FAA Global Navigation Satellite System Update

ICG-6

5 September 2011

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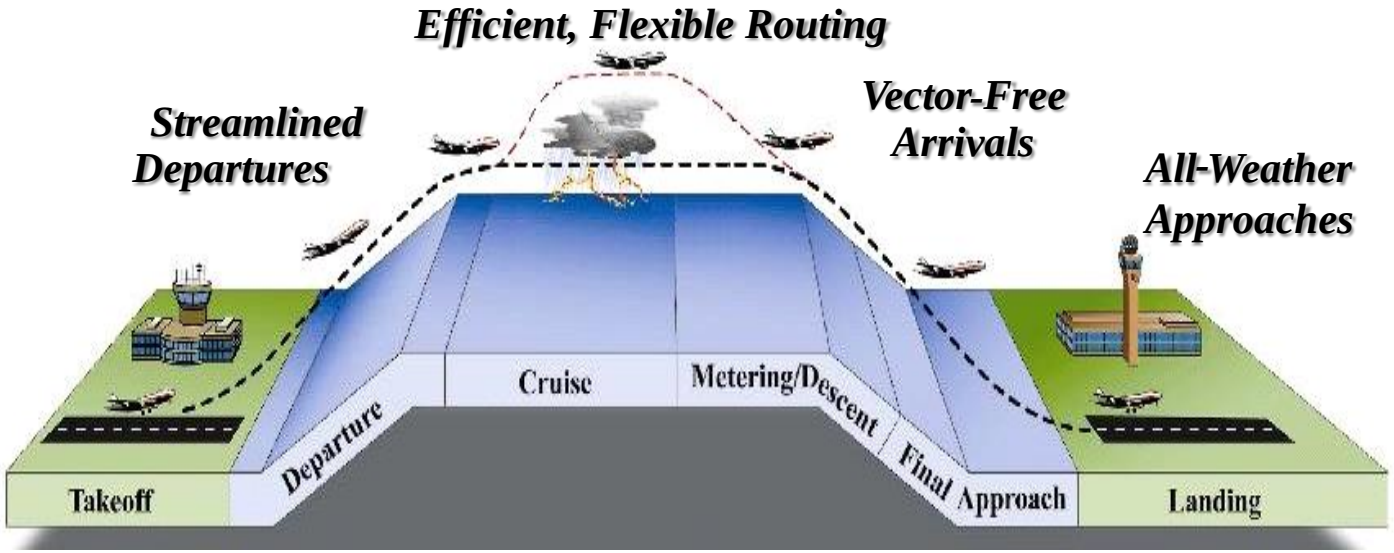
Federal Aviation Administration

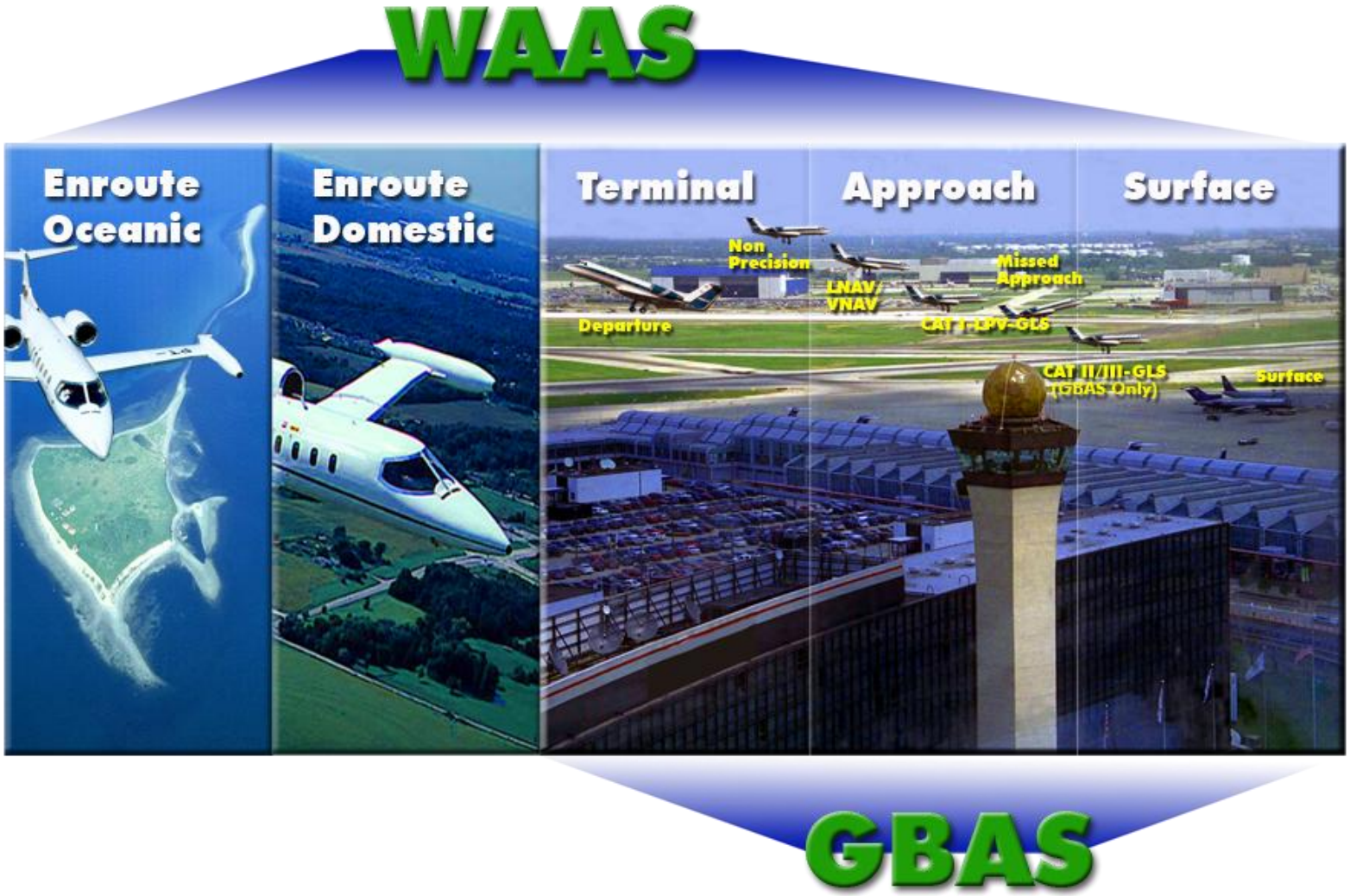
Wide Area Augmentation System (WAAS)
Program Manager

