

# Wide Area Augmentation System (WAAS)

Ionospheric Effects  
Symposium

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**Federal Aviation Administration**

**Date: May 12, 2015**



Federal Aviation  
Administration



# Agenda

- **WAAS Overview**
- **Ionospheric Effects on WAAS**
- **Future Plans**
- **User Segment Update**

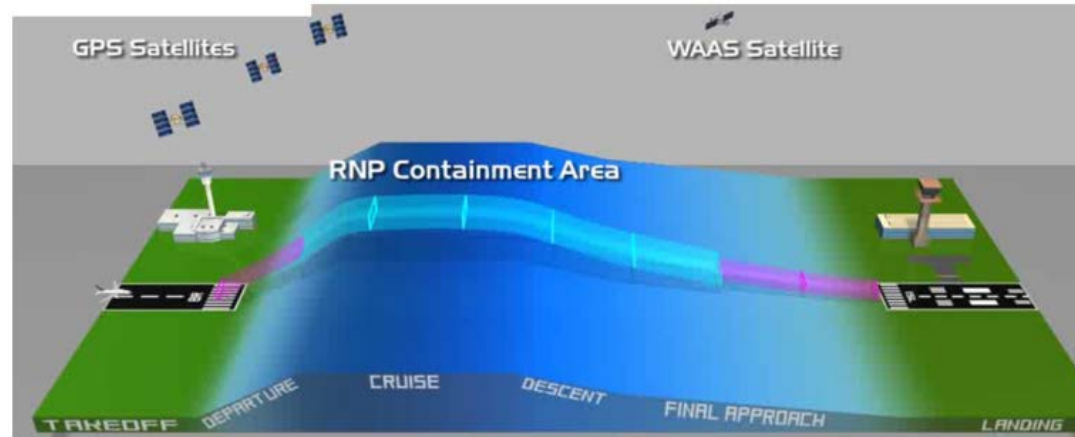


# WAAS Overview

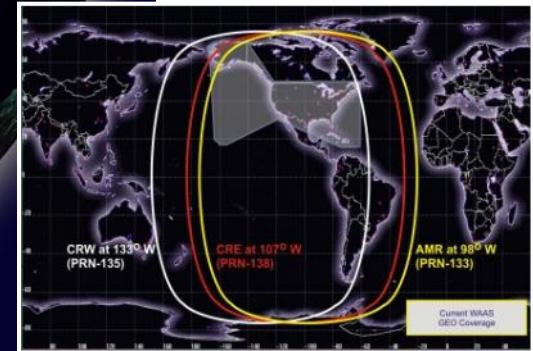


# WAAS Program Overview

- **WAAS provides precise navigation and landing guidance covering the entire National Air Space (NAS)**
- **Combination of ground-based and space-based assets**
- **Augments the Global Positioning System (GPS) Standard Positioning Service (SPS)**
- **Provides both safety and capacity improvements in the NAS and has been operational since 2003**
- **Can reduce FAA operations costs by enabling the removal of legacy ground-based navigation infrastructure**

