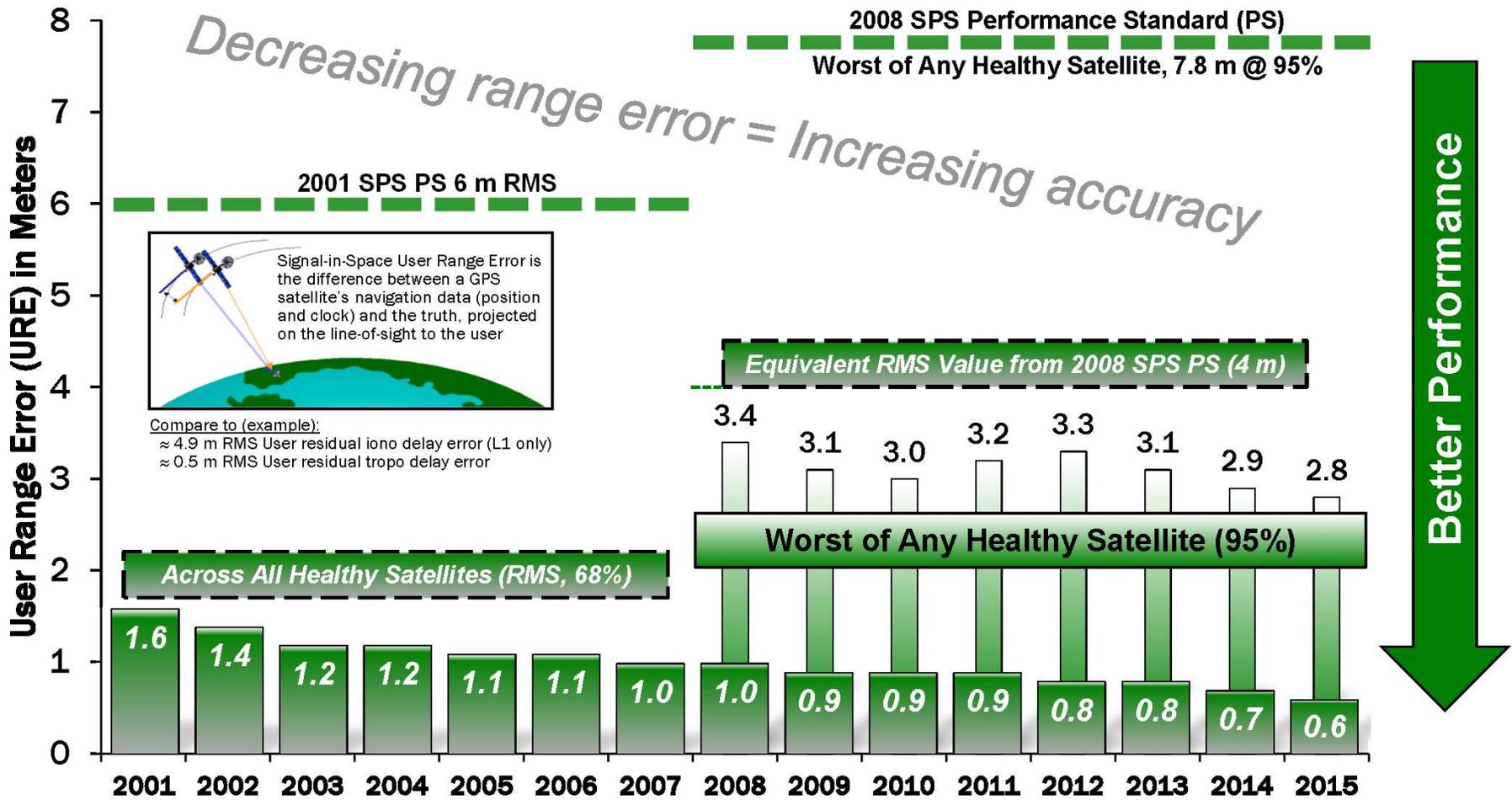
***GPS provides continuously improving, predictable, and dependable Global Public Service***



# 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)  
<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	≤ $1 \times 10^{-5}$ 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	✓+
	≥ 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



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- **Constellation Status and Modernization**
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# *GPS Constellation Status*

