U.S. GPS Program Update and International Activities to Protect GNSS Spectrum

UN/Philippines GNSS Applications Workshop

Office of Space Affairs
U.S. Department of State

22 April 2024

Agenda

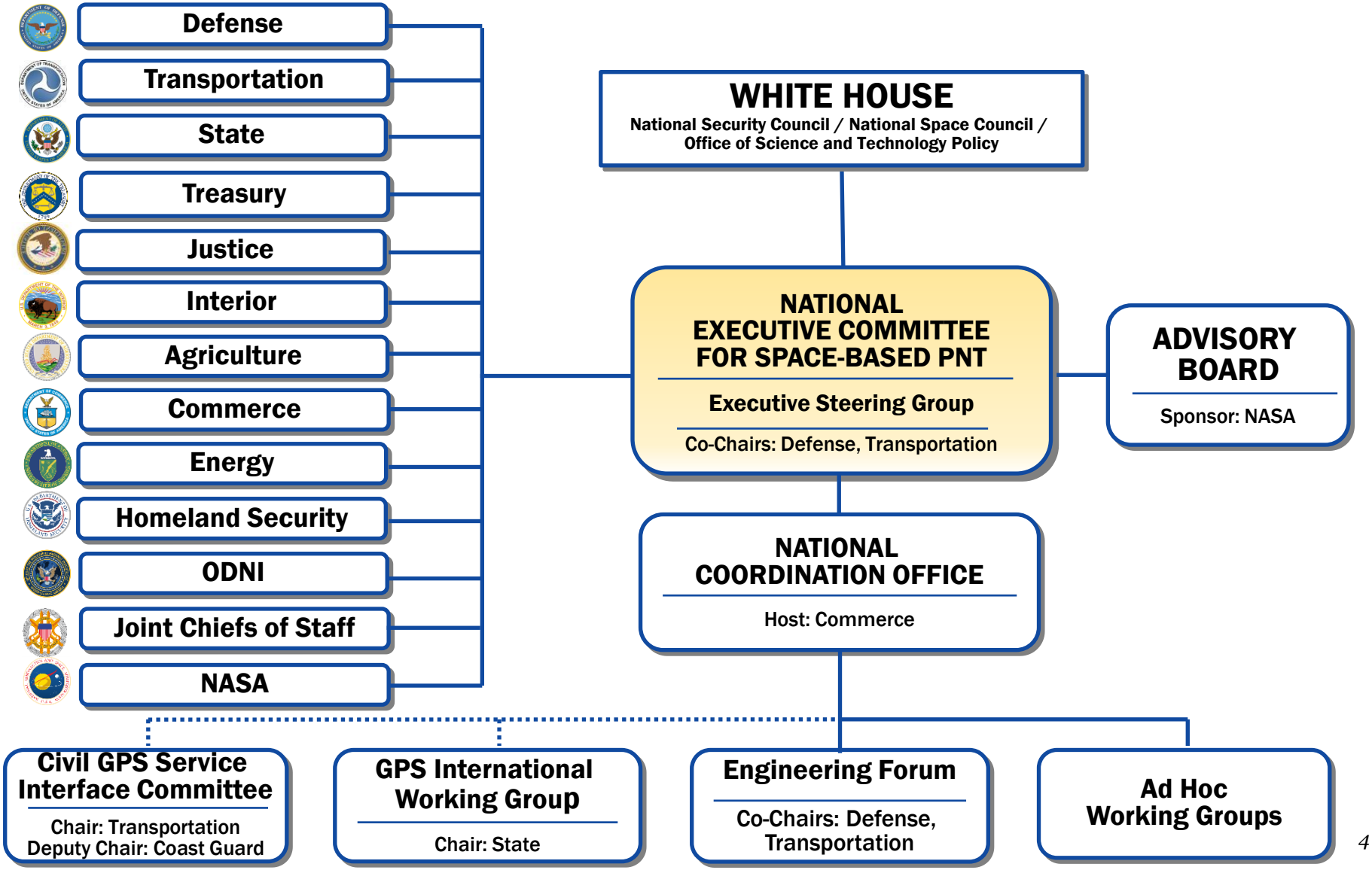
- PNT Policy
- Program Update
- GNSS Spectrum Protection, IDM and the ICG

