Asia-Pacific Economic Cooperation

Advancing
Free Trade for Asia-Pacific
Prosperity

WAAS, Resiliency and Outreach

16 October 2018 – Lima, Peru

Presented by
Ken Alexander, U.S.

Overview

Asia-Pacific Economic Cooperation

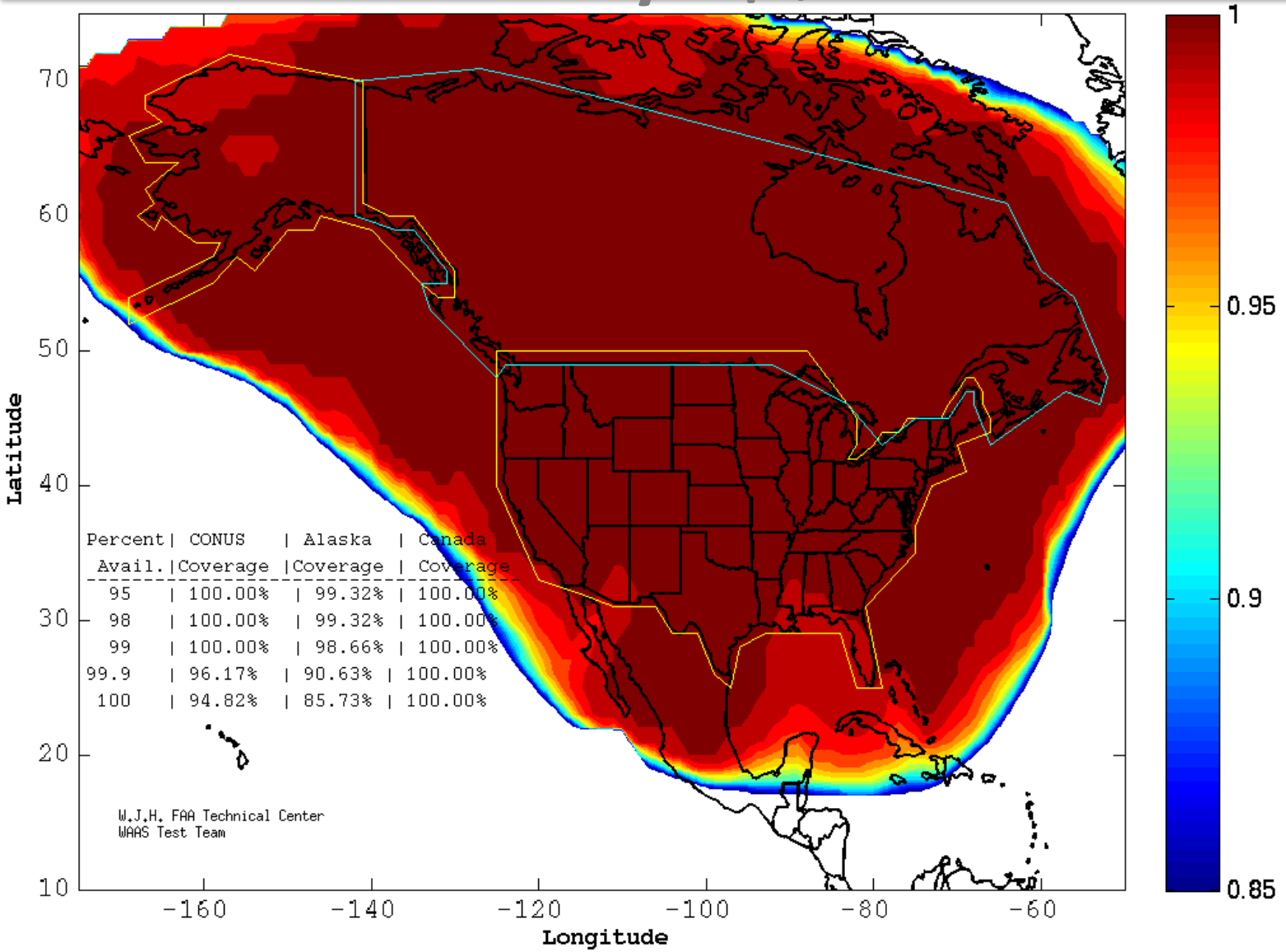
- Wide Area Augmentation System (WAAS) Satellite Based Augmentation System (SBAS)
- GPS Resiliency and Robustness
- Educational Outreach

Wide Area Augmentation System (WAAS)

- Overview and Strategy
- Coverage
- Performance
- GEO Sustainment
- Dual Frequency Operations
- LP/LPV Procedures

Current WAAS Components

WAAS Localizer Performance Vertical LPV-200 Availability Sept, 2018



Performance Monitoring

- Daily review of performance at 38 WAAS reference stations and up to 10 NSTB stations
  - Precision approach
    - Daily results: http://www.nstb.tc.faa.gov/pasummary/
  - Non-Precision approach
    - Daily results: http://www.nstb.tc.faa.gov/npa_sps_summary/
  - GPS Standard Positioning Service (SPS)
    - Daily results: http://www.nstb.tc.faa.gov/sps_summaryDB3/
- Daily review of LPV and LPV-200 performance at airports with RNAV instrument approach procedures (IAP)
- Airport predictions
  - Publish WAAS availability prediction for airports with LPV IAP
    - Prediction tool: http://www.nstb.tc.faa.gov/AirportSchedules/

