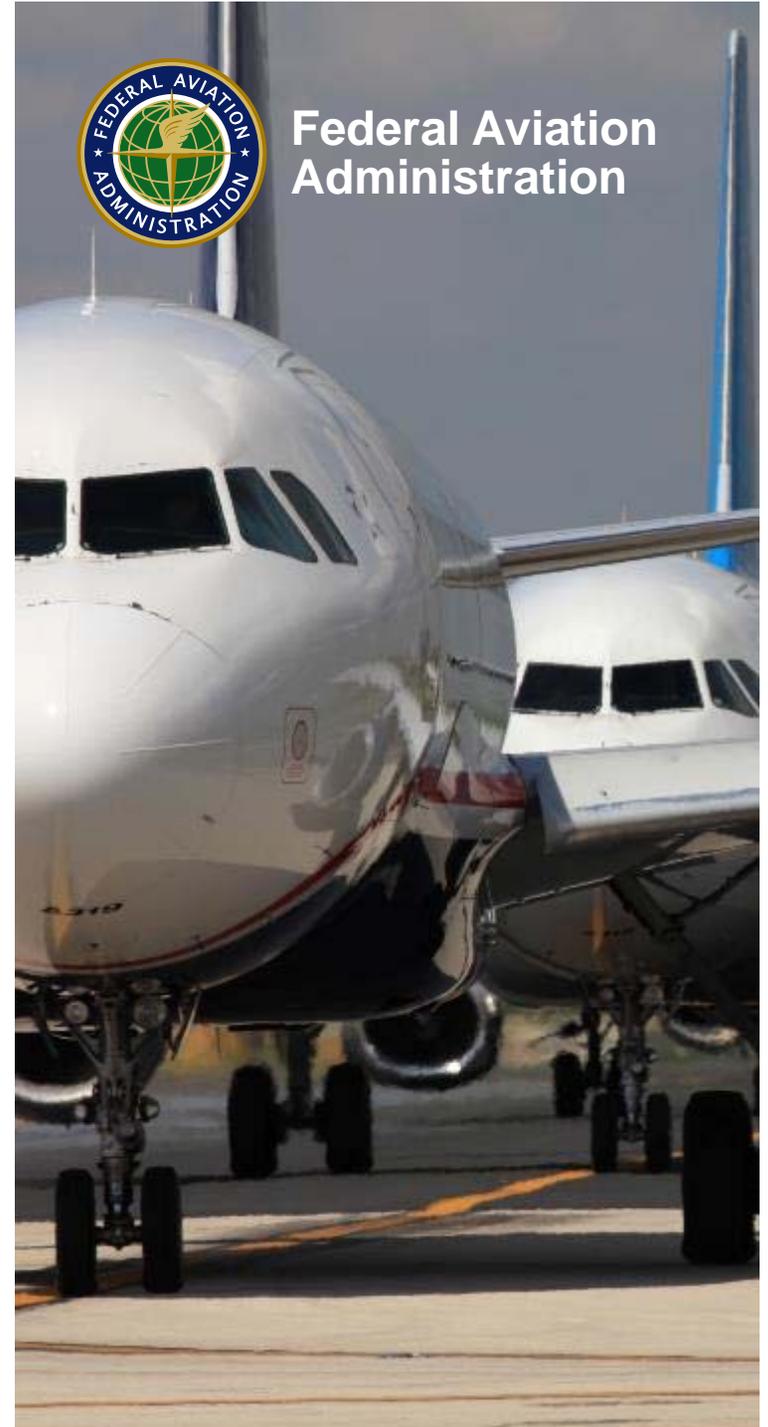


Wide Area Augmentation System (WAAS) – Program Overview

By: Greg Thompson

FAA Manager, WAAS Program

Date: February 4, 2020



Overview

- **Coverage and Performance**
- **Schedule/Milestones**
- **Current GEO System**
- **Phase 4A/4B Transition**
- **Dual Frequency Operations**
- **Procedures and Avionics**
- **Future Development**
- **Websites**