U.S. Space-based PNT Policy (2020 NSP & SPD-7)

Maintain U.S. leadership in the service provision, and responsible use of GNSS, including GPS and foreign systems

- 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
- Encourage **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
- Promote **transparency** in civil service provision and enable **market access** for U.S. industry
- Promote and support the **responsible use of GPS** as the pre-eminent space-based PNT service
- Foreign space-based PNT services may be used to complement civil GPS service
  - Receiver manufacturers should continue to improve security, integrity, and resilience in the face of growing cyber threats
- Encourage foreign development of PNT services and systems based on GPS
- Support international activities to **detect, mitigate, and increase resilience** to harmful disruption or manipulation of GPS

National Space-Based PNT Organizations



GPS Constellation Status

38 Satellites • 31 Set Healthy
Baseline Constellation: 24 Satellites

Satellite Block	Quantity	Average Age (yrs)	Oldest
GPS IIR	7 (3*)	22.1	26.5
GPS IIR-M	7 (1*)	16.3	18.3
GPS IIF	11 (1*)	10.0	13.7
GPS III	6 (1*)	3.3	5.1

*Not set healthy

As of 01 Feb 2024

GPS Signal in Space (SIS) Performance

From 31 Dec 22 to 31 Dec 23

Average URE*	Best Day URE	Worst Day URE
48.7 cm	33.4 cm (22 Jun 23)	165.7 cm (25 Jan 23)

*All User Range Errors (UREs) are Root Mean Square values

GPS Modernization

Space Segment

SV families provide L-Band broadcast to User Segment

GPS IIA/IIR
- Basic GPS
- Nuclear Detonation Detection System (NDS)

GPS IIR-M
- 2nd Civil Signal (L2C)
- New Military Signal
- Increased Anti-Jam Power

GPS IIF
- 3rd Civil Signal (L5)
- Longer Life
- Better Clocks

GPS III (SV01-10)
- Accuracy & Power
- Increased Anti-Jam Power
- Inherent Signal Integrity
- 4th Civil Signal (L1C)
- Longer Life
- Better Clocks

GPS IIIF (SV11-32)
- Unified S-Band Telemetry, Tracking & Commanding
- Search & Rescue (SAR) Payload
- Laser Retroreflector Array
- Redesigned NDS Payload

Control Segment

TT&C of Space Segment assets & distribution of data to user interfaces

Legacy (OCS)
- Mainframe System
- Command & Control
- Signal Monitoring

Architecture Evolution Plan (AEP)
- Distributed Architecture
- Increased Signal Monitoring Coverage
- Security
- Accuracy

OCX Block 0
- GPS III Launch & Checkout System

GPS III Contingency Ops (COps)
- GPS III Mission on AEP

OCX Block 1/2
- Fly Constellation & GPS III
- Begin New Signal Control
- Upgraded Information Assurance

OCX Block 2+
- Control all signals
- Capability On-Ramps
- GPS IIIF Evolution

User Segment

Applies Space and Control Segment data for PNT applications

Continued support to an ever-growing number of applications
- Annual Public Interface Control Working Group (ICWG)
- Standard Positioning Service (SPS) Performance Standard Updates
- Precise Positioning Service (PPS) Enhancements
- Sustained commitment to transparency
- Visit GPS.gov for more info