Navigation Services Vision

- *Provide safe and cost effective position, navigation, and timing services (PNT) to meet the operational needs of aviation customers.*

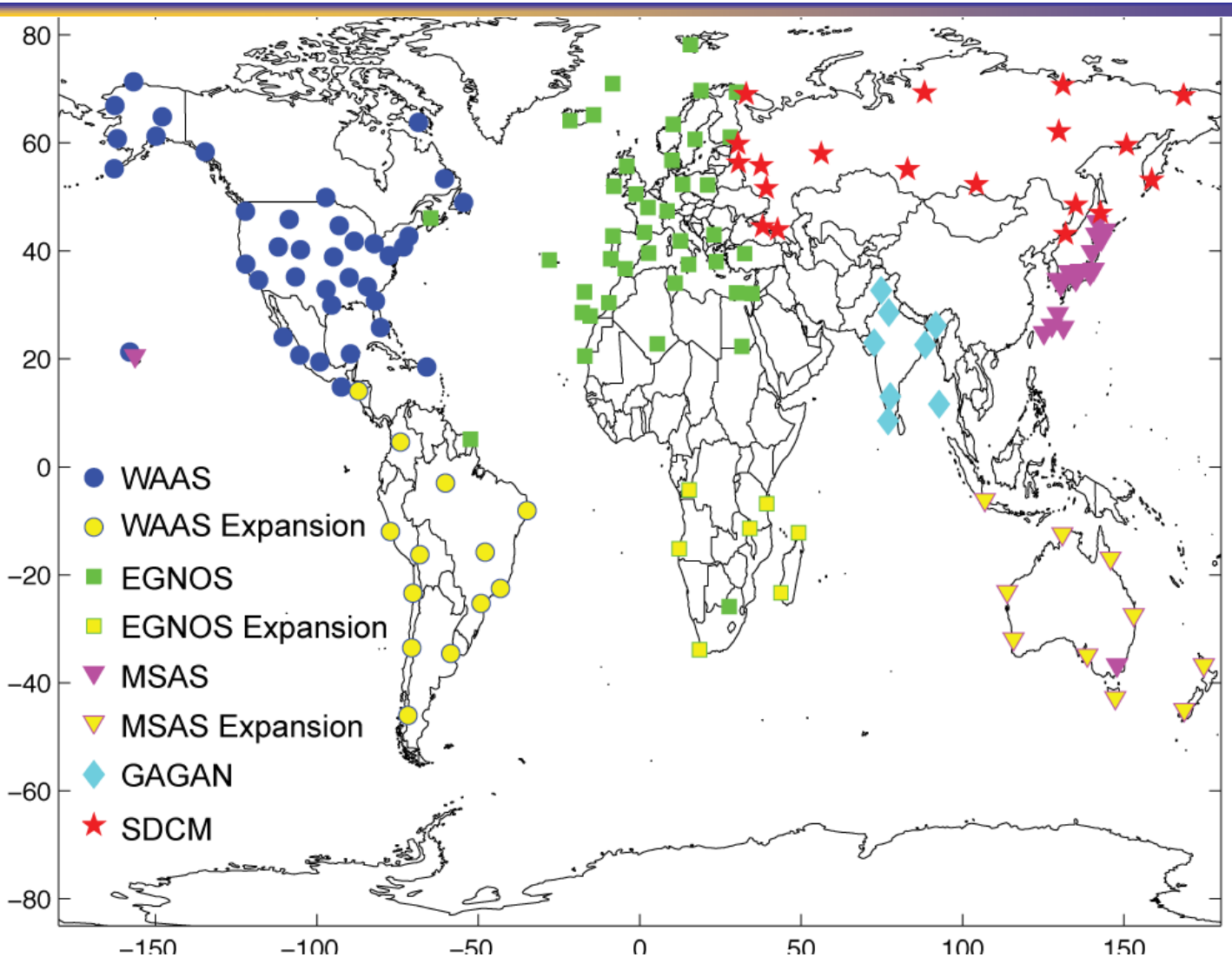


FAA GNSS Service Programs



SBAS Overview

Combined SBAS Snapshot

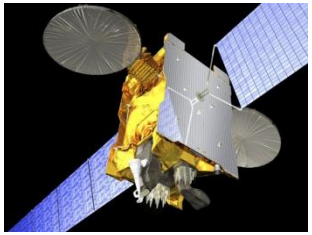


WAAS Architecture

38 Reference Stations

3 Master Stations

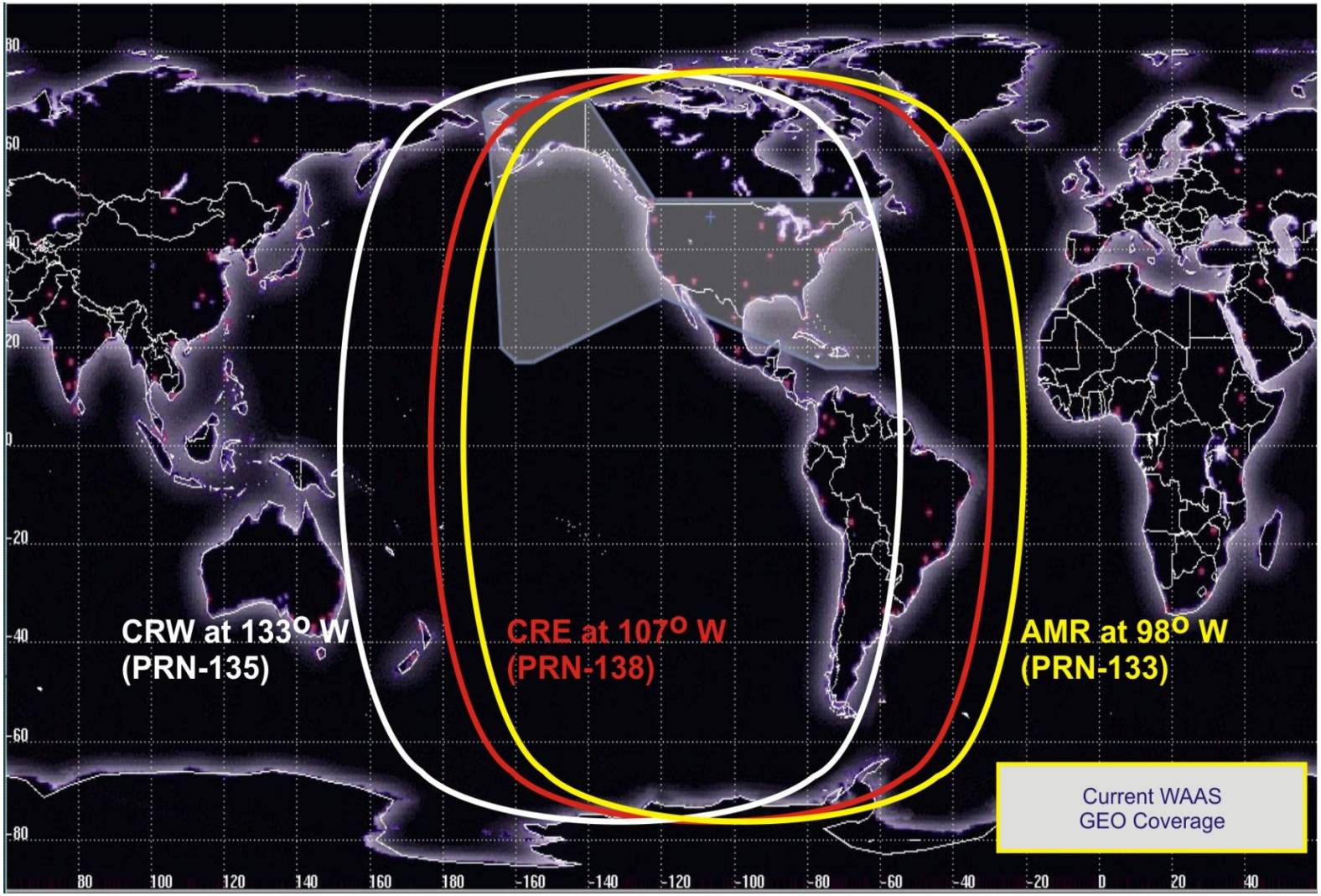
6 Ground Earth Stations



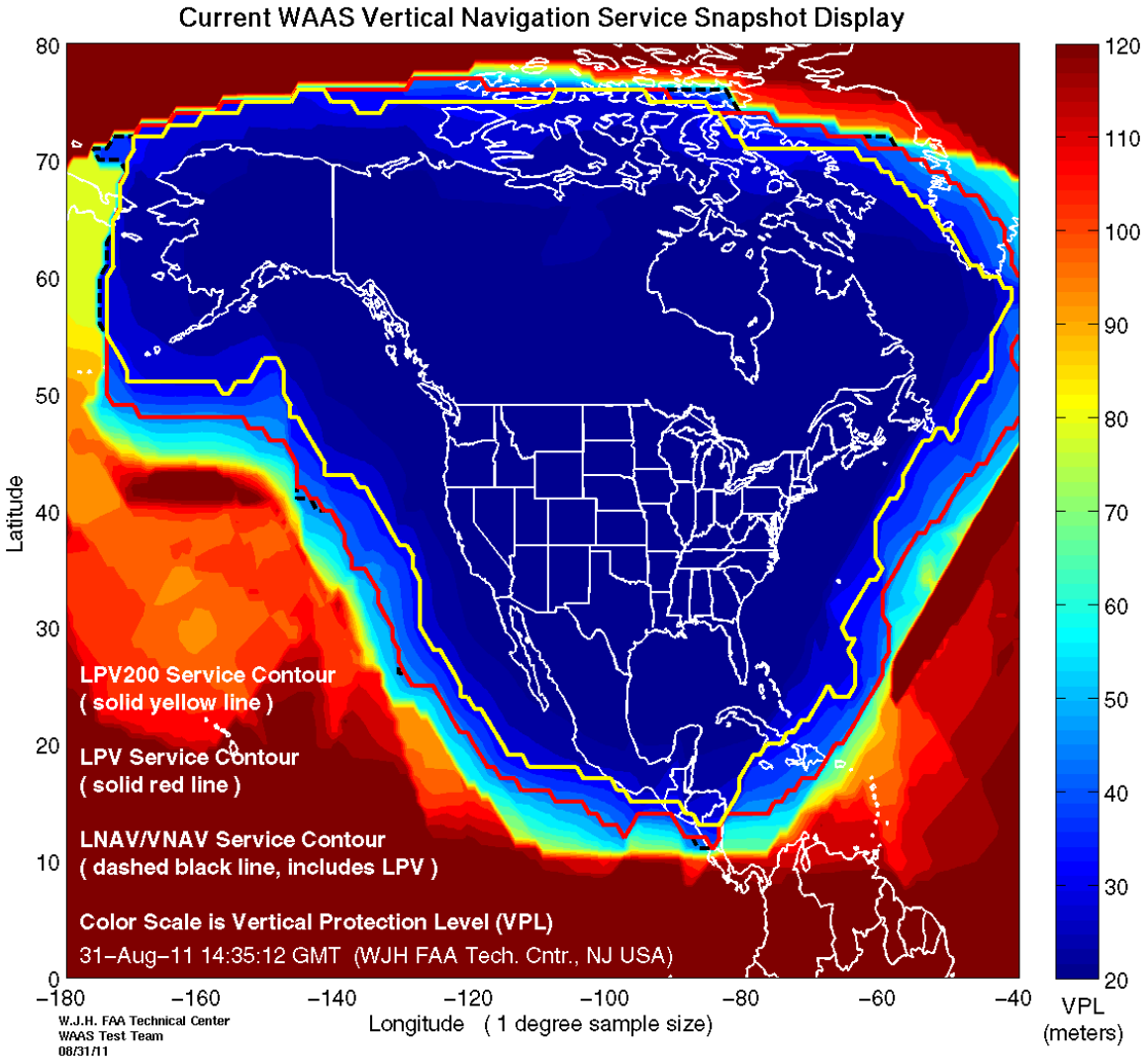
3 Geostationary Satellite Links

2 Operational Control Centers

Current WAAS GEOs



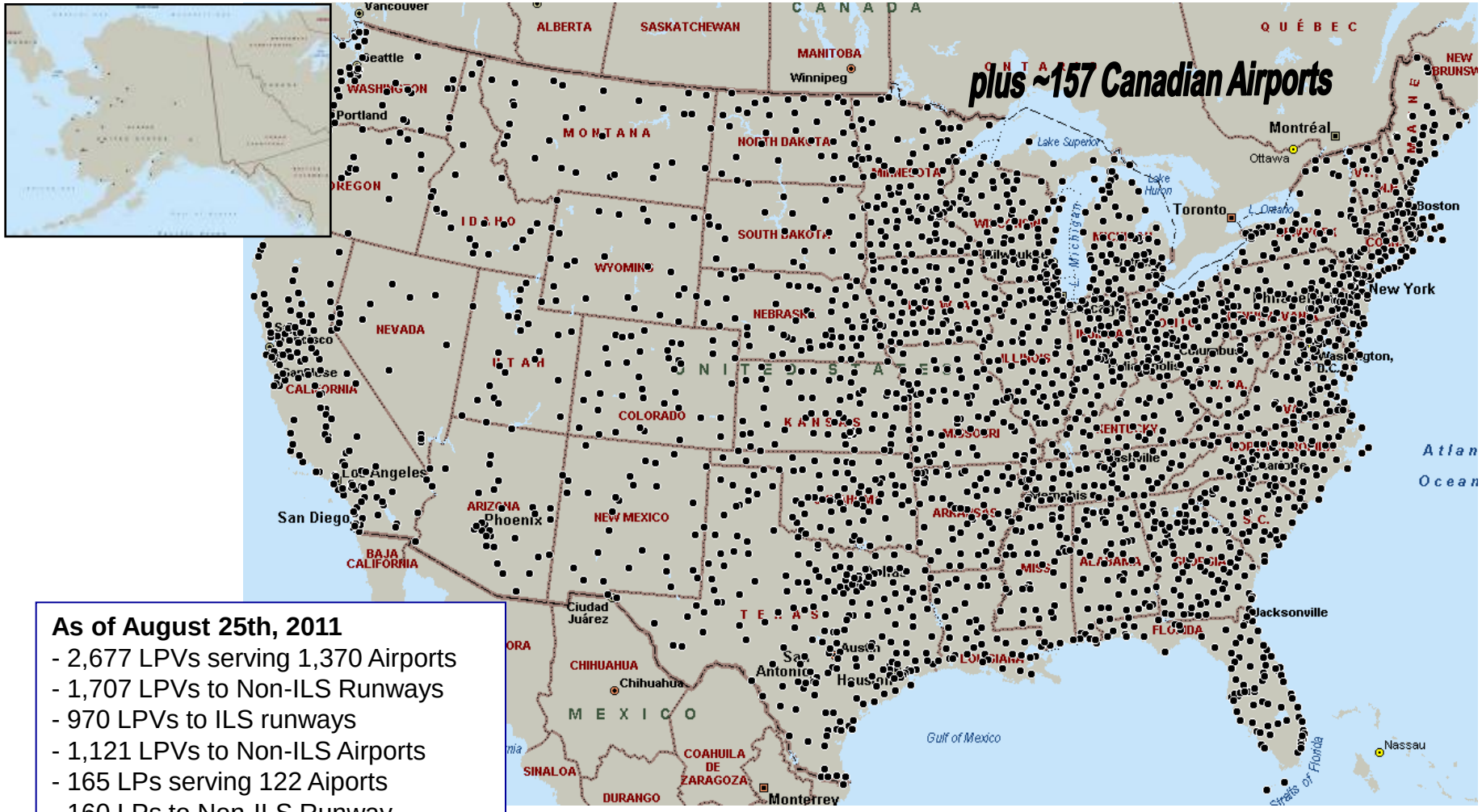
Current WAAS LPV Performance



WAAS 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
- Phase III: Full LPV-200 Performance (2009 – 2013)
  - Development, modifications, and enhancements to include tech refresh
  - Steady state operations and maintenance
  - Transition to FAA performed 2nd level engineering support
  - Begin GPS L5 transition activities
- Phase IV: Dual Frequency (L1,L5) Operations (2014 – 2028)
  - Complete GPS L5 transition
  - Will significantly improve availability and continuity during severe solar activity
  - Will continue to support single frequency users
  - Steady state operations and maintenance

