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

CSIS/UTokyo/ICG GNSS Training Programme

Office of Space Affairs
U.S. Department of State

11 January 2022

PART 1:

U.S. Program Update

GPS Constellation Status

37 Satellites • 29 Set Healthy
Baseline Constellation: 24 Satellites

Satellite Block	Quantity	Average Age (yrs)	Oldest
GPS IIR	6 (6*)	20.0	24.4
GPS IIR-M	7 (1*)	14.2	16.3
GPS IIF	12	8.0	11.6
GPS III	4 (1*)	1.7	3.0

*Not set healthy

As of 01 Jan 2022

GPS Signal in Space (SIS) Performance

From 01 Jan 21 to 01 Jan 22

Average URE*	Best Day URE	Worst Day URE
47.3 cm	31.5 cm (20 Apr 21)	70.4 cm (13 Mar 21)

*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

M-Code Early Use (MCEU)
- Update OCS to operationalize Core M-Code for MGUE

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)

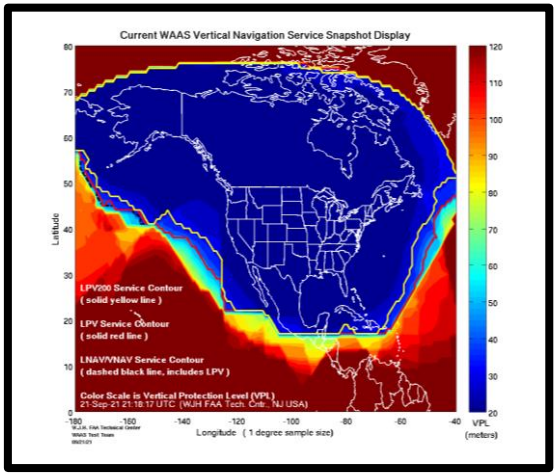
Wide Area Augmentation System (WAAS) Current Status

- Current WAAS provides high availability service to aviation user in North America
  - 4,086 Localizer Performance with Vertical Guidance (LPV) approaches in the NAS
    - Over 1050 LPVs are LPV-200's which provides CAT I equivalent instrument approach performance
- Preparing WAAS to take advantage of Dual Frequency service that will be provided by GPS
  - To continue high availability of WAAS vertical service during ionospheric disturbances
- GEO Sustainability
  - Currently maintaining 3 GEO's (Anik F1R [CRE], Eutelsat 117 WB [GEO 5], SES-15 [GEO 6])
  - Intelsat Galaxy 30 (GEO 7), launched August 2020, currently being integrated, expect operational in 2022

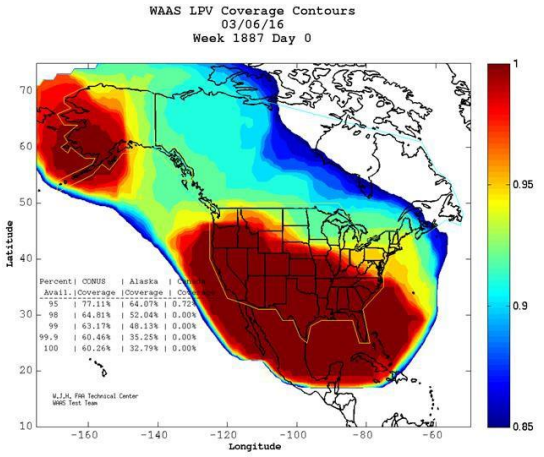
WAAS Modernization Efforts

- Dual Frequency Multi-Constellation (DFMC)
- Advanced Receiver Integrity Monitoring (ARAIM)