WAAS Performance Apr 1– Jun 30 2018

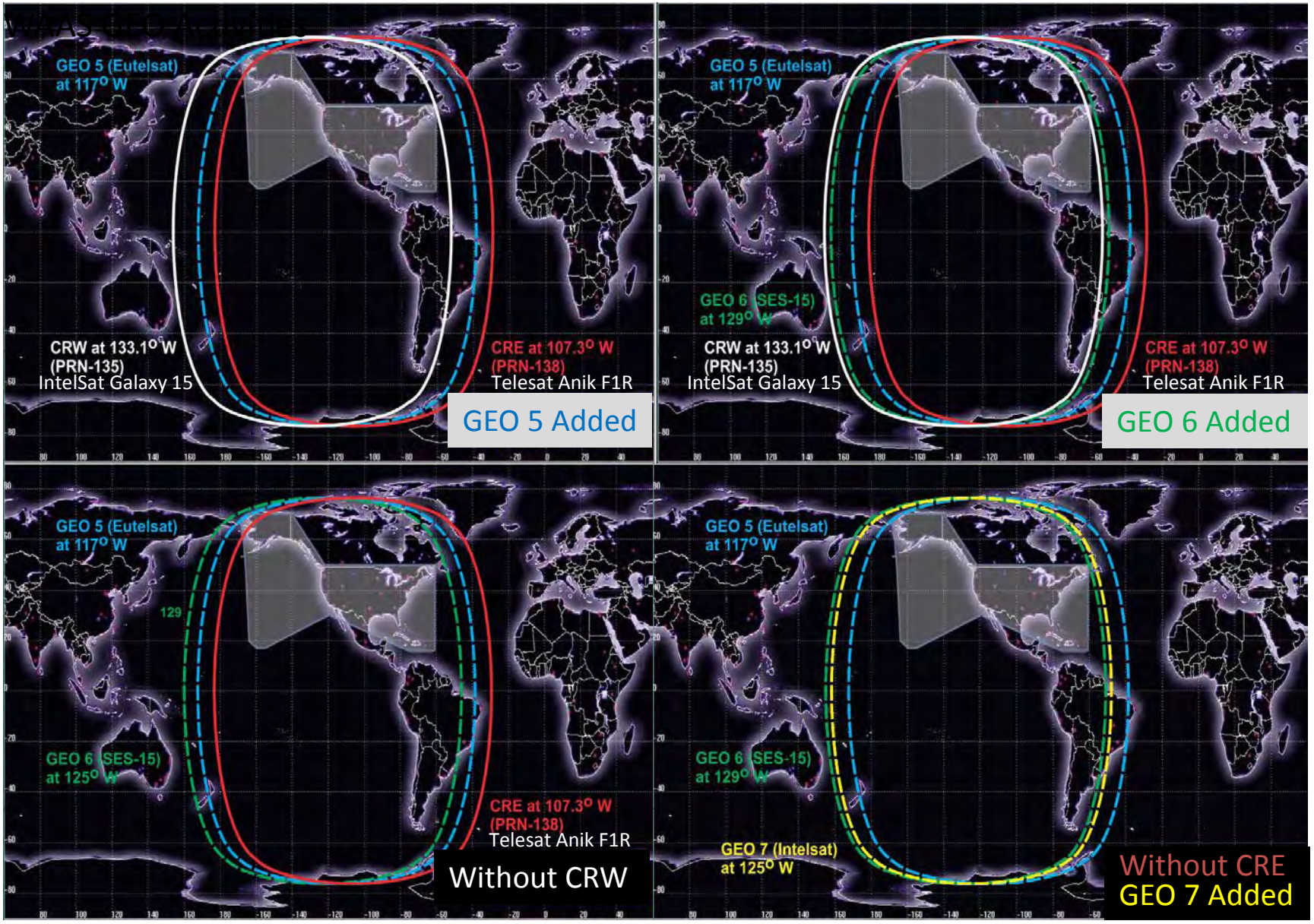
Parameter	CONUS Site/Maximum	CONUS Site/Minimum	Alaska Site/Maximum	Alaska Site/Minimum
95% Horizontal Accuracy (HPL <= 40 meters)	Atlantic City 1.303 meters	Memphis 0.507 meters	Anchorage 0.761 meters	Bethel 0.576 meters
95% Vertical Accuracy (VPL <= 50 meters)	Atlantic City 1.464 meters	Billings 0.745 meters	Anchorage 1.482 meters	Bethel 1.047 meters
LP Availability (HPL <= 40 meters)	All Sites 100%	All Sites 100%	All Sites 100%	All Sites 100%
LPV Availability (HPL <= 40 meters & VPL <= 50 meters)	All Sites 100%	All Sites 100%	All Sites 100%	All Sites 100%
LPV200 Availability (HPL <= 40 meters & VPL <= 35 meters)	Multiple Sites 100%	Oakland 98.88%	Multiple Sites 100%	Barrow 99.53%
99% HPL	Miami 17.974 meters	Denver 10.717 meters	Cold Bay 21.088 meters	Juneau 12.74meters
99% VPL	Oakland 35.382 meters	Kansas City 19.404 meters	Barrow 31.395 meters	Anchorage 23.125 meters

*** Localizer Performance (LP) service is available when the calculated Horizontal Protection Level (HPL) is less than 40 meters. Localizer Performance with Vertical Guidance (LPV) service is available when the calculated HPL is less than 40 meters and the Vertical Protection Level (VPL) is less than 50 meters. Localizer Performance with Vertical Guidance to 200 foot decision height (LPV200) service is available when the calculated HPL is less than 40 meters and the VPL is less than 35 meters**

GEO Sustainment (GEOs 5/6/7)

- GEO 5 (Eutelsat) at 117W
  - Operational March 2018
- GEO 6 (SES-15) at 129W
  - Provides full coverage of CONUS and Alaska
  - launched 18 May 2017
  - Concluded Phase 1 development May 2018 with completion of:
    - Signal Generator Sub-system (SGS),
    - Radio Frequency Uplink (RFU), and
    - Satellite integration
    - Phase 2 cutover in 2nd quarter CY2019
  - Expected operational capability June 2019
- GEO 7 Satellite Acquisition
  - Contract awarded March 2018
  - Leidos (Intelsat)
  - Completed Integrated Baseline Review (IBR) September 2018