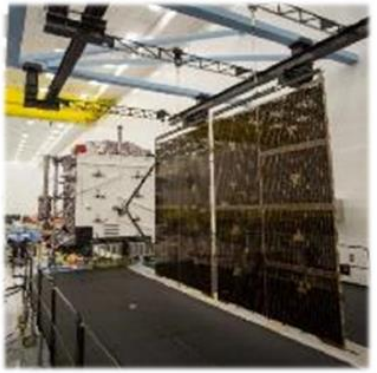
Modernized Civil Signals
- L2C (Various commercial applications)
- L5 (Safety-of-life, frequency band protected)
- L1C (Multi-GNSS interoperability)

GPS III

- SV01 Set healthy and available for use on 13 Jan 20
- SV02 Set healthy and available for use on 1 Apr 20
- SV03Set healthy and available for use on 1 Oct 20
- SV04 Set healthy and available for use on 2 Dec 20
- SV05 Set healthy and available for use on 25 May 22
- SV06 Set healthy and available for use on 16 Feb 23

Additional GPS III SVs in storage

- SV07 in storage – Target June 2024 launch
- SV08 in storage – Target Fiscal Year 2025 launch
- SV09 in storage – Target Fiscal Year 2025 launch
- SV10 in Storage – Target Fiscal Year 2026 launch



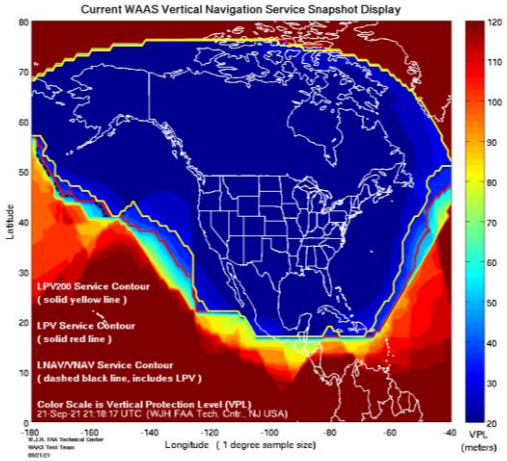
Next Generation Operational Control System (OCX)

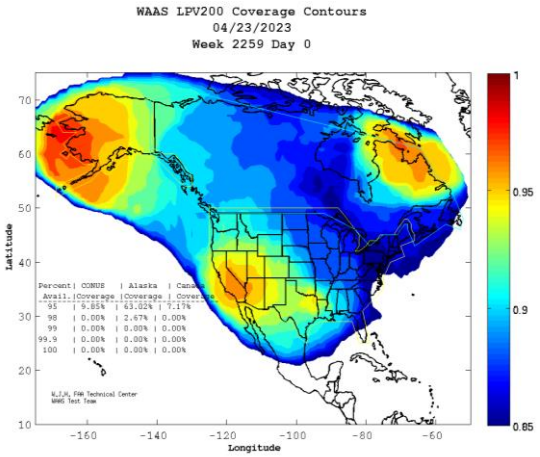
- Next-generation command, control and cyber-defense for GPS
  - Enhanced command and control capability
  - Modernized architecture
  - Robust information assurance and cyber security
- Incremental Development
  - OCX Block 0: Launch and Checkout System (LCS) for GPS III
  - OCX Blocks 1 and 2: Controls and manages all GPS spacecraft and signals
  - OCX 3F: Adds support for GPS IIIF vehicle and new capabilities
- Current Status
  - Launch and Checkout for GPS III SV01-SV06
  - OCX Block 1 completed factory integration and in Golden Dry Run for factory qualification

OCX program continues to execute and is nearing completion

Wide Area Augmentation System (WAAS)

