



GPS/WAAS Program Update

Baska GNSS Conference

07 May 2018

Baska, Krk Island, Croatia



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 augment and strengthen the resiliency of 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 increase resiliency to harmful interference

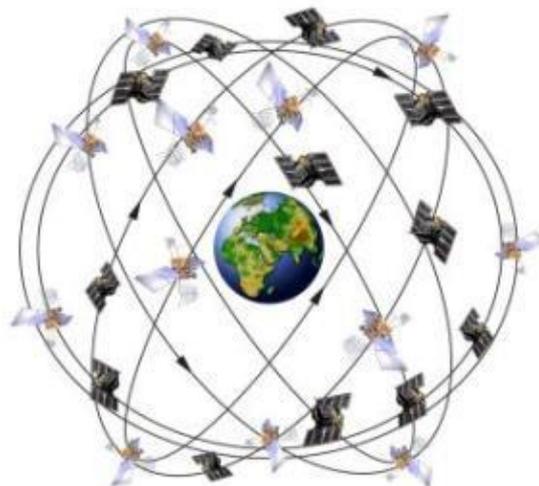


GPS Status

34 Satellites / 31 Set Healthy
Baseline Constellation: 24 Satellites

Satellite Block	Quantity	Average Age	Oldest
GPS IIA	1	24.4	24.4
GPS IIR	11	16.2	20.7
GPS IIR-M	7	10.7	12.5
GPS IIF	12	4.2	7.8
Constellation	31	10.6	24.4

AS OF 3 APR 18





Current GPS Constellation

Four Generations of Operational Satellites

- Block IIA – 1 Operational
 - 7.5 year design life
 - Launched 1990 to 1997
- Block IIR - 11 Operational
 - 7.5 year design life
 - Launched 1997 to 2004
- Block IIR-M - 7 Operational
 - 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 IIR/IIR-M Satellite – Designed & Built by Lockheed Martin



Block IIF Satellite – Designed & Built by Boeing



GPS III: Newest Block of GPS Satellites

- 4 civil signals: L1 C/A, L1C, L2C, L5
 - First satellites to broadcast common L1C signal
- 3 improved Rubidium atomic clocks
- Better User Range Error than IIF Satellites
- Increased availability
- Increased integrity
- 15 year design life





GPS Ground Segment

- 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
- Next Generation Operational Control System (OCX)
 - Modernized command and control system - replaces legacy system and adds modern features
 - Worldwide, 24 hr/day, all weather, position, velocity and time source for military & civilian users
 - Modern civil signal monitoring and improved PNT performance
 - Robust cyber security infrastructure
 - New capabilities including civil signal performance monitoring capability



Monitor Station



Ground Antenna



Modernized GPS Civil Signals

- Second civil signal “L2C”
 - Designed to meet commercial needs
 - Broadcast since 2005
 - Currently 19 satellites broadcasting L2C



- Third civil signal “L5”
 - Meets transportation safety of life requirements
 - Uses Aeronautical Radio Navigation Service band
 - Enables triple-frequency positioning techniques
 - Currently 12 satellites broadcasting L5

- Fourth civil signal “L1C”
 - Designed for GNSS interoperability
 - Specification developed in cooperation with industry
 - Improved performance in challenged environments
 - Launches with GPS III in 2018



Continuous Broadcast of the new civil navigation “CNAV” message on L2C and L5 began April 28, 2014



GPS SIS Performance Scoreboard

GPS SIGNAL IN SPACE (SIS) PERFORMANCE (CM)

BEST WEEK*

BEST DAY*

WORST DAY*

ENDING

SIS

ENDING

SIS

ENDING

SIS

ROLLING YEAR

20 SEP 17

48.9

26 JAN 17

35.0

1 DEC 17

77.7



BEST WEEK EVER

29 NOV 16

44.1

**ROLLING YEAR*





GPS Performance Report Cards

- 2013-2016 performance reports now available on gps.gov
- 2017 performance report in coordination
- These reports measure GPS performance against GPS SPS PS commitments
- Reports generated by Applied Research Laboratories at the University of Texas at Austin

