Wide Area Augmentation System (WAAS) Overview

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To: UN/ICTP Workshop on the Use of Global Navigation Satellite Systems for Scientific Applications

Date: December 2014

Agenda

- WAAS Status and History
- Current Projects
- User Adoption
- Future Efforts

Wide Area Augmentation System

- WAAS is a combination of ground based and space based systems that augments the GPS Standard Positioning Service (SPS)
- WAAS provides the capability for increased availability and accuracy in position reporting, allowing more time for uniform and high quality worldwide air traffic management
- WAAS provides coverage over the entire National Airspace, with a precision approach capability at over 3,000 runway ends

3 Geostationary Satellite Links

2 Operational Control Centers

38 Reference Stations

3 Master Stations

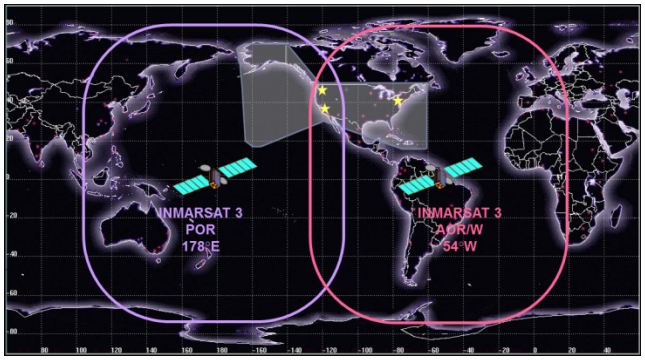
6 Ground Earth Stations

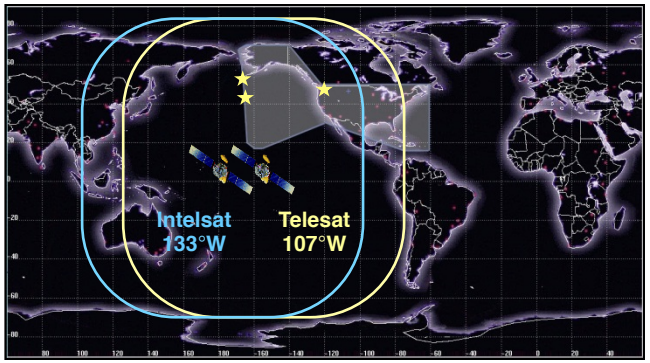
WAAS Development Phases

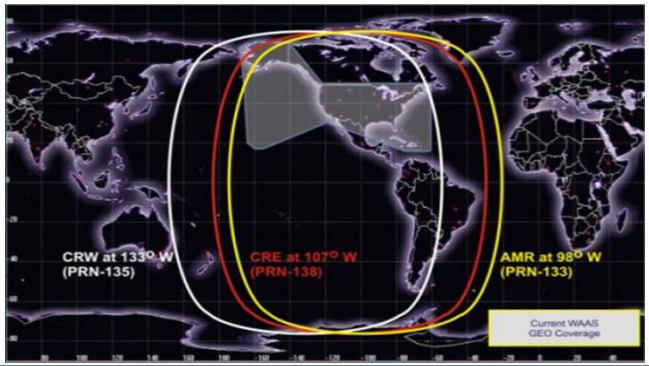
- **Phase I: IOC (July 2003) Completed**
  - Included Development of a robust safety architecture
  - Included establishment of WAAS expert panel to evaluate potential integrity threats
- **Phase II: Full LPV (FLP) (2003 – 2008) Completed**
  - Completed a Safety Risk Management Decision (SRMD) to support LPV-200 (VAL of 35m)
  - Expanded WAAS coverage to Mexico and Canada while modifying the System to address observed Ionospheric threats
- **Phase III: Full LPV-200 Performance (2009 – 2013)**
  - Completed System updates to improve performance during moderate ionospheric activity
  - Supported continuous monitoring of system data that contributes to continued integrity assurance
  - Began transition of Second Level Engineering from contractor based to organic FAA capability
- **Phase IV: Dual Frequency (L1,L5) Operations (2014 – 2044)**
  - Includes the transition from use of L2 to L5 in WAAS reference stations
  - Infrastructure modifications to support future L1/L5 user capability
  - Support sustainment of WAAS GEOs