WAAS GEO Transitions



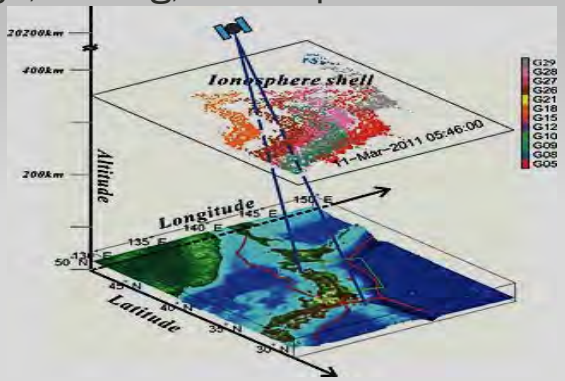
WAAS Phase IV-A (5 Releases)

- Release 1 (Processor Upgrades) - completed April 2017
  - Replaced obsolete WAAS Reference Station (WRS), WAAS Master Station (WMS) and GEO Uplink Station (GUS) processors which support processing of L5 measurements
- Release 2 (GEO 5) - cutover March 2018
  - Replaced existing AMR satellite with new GEO 5 satellite
  - Provides dual coverage over entire service area
- Release 3 (G-III Multicast Structure) - cutover July 2018
  - Upgrades the G-III multicast structure
  - Software updated to begin to transmit/process for L5 data
- Release 4 (Correction & Verification (C&V) Safety Computer Validation and Deployment)
  - Validation testing completed September 2018
  - Cutover/deployment complete by Feb 2019
  - Updates safety computer within WAAS C&V Subsystem
  - Addresses obsolescence issues and adds additional capacity to support L5 signals and dual frequency services
- Release 5 (GPT SC Validation & GEO 6)
  - GEO 6 on scheduled to be cutover September 2019
  - Integrates GEO 6 and includes an update to the GEO Uplink Station (GUS) design using the new safety computer

WAAS Phase IV-B

Dual Frequency Operations

Design, testing, and implementation of DFO



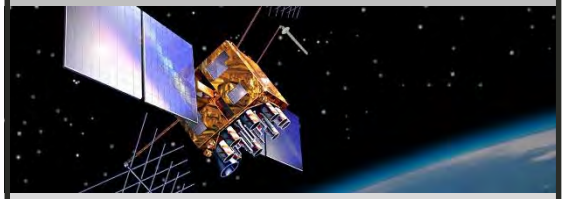
Software

- L5 Message Generation
- Correction & Verification
- AIX to Linux
- L2 to L5

Hardware

- C&V Hardware
- Obsolete Processor Upgrade
- SIGGEN
- GUS Receivers

GEO Acquisition & Integration



- GEO7 Integration
- GEO 8 Acquisition & Integration

H-ARAIM

Evaluation & testing of Horizontal Advanced Receiver Autonomous Integrity Monitoring Capabilities

TDM-IP Transition

Design, testing, and implementation of TDM-IP transition

WAAS Phase IV Investigations

Dual-Frequency Multi-constellation Capability (DFMC)

- International Focus on leveraging GPS like constellations
  - International Civil Aviation Organization (ICAO) Navigation Systems Panel (NSP) has developed work plan that supports development of future standards for use of other Global Navigation Satellite Systems (GNSS)
  - ICAO SARPS with planned completion by Nov 2018
- SBAS Interoperability Working Group (IWG) proposed preliminary DFMC requirements & SBAS interface control standard
- ICAO NSP, RTCA and EUROCAE developing draft standards
  - Aircraft equipage expected no earlier than 2026
  - EU expected to offer interim services for a wide range of users
- FAA supporting DFMC SBAS standards development
  - SARPS and MOPS development and validation

http://www.gps.gov/policy/cooperation/#europe

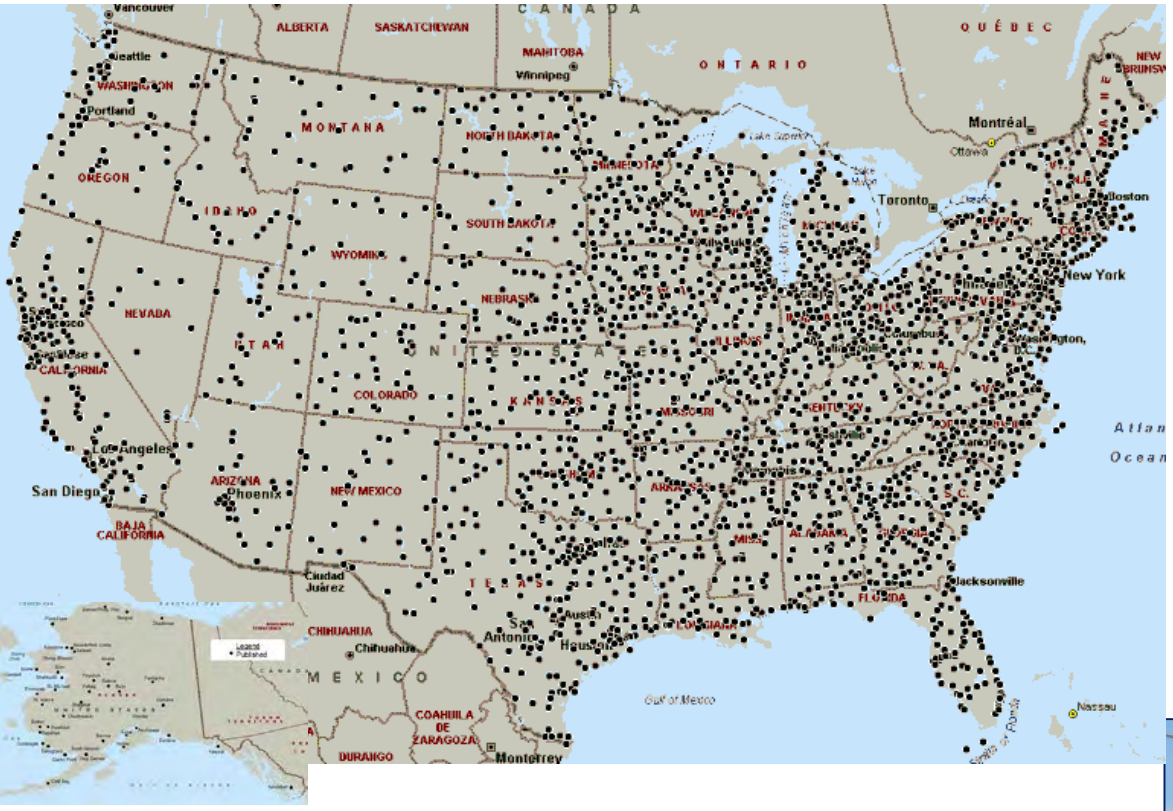
WAAS Phase IV Investigations (continued)

