

# Wide Area Augmentation System (WAAS)

## Current Performance and Modernization

**Presented By: Jason Burns**

**Presented To: IES 2017**

**Date: May 9, 2017**



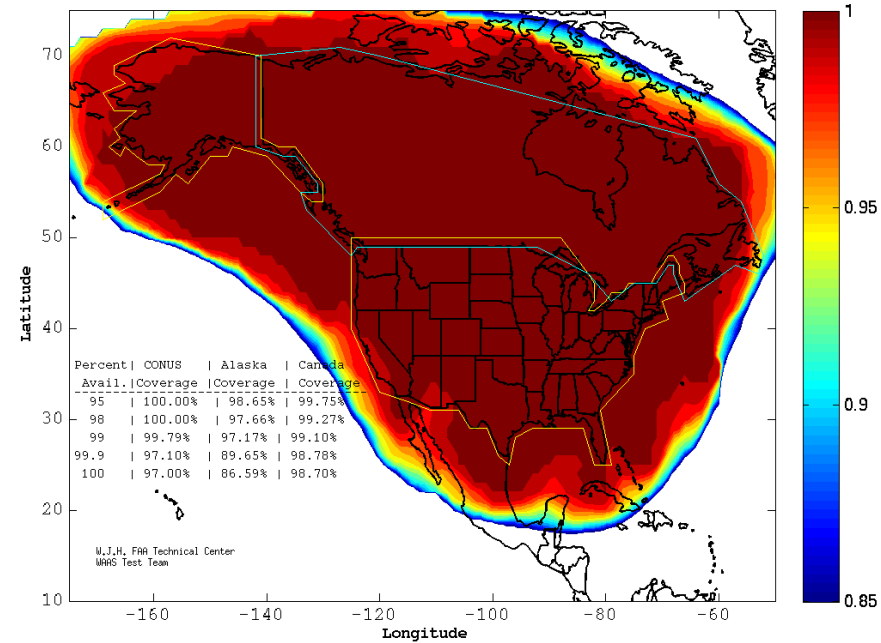
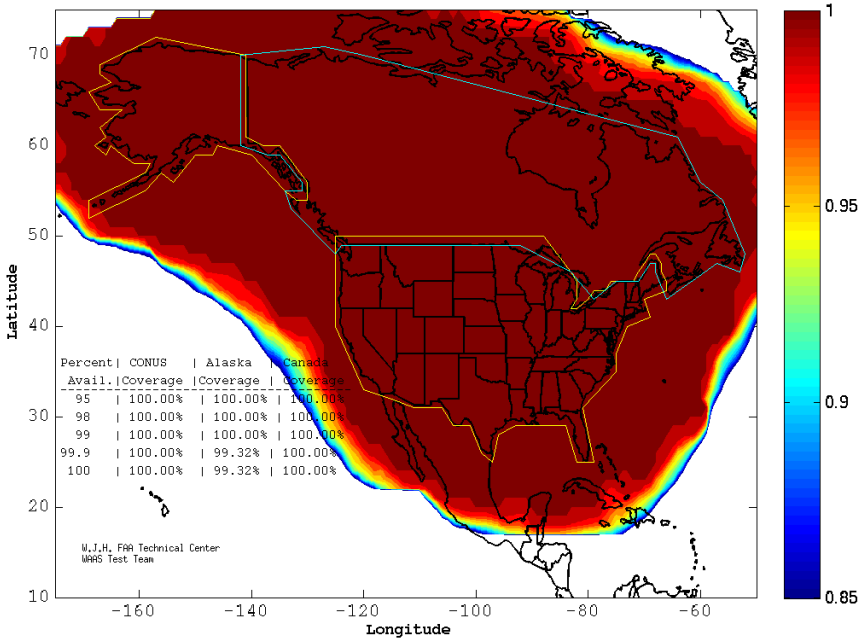
**Federal Aviation  
Administration**