GEO Satellite Availability Improvements

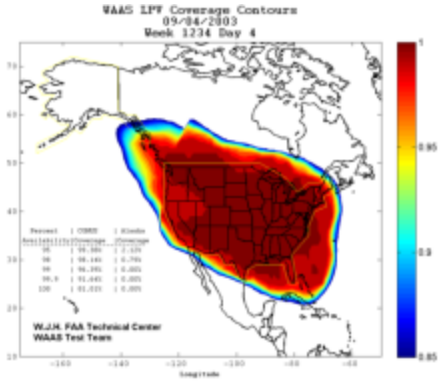
- **IOC WAAS (Commissioned system) utilized two Inmarsat satellites**
  - Provided single satellite coverage over the majority of the U.S.
  - Removed from WAAS July 2007
- **Replacement satellites launched in 2005**
  - Intelsat (Galaxy XV) - Operational November 2006
  - Telesat Canada (Anik F1R) - Operational July 2007
- **Implemented Gap-filler GEO**
  - Inmarsat I4F3 (AMR) - Operational December 2010



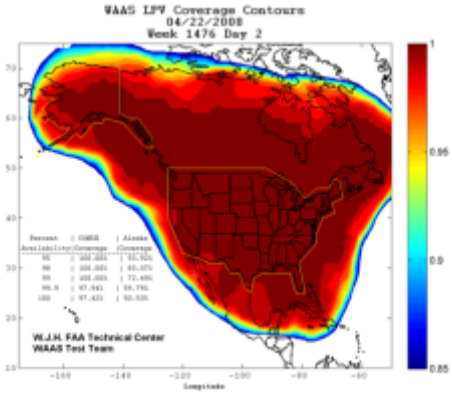




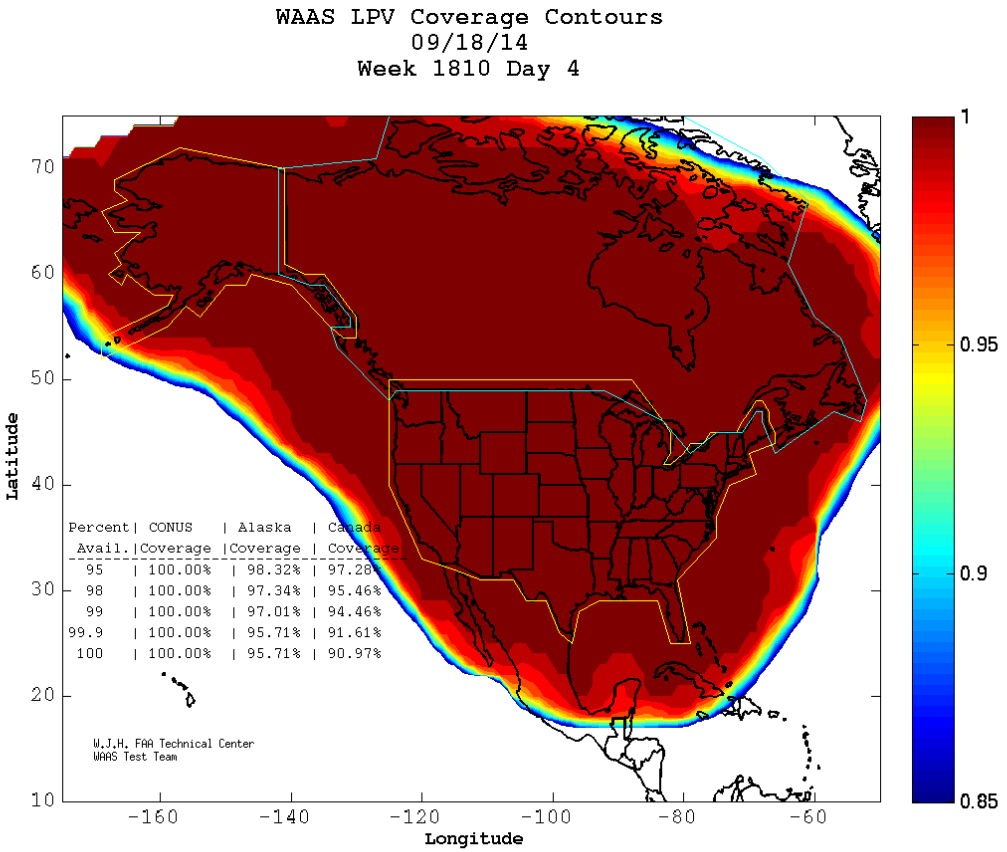
WAAS Coverage Improvements



2003 IOC – LPV Coverage in lower 48 states only



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



2014 Coverage - Full LPV 200 Coverage in CONUS (3 Satellites)

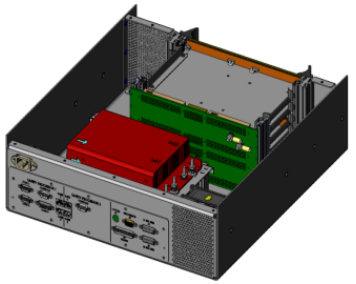
GEO Sustainment

- **GEO 5/6 Satellite Acquisition**
  - Awarded GEO 5/6 Satellite Service Lease contract to Raytheon September 2012
  - SatMex 9 satellite will host the WAAS GEO Satellite Payload
    - Orbital slot (117°W) will provide full coverage over CONUS and Alaska
    - Critical Design Review (CDR) completed July 2014
    - Scheduled for operations in the 2017 timeframe
  - GEO 6 Satellite opportunities currently under investigation

Ground Based Updates

- **WAAS Reference Receiver (G-III)**
  - Next Generation (G-III) receiver adds significant new capability and will support WAAS Dual Frequency upgrades in 2014 – 2019 timeframe
    - Tracks up to 18 GPS satellites and 8 SBAS satellites
    - Capable of tracking GPS L1C/A, L1C, L2C, L2 P(Y), and L5 signal types
    - Expandable to support additional GNSS signals in the future
  - Current Status
    - Six G-III test racks installed into the field to support integration activities
    - 100 production receivers delivered to support fielding in FY2015 – 2016
      - Balance of receivers will be ordered in 1stQ FY15