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

## **Four Generations of Operational Satellites**

- **Block IIA - 4 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 placed into storage 27 Feb 17
  - SV02/03 in assembly & integration
  - SV04-08 in box level assembly



***First GPS III Launch - Spring 2018***



# *GPS Ground Segment Status*

- Current 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
- Contingency Operations (COps) provides limited operations of GPS IIIs until OCX Block 1 delivery
  - Legacy signal operations and test-only support for modernized signals
- Next Generation Operational Control System (OCX)
  - Modernized command and control system - currently in integration and test
  - Modern civil signal monitoring and improved PNT performance
  - Robust cyber security infrastructure
  - 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*

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- 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



# ***WAAS Program Strategy***

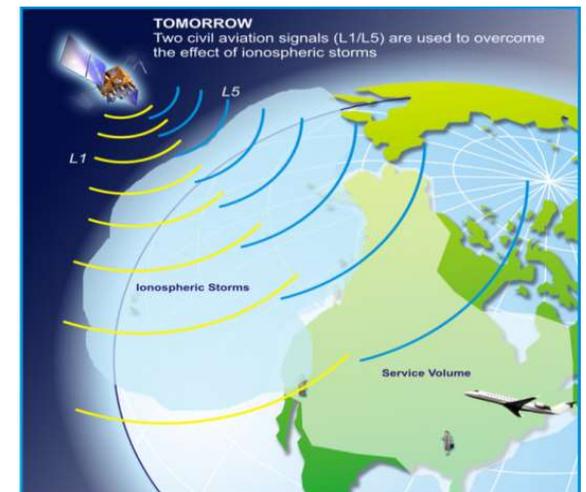
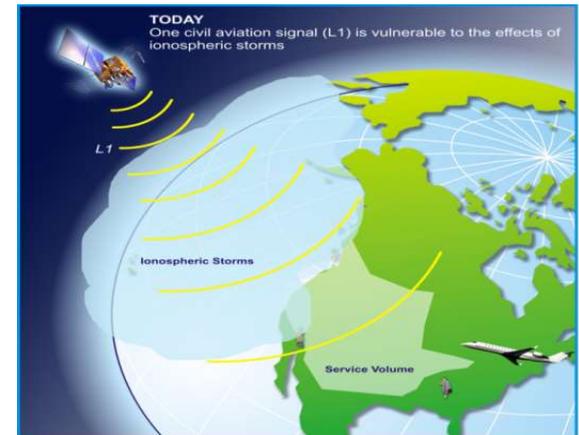
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- **Integrate 5<sup>th</sup> and 6<sup>th</sup> GEOs**
- **Establish procurement strategy for 7<sup>th</sup> GEO**
- **Continue 2<sup>nd</sup> civil signal L5 implementation**
- **Develop Dual-Frequency Avionics Standards (MOPS)**
- **Evaluate Dual-Frequency, Multi-Constellation Avionics**
- **Evaluate Advanced Receiver Autonomous Integrity Monitoring (ARAIM)**
- **Continue technical refresh activities**



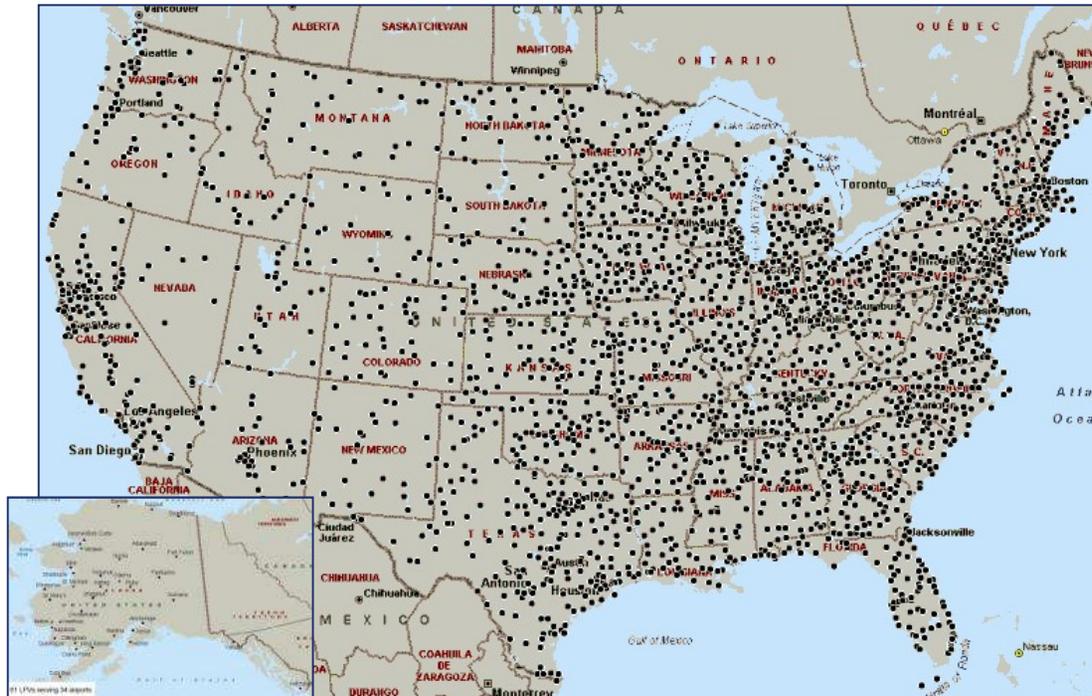
# WAAS Phase IV Dual Frequency Operations Status