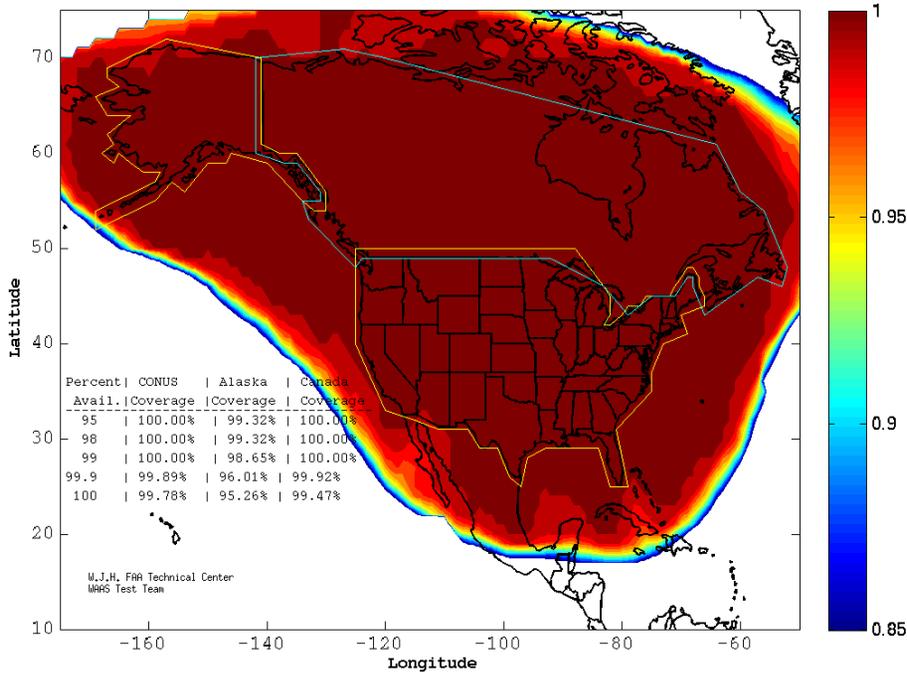


Coverage and Performance

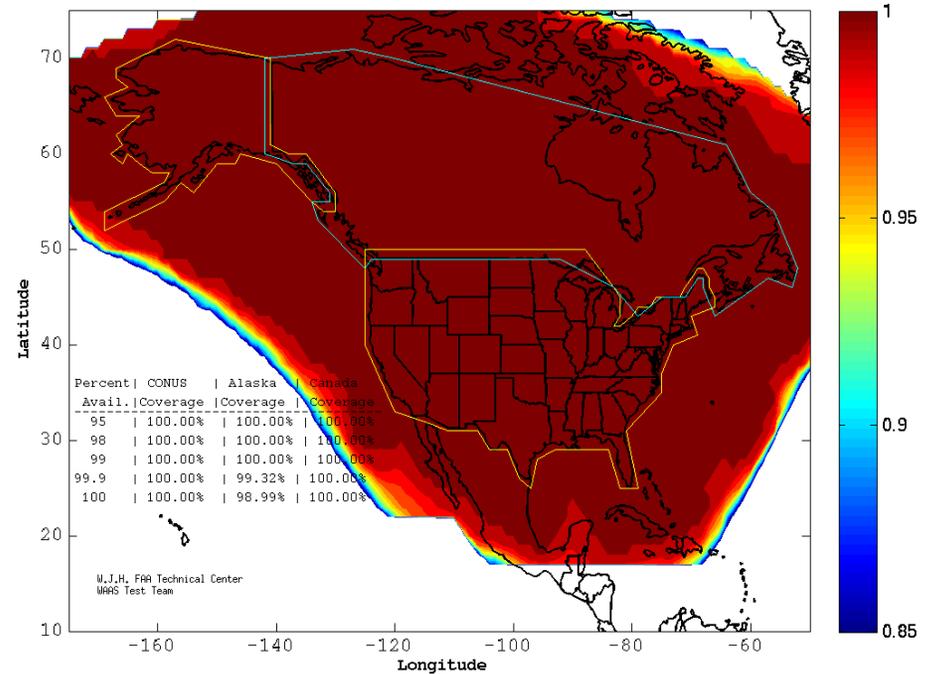


Current WAAS LPV/LPV-200 Performance

WAAS LPV200 Coverage Contours
01/29/20
Week 2090 Day 3



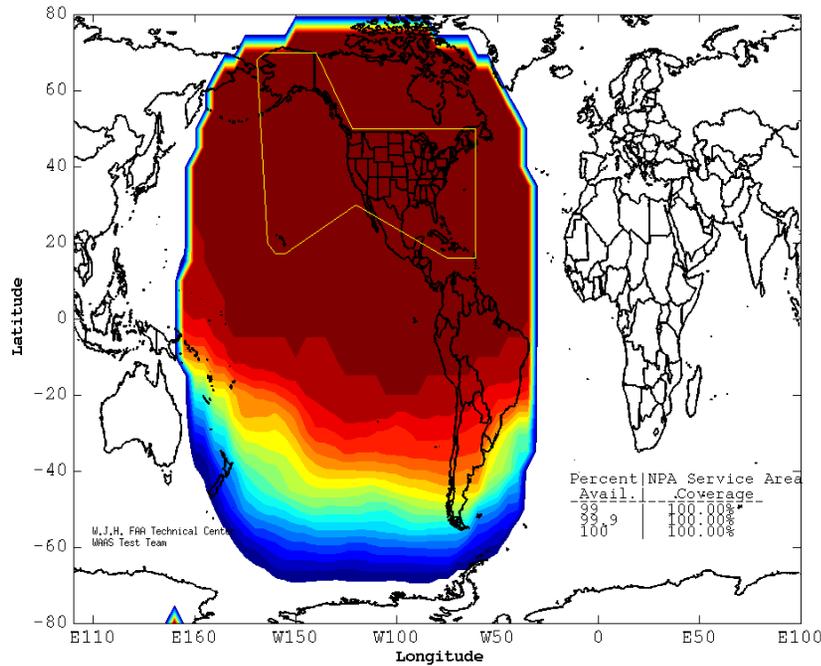
WAAS LPV Coverage Contours
01/29/20
Week 2090 Day 3



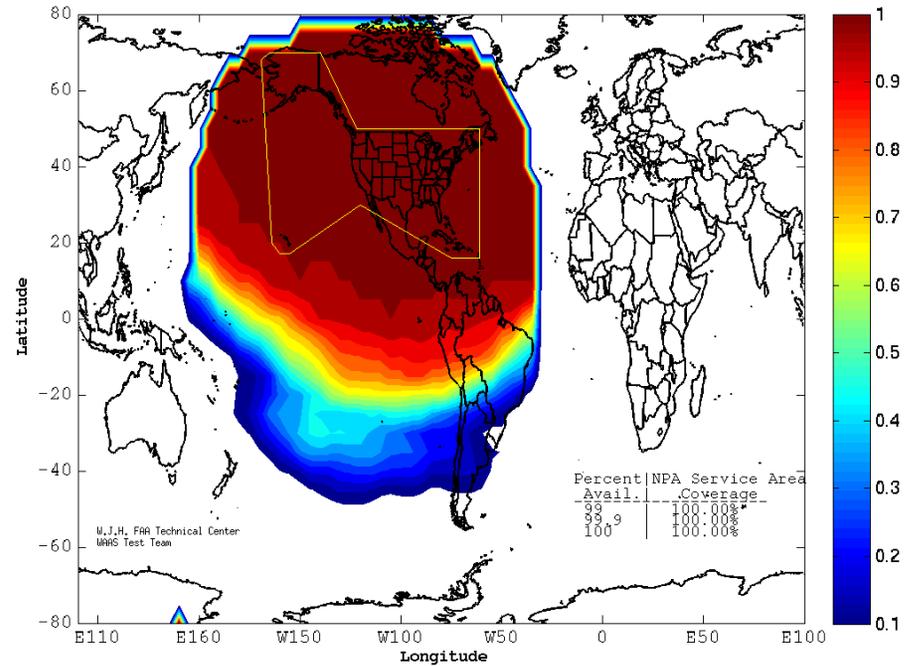
Throughout the Continental US WAAS LPV and LPV-200 remains above 99%

Current WAAS RNP 0.3/0.1 Performance

WAAS RNP 0.3 Coverage Contours
01/29/20
Week 2090 Day 3



WAAS RNP 0.1 Coverage Contours
01/29/20
Week 2090 Day 3



RNP coverage goes to the lowest possible levels throughout all phases of flight within the Continental US and Hawaii