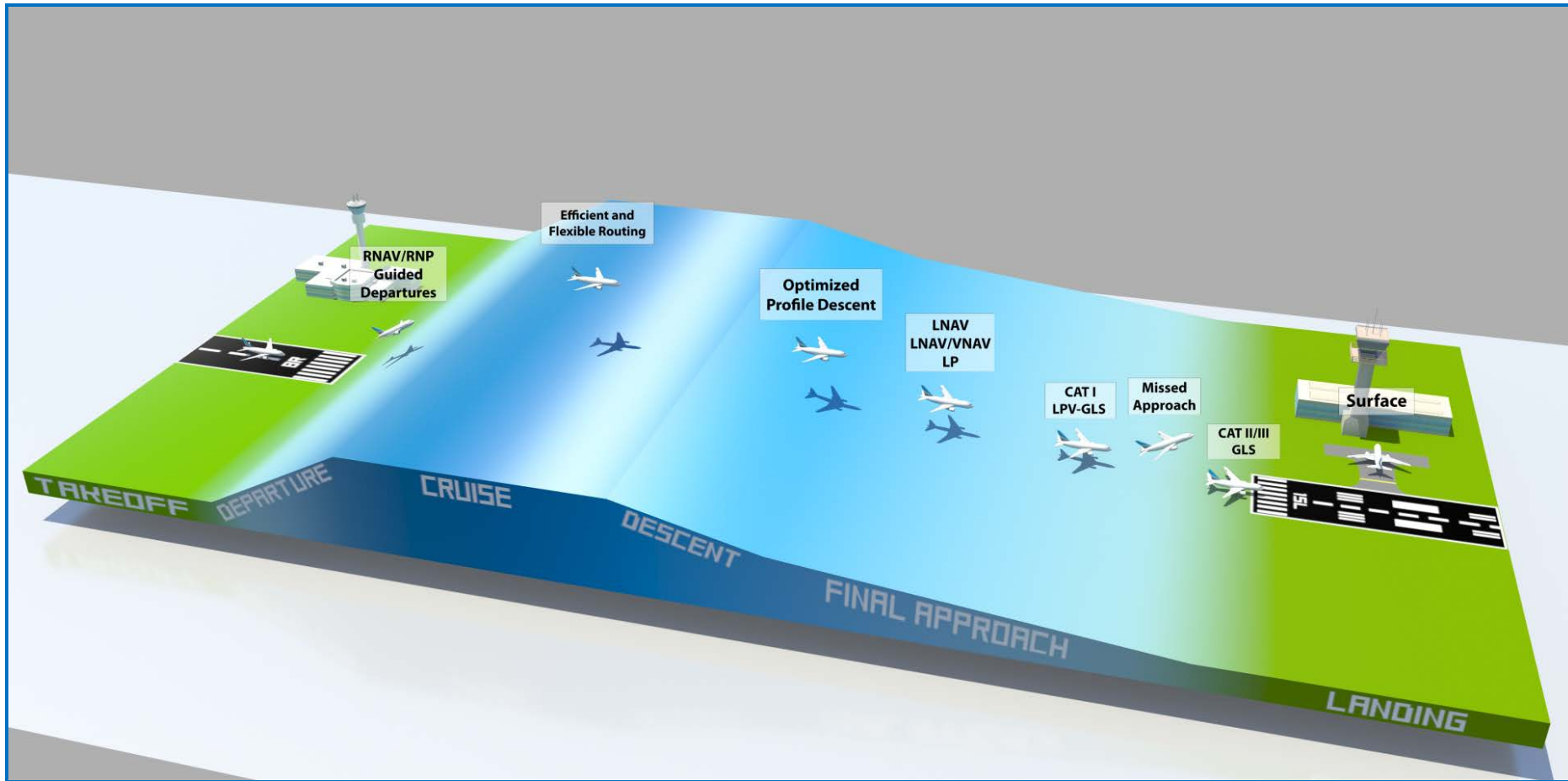


# WAAS Infrastructure

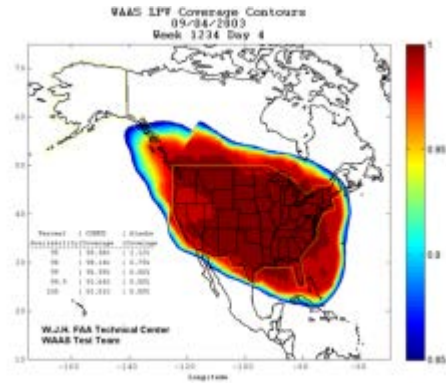


as of 6/6/2103

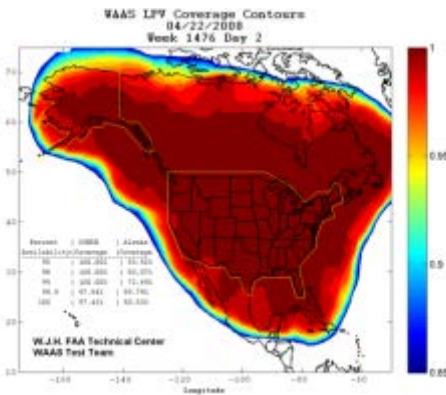
# WAAS Supported Operations



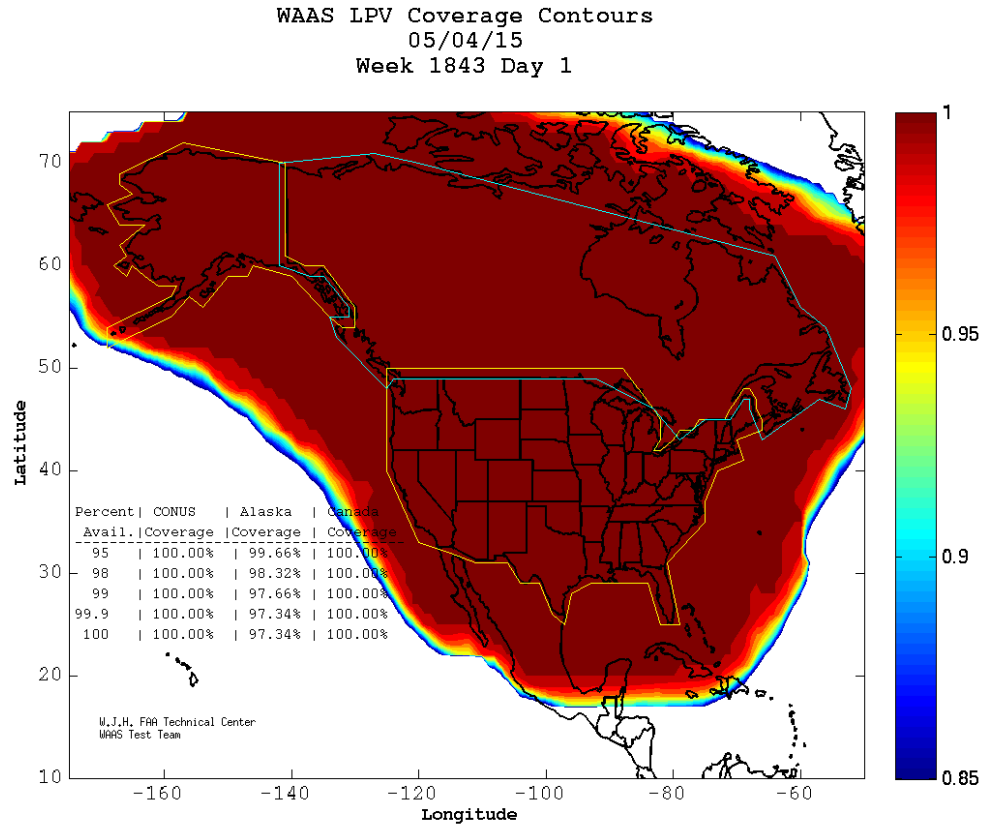
# WAAS Coverage



2003 IOC – LPV Coverage in lower 48 states only



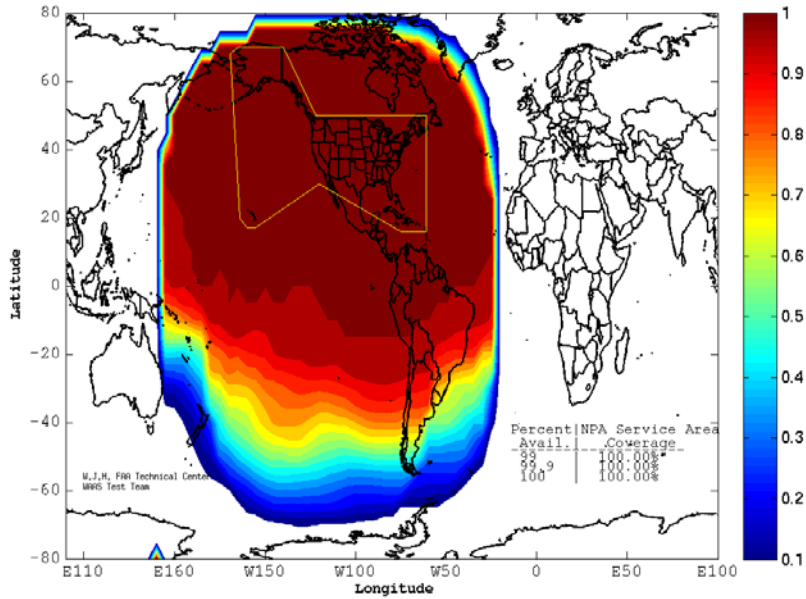
2008 Coverage - Full LPV 200 Coverage in CONUS (2 Satellites)



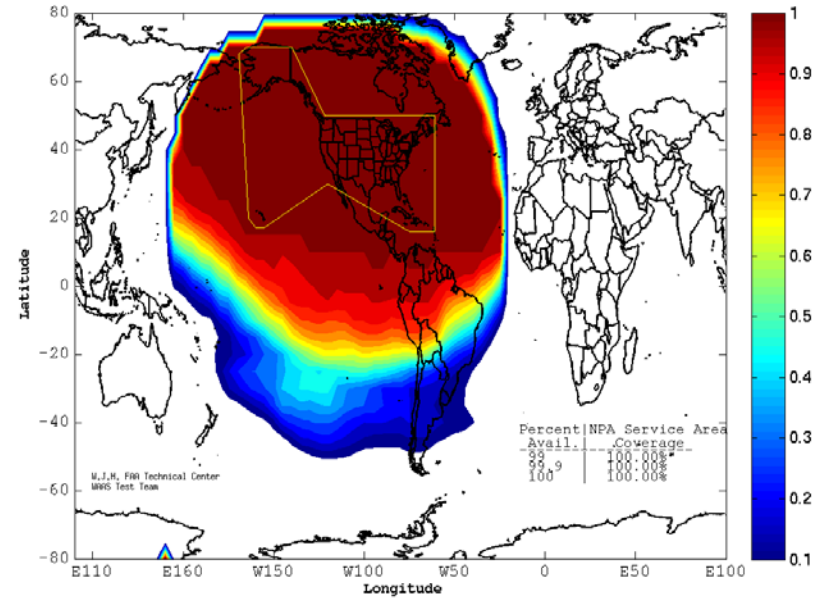
2015 Coverage - Full LPV 200 Coverage in CONUS (3 Satellites)