Advanced RAIM (ARAIM)

- Avionics-centric approach to dual-frequency multi-constellation
- WG-C is developing a new work plan to develop standards and supporting validation information
  - User Algorithm Documentation, Draft SARPs and CONOPS – Completed 2018
  - Safety Documentation – Due 2018
- FAA focus on development of initial requirements for horizontal navigation (H-ARAIM)
  - Developing airborne prototypes for flight testing
  - Document ground offline monitoring and begin prototyping if needed
  - Preliminary H-ARAIM safety case (include V-ARAIM as time allows)
  - Preliminary ICAO/RTCA requirements
  - Propose and validate new GPS/Galileo commitments
  - Approval for SARPS changes in 2020
  - Add material to DFMC MOPS to incorporate ARAIM function

http://www.gps.gov/policy/cooperation/#europe

WAAS Procedures and Users



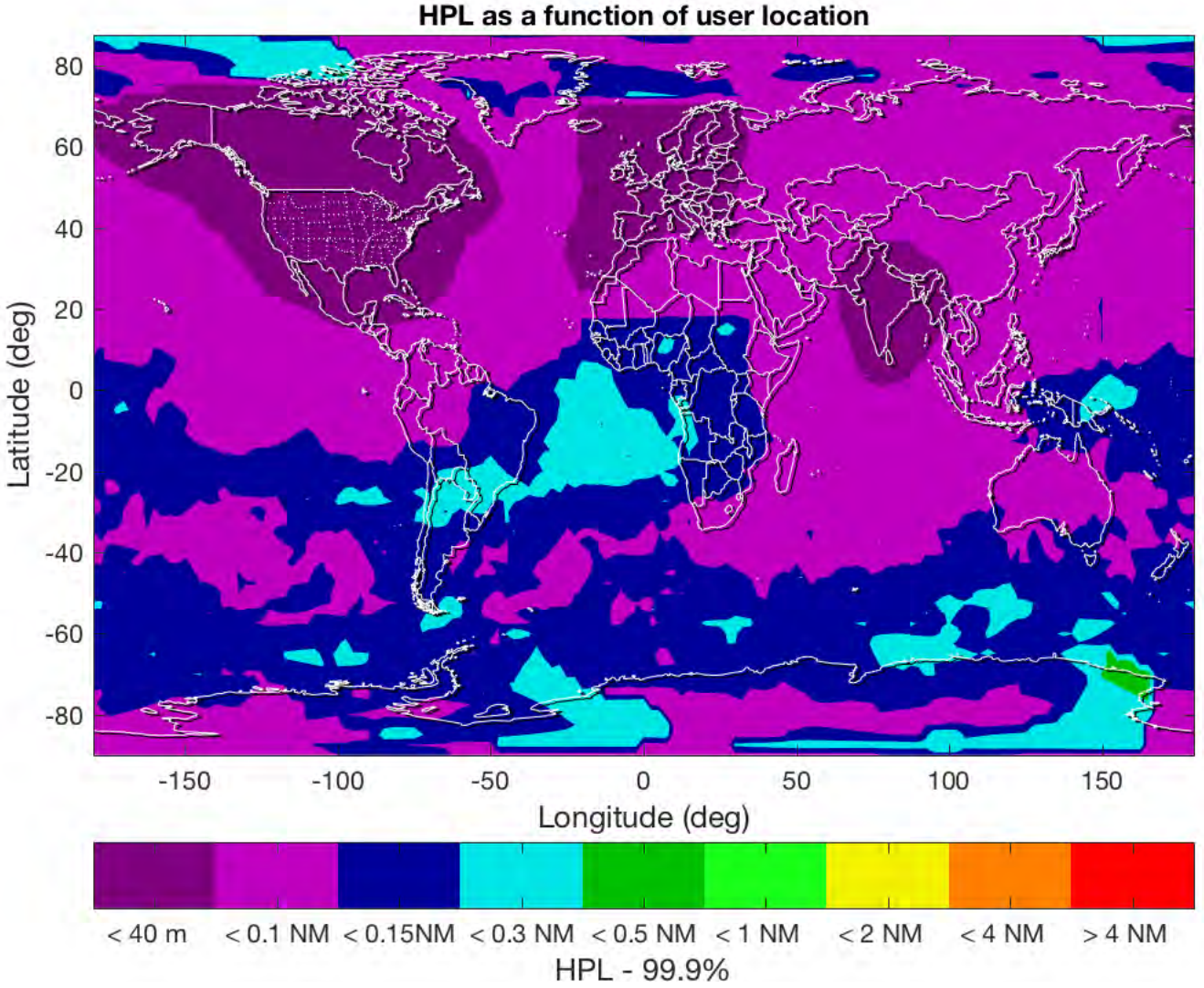
Approach Procedures

- 1,549 ILS procedures
- 4,639 WAAS LP & LPV Procedures (Sept 2018)
  - 3,956 Localizer Precision Vertical (LPV) procedures
    - Serving over 1,900 airports