# Current WAAS LPV/LPV-200 Performance

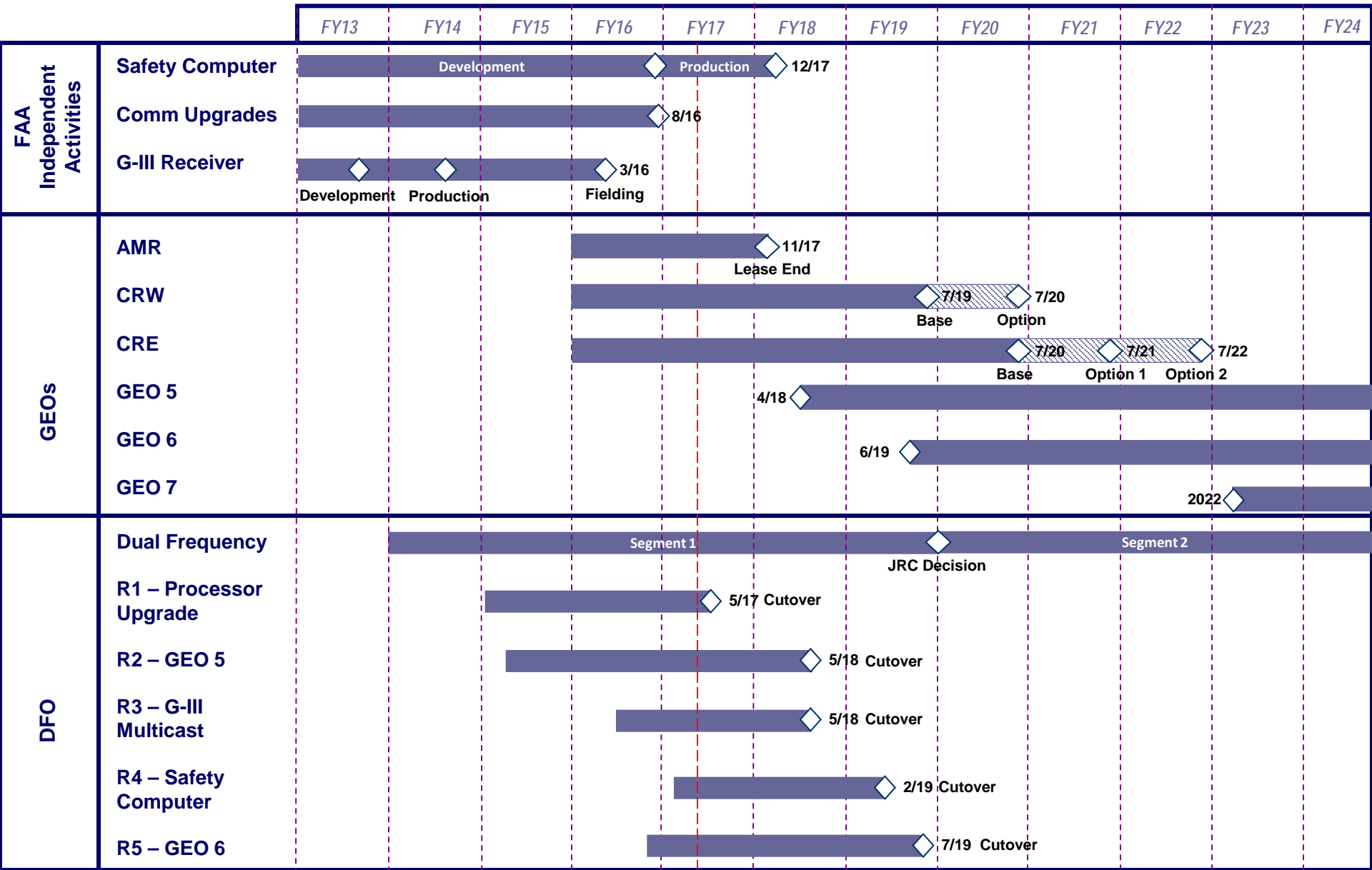
WAAS LPV Coverage Contours  
05/04/17  
Week 1947 Day 4