# WAAS RNP 0.3 and RNP 0.1 Coverage

WAAS RNP 0.3 Coverage Contours  
05/04/15  
Week 1843 Day 1



WAAS RNP 0.1 Coverage Contours  
05/04/15  
Week 1843 Day 1



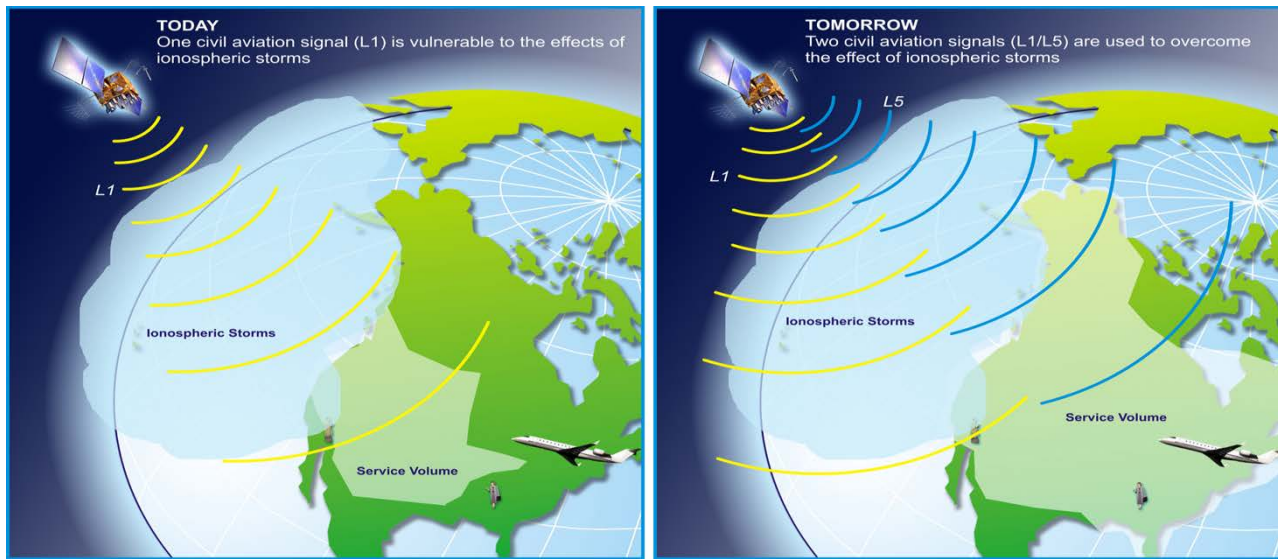


# WAAS Development Phases

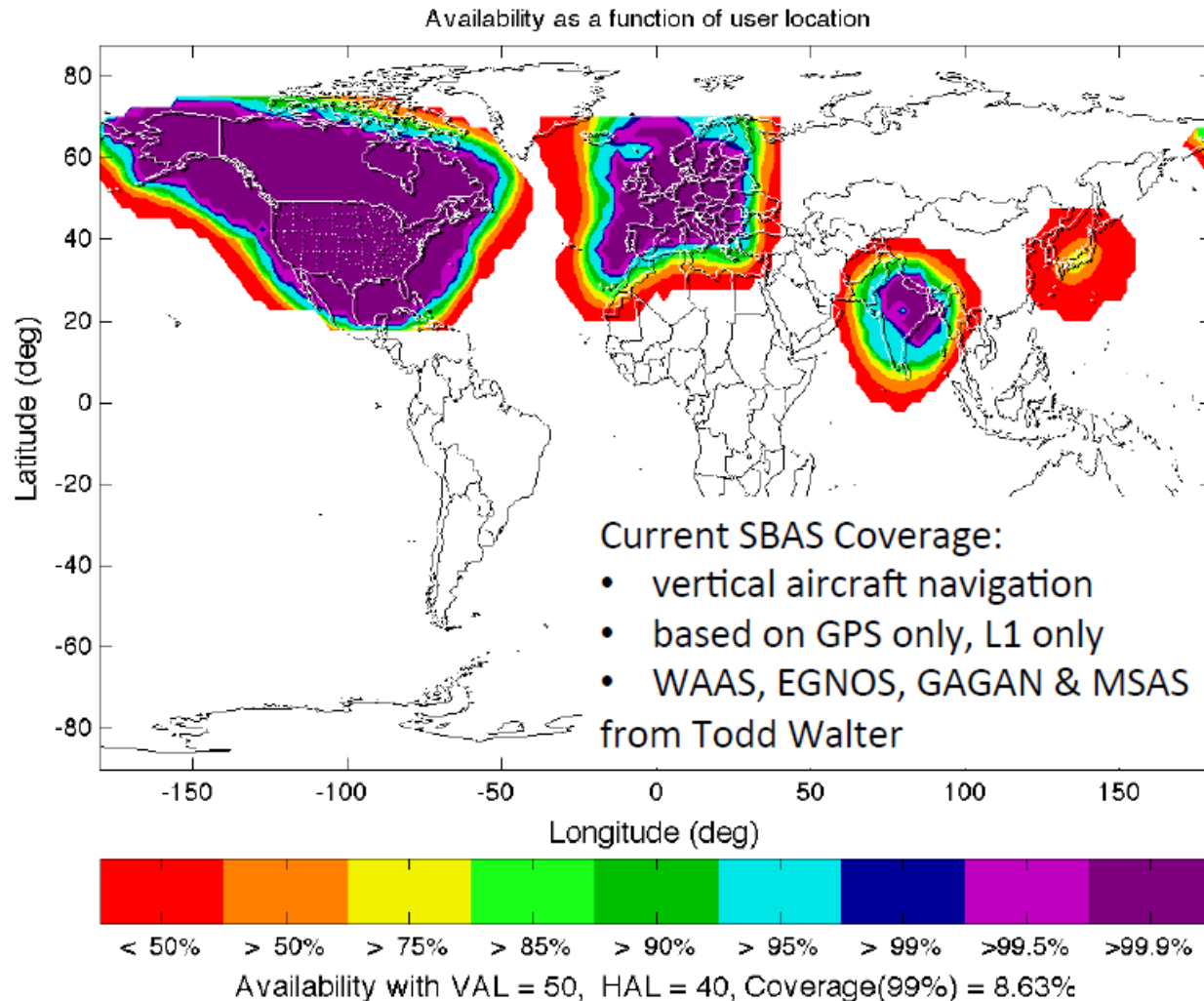
- **Phase I: IOC (July 2003) Completed**
  - Provided LNAV/VNAV/Limited LPV Capability
- **Phase II: Full LPV (FLP) (2003 – 2008) Completed**
  - Improved LPV availability in CONUS and Alaska
  - Expanded WAAS coverage to Mexico and Canada
    - Implemented new WRSs in these countries which increased the number of ionospheric measurements at the edge of WAAS service volume
    - New GEOs implemented with improved ranging performance. This provided increased continuity and availability for WAAS operations.
- **Phase III: Full LPV-200 Performance (2009 – 2014) Completed**
  - Improve performance during moderate ionospheric activity
    - Implemented Kriging to reduce conservatism in models and increase availability
  - Preparation for GPS L5 transition
- **Phase IV: Dual Frequency (L1,L5) Operations (2014 – 2044)**
  - Sustain WAAS GEOs
  - Technology refresh to address equipment obsolescence
  - Infrastructure modifications to support future L1/L5 user capability
  - Transition from use of L2 P(Y) to L5 in WAAS and provide dual-frequency service
    - Planning to transition within 2 years of GPS L5-signal Full Operational Capability (FOC)