Performance Monitoring

- **Daily review of performance at 38 WAAS reference stations and up to 10 NSTRB stations**
 - Precision approach
 - Daily results documented at <http://www.nstrb.tc.faa.gov/pasummary/>
 - Non-Precision approach
 - Daily results documented at http://www.nstrb.tc.faa.gov/npa_sps_summary/
 - GPS Standard Positioning Service (SPS)
 - Daily results documented at http://www.nstrb.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 available at <http://www.nstrb.tc.faa.gov/AirportSchedules/>

WAAS Performance Jan 1– Mar 31 2019

Parameter	CONUS Site/Maximum	CONUS Site/Minimum	Alaska Site/Maximum	Alaska Site/Minimum
95% Horizontal Accuracy (HPL <= 40 meters)	Arcata 1.416 meters	Dallas 0.435 meters	Barrow 0.564 meters	Bethel 0.515 meters
95% Vertical Accuracy (VPL <= 50 meters)	Arcata 1.439 meters	Seattle 0.740 meters	Barrow 1.138 meters	Cold Bay 0.793 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 100%	Barrow 99.99%
LPV200 Availability (HPL <= 40 meters & VPL <= 35 meters)	Multiple Sites 100%	Miami 99.82%	Multiple Sites 100%	Barrow 99.35%
99% HPL	Cleveland 16.434 meters	Denver 11.034 meters	Cold Bay 20.899 meters	Juneau 13.190 meters
99% VPL	Arcata 30.602 meters	Billings 19.669 meters	Barrow 32.711 meters	Anchorage 22.178 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