Airports with WAAS LPV/LP Instrument Approaches

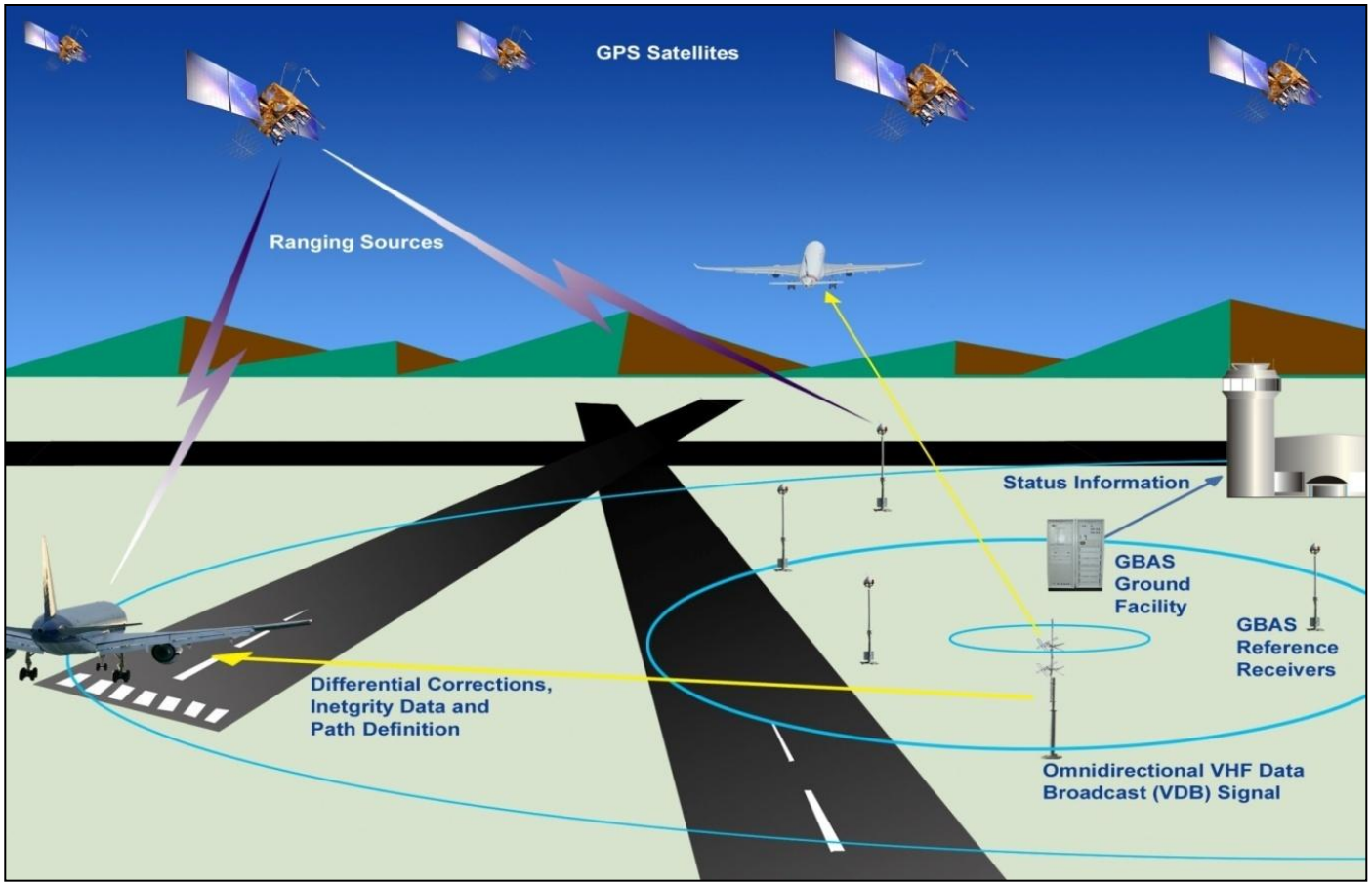


As of August 25th, 2011

- 2,677 LPVs serving 1,370 Airports
- 1,707 LPVs to Non-ILS Runways
- 970 LPVs to ILS runways
- 1,121 LPVs to Non-ILS Airports
- 165 LPs serving 122 Aiports
- 160 LPs to Non-ILS Runway
- 5 LPs to ILS Runways

GBAS Overview

GBAS (Ground Based Augmentation System)



GBAS Activities Highlights

- CAT I Non Fed Implementation
  - Ongoing activities for Newark International Airport and Houston Intercontinental Airport in coordination with Continental Airlines
  - Newark
    - Honeywell SLS-4000 installed, GBAS procedures developed and included in FAATC simulations with ATC participation
    - At Newark RFI detected during installation testing, GPS Privacy Jammers are proliferating, transmitting on GPS L1 frequency
    - The SLS-4000 is required to detect RFI and operates properly.
    - System modifications have been identified and are being implemented to reduce the operational impact of jammers at the ground station.
  - Houston
    - Houston GBAS installation planned for 2011
    - Respective planning documents (site assessment, installation documents) completed
    - New RFI mitigation concepts incorporated

GBAS Activities Highlights

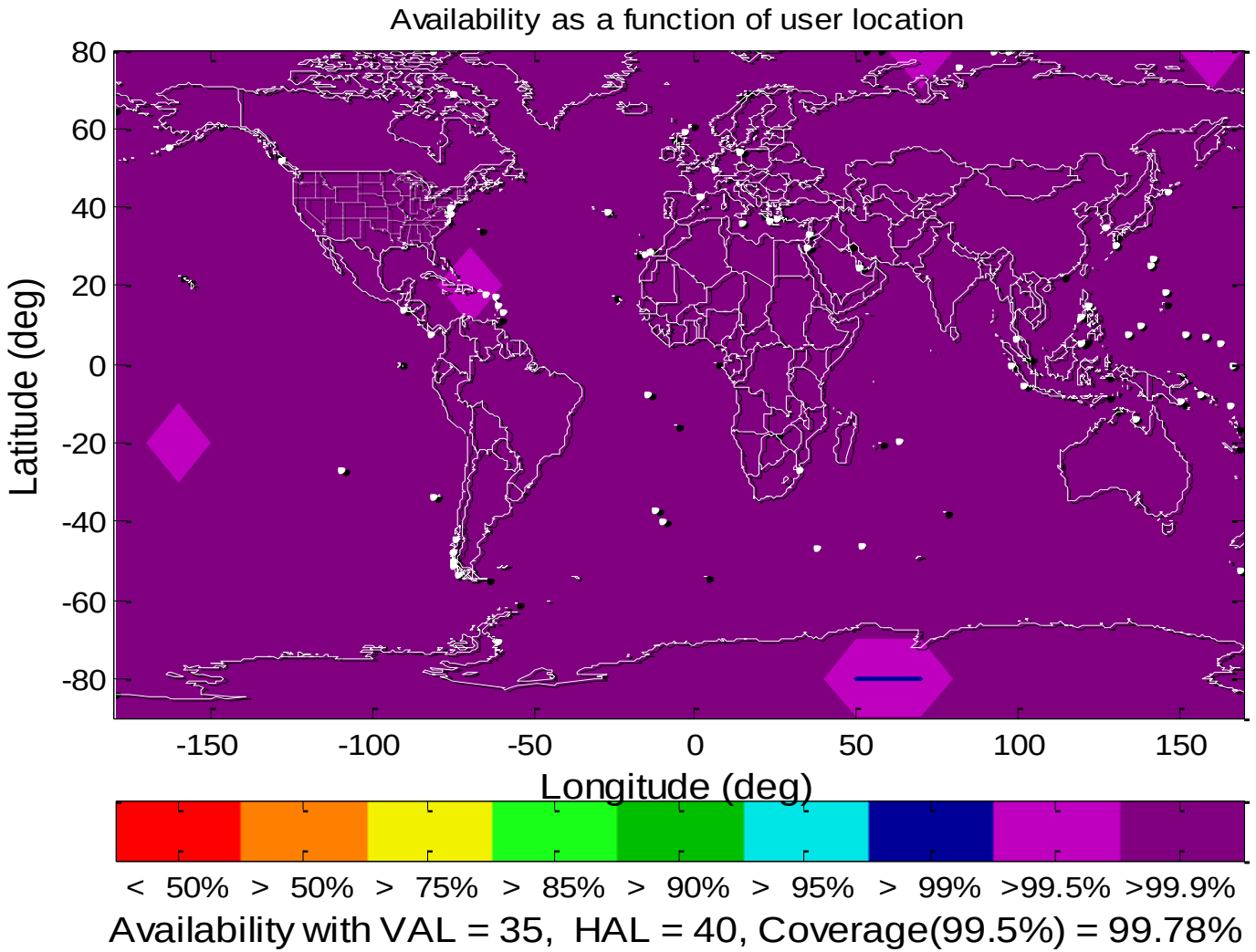
- ICAO CAT II/III validation efforts
  - GBAS validation and prototype development supports ICAO standards validation
    - WJHTC developing CAT III ground facility prototype, CAT III avionics prototype to validate requirements and interoperability
- International cooperation
  - International GBAS Working Group supports international coordination of GBAS implementation and use of common approaches and tools
    - Next IGWG is planned at the FAA Technical Center November 2011
  - EUROCONTROL and SESAR coordination for coordinating GBAS R&D and CONOPS development
  - Multiple FAA MoAs with nations/service providers on development and implementation of GBAS

ARAIM Overview

ARAIM Overview

- GNSS Evolutionary Architecture Study (GEAS) Phase II Report Recommendations
  - Implementation of dual frequency SBAS
  - Development of architectures and algorithms for Advanced Receiver Autonomous Integrity Monitoring (ARAIM), based on
    - Dual frequency ARNS (L1 and L5) signals
    - At least two independent GNSS core constellations for civil aviation
- GEAS determined ARAIM could enable worldwide LPV-200 performance, provided:
  - Measurement redundancy and geometric diversity are assured
  - Performance of specific parameters for the core GNSS constellations are assured

Dual Frequency ARAIM With 27 GPS + 27 Other GNSS



Allow other constellations..