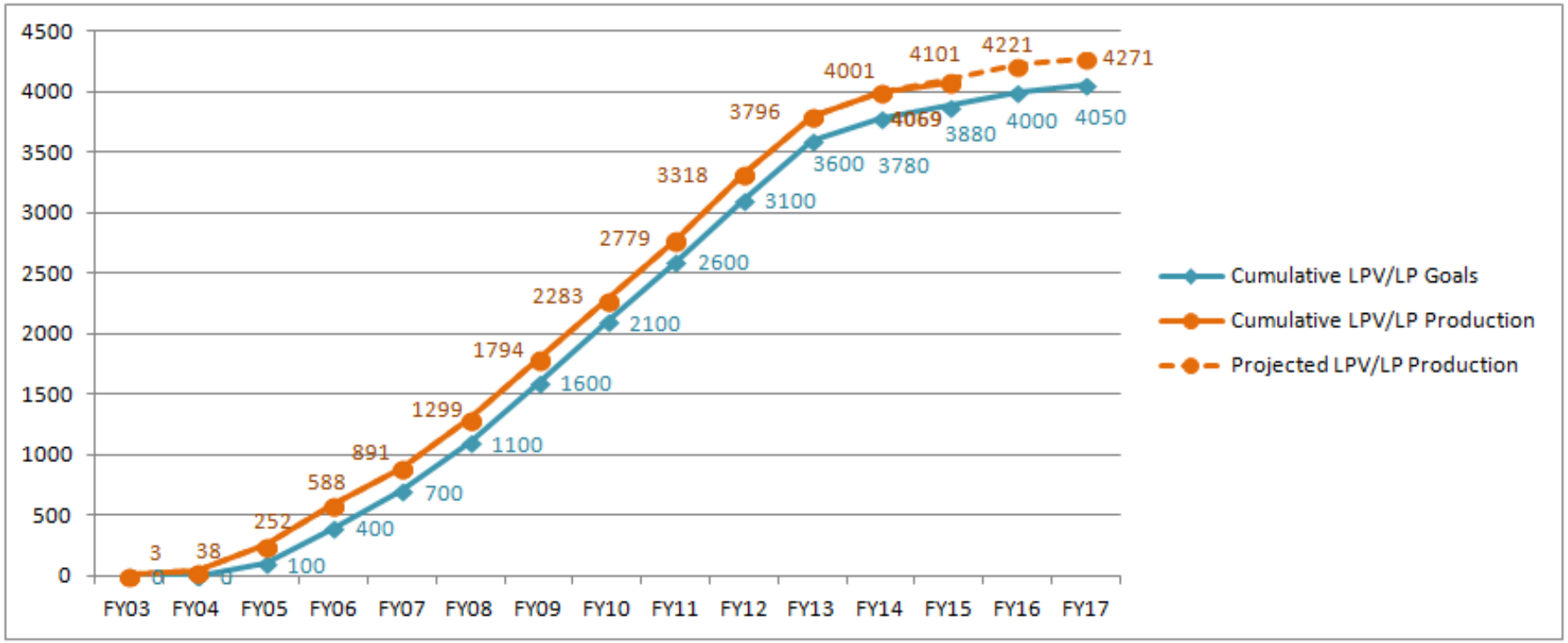
- **WAAS Safety Computer**
  - The SC adds significant new capability and support to WAAS Dual Frequency upgrades
    - The SC will be capable of hosting either WAAS Master Station (WMS) application or the GEO Uplink Station (GUS) without changing the WAAS SC hardware or Infrastructure of software
  - WMS type SCs
    - Preclude broadcast of Hazardously Misleading Information (HMI) to WAAS users
  - Current Status
    - Verification Phase completed
    - Initial Pre-Production units delivered
    - Vendor contract extended to May 2015
    - Testing software and hardware to ensure error free operation