Users

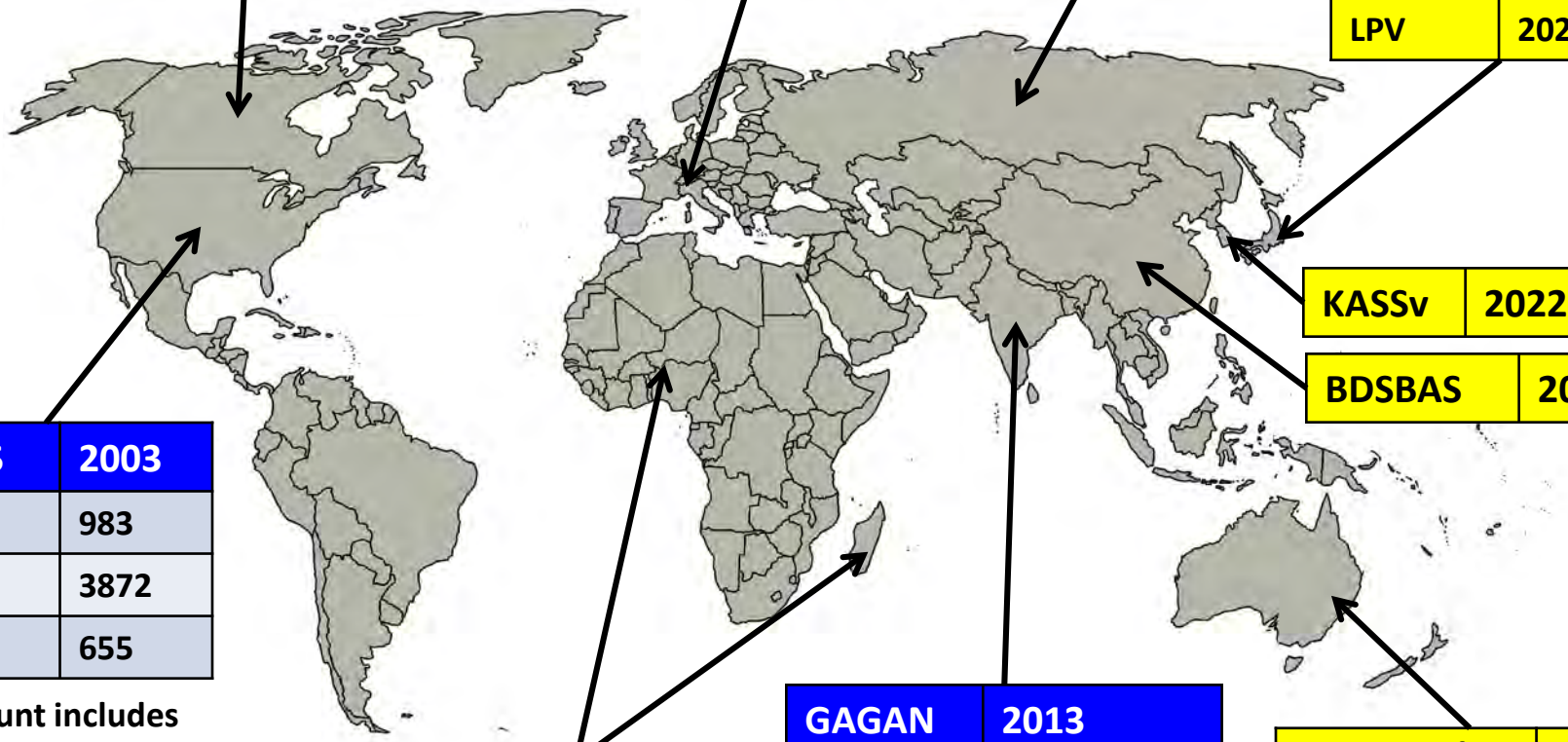
- Over 118,000 WAAS equipped aircraft
- WAAS/SBAS enabling technology for FAA NextGen
  - Automatic Dependent Surveillance Broadcast (ADS-B)
  - Performance Based Navigation (PBN)

Combined SBAS/RAIM Receiver Nominal Horizontal Performance



Combined SBAS/RAIM receiver supports enroute and terminal navigation globally with much higher availability in SBAS coverage

Operational and Planned SBAS
with number of Published Procedures



CWAAS	2007
LPV	355

EGNOS	2011
Cat-1	93
LPV*	368

SDCM	2018

MSAS	2007
NPA only	
LPV	2023

KASSv	2022

BDSBAS	2020

WAAS	2003
Cat-I	983
LPV*	3872
LP	655

*LPV count includes Category 1 approaches

ASECNA	2022

GAGAN	2013
LPV	Pending publication

Australia/+ SBAS	2023

Localizer Performance (LP) with vertical guidance (LPV)

Operational	Planned

PNT Resilience--What can you do now?

- Protect GPS and Critical Infrastructure that Relies on GPS
- Include GPS enabled devices in Cybersecurity plans
- Be a demanding customer - toughen GPS devices:
  - Incorporate valid range checking and other elements of latest GPS Interface Specification (IS-GPS-200 *)
  - Incorporate DHS Best Practices (*Improving the Operation and Development of Global Positioning System (GPS) Equipment Used by Critical Infrastructure *)*