URA = 1m

$P_{sat}=10^{-3}$

$P_{const} = 10^{-6}$

SBAS with ARAIM

- SBAS GEOs can provide corrections and monitoring to keep the URE and fault-free UDRE small
- SBAS can identify and eliminate common mode threats such as EOP
- ARAIM can extend the required TTA and handle some multiple fault cases for SBAS
  - Must meet low probability for TTA used by ARAIM
- SBAS then mainly needs to assure the fault-free performance
  - Easier than 10^{-7} integrity within 6 sec.

Multi-Constellation SBAS w/ARAIM Implementation Considerations

- Dual frequency GNSS minimum user for ARAIM
- Universal SBAS message set is needed with room for growth
  - PRNs for all global and regional GNSS
  - PRNs for all existing and planned SBAS
  - Sufficient margin for growth
  - Ensure *all* PRNs useable to avoid mistakes from L1 experience
  - SBAS providers should have latitude to augment all GNSS if desired
- If Multi-constellation timing offset corrections are needed
  - To what time reference will the offsets be aligned?

ARAIM Summary

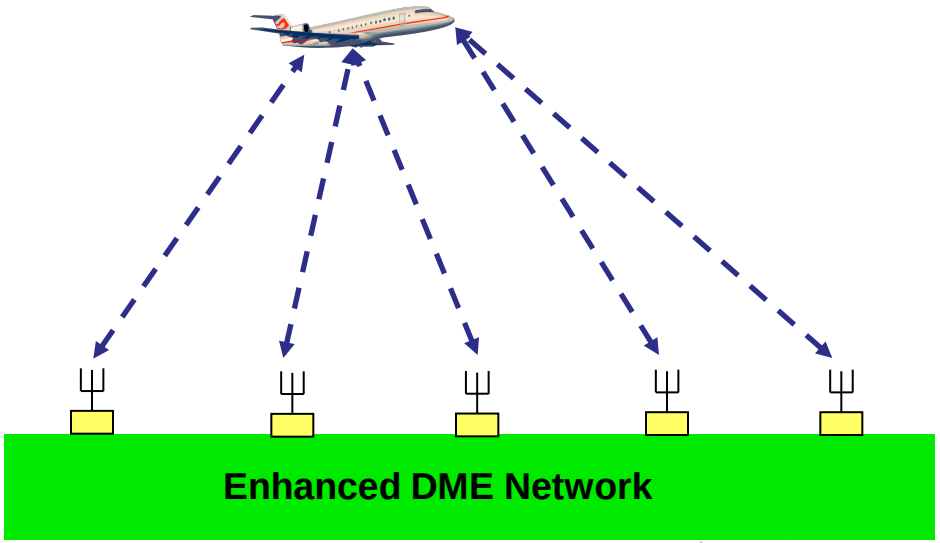
- Four basic parameters are needed to enable ARAIM
- A common understanding of these parameters must be developed and agreed upon by the service providers for interoperability
- GNSS service providers need to include these parameters in Performance Standards
- ISM is a mechanism to deliver these parameters to users
- Delivery of ISM could be from multiple sources
- SBAS needs a strategy to broadcast ISMs for Multi-Constellation