WAAS LPV200 Coverage Contours  
05/04/17  
Week 1947 Day 4

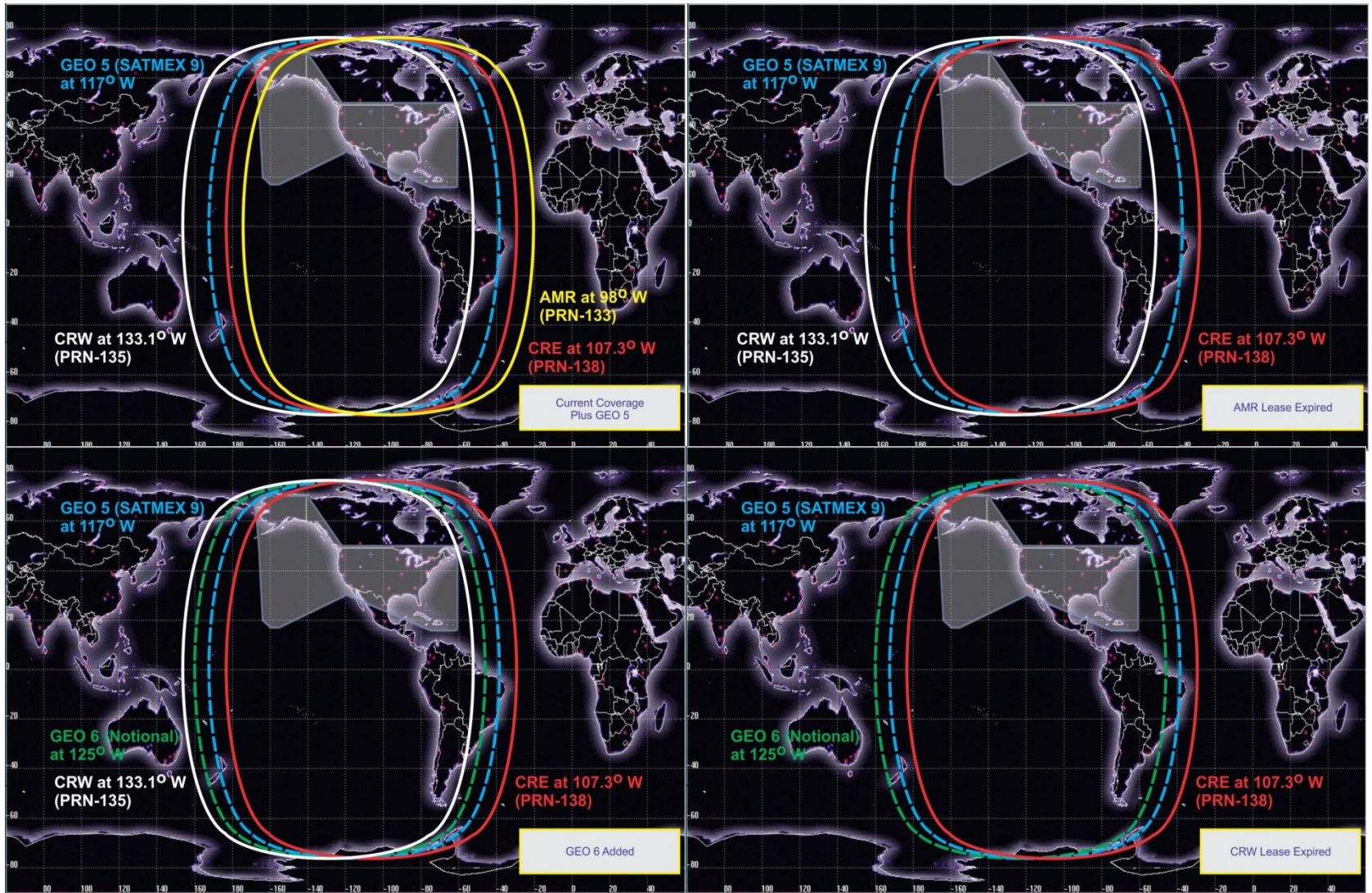


Legend	
	Milestone
	Satellite Option Years

# WAAS Schedule



# WAAS GEO Activities



# Dual-Frequency Multi-constellation Capability (DFMC)

- Preliminary requirements proposed by international SBAS providers
- Draft standards under review within ICAO and EUROCAE organizations
- Many SBAS providers developing prototypes and researching implementation within their own systems
- **Near term milestones:**
  - Draft avionics standards by 2019 – supports development and testing work
  - Final avionics standards by 2022 – supports final product development and certification

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



# Advanced RAIM (ARAIM)

- **Avionics-centric approach to dual-frequency multi-constellation**
- **US/EU WG-C has published their Milestone 3 report describing the overall concept and assessing its feasibility**
  - Will be used to coordinate standards development with ICAO, RTCA and EUROCAE
  - US/EU Milestone 3 report published at the following links:
    - [http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item\\_id=8690](http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8690)
    - <http://www.gps.gov/policy/cooperation/europe/2016/working-group-c/>
- **WG-C is developing a new work plan to develop standards and supporting validation information**
- **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

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



# G-III Receiver Galileo Prototype

- **Next generation WAAS receiver (G-III) fielded at all reference stations since June 2016**
- **Prototype effort initiated to add Galileo processing to G-III receiver platform via software update**
- **G-III/Galileo prototype intended for DFMC research and Galileo signal monitoring**
- **Galileo prototype G-III software currently undergoing testing with an expected formal delivery in mid 2017**
  - Will allow for tracking of 14 GPS, 4 SBAS and 12 Galileo satellites across all US and EU GNSS bands