- GPS L1 Plus L5 provides high availability of SBAS vertical service during ionospheric disturbances
- Release 1 – Processor Upgrades
  - System integration and test complete
  - Over 31 sites completed cutover, remaining sites to complete by summer 2017
- Release 2 – GEO-5 Integration
  - Integration and testing throughout 2017
  - Scheduled operational mid CY 2018





# 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)





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## ***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***

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- *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
  - 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*

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- *Canada:* Civil GNSS meeting held in Ottawa – May 2015
  - Discussed expanding cooperation on interference detection and mitigation, jammer enforcement, and geodetic network ground station coverage in Canada
- *Republic of Korea:* 2nd bilateral Civil Space Dialogue held in Seoul – Apr. 2016
  - Discussion about Korea’s development of their SBAS
- *Vietnam:* First U.S.-Vietnam Civil Space Dialogue held in Washington – Dec. 2014
- *Australia:* Joint Delegation Statement on Cooperation in the Civil Use of GPS in 2007
  - Last formal space bilateral meeting held in Oct. 2010



# ***GNSS: A Global Navigation Satellite System of Systems for Civil Use***

- Global Constellations
  - **GPS (24+3)**
  - GLONASS (24+)
  - GALILEO (24+3)
  - BDS/BEIDOU (27+3 IGSO + 5 GEO)
- Regional Constellations
  - QZSS (4+3)
  - IRNSS (7)
- Satellite-Based Augmentations
  - **WAAS (3)**
  - MSAS (2)
  - EGNOS (3)
  - GAGAN (2)
  - SDCM (3)





## *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



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



# *11<sup>th</sup> Meeting of the International Committee on GNSS (ICG-11)*



- 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***

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- **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
  - 6<sup>th</sup> IDM workshop to take place next week 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)***

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- 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
- 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



# *Summary*

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- 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, continues to pursue a **Global Navigation Satellite System-of-Systems** to provide civil GNSS services that benefit users worldwide



# For Additional Information...

## GPS.GOV

Official U.S. government information about the Global Positioning System (GPS) and related topics



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## GPS Service Outages & Status Reports

Users experiencing GPS service problems can get support from one of three federal agencies, depending on their application: civil non-aviation, civil aviation, or military. The responsibilities of the support agencies are documented in an interagency agreement. [VIEW AGREEMENT](#) →

### Civilian User Support – Non-Aviation

The U.S. Coast Guard Navigation Center (NAVCEN) is the primary point of contact in the government for providing operational GPS user support to the civilian community. The following links lead to pages on the NAVCEN website.



- [Check the operational status of the GPS satellites](#) →
- [Look up planned GPS service disruptions due to interference testing](#) →
- [Report a GPS service outage or anomaly \(non-aviation\)](#) →
- [Receive GPS status messages & user advisories via email](#) →

If you suspect a GPS disruption due to illegal signal jamming ([LEARN MORE](#) →), please call the FCC Jammer Tip Line immediately at 1-855-55-NOJAM, then submit an outage report to NAVCEN.

[www.gps.gov](http://www.gps.gov)



***THANK YOU !  
MAHALO !***

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