* Documents available at www.gps.gov

Aviation Resiliency and Robustness

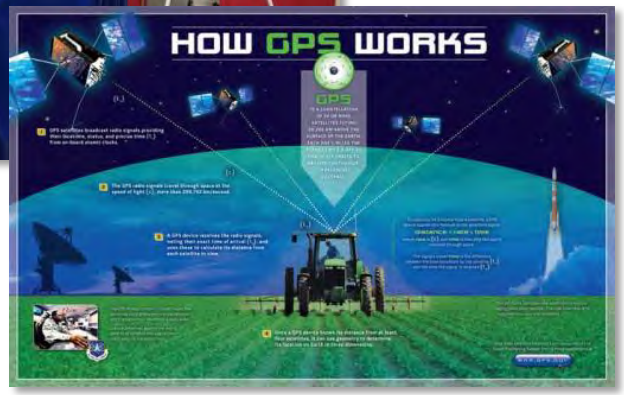
- DME/VOR/TACAN service required for foreseeable future to ensure resilient and robust navigation infrastructure
- Supports Performance Based Navigation (PBN) operations in event of GNSS disruptions
- NextGen DME Program
  - Established siting criteria
  - 100 DME targeted for discontinuance
  - Planning <124 New DMEs
- VOR Minimum Operational Ntework (MON)
  - Discontinued 34 VORs (Phase 1: 74 to be discontinued by 2020)
  - Next phase decision anticipated in 2020
  - Current Phase 2 plan would discontinue 237 VORs (Approximate 40% of Total VORs)
- ILS Rationalization planned in 2019

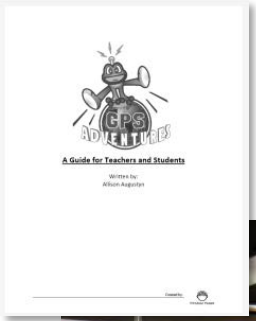
U.S. Outreach and Education

U.S. Space Policy Includes:

Develop and Retain Space Professionals. …Departments and agencies also shall promote and expand public-private partnerships to **foster educational achievement in Science, Technology, Engineering, and Mathematics (STEM) programs**, supported by targeted investments in such initiatives.

GPS Outreach & Education





GPS-Based STEM Curriculum

- Uses GPS concepts & applications to stimulate student interest in STEM
- Designed for middle school
- Highlights STEM careers and diversity
- Low/no-cost classroom activities
- Maps to Next Generation Science Standards (NGSS) and Common CORE
- Inquiry-based learning using stories, videos, etc.

Inquiry Based Learning – **"IDEA"**

Inquire: Present an event for inquiry

Discuss: Open discussion

Explain: Mini lecture

Apply: Exercise

Curriculum Structure

Courses	Lessons (3 Per Course)		
Earth	Are we there Yet? Mapping it out with Longitude & Latitude	Do you read me? Radio, Magnets & Information Transfer	I'm on my way! Navigation & Global Positioning System
Space	Launching Explorations Satellites & Orbits	Living Weightless: International Space Station	Orbital Rendezvous: Calculating Resupply for ISS
Life	Baby is it Cold Outside? Weather Forecasting	Saving Mother Nature: Environmental Conservation	Feed the World: Agriculture & Precision Farming
Movement	Up Up & Away! Aviation Moves Us	Networks of Power: Energy & Information	Global Supply Chain: Planes, Trains & Automobiles

12 Lesson Plans are downloadable and Free for Use

Sample Materials (1 of 3)

Are We There Yet?!

Get 3 classmates and plan a trip from here to Orlando, FL...you're going to Disney World!

To plan your trip, what will your team need to determine?

- What are your Longitude and Latitude right now?
- What are the Longitude and Latitude of Orlando, Fl?
- How long will you drive before taking a break? Where will that be?
- Using your map and a ruler, calculate the number of miles that you will need to drive to get to Orlando
- Given that ***Distance = Time x Speed***, how long will it take to drive there if you travel an average of 60 miles per hour when driving (remember your breaks!)?

Version 1.0

Sample Materials (2 of 3)

GEOID & ELLIPSOIDS:

The Earth is an imperfect sphere

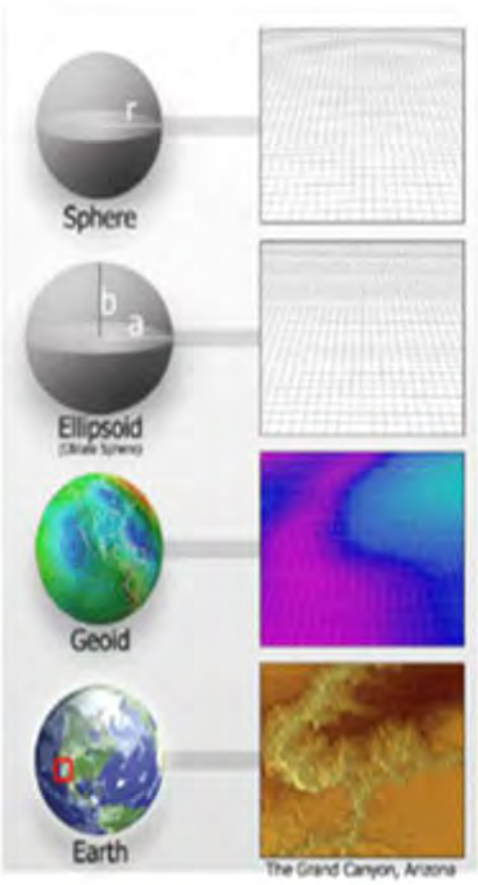
-It is Nearly Impossible to measure the surface of the Earth due to the irregularities such as mountains or valleys; and the rise and fall of the ocean tides

-To compensate, scientists use theoretical models: Geoids and Ellipsoids

Let's do an exercise...