# Ground Based Augmentation System

Presented to: Iono Effects Symposium

Prepared By: Shelly Beauchamp

FAA NextGen Portfolio Management & Technology  
Development Office

Engineering and Development Services Division  
Navigation Branch

Presented By: Jason Burns

Navigation Programs

Date: May 9, 2017



Federal Aviation  
Administration





# U.S. CAT-I GBAS Implementation

- **CAT-I GBAS being fielded as a non-Federal system**
  - Honeywell SLS-4000 has received FAA System Design Approval (SDA)
  - Public sites operational at Newark Liberty Int'l Airport (EWR) & George Bush Intercontinental Airport (IAH)
    - Over 4000 operations as of April 2017
    - Users include United Airlines, Delta Air Lines, Lufthansa, British Airways, Emirates, CargoLux, Cathay Pacific
  - Private sites owned by Boeing operational at Grant County Int'l Airport (MWH) & Charleston Int'l Airport (CHS)



# GAST-D SARPS Validation - Overview

- **GAST-D will support operations to CAT-III minima via use of single-frequency GPS**
- **Validation of requirements (included in amendment to ICAO Annex 10) was completed December 2016**
  - Ionospheric threat model used in validation bounds the threat in mid-latitude regions
- **State letter for comments to Annex 10 changes out March 30 2017, due May 30 2017**
- **Expected applicability date November 2018**

# GAST-D SARPS Validation

- **Full mitigation of integrity risk due to ionospheric delay was the most challenging issue in completing validation of the GAST-D GBAS SARPS**
- **In the course of an FAA GAST-D prototyping contract with Honeywell Int'l, tropospheric activity was observed that could lead to excessive false alerts and/or blinding of the ground system Ionospheric Gradient Monitor (IGM)**
  - Considerable work completed to find a way to mitigate iono threat in the presence of tropospheric gradients
  - IGM requirements were retooled to make as solution possible

# GAST-D Ionospheric Mitigation Scheme

- **GAST-D iono mitigation scheme relies on a combination of ground and airborne monitors**
- **Ground Monitors:**
  - Code-Carrier Divergence (CCD) monitor
  - Ionospheric Gradient Monitor (IGM)
- **Airborne Monitors:**
  - Code-Carrier Divergence (CCD) monitor
  - Dual Solution Ionospheric Gradient Monitor (DSIGMA)
    - Compares difference in pseudoranges smoothed with 30 and 100 second time constants with corresponding ground corrections applied to a set threshold

# GAST-D SARPS Validation – Summary of Final Work to Close

- **Papers by two ground system manufacturers illustrate that the mid-latitude iono threat could be mitigated (as required by the SARPS) with a combination of all proposed ground and airborne monitors**
- **Paper by one ground system manufacturer to show sufficient IGM performance in the presence of tropospheric noise**
- **Paper describing data collection and analysis done to arrive at final a airborne DSIGMA monitor requirements**
  - Requires reduction in maximum receiver correlator spacing from 0.2 to 0.1 chip to reduce noise

# GAST-D SARPS Validation – Summary of Final Work to Close

- **IGM Guidance Material Updates**
  - New text describing uplink parameter added to place limit on allowable tropospheric error
  - Clarification on iono threat model used in validation and its applicability
  - Identification of considerations when iono mitigation includes multiple monitors (monitor & sampling independence)
  - Addition of new RANGE domain DSIGMA monitor

# GAST-D SARPS Validation – Ongoing Work

- **Low-latitude environments exist where the ionospheric threat exceeds the bounds of the model used for GAST-D Validation**
- **Ongoing work by Iono Ad-hoc group of ICAO Navigation Systems Panel (NSP) GBAS Working Group (GWG)**
  - Supports efforts to validate GAST-D/CAT-III requirements in low-latitude regions
  - Focusing on:
    - Collection of data from ionosphere-rich regions
    - Evaluation of regional models against GAST-C & GAST-D performance
    - Evaluation of impacts of ionospheric bubbles and scintillation on integrity and continuity