# Dual Frequency Operations

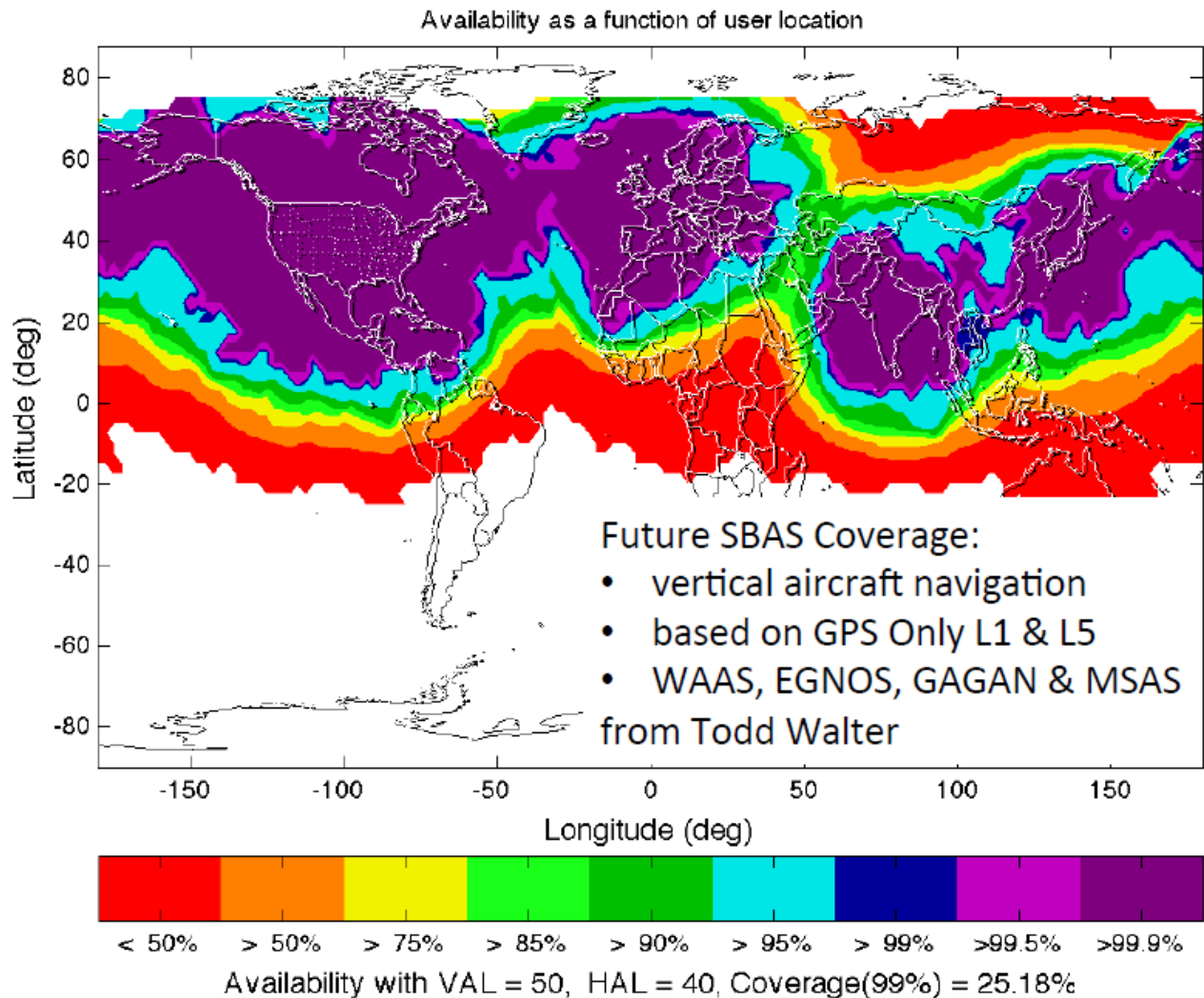
- **‘Sunset’ of L2 P(Y) semi-codeless technique compels WAAS to use another signal to maintain current service**
  - USG Federal Register Notice identified ‘sunset’ in December 2020
  - L2C/L5 readiness dates slipping (updates in Federal Radio-navigation Plan)
- **In May 2014 WAAS Final Investment Decision for Phase IV Segment 1 Dual Frequency Operations (DFO) was approved**
  - Segment 1 - Develop infrastructure improvements to support L5 & Tech Refresh
  - Segment 2 - Implementation of L1/L5 user capability