Performance Standard Metric		2013	2014	2015	2016
SIS Accuracy	URE Accuracy	✓	✓	✓	✓
	UTC OE Accuracy	N/A	N/A	✓	✓
SIS Integrity	Instantaneous URE Integrity	✓	✓	✓	✓
	Instantaneous UTC OE Integrity	N/A	N/A	✓	✓
SIS Continuity	Unscheduled Failure Interruptions	✓	✓	✓	✓
	Status and Problem Reporting	N/A	✗	✓	✗
SIS Availability	Per-Slot Availability	✓	✓	✓	✓
	Constellation Availability	✓	✓	✓	✓
	Operational Satellite Counts	✓	✓	✓	✓
Position/Time Standards	PDOP Availability	✓	✓	✓	✓
	Position Service Availability	✓	✓	✓	✓
	Position Accuracy	✓	✓	✓	✓



Wide Area Augmentation System (WAAS)

- Satellite Based Augmentation System (SBAS)
- Designed for aviation use, but available and used by many GPS users today
- Localizer Performance with Vertical Guidance (LPV)-200 approach is comparable to ILS Category I
- Provides the capability for increased availability and accuracy in position reporting, allowing more time for uniform and high quality air traffic management.
- Provides service for all classes of aircraft in all phases of flight



WAAS Architecture