# Questions

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**202-267-9403**



# FAA GBAS Program Overview

- **NextGen funding thru ~CY 2017**
  - Review of non-Federal CAT-III SDA artifacts from vendor applicant (Honeywell Int'l)
    - Approval basis will be the ICAO GAST-D SARPS
  - Support of ICAO Navigation Systems Panel GBAS Working Group (GWG), RTCA SC-159 WG4, and International GBAS Working Group (held April 2017)
  - Limited CAT-I Implementation support
    - Data collection at Newark, Houston, Moses Lake WA
    - Provision of required GLS service predictions

# APAC Threat Model

- **APAC state letter announcing adoption of GBAS Ionospheric Threat Model for APAC region, April 2017**
- **Guidance document prepared by ISTF (Iono Studies Task Force) to assist APAC states with their safety assessment of iono threat and mitigation to GBAS**



# GBAS Certification Efforts in Brazil

- **GBAS Annex to FAA/DECEA MOU signed March 2017**
  - Will allow the FAA to support DECEA in completing a safety case to allow certification of the first GBAS in Brazil
    - Safety case will be used in the completion of System Design Approval of GBAS in Brazil
    - Goal of initial CAT-I operations
  - DECEA certification effort will leverage FAA System Design Approval work where feasible
    - No changes planned to system software/hardware
  - Work to include data collection, analysis and safety management system documentation
- **Current goal date for completion of safety case December 2018**



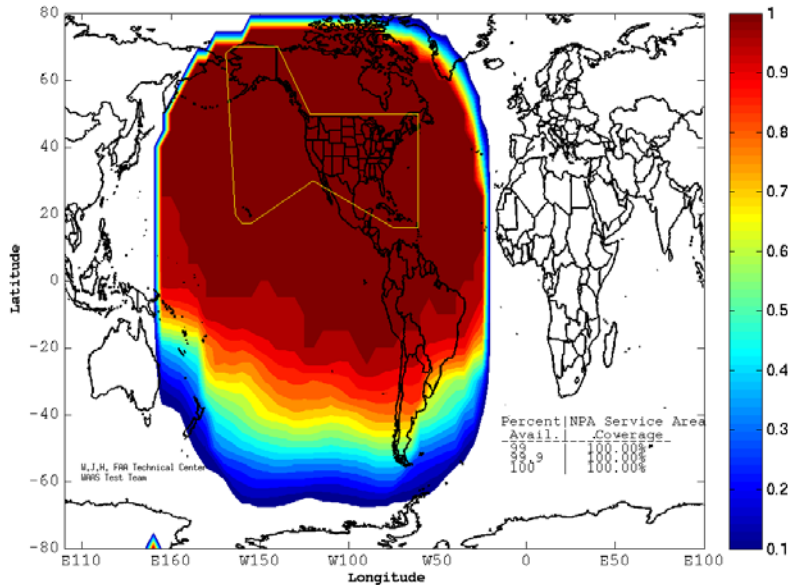
# WAAS Performance Jan 1 – Mar 31 2017

Parameter	CONUS Site/Maximum	CONUS Site/Minimum	Alaska Site/Maximum	Alaska Site/Minimum
95% Horizontal Accuracy (HPL <= 40 meters)	Atlantic City 1.322 meters	Salt Lake City 0.582 meters	Anchorage 0.738 meters	Bethel 0.575 meters
95% Vertical Accuracy (VPL <= 50 meters)	Miami 1.662 meters	Denver 0.744 meters	Barrow 1.362 meters	Bethel 0.987 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%	Multiple Sites 99.98%	Barrow 99.98%
LPV200 Availability (HPL <= 40 meters & VPL <= 35 meters)	Multiple Sites 100%	Oakland 99.33%	Multiple Sites 100%	Kotzebue 99.99%
99% HPL	Cleveland 15.57 meters	Denver 10.97 meters	Cold Bay 20.60 meters	Juneau 13.09 meters
99% VPL	Oakland 32.50 meters	Kansas 18.52 meters	Barrow 34.847	Juneau 22.53 meters