SC Conceptual Design: Rearview

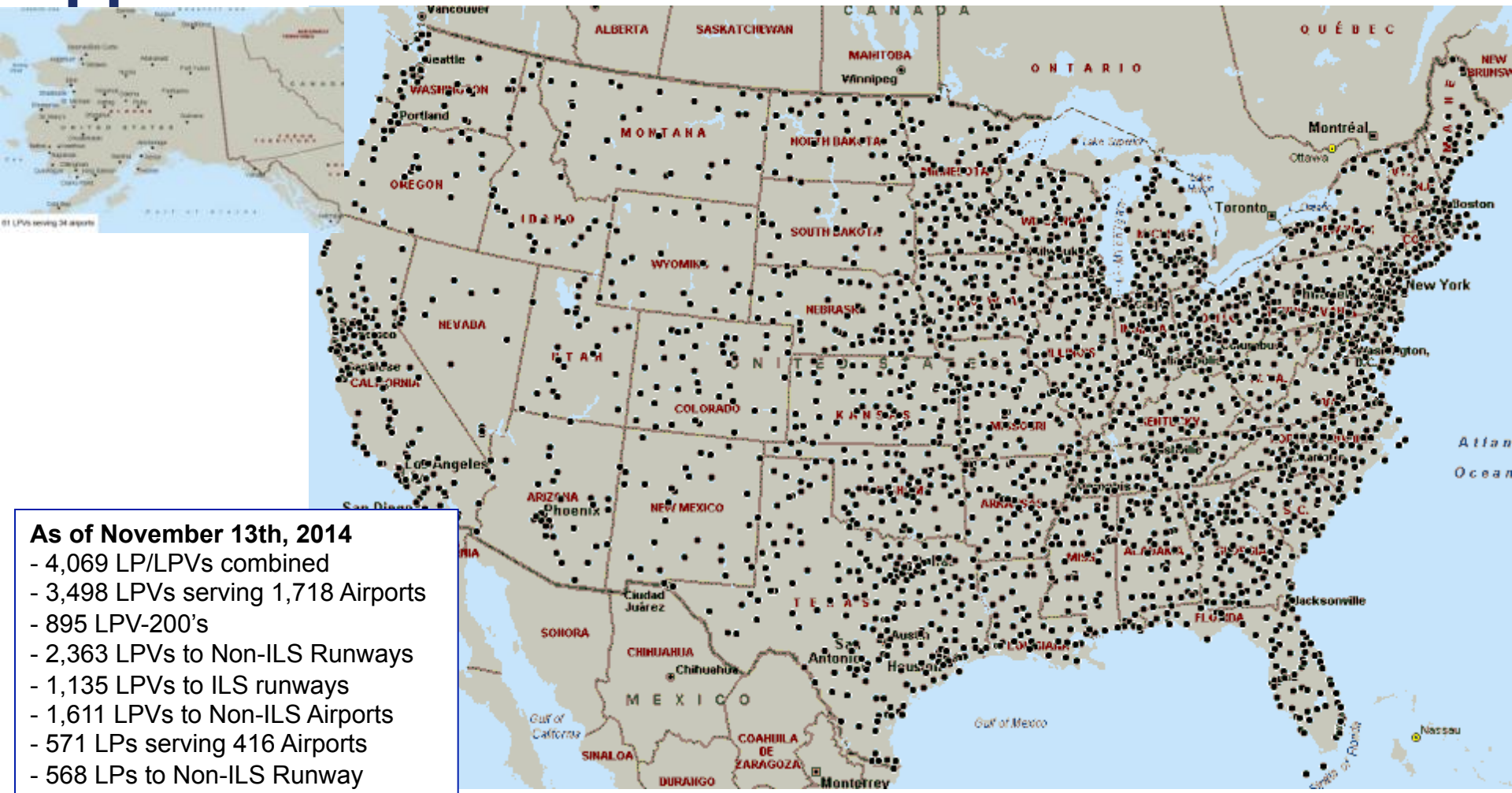
- **WAAS Communication Upgrade**
  - Hardware procurement to address obsolescence at selected WAAS sites
  - Upgraded circuit procurements for Operations Control Center's (OCC's) (National Operations Control Center [NOCC] &Pacific Operations Control Center [POCC]) and Core Node
  - Successful Completion of Provisioning Conference (PCA)

Annual LPV and LP Production



	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17
Non-ILS Runway Ends	0	7	80	188	195	263	259	375	412	463	443	182	64	0	0
ILS Runway Ends	3	28	134	148	108	145	236	114	84	76	35	23	4	0	0
LPVs/LPs	3	35	214	336	303	408	495	489	496	539	478	205	68	0	0
Annual LPV/LP Goals	0	0	100	300	300	400	500	500	500	500	500	180	100	120	50
Cumulative LPV/LP Goals	0	0	100	400	700	1100	1600	2100	2600	3100	3600	3780	3880	4000	4050
Cumulative LPV/LP Production	3	38	252	588	891	1299	1794	2283	2779	3318	3796	4001	4101	4221	4271