38 Reference Stations



3 Master Stations



6 Ground Earth Stations



3 Geostationary Satellite Links

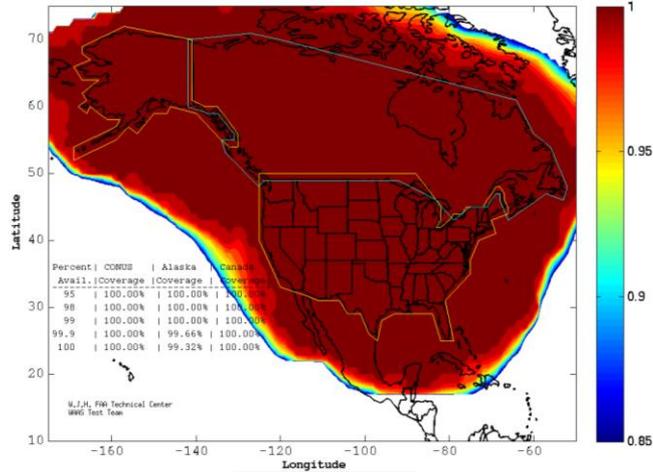


2 Operational Control Centers

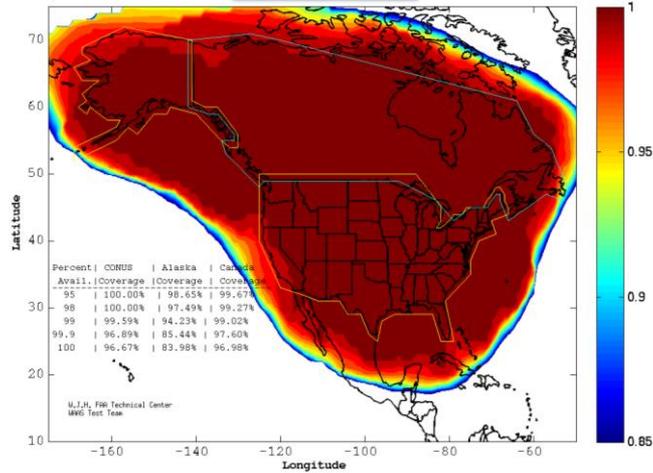


Current WAAS Performance

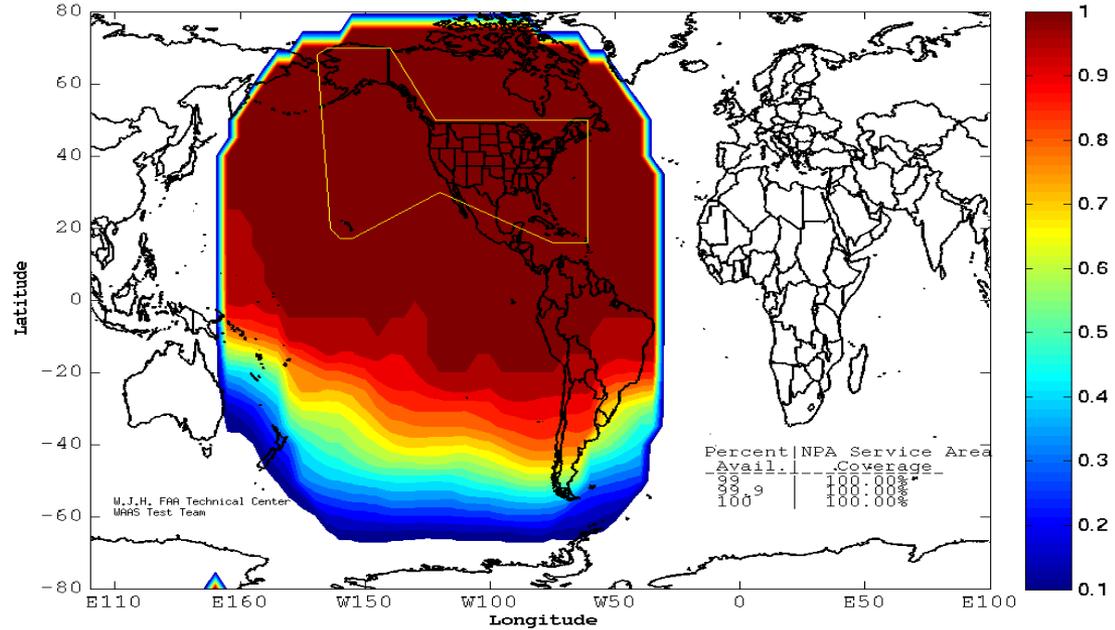
LPV



LPV - 200



RNP 0.3





WAAS Dual Frequency Service

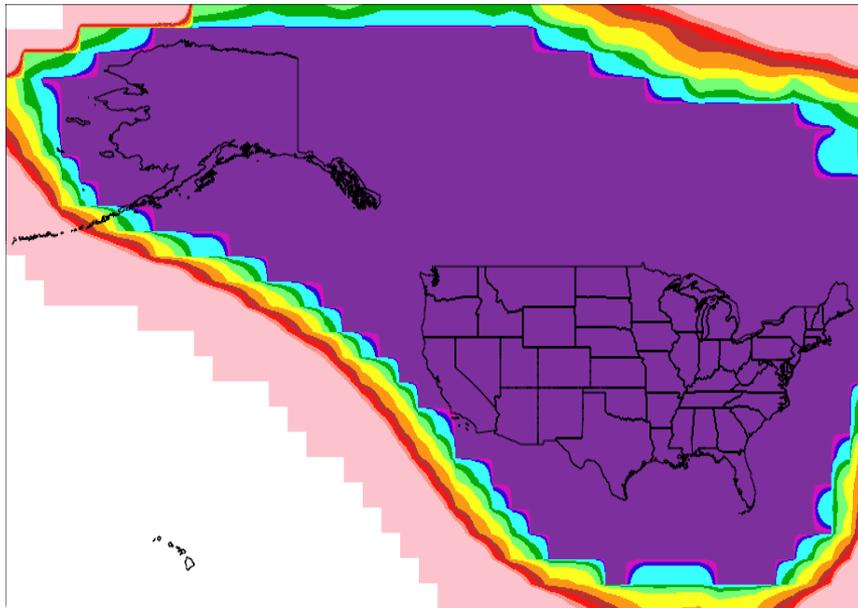
- WAAS has implemented system changes to enable a L1/L5 user
 - Upgraded reference station receivers to receive L5
 - Upgraded communication network to handle additional data (Dec 2017)
 - New safety computer with improved processor performance (Sep 2019)
- Minimum Operational Performance Standards (MOPS) and Standards And Recommended Practices (SARPS) requirements development is underway
- Significant additional work needed to implement a dual frequency WAAS Service
 - Preparing for FAA investment decision in 2019
- Have also installed non-operational test receivers at 6 WAAS reference sites to record Galileo data
 - Currently being collected for research purposes only