# Current SBAS Availability



# SBAS Availability w/ L1/L5 User

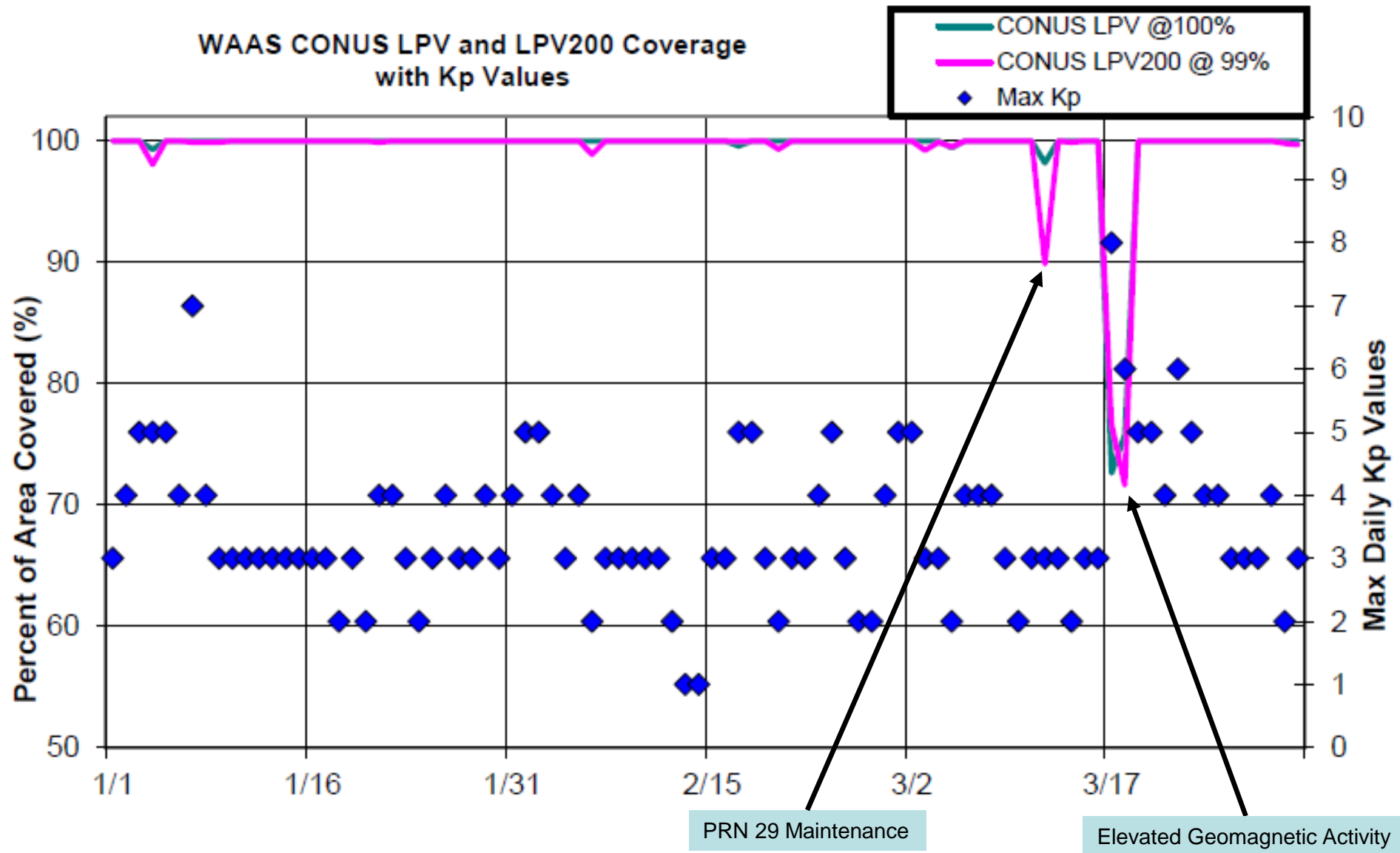


# Ionospheric Effects on WAAS



Figure 4-6 Daily LPV and LPV 200 CONUS Coverage

### WAAS CONUS LPV and LPV200 Coverage with Kp Values

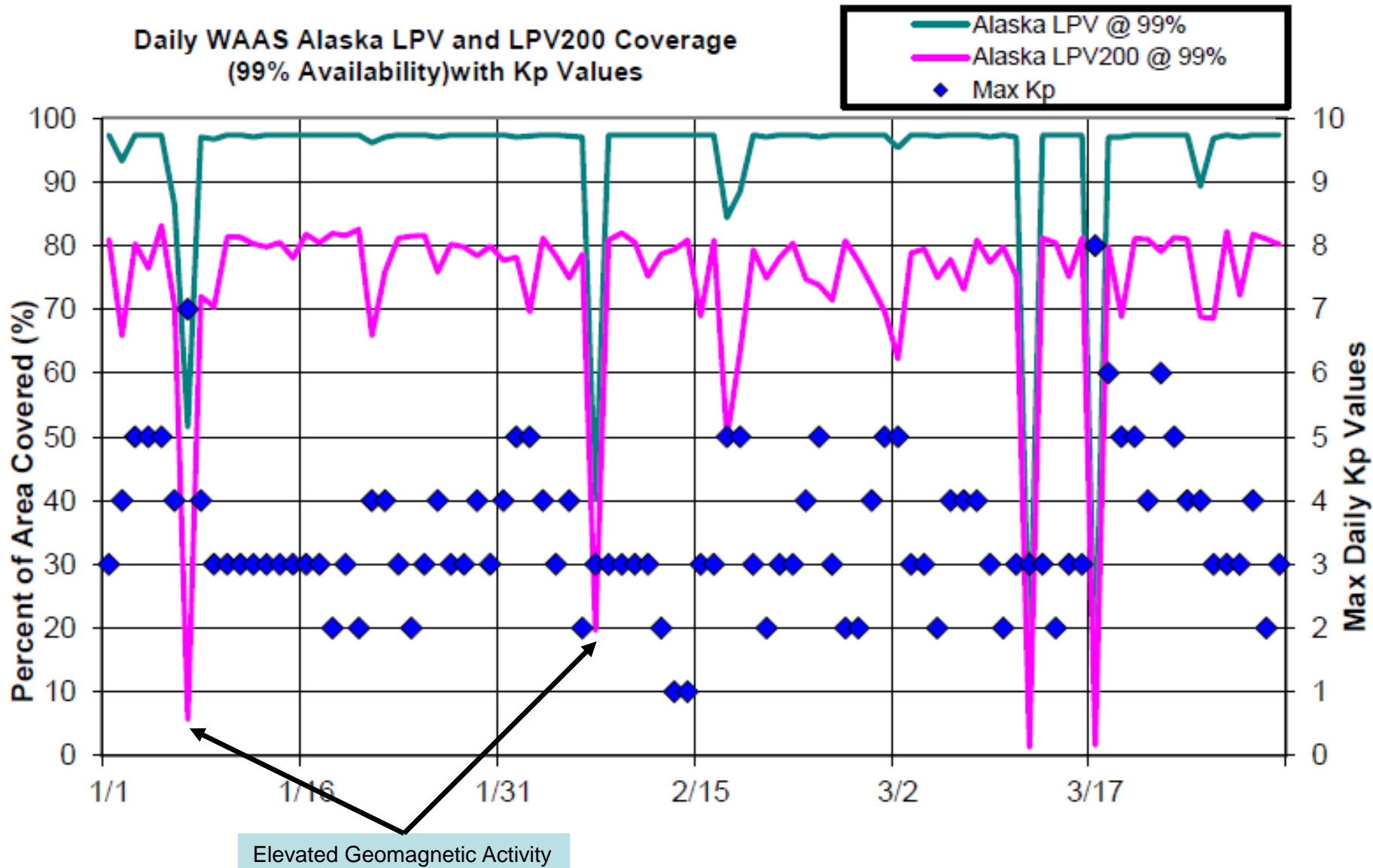


"WAAS Performance Analysis Report", Report #52, <http://www.nstb.tc.faa.gov/reports/waaspan52.pdf>, Apr 2015.