Current WAAS LPV Coverage



WAAS LPV Coverage March 6, 2016 Iono event



WAAS Avionics Equipage Status

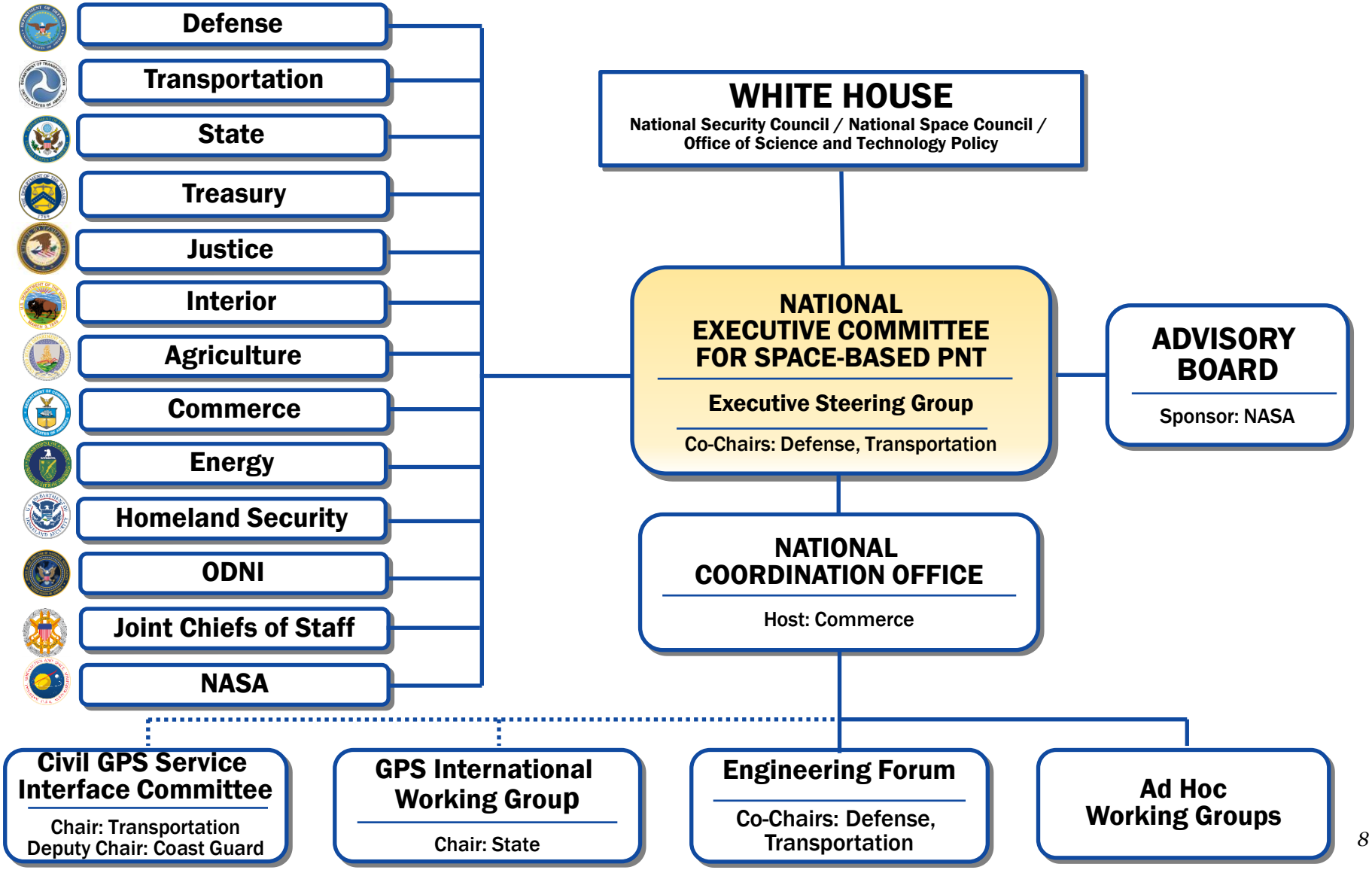
- Over 144,000 WAAS equipped aircraft in the NAS
  - WAAS receivers provided by companies such as: Garmin, Universal, Rockwell Collins, Honeywell, Avidyne, Innovative Solutions & Support (IS&S), Thales and Genesys Aerosystem (Chelton)
- Since 2006, aircraft equipage rates have increased each year
- All classes of aircraft are served in all phases of Flight
  - Recent STC for Boeing 737-600/700/800 avionics
- Enabling technology for NextGen programs
  - Automatic Dependent Surveillance Broadcast (ADS-B)
  - Performance Based Navigation (PBN)

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



Bilateral International Cooperation

Europe

- GPS-Galileo Cooperation Agreement signed in 2004
- U.S.-EU Space Dialogue and three Working Groups meet regularly

Japan

- Comprehensive Space Dialogue held August 2020
- Technical Working Group discusses GPS and QZSS compatibility and interoperability

India

- U.S.–India Joint statement on GNSS Cooperation – 2007
- Civil Space Joint Working Group (CSJWG) met November 2019

China

- Three Working Groups and GNSS Plenary meeting held May 2018
- Joint Statement of Cooperation on Civil Signal Compatibility and Interoperability – November 2017

Multilateral International Cooperation

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
- 15th Meeting held in Vienna, Austria in September 2021
- UAE will host the 16th Meeting in 2022

PART 2:

GNSS Spectrum Protection, IDM and the ICG

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
  - Nine IDM Workshops held since 2012

9th ICG Workshop on IDM

- Workshop held virtually on 24 August 2021
- Agenda included:
  - Incorporating Resilience into IDM – Department of Homeland Security, United States
  - Implementation and Definition of Interference Protection Standards at Space Segment for the European Space Agency - European Space Agency
  - Environment-aware GNSS Position Estimation Process Realisation in Software-Defined Radio (SDR) - University of Rijeka, Croatia
  - Air-Ground coordinated RFI detection system in airport - China Research Institute of Radio-wave Propagation
  - Development of the European GNSS Interference Detection Network - European Union Agency for Space Programmes
  - Characterization of ADS-B Performance under GNSS Interference – Standford University, U.S.
  - Madrid Airport and TMA GNSS RFI Monitoring System (DYLEMA-Madrid) - Spanish Ministry of Transport
  - Interference scenario in S-band: NavIC experience - Indian Space Research Organisation

ICG Recommendations Related to IDM and Spectrum Protection

Recent Recommendations Adopted by the ICG	
2014	Evaluate existing and emerging IDM capabilities and consider developing, testing and implementing these or similar capabilities
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

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