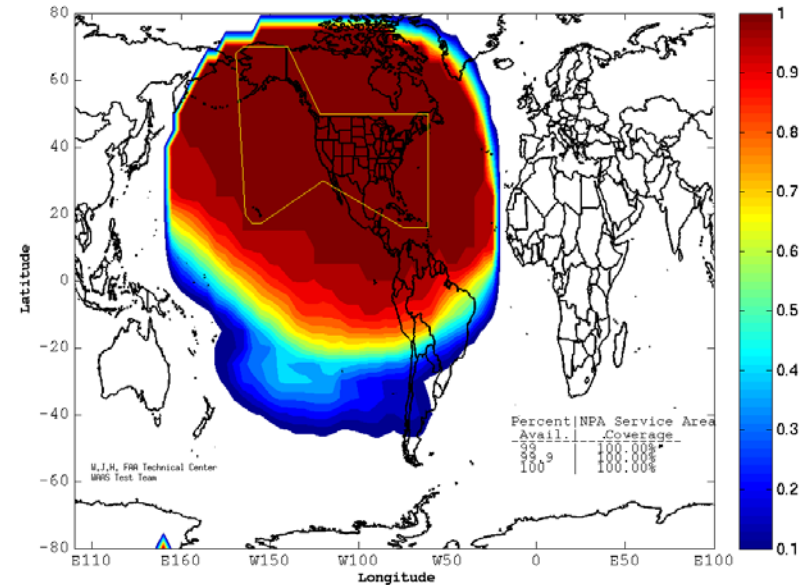
\* Localizer Performance (LP) service is available when the calculated Horizontal Protection Level (HPL) is less than 40 meters. Localizer Performance with Vertical Guidance (LPV) service is available when the calculated HPL is less than 40 meters and the Vertical Protection Level (VPL) is less than 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

# Current WAAS RNP 0.3/0.1 Performance

WAAS RNP 0.3 Coverage Contours  
05/04/17  
Week 1947 Day 4



WAAS RNP 0.1 Coverage Contours  
05/04/17  
Week 1947 Day 4



# GEO Sustainment (GEOs 5/6/7)

- **GEO 5/6 Satellite Acquisition**

- GEO 5

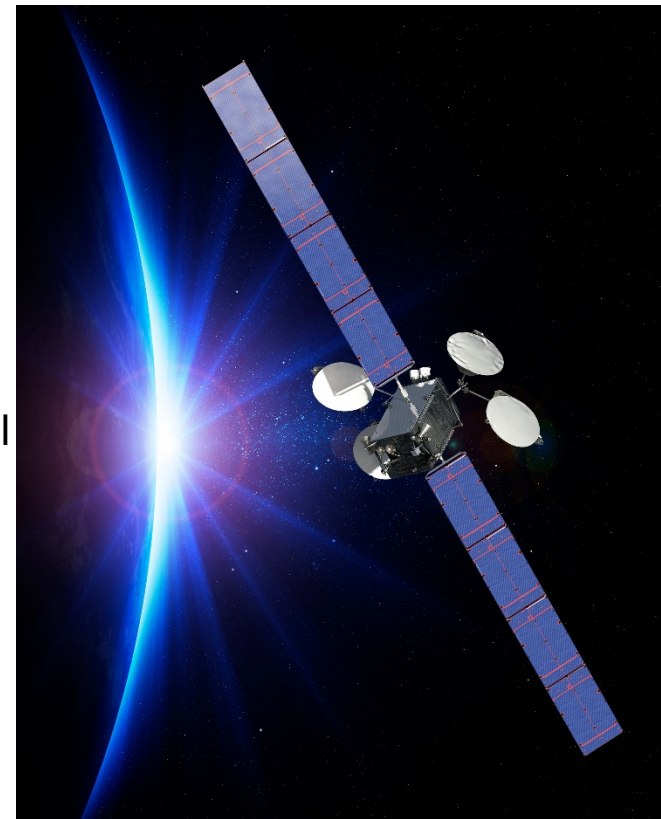
- EUTELSAT 117 West B (ex SatMex 9) satellite
      - Located at 117 West, provides full coverage of CONUS and Alaska
    - Successful satellite launch June 2016
    - In-Orbit Testing completed January 2017
    - Integration activities started, expected operational in 2018

- GEO 6

- GUS site build out in progress
    - Host satellite is SES-15, planned for 129 West
      - Provides full coverage of CONUS and Alaska
      - Launch currently anticipated May 2017
    - Signal Testing early CY2018
    - Expected Operational in 2019