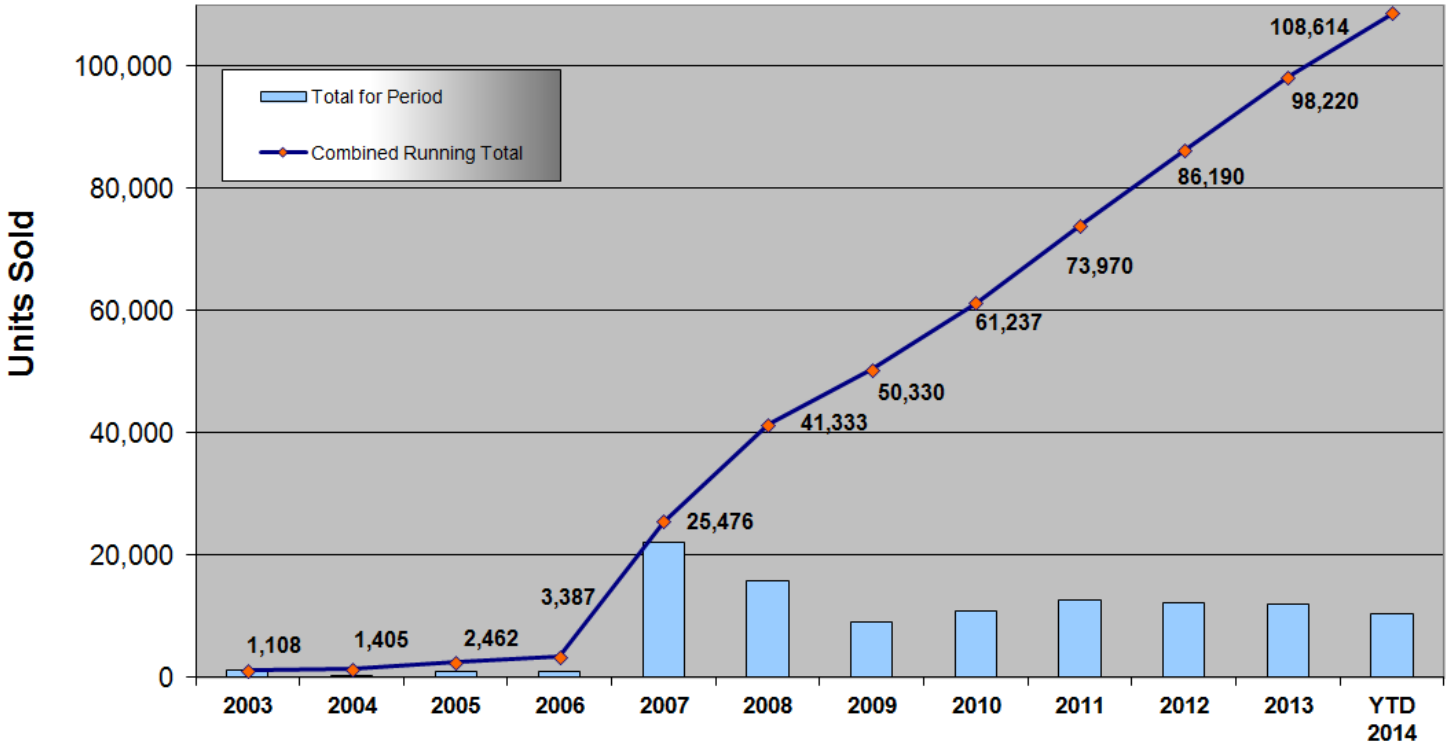
Airports with WAAS LPV/LP Instrument Approaches



As of November 13th, 2014
- 4,069 LP/LPVs combined
- 3,498 LPVs serving 1,718 Airports
- 895 LPV-200's
- 2,363 LPVs to Non-ILS Runways
- 1,135 LPVs to ILS runways
- 1,611 LPVs to Non-ILS Airports
- 571 LPs serving 416 Airports
- 568 LPs to Non-ILS Runway
- 3 LPs to ILS Runways

WAAS LPV Annual Avionics Sales

Garmin, Universal, Rockwell Collins, Avidyne, Cobham, Honeywell/CMC, IS&S and Thales WAAS Avionics Sales by Year



Data current as of October 31, 2014

Total combined avionics sales (all vendors): 108,614 units

Program office estimate for total WAAS-LPV equipped aircraft: 78,045 (all vendors)

WAAS LPV Equipped Aircraft October 2014

Garmin
- GA Aircraft (See FAA Garmin Approved Model List (AML)). Most GA Part 23 aircraft.
- GTN series – Lear 35/35A, 36/36A,24 – Phenom 300 with G-3000

Universal Avionics
- 122 fixed wing and 12 helicopter types and models

RockwellCollins
- 39 Types and models

Honeywell /CMC Electronics)
- 22 types and models

Avidyne
- 6 types and models (Cirrus SR 20 & 22, Piper Matrix & Mirage, Piper Saratoga NX, and EA-500)
- IFD 540 WAAS LPV - (STC complete July 2014 – AML STC approved for over 1,000 aircraft makes and models)