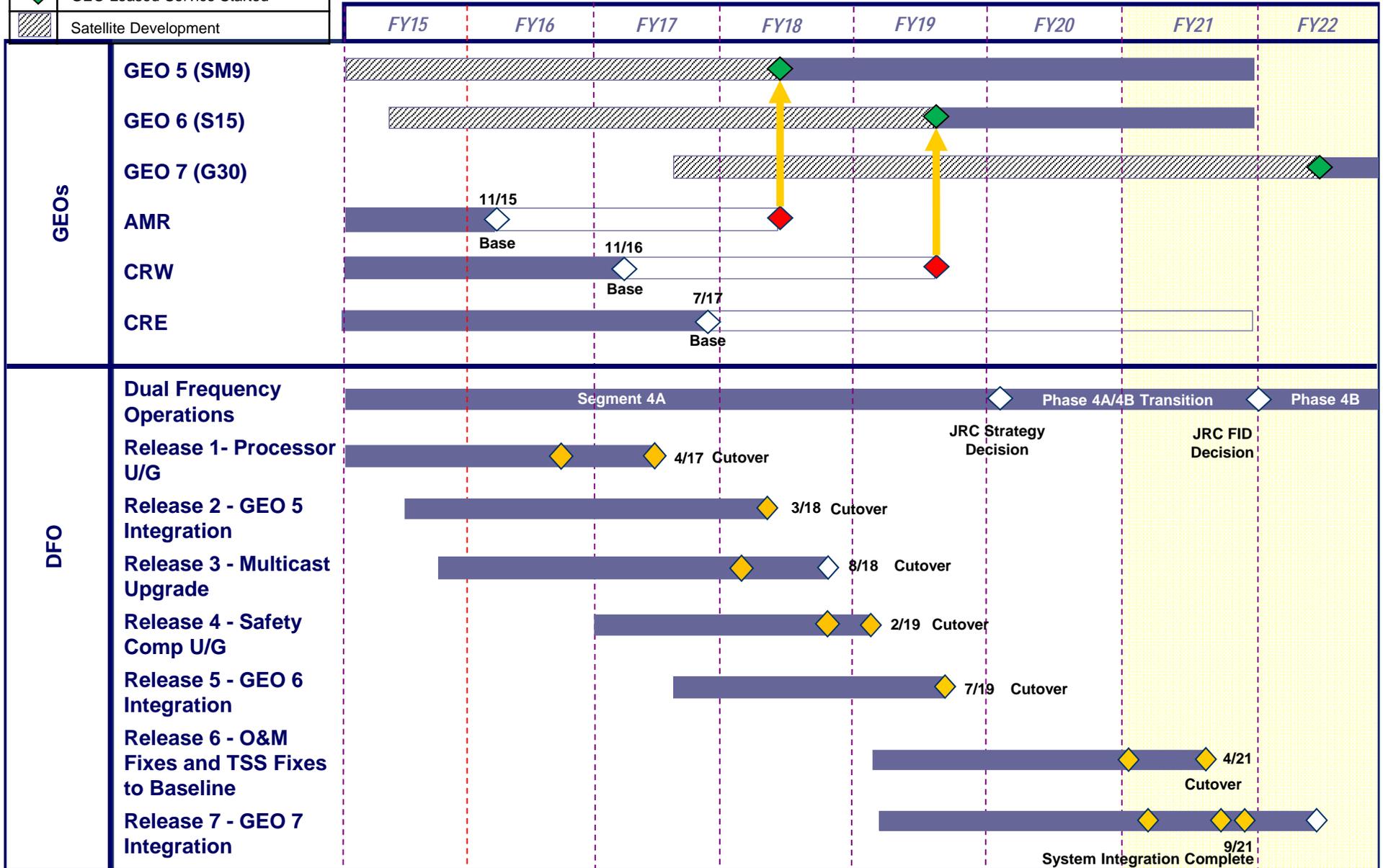


WAAS Schedule



WAAS Schedule (2015-2022)

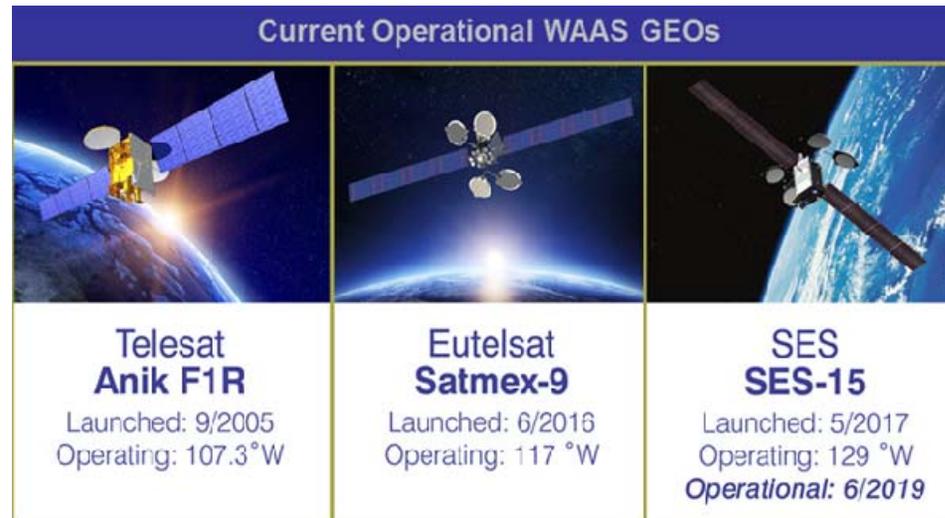
Legend	
	Milestone
	ABP/Execution Plan Milestone
	GEO Leased Service Ended
	GEO Leased Service Started
	Satellite Development



GEO System



WAAS GEOs



- **Anik F1R (CRE)**
 - On contract thru July 2020 with options thru July 2022
- **Eutelsat 117 WB [ex SatMex 9] (GEO 5)**
 - Completed WAAS integration on March 27, 2018
- **SES-15 (GEO 6)**
 - Completed WAAS integration on June 15, 2019