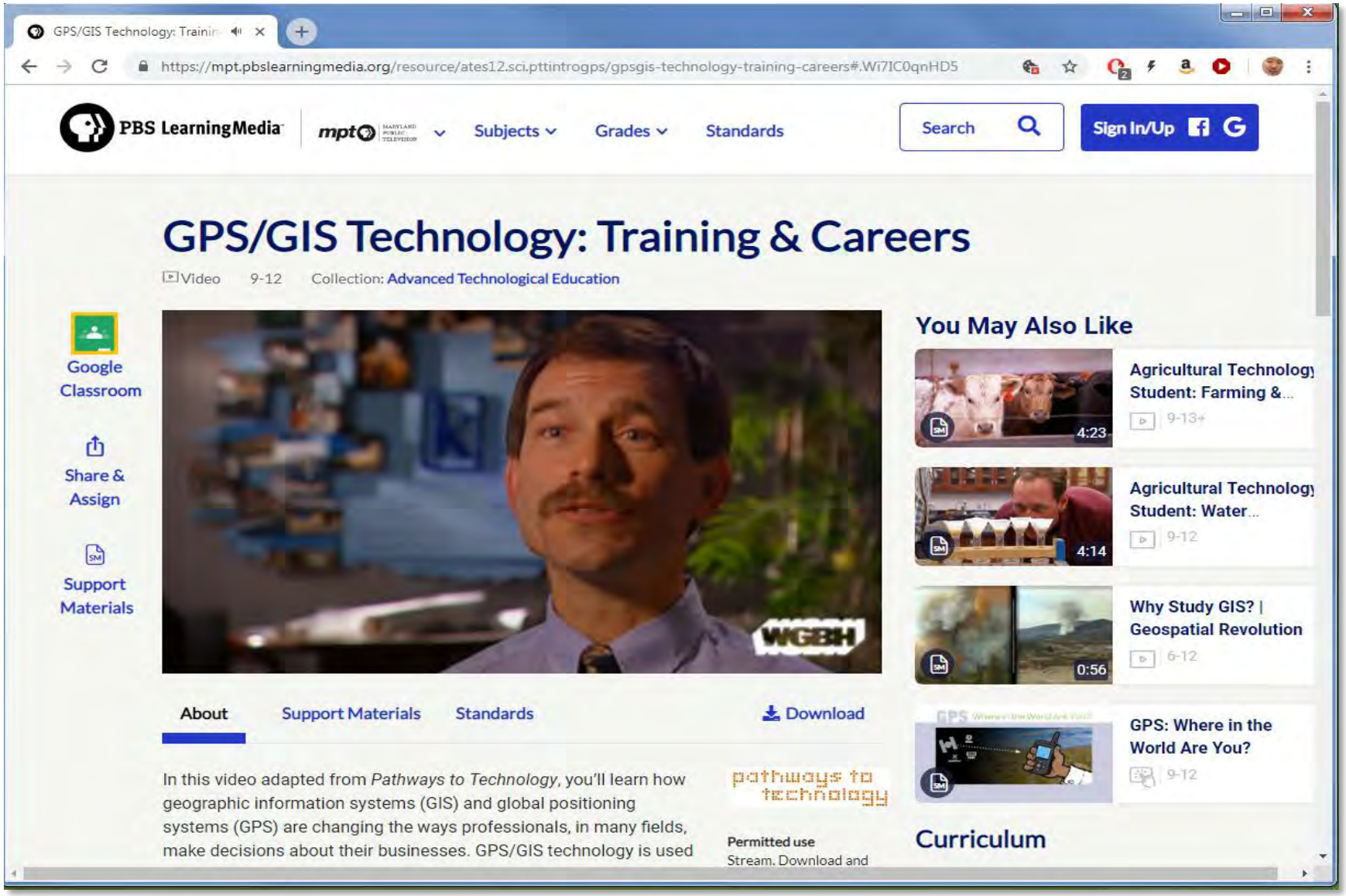
Punching out the globe!

[POTENTIAL BREAKPOINT FOR CLASS SESSION AFTER THE EXERCISE]



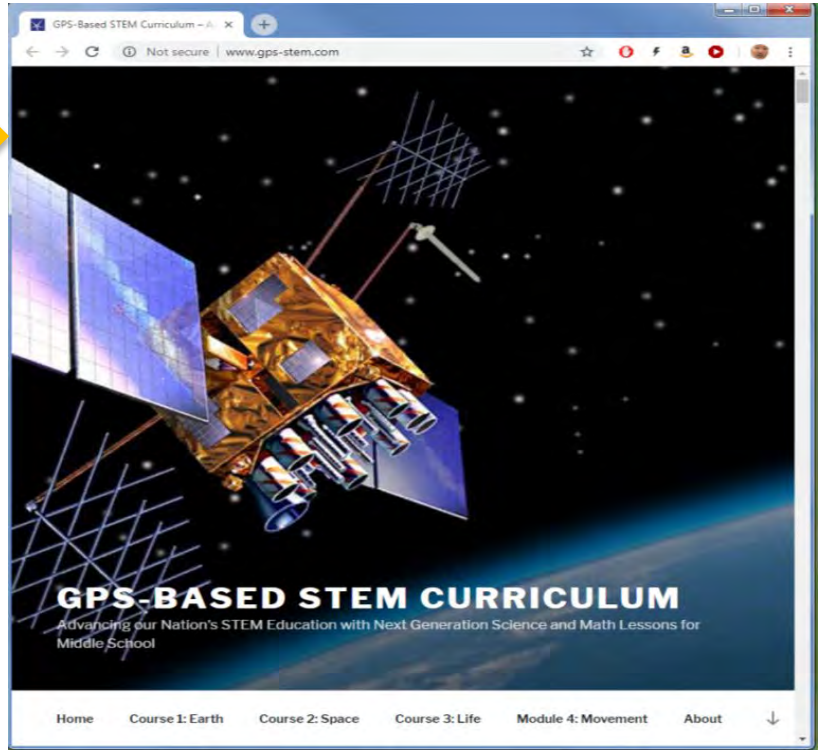
Version 1.0

Sample Materials (3 of 3)