- **GEO 7 Satellite acquisition**

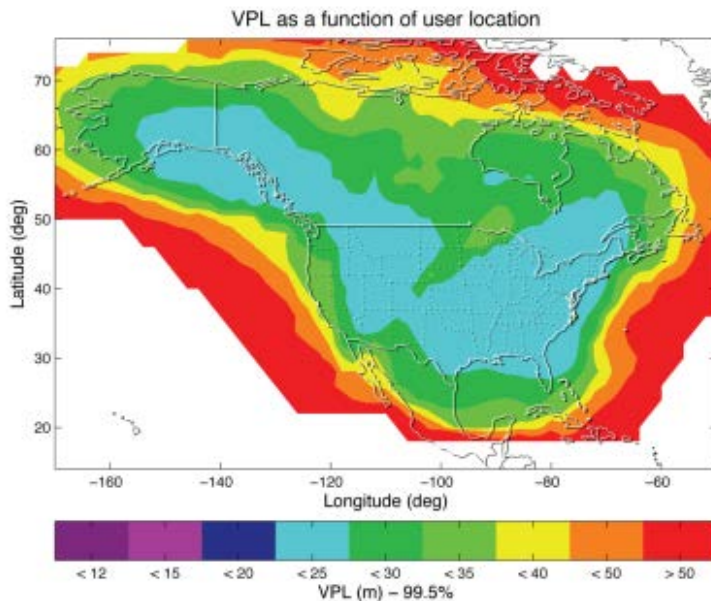
- Targeting 2018 for a contract award



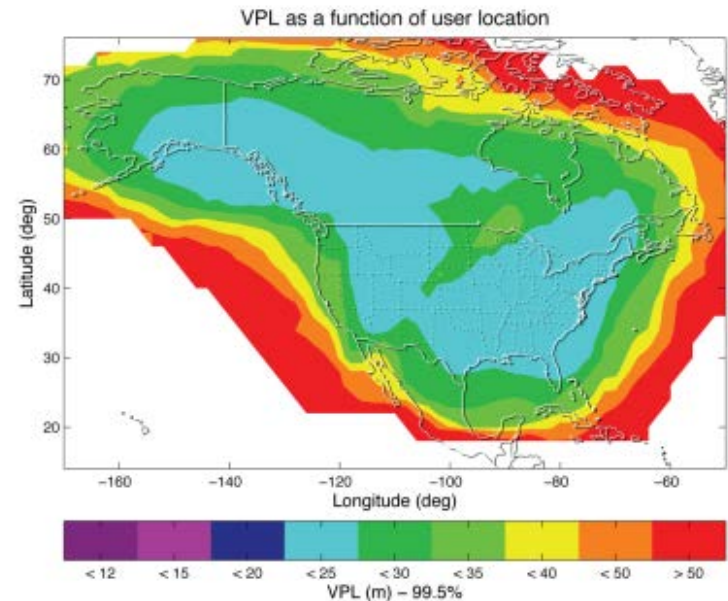
Eutelsat 117WB

# Moderate Storm Detector (MSD)

- Implemented in CY16 annual maintenance release
- Second branch in system-wide ionospheric perturbation detection
  - Disturbed: more conservative threat model
  - Quiet:
    - Reduces the under sampled threat
    - Lowers GIVES at the edge of coverage