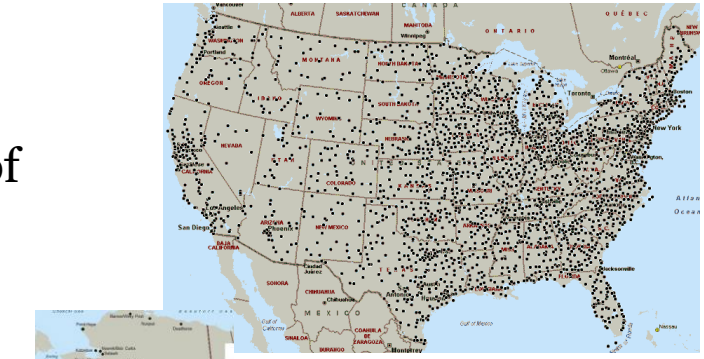
- WAAS provides high availability service to aviation users in North America
- Developing Dual Frequency WAAS
  - Will enable high availability of WAAS vertical service during ionospheric disturbances
- GEO Sustainability
  - Currently maintaining 3 GEO constellation
- WAAS Modernization Efforts
  - Dual Frequency Multi-Constellation (DFMC)
  - Advanced Receiver Integrity Monitoring (ARAIM)
  - Authentication/Resiliency
  - Transition to IP based communications network
  - Security Upgrades





WAAS Procedures and Avionics Equipage

- Procedures:
  - 4,127 Localizer Performance with Vertical Guidance (LPV) approaches in the NAS (as of Feb 2024)
  - 1,116 provide CAT I (200') equivalent performance
- Equipage
  - General Aviation:
    - Over 131,000 equipped aircraft in the NAS
    - All classes of aircraft are served in all phases of flight
  - Airlines
    - Airline integration through MMRs
    - Main aircraft with SBAS capability in the US - A220
- Enabling technology for NextGen Programs
  - Automatic Dependent Surveillance Broadcast (ADS-B)
  - Performance Based Navigation (PBN)



Global Perspective

- Global Constellations
  - **GPS (24+3)**
  - GLONASS (24+)
  - GALILEO (24+3)
  - BDS/BEIDOU (27+3 IGSO + 5 GEO)

- Regional Constellations
  - QZSS (4+3)
  - IRNSS/NAVIC (7)
  - Korea – KPS (7)
- Satellite-Based Augmentations
  - **WAAS (3)**
  - MSAS (2)
  - EGNOS (3)
  - GAGAN (3)
  - SDCM (3)
  - BDSBAS (3)
  - KASS - Korea (2)
  - SPAN – Australia/NZ (2)

International Committee on GNSS (ICG)

- Pursuing a Global Navigation Satellite System-of-Systems to provide civil GNSS services that benefit users worldwide
  - Promote the use of GNSS and its integration into infrastructures, particularly in developing countries
  - Encourage compatibility and interoperability among global and regional systems
- U.S. priorities include spectrum protection, system interoperability and information dissemination
- 17th Meeting held in Madrid, Spain in October 2023
- New Zealand will host the 18th Meeting in October 2024

What is Spectrum Protection?

- "Protection" is about keeping the spectrum 'clean'
- Clean spectrum means keeping the frequencies near to GNSS free from licenced, unlicensed and illegal transmissions that interfere with GNSS reception, e.g.
  - GNSS jammers
  - Uncontrolled GNSS repeater installations
  - Spurious emissions from radio equipment, e.g. motors
  - Other radio services, e.g. TV broadcasts
  - Malfunctioning electronic equipment

Clean Spectrum

- Clean spectrum for GNSS minimizes signal errors and maximizes the performance for GNSS receivers
  - Better and more reliable positioning and timing
  - Faster time to first fix
  - Better tracking performance in challenging environments
- Keeping spectrum clean requires technical means to detect when such interference occurs
- National regulators usually have the capacity to detect **strong** interferers
  - Direction finding equipment or geolocation techniques
  - The ITU can also help coordinate such activities when cross border interference occurs

GNSS Interference

- Strong interferers are relatively easy to detect
- However, if weak interferers are far away from the detectors, they will not be seen
- The weak interfering signals are still stronger than GNSS and will have widespread impact on GNSS reception
- To find weak interferers (e.g. 'personal' GNSS jammers) requires more specialised local equipment or a dense detector network
- The ICG has been considering this challenge