Figure 4-7 Daily LPV and LPV 200 Alaska Coverage

Daily WAAS Alaska LPV and LPV200 Coverage  
(99% Availability) with Kp Values

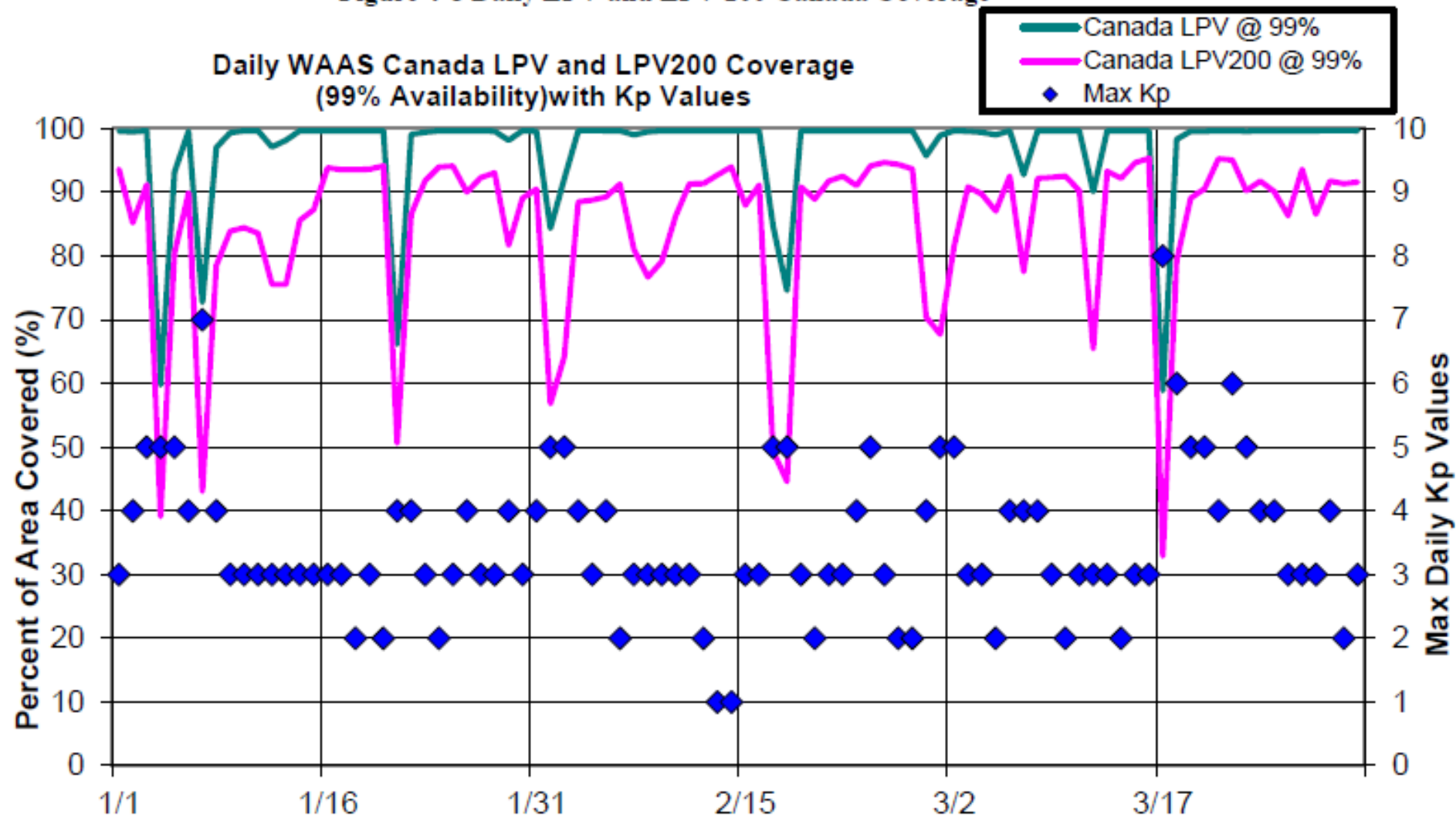


“WAAS Performance Analysis Report”, Report #52, <http://www.nstb.tc.faa.gov/reports/waaspan52.pdf>, Apr 2015.



Figure 4-8 Daily LPV and LPV 200 Canada Coverage

Daily WAAS Canada LPV and LPV200 Coverage  
(99% Availability)with Kp Values

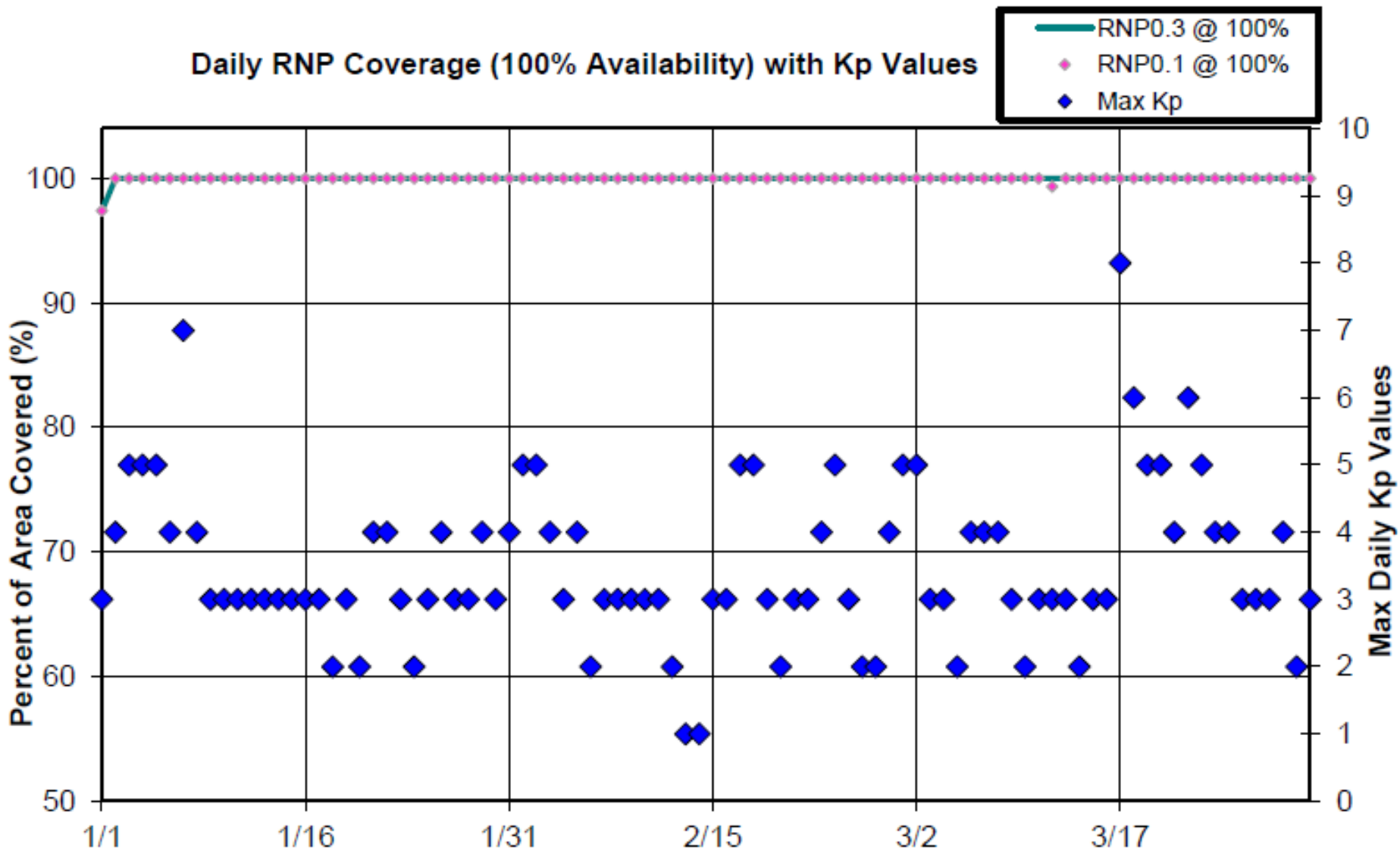


"WAAS Performance Analysis Report", Report #52, <http://www.nstb.tc.faa.gov/reports/waaspan52.pdf>, Apr 2015.





# Daily RNP Coverage (100% Availability) with Kp Values



“WAAS Performance Analysis Report”, Report #52, <http://www.nstb.tc.faa.gov/reports/waaspan52.pdf>, Apr 2015.



# Future Planning



# WAAS Phase IV Investigations

- **Dual-Frequency Multi-constellation Capability**

- International focus is on taking advantage of other 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 working on CONOPS addressing all DFMC applications (e.g. SBAS, GBAS)
- User equipment standards for Dual-Frequency operations
  - FAA working with SBAS Interoperability Working Group (IWG) on definition document that provides the basis for interface design and MOPS development for L1/L5 and multi-constellation

- **Advanced RAIM (ARAIM)**

- Avionics-centric approach to dual-frequency multi-constellation
- ARAIM subgroup developing more detailed concept definition
  - Will be used to coordinate standards development with ICAO, RTCA and EUROCAE
  - Updated Milestone 2b report analysis and conclusions based on public feedback and incorporate in Milestone 3 report at meeting held the week of March 23<sup>rd</sup> 2015
  - The Milestone 2b report to be published at following meeting when formal review cycle completes