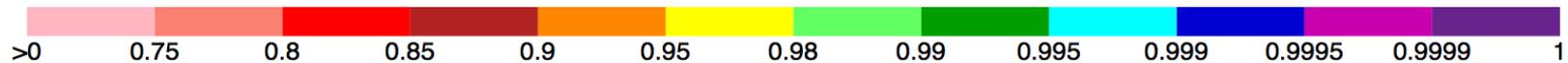
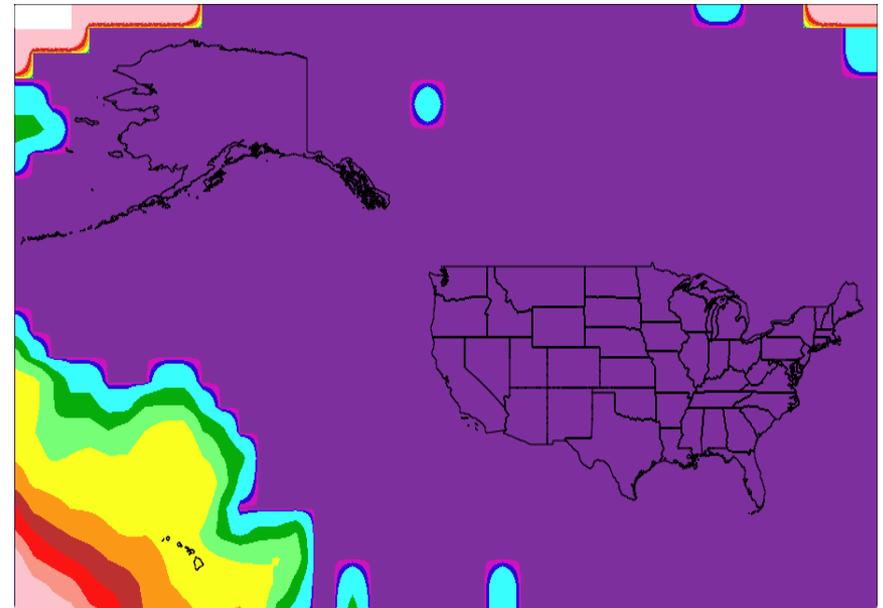
Benefits of Dual Frequency Operations

- Dual frequency L1/L5 service improves availability and continuity

L1



L1, L5



Simulation



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 April 2018
 - Working Group on Trade & Civil Applications meets as needed
 - PRS access negotiations are under way
- *China:* Most recent civil GNSS Plenary – June 2015
 - Sub-group on compatibility and interoperability met June 2017 in Los Angeles – Joint Statement on Cooperation in November 2017
 - GNSS discussed at U.S.-China Civil Space Dialogue – Nov 2017
- *Japan:* Civil Space Dialogue hosted by U.S. – May 2017
 - Technical Working discusses compatibility between GPS & QZSS
- *India:* Civil Space Joint Working Group Meeting in Washington – October 2017
 - ITU compatibility coordination completed



GNSS: A Global Navigation Satellite System of Systems

- 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)

- Satellite-Based Augmentations

- **WAAS (3)**
- MSAS (2)
- EGNOS (3)
- GAGAN (3)
- SDCM (3)
- BDSBAS (3)
- KASS (2)





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 Meetings

Past ICG Meetings

- ICG-1: UN Vienna, Austria – November 2006
- ICG-2: Bangalore, India – September 2007
- ICG-3: Pasadena, CA, USA – December 2008
- ICG-4: St Petersburg, Russia – September 2009
- ICG-5: Turin, Italy – October 2010
- ICG-6: Tokyo, Japan – September 2011
- ICG-7: Beijing, China – November 2012
- ICG-8: Dubai, UAE – November 2013
- ICG-9: Prague, Czech Republic – November 2014
- ICG-10: Boulder, CO, USA – November 2015
- ICG-11: Sochi, Russia – November 2016
- ICG-12: Japan – December 2017