APNT Overview

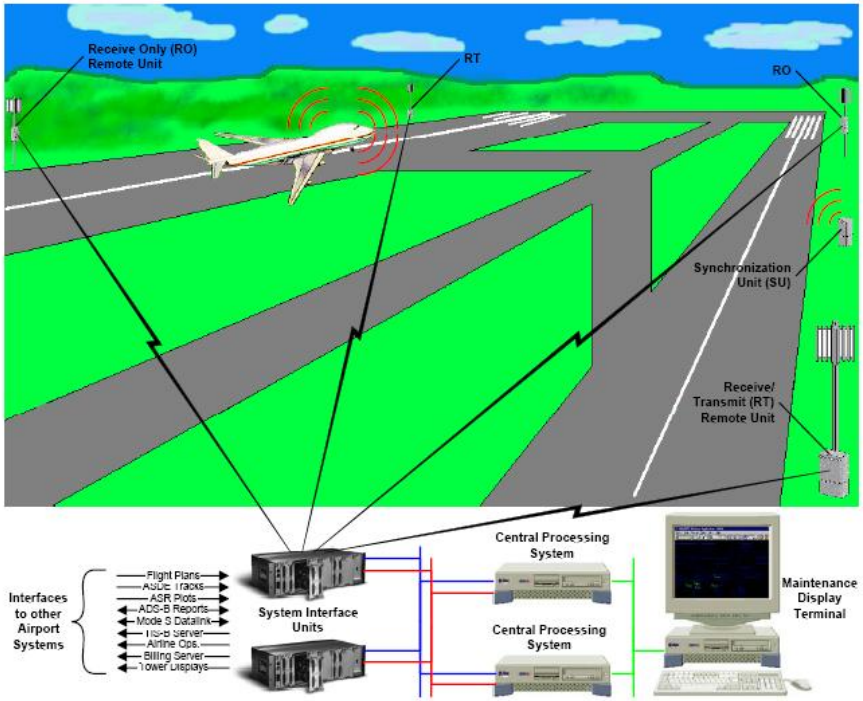
APNT Background

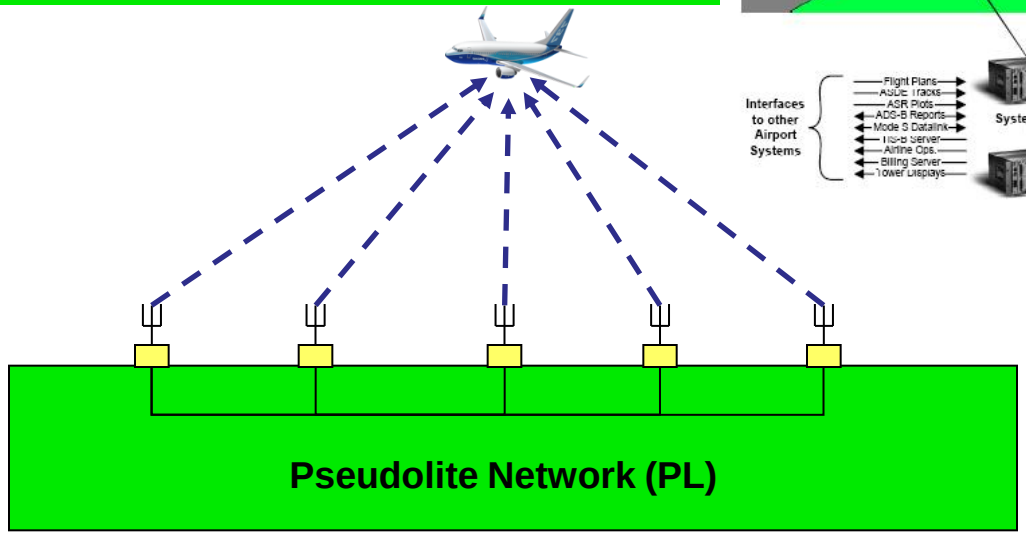
- National Policy requires FAA to provide a backup in the event of a Global Positioning System (GPS) interference event or outage
  - National Policy HSPD-7/NSPD-39
  - Waiting for the interference source to be turned off is unacceptable
  - Continuity of operations must be assured at high density airports
  - Ensure safety and security while minimizing economic impacts
- NextGen APNT provides backup for GPS in Performance-Based Navigation
  - Provides a 92.6 meter NACp at 99.9% availability to guarantee limit of performance requirements
  - Provides 3 nm separation between aircraft
  - Supports Navigation and Surveillance
- Candidate airports
  - 135 airports where significant capacity is required and where loss of capacity would cause significant economic impact

Alternatives Overview



Wide Area Multi-Lateration (WAM)





Recent Accomplishments and Current Activities

- CRD Readiness Decision Approved June 2011
  - Preliminary Shortfall Analysis Report
  - Update Enterprise Architecture Roadmap
  - Preliminary ACAT Level 2 Designation
  - Concept Requirements Definition Plan
- Initiative to Award Industry Study Contract to be completed by January 2012
  - Statement of Work
  - Independent Government Cost Estimate
- Investment Analysis Readiness Decision to be completed by September 2014
  - Concept of Use Document
  - Functional Analysis Document and Diagram
  - Enterprise Architecture Products: OV-1, AV-1, AV-2, OV-5, OV-6c, SV-4
  - Range of Alternatives Documentation

GNSS Summary

- WAAS Phase I and II Completed
- WAAS Dual Frequency Upgrade for GPS Modernization by 2020
- GBAS Cat-I System Design Approved
- RFI Issues Being Investigated
- GBAS Cat-III Prototyping Activities Continue
- Federal Acquisition of GBAS On Hold
- GEAS Assessing Alternatives for Multi-GNSS
- APNT Alternatives being investigated with a target date for final decision, September 2016

Backup

WAAS Avionics Status

- Garmin:
  - 64,000+ WAAS LPV receivers sold
  - Currently sole GA panel mount WAAS Avionics supplier
  - New 650/750 WAAS capable units brought to market at the end of March 2011 to replace 430/530W units
- AVIDYNE & Bendix-King:
  - 140 Avidyne release 9 units sold to date
  - SmartDeck glass panel and KSN-770 certification pending
- Universal Avionics:
  - Full line of UNS-1FW Flight Management Systems (FMS) achieved avionics approval Technical Standards Orders Authorization (TSOA) in 2007/2008
  - 1800+ units sold
- Rockwell Collins:
  - Approximately 1900 WAAS/SBAS units sold to date
- CMC Electronics:
  - Achieved Technical Standards Orders Authorization (TSOA) certification on their 5024 and 3024 WAAS Sensors
  - Convair aircraft will have WAAS LPV capable units installed December 2011
  - Canadian North B-737-300 obtained STC for SBAS(WAAS) LPV using dual GLSSU-5024 receivers
- Honeywell:
  - Primus Epic and Primus 2000 w/NZ 2000 & CMC 3024 TSO Approval
  - Primus 2000 FMS w/CMC 5024 TSO pending

Who Is Using WAAS?

General Aviation

Air Carrier & Cargo Aircraft

Helicopters

Air Taxi

Business & Regional Aircraft

Aircraft Supplemental Type Certificates (STC): Completed & In-Work

Completed:

- **Astra 1125**
- **ATR-42**
- **Beech: Be-400 KingAir- 200, 200GT, 200C, 200CGT, 350, 350C, 300 (special FAA config.), C90A, C90GTi, Premier 1/A**
- **Bell: 412, 429**
- **Boeing-737-200 (Northern Air Cargo & Canadian North),737-300, 727-200**
- **Bombardier: CL-600/601 (Universal Avionics company acft)**
- **Bombardier Challenger 300, 601-3A, 604**
- **Bombardier CRJ-200, 700, 900**
- **Bombardier Q-series, Q300, Q-400**
- **Cessna: Citation 501, 525, 550 Bravo Series, V 560 Series, 650, Excel & Encore +, Citation Jet CJ-1+, 2+, 3, Caravan**
- **DeHaviland: DHC-6,7-102,8 series**
- **Eclipse VLJ 500**
- **Embraer Phenom: 100, 300**
- **Falcon: 10, 20, 50, 50EX, 900B, 900EASy 11, 2000, 2000EX**
- **Gulfstream: G-II, G-III, G-100, G-150, G-450, G-550**
- **Hawker: 400, 700, 750, 800, 800A, 800XP, 900, 4000**
- **LEAR: 31A, 35, 35A, 40, 40XR, 45, 45XR, 55, 60**
- **MD-87**
- **PC-12**
- **S-76, S-76B, S-76C++**
- **SAAB: 340A/B**
- **Sabre 65**
- **Westwind 1124**

In-Work:

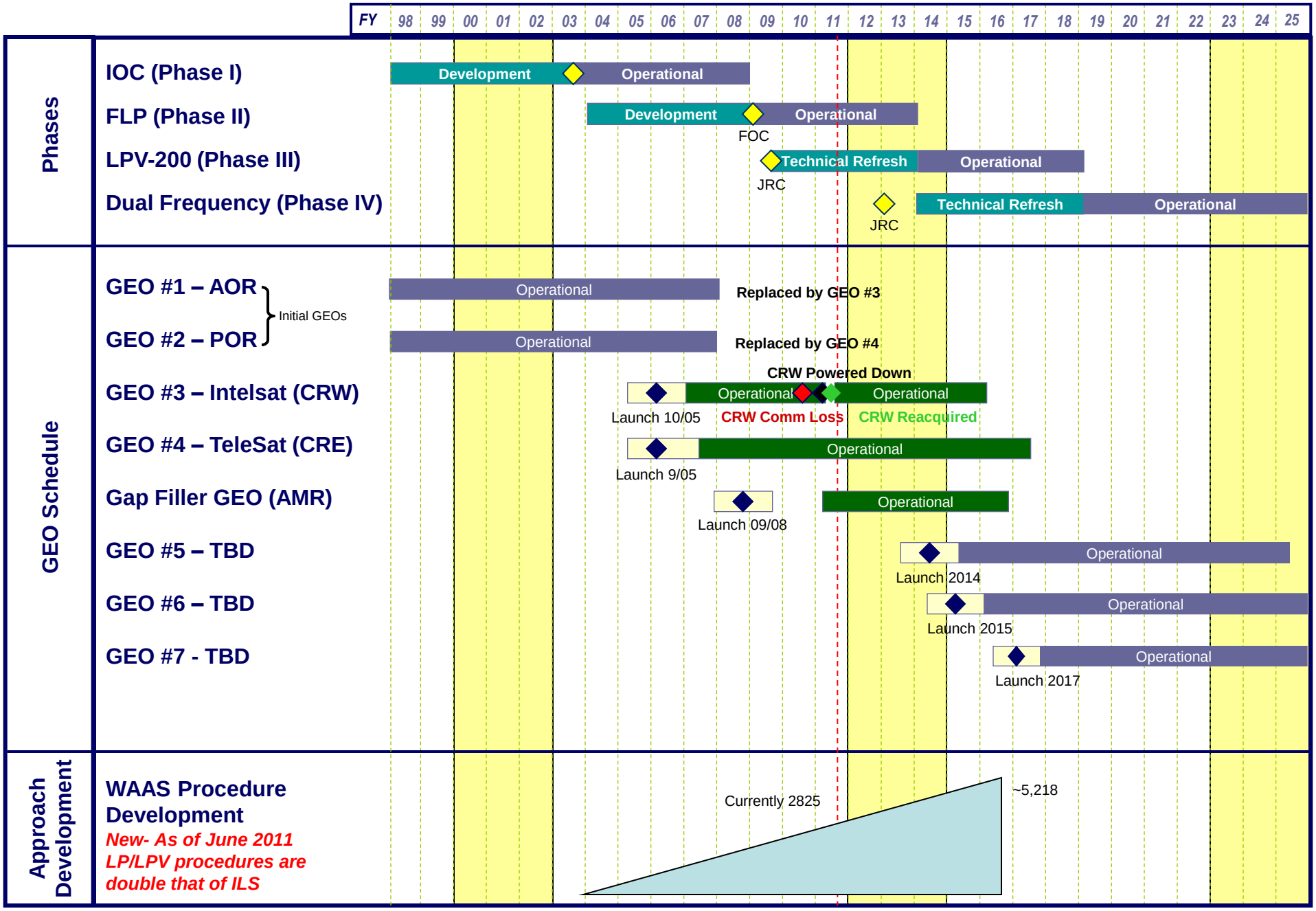
- **Aerospatiale: SN 601 Corvette**
- **Agusta: A-109**
- **Airbus: A350, A400**
- **Astra SPX**
- **Beech: Be-200, Be-300, BeechJet 400A,**
- **Bombardier: Global 5000/Express,CL-300, CL-605, CRJ-700/900**
- **Cessna: Sovereign**
- **Cessna Citation: I/SP501, II, 560 XL/XLS, 650, VII, X**
- **C-9**
- **Dassault: EASy**
- **Embraer NB-145, 600/650**
- **Gulfstream: G-IV, G-200**
- **Hawker: 125-700B, 400XP**
- **King Air: RC-12**
- **LEAR: C-21A**
- **Lockheed Martin: C130J**
- **Piaggio: P-180**

Historical WAAS Performance

	GPS Standard	GPS Actual	WAAS LPV-200 Standard	WAAS LPV-200 Actual
Horizontal 95%	**36 m**	**2.74 m**	**16 m**	**1.08 m**
Vertical 95%	**77 m**	***3.89 m**	**4 m**	**1.26 m**

** Use of GPS vertical not authorized for aviation without augmentation (SBAS or GBAS)*

WAAS Enterprise Schedule



Global GBAS Implementation Status

- ANSPs with implementation / certification plans (2010-11)
  - USA, Australia, Germany, Spain, Brazil, Chile, India, Russia
- ANSPs with R&D activities
  - Japan/ENRI, Korea/Kari, Italy, Spain, France, Portugal
- Ground System Manufacturers
  - Established: Honeywell, Thales, NPPF Spectr,
  - New/prototypes: NEC, Indra, Selex,

GBAS Project Description

- **Ground-Based Augmentation System (GBAS) is the only GNSS solution/alternative for CAT III precision approach and supports the transition goal to GNSS CAT II/III approach and landing**
- **The FAA plans to replace legacy navigation systems with satellite based technology,**
- **GBAS provides an internationally harmonized satellite based alternative to the Instrument Landing System (ILS) for precision approach and landing**
  - GBAS improves all-weather approach and landing as well as surface navigation capabilities with significant improvements in service flexibility, safety, and user operating costs
  - GBAS eliminates the capacity constraint due to the ILS critical areas
- **FAA GBAS R&D activities are led by William J Hughes Technical Center in Atlantic City, NJ**
- **The current FAA project includes**
  - Support implementation and upgrade of non-federal GBAS CAT I systems
  - Validation of ICAO GBAS SARPS and produce a robust GBAS prototype
  - International coordination of standards (SESAR/EUROCONTROL)
  - Support for DoD JPALS (Joint Precision and Landing System) acquisition decision

Parameters for ARAIM

- Previous parameters were defined to be the object of ground monitoring
- These Parameters are:
  - Overbound of the satellite error variance
  - Overbound of the satellite error bias
  - Nominal Satellite error variance
  - Nominal satellite error bias
  - Probability of fault for the satellite
  - Flag indicating whether the satellite conforms to the above five parameters