ICG and GNSS Spectrum Protection

- ITU is responsible for international spectrum framework, including the protection of radio services
- Actual implementation of this framework is accomplished by national telecommunication administrations
- National telecommunication administrations work with relevant industries and stake holders
- ICG provides a forum that can facilitate and encourage the protection of GNSS spectrum by its members and participants in a voluntary, non-binding way

ICG Working Groups

- Systems, Signals and Services (Co-Chairs: U.S. & Russia)
  - Focus on compatibility and interoperability, encouraging development of complimentary systems
  - Exchange information on systems and service provision plans
  - Includes **spectrum protection** and **IDM**
- Enhancement of GNSS Performance, New Services and Capabilities (Co-Chairs: India, European Space Agency, China)
  - Focus on system enhancements (multipath, integrity, interference, etc.) to meet future needs
- Capacity Building, Education and Outreach (Chair: UN Office for Outer Space Affairs)
  - Focus on training/workshops, promoting scientific applications, space weather
- Reference Frames, Timing and Applications (Co-Chairs: IAG, IGS & FIG)
  - Focus on timing, monitoring and reference station networks

Addressing Spectrum Protection and IDM within ICG

- Establishment of Compatibility Subgroup in 2011
  - Focused on compatibility issues to include spectrum protection and IDM
- Establishment of Interference Detection and Mitigation Task Force in 2013
  - Objectives include:
    1) Develop a common set of information to be reported to GNSS civil service centers
    2) Establish routine communications among the (provider service) centers
    3) Develop guidelines for common capabilities to be considered in the development of future national IDM networks
  - Ten (11) IDM Workshops held since 2012

11th ICG Workshop on IDM

- Workshop held on 15 April 2024, hosted by U.S.
- Agenda included:

1) **PNT from Low Earth Orbit** – *Mr. Bryan Chan, Co-Founder, XONA Space Systems*
2) **GNSS Interference Detection from Low Earth Orbit** – *Mr. Iain Goodridge, Federal Space Systems, SPIRE*
3) **Data Exploitation and Enhanced Processing (DEEP)** – *Dr. Steve Lewis, DEEP Chief Engineer, Aerospace Corp*
4) **USDOT IDM Update** – *Mr. James Aviles, Senior RF Engineer, Office of Research and Technology, U.S. Department of Transportation*
5) **EASA/IATA PNT Resiliency Workshop, 25 Jan, Cologne Germany** – *Ms. Christina Clausnitzer, U.S. Federal Aviation Administration*
6) **ICAO EUR/MID Radio Navigation Symposium, Antalya, Turkey** – *Mr. Ken Alexander, Chief Scientist, U.S. Federal Aviation Administration*
7) **Ambient-Aware PNT** – *Professor Dr Renato Filjar, FRIN, Faculty of Engineering, University of Rijeka, Rijeka, Croatia*

ICG Recommendations Related to IDM and Spectrum Protection

Recent Recommendations Adopted by the ICG	
2014/2017	Crowdsourcing capabilities analysis for IDM
2015/2016/2017	UN regional workshops on GNSS spectrum protection and IDM
2015/2016	Campaign of Protection of RNSS operations – GNSS providers and GNSS user community member states promote spectrum protection
2015/2016	UN COPUOS multi-year agenda item focused on National Efforts to protect RNSS Spectrum, and develop IDM capability
2017	Encourage national regulators to use the protection criteria in relevant ITU-R Recommendations
2019	Produce a draft booklet on GNSS/RNSS spectrum Protection based on material used for the ongoing spectrum seminars
2022	Incorporating Resilience into GNSS Interference Detection and Mitigation

Other Related Topics Discussed within the ICG

- Adjacent Band Compatibility
- Unintentional Interference
  - Electromagnetic emissions limits from non-licensed transmitters
- Interference Detection and Geo-Location Capabilities
- Critical Infrastructure

For Additional Information...

www.gps.gov