Future Meetings

- **ICG-13: China – 2018**
- ICG-14: India – 2019
- ICG-15: UN Vienna, Austria - 2020



12th Meeting of the International Committee on GNSS (ICG-12)



- More than 200 participants
 - Representatives from 20 countries/organizations
 - Representation from 5 GNSS Providers
- Agenda included:
 - Meeting of the Providers' Forum
 - System Provider Updates
 - Applications and Experts Session
 - Meeting of all four Working Groups





GNSS Interference and Spectrum Protection: A Multilateral Effort

- Core Area of Focus of the International Committee on GNSS (ICG)
 - Primarily discussed within the Working Group on Systems, Signals and Services (WG-S)
 - Subgroup on Compatibility and Spectrum Protection established in 2010
 - Task Force on Interference Detection and Mitigation (IDM) established in 2013
 - Six IDM Workshops have been held since 2012 – organized by the ICG
- Recent and Near Future Activities in the ICG
 - Three Seminars on Spectrum Protection (2015-2018)
 - Presentation to the UN Committee on the Peaceful Uses of Outer Space (COPUOS) Science and Technical Subcommittee on the importance of GNSS Spectrum Protection and IDM (February 2017)

7th IDM Workshop: 08 May 2018 as part of Baska GNSS Conference – All are welcome to participate!



Other Significant Accomplishments from ICG-12

- International Multi-GNSS monitoring (IGMA)
 - Recommendation for ICG workshop in 2018, to discuss the multi-GNSS monitoring trial project established in 2016 between the ICG and IGS
- Performance Standards
 - Recommendation for ICG workshop in 2018, focused on promoting common terminology and definitions in individual GNSS Open Service Signal Specifications by creating a template for providers to use to publish their performance standards
- Interoperability – Timing
 - Recommendation for 2nd ICG expert level workshop to be held in 2018 to further discuss GNSS system time offsets among the systems
- Space Service Volume
 - Completion of booklet on space service volume by GNSS Providers – published in 2018
 - Continued outreach effort on benefits of an interoperable space service volume
- Orbital Debris Mitigation
 - Discussion and exchange of information on debris mitigation plans by GNSS providers



Progress at ICG in GNSS Civil Service Provision

✓ Providers Forum

✓ Providers Forum System Report

✓ Principles of Compatibility, Interoperability, and Transparency

➤ Template for Performance Standards (and ICDs)

➤ *Postulated Performance Standards for future services*

- Service Assurances or
Commitments

- *Monitoring of service
performance*

- *Interference monitoring*



For Additional Information...

The screenshot shows a web browser window with the address bar containing www.gps.gov. The page content includes:

- Navigation links: [How accurate is GPS?](#) and [How vulnerable is GPS to malicious jamming?](#) with a [VIEW MORE](#) button.
- Featured Content** section with four items:
 - [What is GPS?](#) (with a globe diagram)
 - [How GPS Works](#) (with a satellite diagram)
 - [Truckers: Don't Use Consumer GPS Devices!](#) (with a 'DANGER LOW CLEARANCE' sign)
 - [GPS Jamming is Illegal](#) (with a 'GPS JAMMERS' sign crossed out by a red circle)
- Radionavigation-Satellite Service** section with a link to [Jan 6: Best Practices for Improving the Operation and Development of GPS Equipment Used by Critical Infrastructure](#) and a [VIEW MORE](#) button.
- Guidance for Critical Infrastructures** section (circled in pink) with three links:
 - [Best Practices for Improving the Operation and Development of GPS Equipment Used by Critical Infrastructure \(PDF\)](#)
 - [Best Practices for Improved Robustness of Time and Frequency Sources in Fixed Locations \(PDF\)](#)
 - [Best Practices for Leap Second Event Occurring on 31 December 2016 \(us-cert.gov\)](#)
- Userful Content** section with links to:
 - [Service Outages & Status Reports](#)
 - [Civil GPS Performance Data](#)
 - [UPDATED Interface Specifications](#)
 - [Other Technical Documentation](#)
 - [Public Presentations](#)
 - [Congressional Legislation & Funding](#)

www.gps.gov