Check Out the Courses/Lesson Plans and Supporting Educational Materials

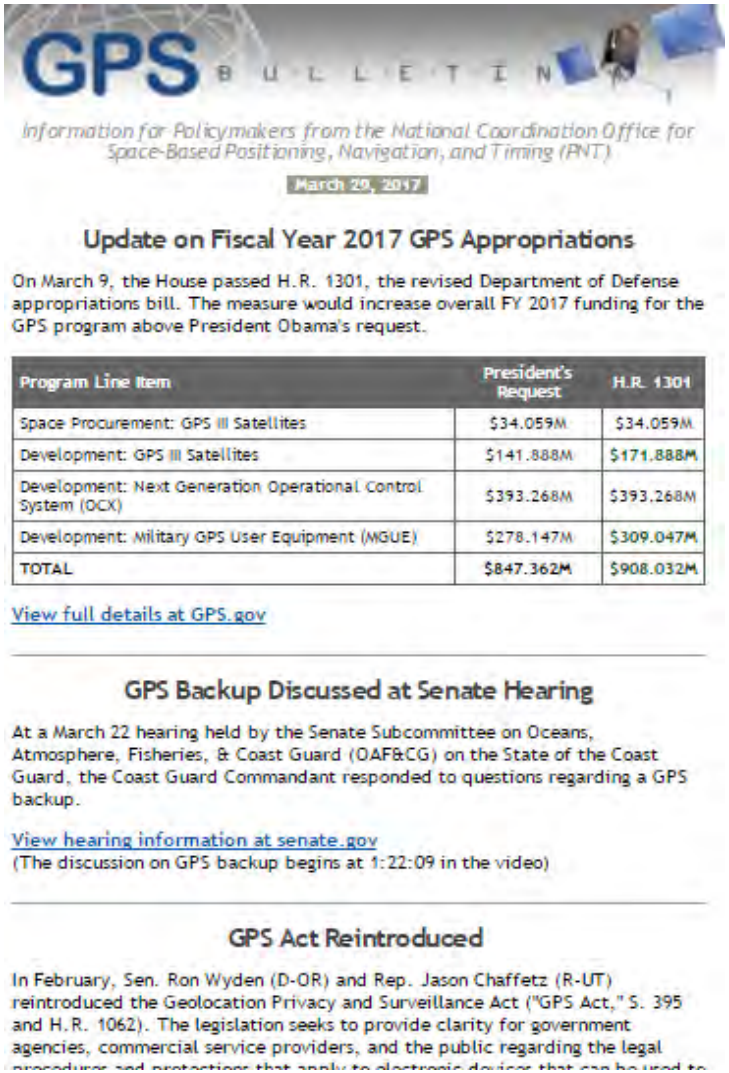
GPS.gov/students



GPS-STEM.com
(temporary URL)

Course Completion Certificates

GPS Information, Presentations, etc.



GPS BULLETIN

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

March 29, 2017

Update on Fiscal Year 2017 GPS Appropriations

On March 9, the House passed H.R. 1301, the revised Department of Defense appropriations bill. The measure would increase overall FY 2017 funding for the GPS program above President Obama's request.

Program Line Item	President's Request	H.R. 1301
Space Procurement: GPS III Satellites	$34.059M	$34.059M
Development: GPS III Satellites	$141.888M	$171.888M
Development: Next Generation Operational Control System (OCX)	$393.268M	$393.268M
Development: Military GPS User Equipment (MGUE)	$278.147M	$309.047M
TOTAL	$847.362M	$908.032M

View full details at GPS.gov

GPS Backup Discussed at Senate Hearing

At a March 22 hearing held by the Senate Subcommittee on Oceans, Atmosphere, Fisheries, & Coast Guard (OAF&CG) on the State of the Coast Guard, the Coast Guard Commandant responded to questions regarding a GPS backup.

View hearing information at senate.gov
(The discussion on GPS backup begins at 1:22:09 in the video)

GPS Act Reintroduced

In February, Sen. Ron Wyden (D-OR) and Rep. Jason Chaffetz (R-UT) reintroduced the Geolocation Privacy and Surveillance Act ("GPS Act," S. 395 and H.R. 1062). The legislation seeks to provide clarity for government agencies, commercial service providers, and the public regarding the legal procedures and protections that apply to electronic devices that can be used to

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Thank You!

Ken Alexander

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GPS: Accessible, Accurate, Interoperable

Backups

RTCA SC-159 Deliverables (1 of 2)

Product	Description	Due Date
DO-229E	Updated GPS/SBAS MOPS (to increase the number of SBAS Pseudorandom Noise [PRN] codes from 19 to 39); Graceful degradation to RAIM	December 2016
DO-253D	Updated GBAS MOPS.	July 2017
DO-246E	Updated GBAS ICD.	July 2017
DO-368	New MOPS for GPS/GLONASS (FDMA + antenna) L1-only airborne equipment.**	July 2017
GNSS L1/L5 Antenna MOPS	New GNSS dual-frequency (1575/1176 MHz) antenna MOPS for airborne equipment	May 2018
DO-235C	Updated L1 interference environment report.	October 2018
DO-292A	Updated L5 interference environment report.	March 2019

RTCA SC-159 Deliverables (2 of 2)

GNSS-Aided Inertial Systems MOPS	**New MOPS for GNSS-aided inertial navigation systems.**	**Apr 2020**
GNSS(SBAS) L1/L5 MOPS*	**Initial GPS/Galileo/SBAS MOPS for Verification and Validation** **Validated GPS/Galileo/SBAS MOPS for dual-frequency equipment****	**2020** **2022**
GNSS(GBAS) L1/L5 MOPS*	**Initial GPS/Galileo/GBAS MOPS for Verification and Validation** **Validated GPS/Galileo GBAS MOPS for dual-frequency equipment.****	**2021** **2023**

* Requirements for core constellations in addition to GPS and Galileo are dependent upon prerequisites

** New MOPS will address, to the extent practicable, the threats of intentional interference and spoofing.
New MOPS should address, to the extent practicable, the possibility of higher levels of adjacent-band interference in the future operational environment.