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



# User Segment Update

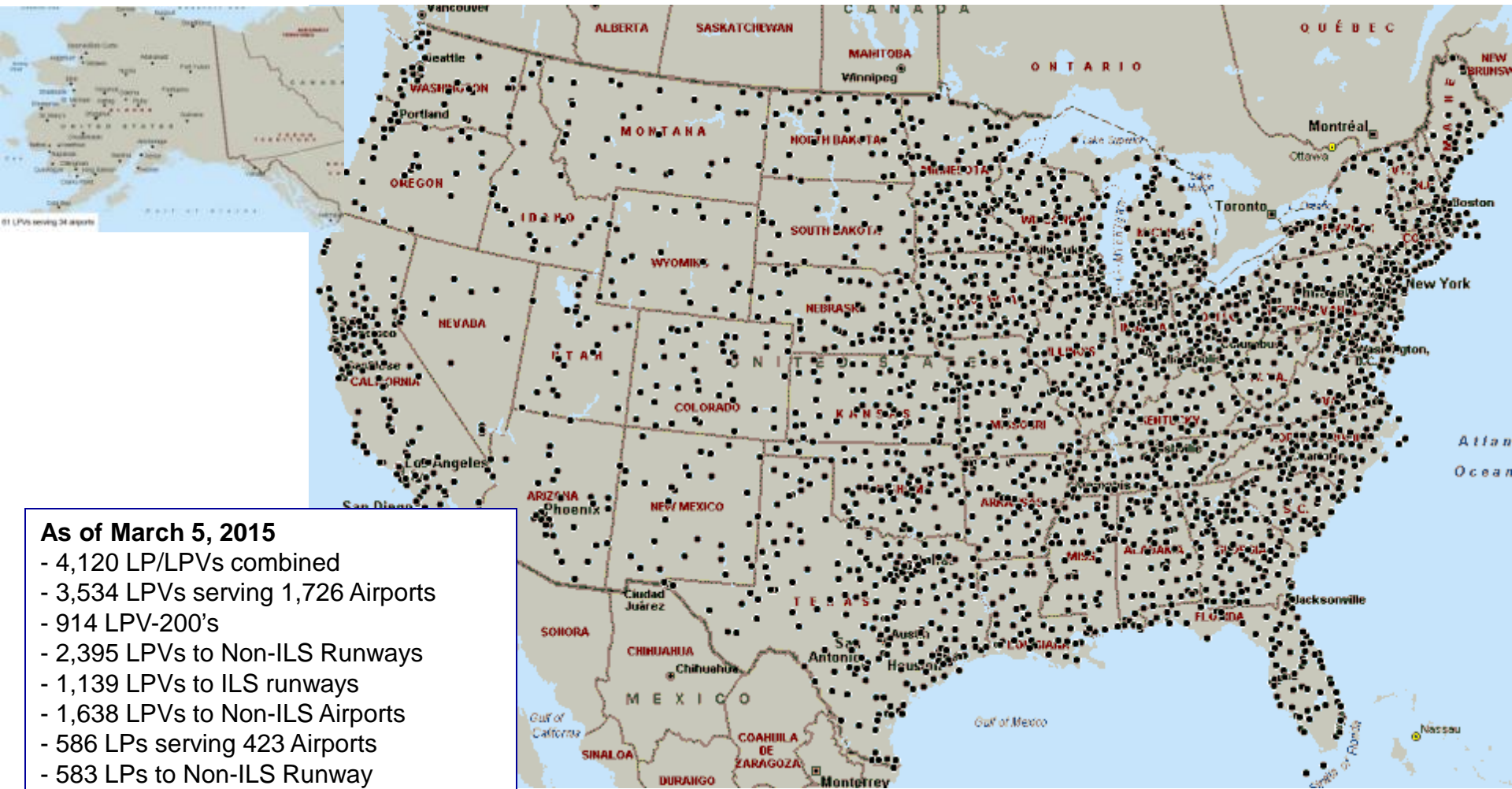


# Users Depending on WAAS

- **Approximately 82,000 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**
- **Smaller airports and communities they serve are within reach, even in low visibility weather conditions**
- **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)
    - Ex. - Area Navigation (RNAV), Required Navigation Performance (RNP), and Point in Space (PinS) procedures



# Airports with WAAS LPV/LP Instrument Approaches



**As of March 5, 2015**

- 4,120 LP/LPVs combined
- 3,534 LPVs serving 1,726 Airports
- 914 LPV-200's
- 2,395 LPVs to Non-ILS Runways
- 1,139 LPVs to ILS runways
- 1,638 LPVs to Non-ILS Airports
- 586 LPs serving 423 Airports
- 583 LPs to Non-ILS Runway
- 3 LPs to ILS Runways