Genesys Aerosystems (Chelton)
- Bell-407 & 412, Cessna 501, 550, Piper PA-42, Beechcraft C-90&A, EurocopterAS-350, AgustaAW109SP, Beechcraft T-34B, Kawsaka

Innovative Solutions & Support (IS&S)
- Eclipse 550/500
- Boeing 737-400 (pending)
- MD-88/90 (pending)

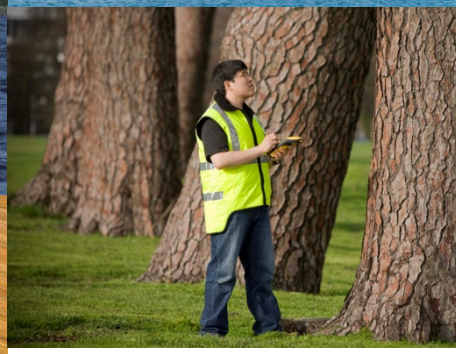
Thales
- Airbus A300-600ST (Beluga)
- Airbus A400M (Military)
- Airbus A350XWB - pending

Transition to Performance Based Navigation

- In September 2008 the number of published LPVs surpassed the number of published ILSs
- As of August 2014 the number of published LPVs are more than twice the number of published ILSs
- In 2013 the FAA policy was to no longer publish any new CAT I ILSs
- In 2016 the FAA has committed to make a decision about the draw down of ILS based on WAAS implementation

WAAS – A Multi User System

- **WAAS has become a relied upon utility for a number of non-aviation uses:**
  - Shipping
    - Navigation of Harbors
  - Recreational Boating
    - Navigation of Channels
    - Location of Crab pots
  - Mapping & Survey
    - Precise location identification
  - Farming
    - Sub-meter accuracy for spreading, seeding and harvesting



Next Steps

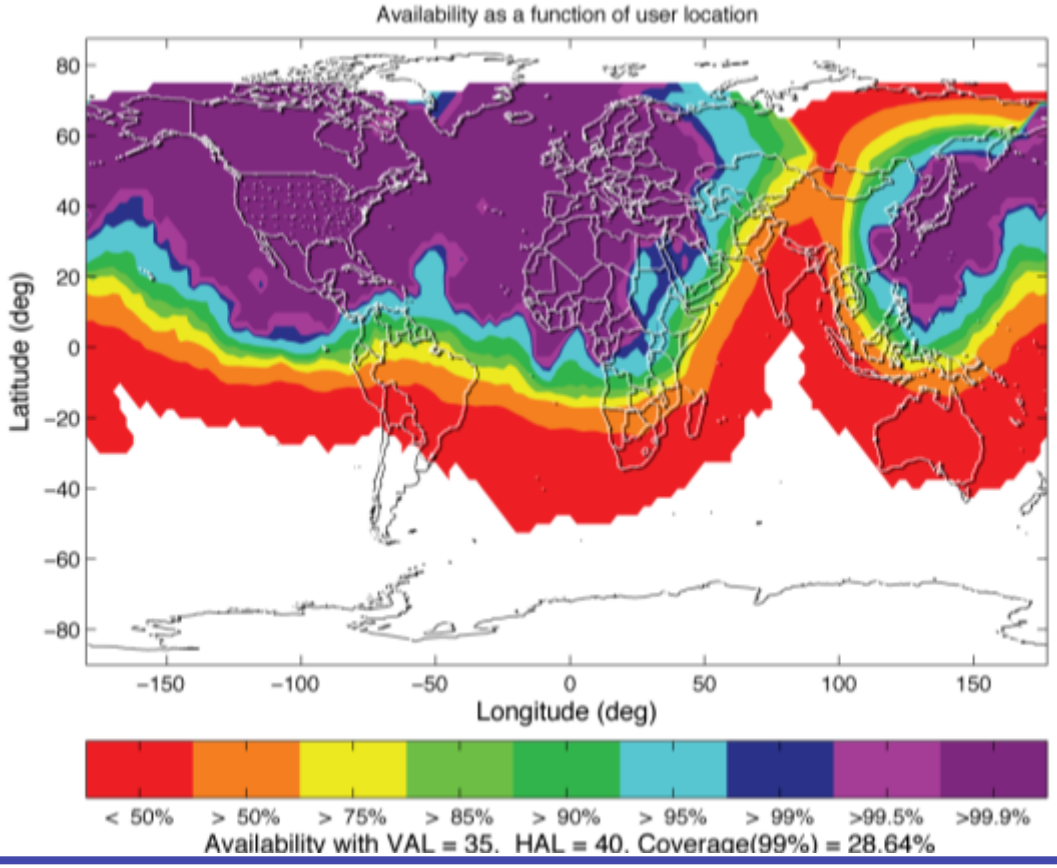
- **Dual Frequency (DF)**
  - Award a Dual Frequency Contract
  - Development of DF WAAS MOPS capability
  - Maintain legacy Single Frequency availability
- **Ground based infrastructure upgrade**
  - Safety Computer
  - G-III Receivers
  - Terrestrial Comm upgrade
- **Develop Dual Frequency User concepts**
  - ARAIM
    - Offline vs Online
  - Dual Frequency Multi-Constellation (DFMC) SBAS
    - Beginning initial research and development
  - Validate concepts and propose standards