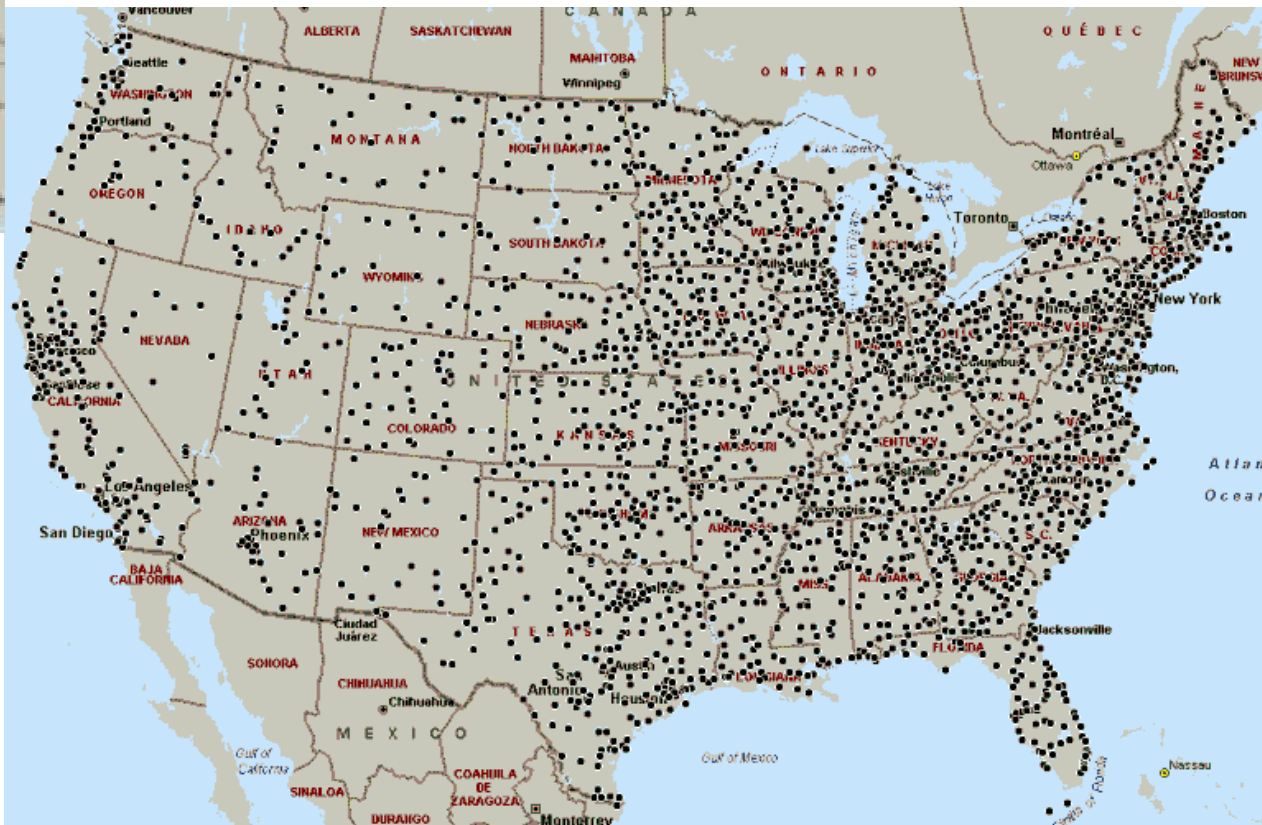


➔  
MSD



# Airports with WAAS LPV/LP Instrument Approaches

- Most of the airports throughout the National Airspace System contain WAAS Procedures



- As of April 2017 there are currently 1,550 ILS procedures while WAAS has 4,421 LPV/LP procedures published

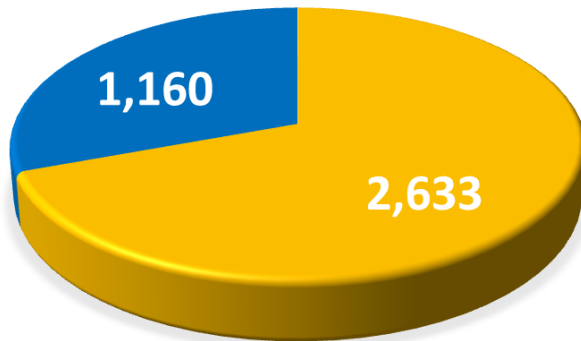


# WAAS LPV and LP Procedures

## LPV UPDATE

3,793 TOTAL LPV'S PUBLISHED TO DATE

- LPVs Published to non-ILS Runways:
- LPVs Published to ILS Runways:

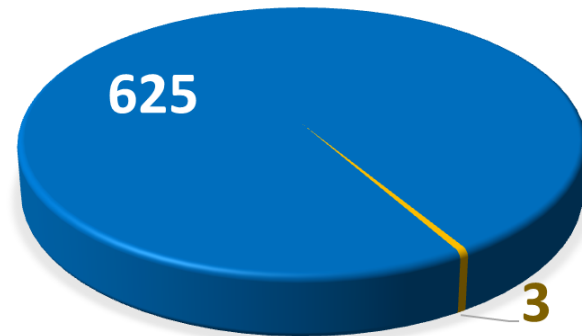


68 LPV's have been added in FY17. To date, 1021 LPVs published to <250' Altitude. 977 LPVs published to exactly 200' Altitude.

## LP UPDATE

628 TOTAL LP'S PUBLISHED TO DATE

- LPs Published to non-ILS Runways
- LPs Published to ILS Runways



17 LP's have been added in FY17.

- **WAAS LPV/LP Goal for FY17 is 170 published procedures.**
- **To date, 68 LPVs and 17 LPs have been added in FY17 for a Total of 85 procedures**

# WAAS Avionics Equipage Status

- **Over 95,000 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 has increased each year**
- **All classes of aircraft are served in all phases of flight**
- **Enabling technology for NextGen programs**
  - Automatic Dependent Surveillance Broadcast (ADS-B)
  - Performance Based Navigation (PBN)



# Aviation Long-term Timeline