# Backup Slides






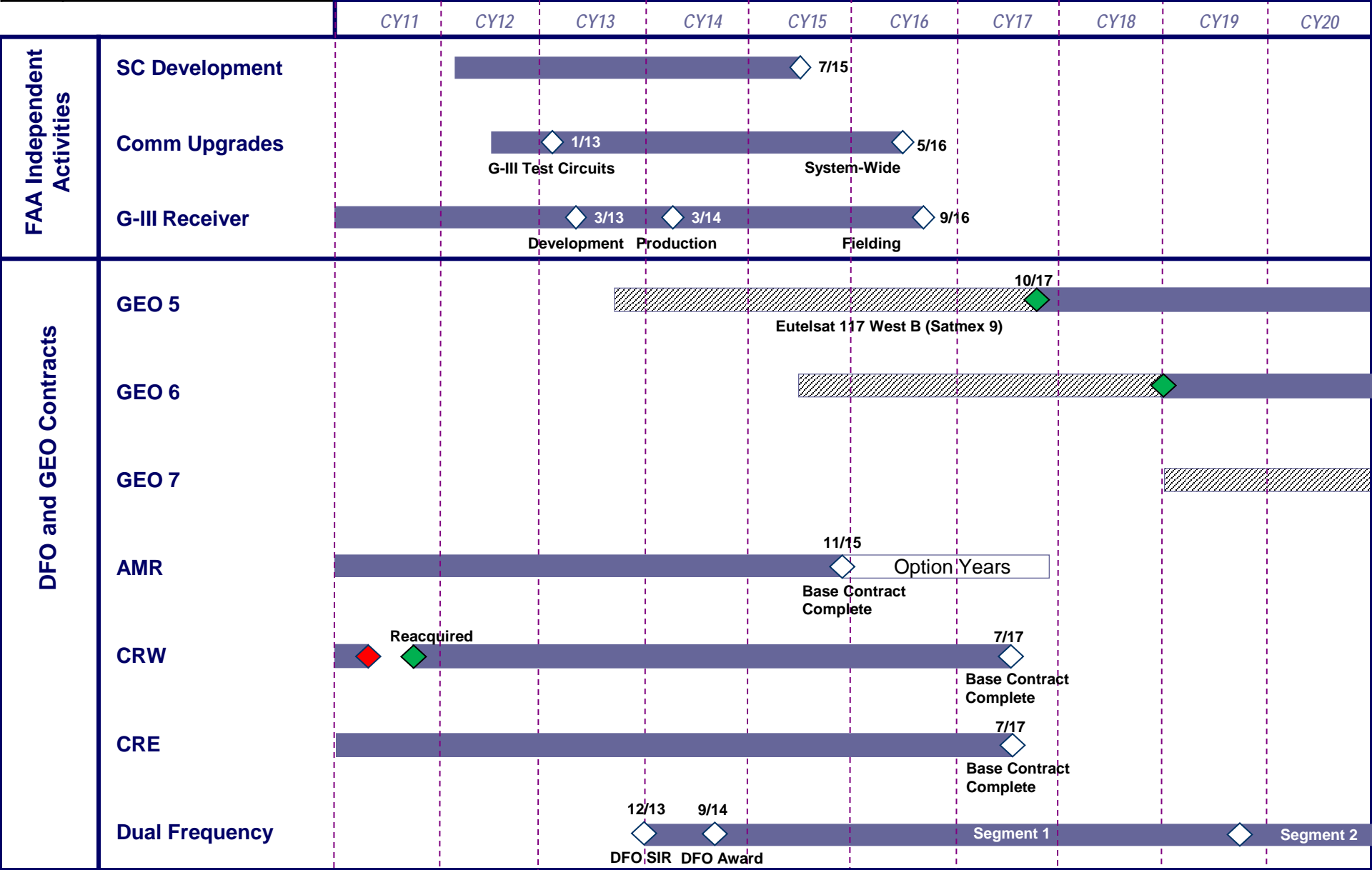
# Federal Register Notice

- **L1/L2 Sunset**

- In 2008 the Office of Space Commercialization produced a Federal Register Notice detailing the U.S. Government's plan to phase out codeless and semi-codeless [L2 P(Y)] access to GPS by 31 December 2020
- FAA concern with the elimination of L2 P(Y) semi-codeless relationship prior to ability to transition to the new L5 signal
- Federal Radionavigation Plan (FRP) is under revision
  - Expect 2014 FRP language to support WAAS transition schedule
- DoD GPS satellite launch plans continue to delay FOC of L2C and L5 service
  - New dates will be included in 2014 FRP

# WAAS Schedule

Legend	
	Milestone
	Service Ended
	Service Started
	Satellite Development



# WAAS Enables Performance Based Navigation

		Performance Based Navigation (≥ 99.0% Availability)		Surveillance <sup>1</sup> (≥ 99.9% Availability)		
		Accuracy (95%)	Containment (10 <sup>-7</sup> /hr)	Separation	NACp (95%)	NIC (10 <sup>-7</sup> )
En Route	RNAV 10	10 nm	20 nm	5 nm	FAA: 8 (92.6m)	FAA: 7 (0.2 nm)
	RNAV 5	5 nm	10 nm			
	RNP 4	4 nm	8 nm			
	RNP 2	2 nm	4 nm			
Terminal (NPA)	RNAV 1 (2)	1 (2) nm	2 (4) nm	3 nm	FAA: 8 (92.6m)	FAA: 7 (0.2 nm)
	RNP APCH / LNAV	0.3 nm	0.6 nm			
	RNP APCH / LP	16 m	40 m			
Approach (APV)	LNAV/VNAV	0.3 nm	0.6 nm	2.5 nm DPA	TBD	FAA: 7 (0.2 nm)
	RNP AR	0.1 nm	0.1 nm <sup>2</sup>			
	LPV	16m/4m	40m/50m <sup>2</sup>			
	LPV-200	16m/4m	40m/35m <sup>2</sup>			
Precision Approach	CAT-I	16m/4m	40m/10-35m <sup>2</sup>	2.0 nm IPA	TBD	FAA: 7 (0.2 nm)
	Autoland <sup>3</sup>	16m/4m	40m/10-12m <sup>2</sup>			

1 – The surveillance requirements reflect the source of the requirements. The current table only includes the FAA requirements.  
 2 – Containment is 1-2x10<sup>-7</sup> per approach  
 3 – The feasibility of autoland with SBAS is under investigation. Requirements and criteria have not been validated. An additional safety assessment will be required to show suitability of VALs above 10.0 m. Weather minima may vary depending on system performance



# Current WAAS GEO Coverage

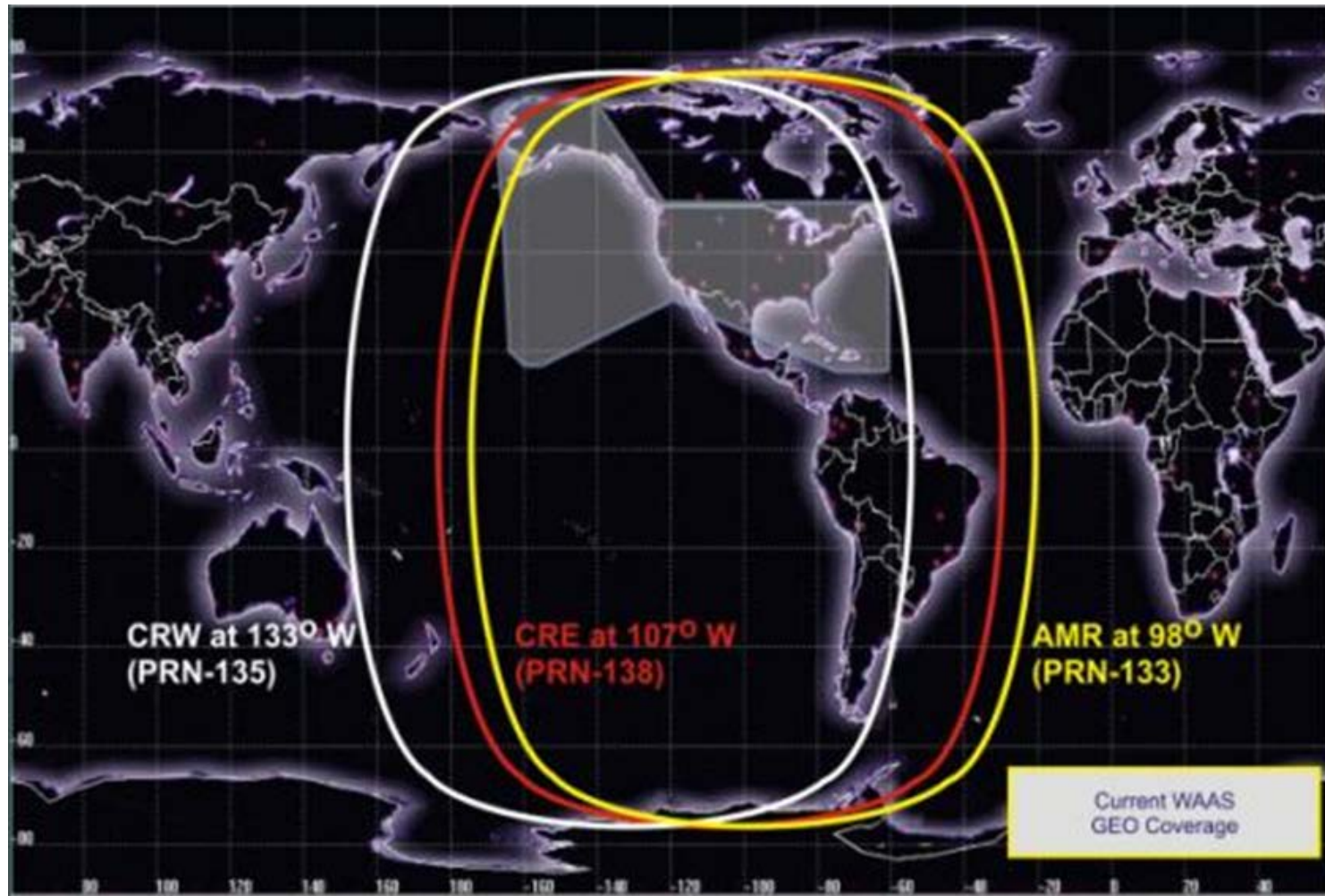


Figure 4-3 LPV 200 North America Coverage for the Quarter

### WAAS LPV200 Coverage Contours January 1 - March 31, 2015