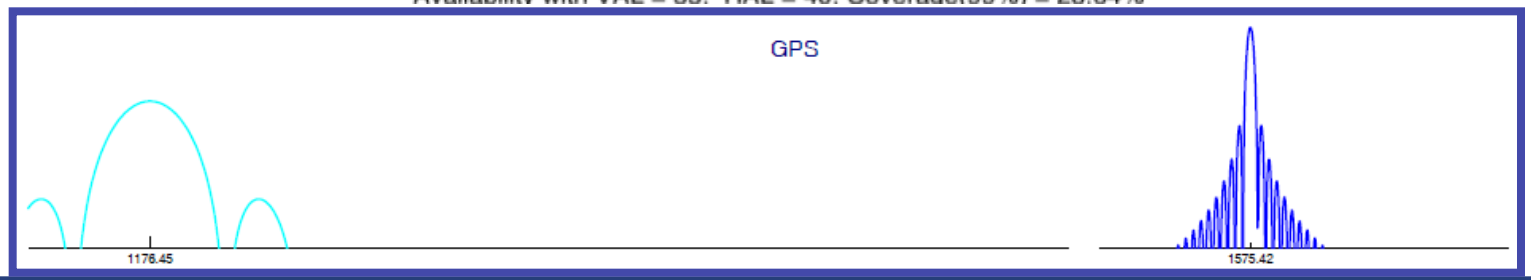
Future Applications

- **WAAS is an enabler for multiple FAA initiatives**
  - Performance-Based Navigation (Area Navigation) (RNAV)
  - Required Navigation Performance (RNP)
    - WAAS meets the requirement for RNP AR as defined in FAA Advisory Circular 90-101A
    - No restriction due to temperature
  - Point in Space (PinS) procedures
  - Automatic Dependent Surveillance Broadcast (ADS-B)
    - WAAS is currently the only technology that meets all of the most stringent requirements for a positioning source for ADS-B

Future LPV-200 Coverage(Dual Frequency GPS)

WAAS
EGNOS
MSAS





Summary

- **WAAS-provided messages improve the accuracy, availability and safety of GPS-derived position information**
- **WAAS results in safety and capacity improvements in the National Airspace System (NAS)**
- **WAAS will reduce FAA operations costs by enabling the decommissioning of some ground-based navigation aids**
  - All new CAT I Approaches in the NAS shall be WAAS LPV Approaches
  - FAA committed to making a decision on the reduction of CAT I ILS in 2016
- **WAAS provides a cost-effective means of integrating a precision approach capability into the cockpit**
- **Nearly 4,000 WAAS procedures are available with half published at runways that previously had no precision approach capability**
- **Continued support of International expansion of SBAS and adoption of future standards**