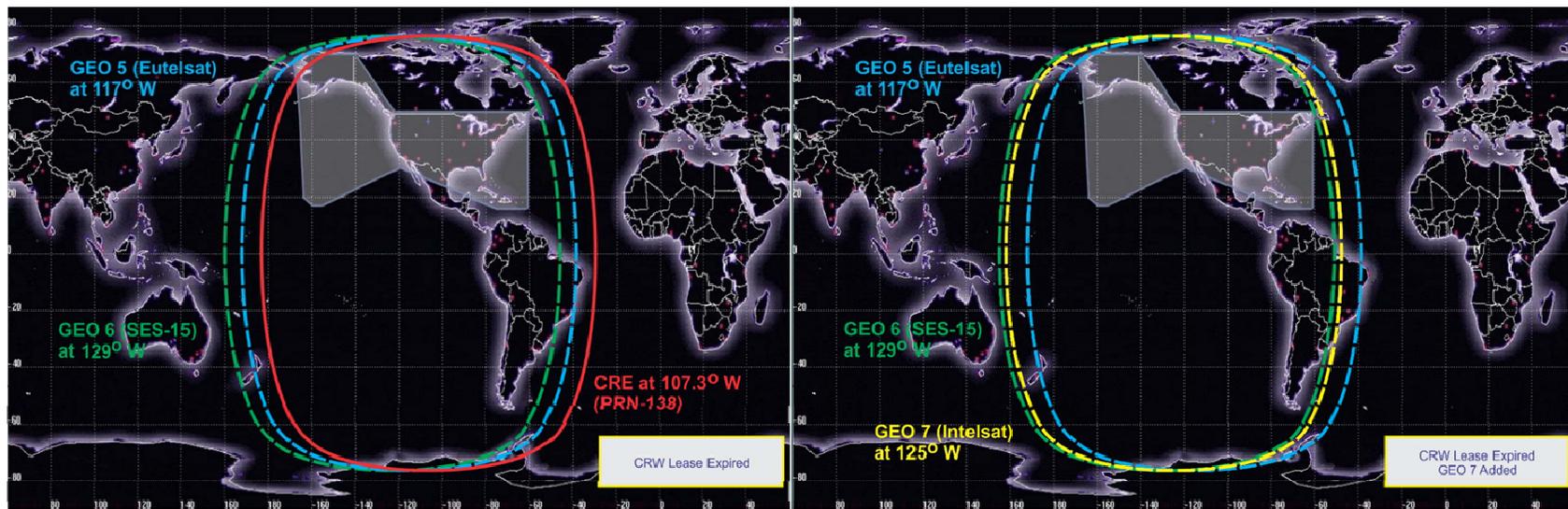
GEO Sustainment (GEO 7)

- **GEO 7 Satellite Acquisition**

- Task Order awarded to Leidos on March 8, 2018
 - GEO is Intelsat at 125 West
- Integrated Baseline Review (IBR) completed September 2018
- Preliminary Design Review (PDR) completed December 2018
- Critical Design Review (CDR) completed April 2019
- GEO Launch projected for June 13, 2020
- GSP IOT projected to be complete October 2020
- Phase 1 Testing (Milestone 1A) projected to be complete February 2021
- WAAS Integration, Test and Cutover projected by September 2021

WAAS GEO Coverage

Current and Future GEO Coverage



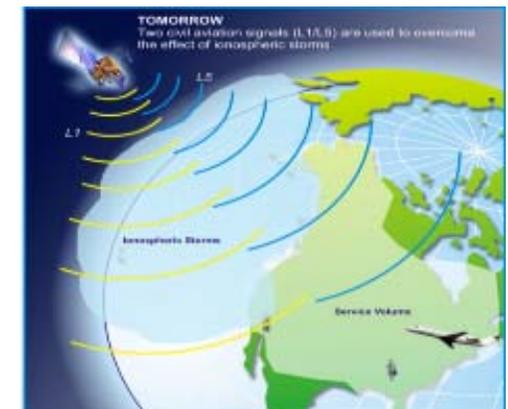
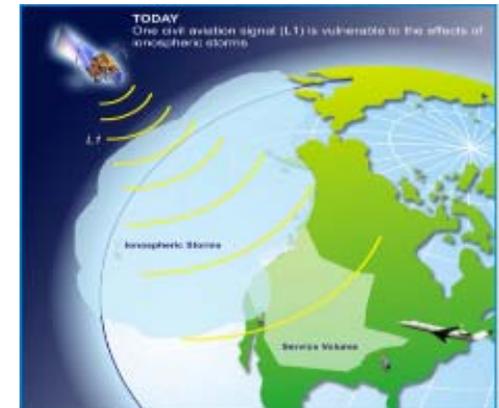
WAAS Phase 4A/4B Transition



WAAS Phase 4A – 4B Transition

- **FY20/21**

- Two year continuation of the WAAS program prior to Phase 4B FID
- Two releases to focused on continued sustainment of the operational WAAS (Releases 6 and 7)
 - Release 6 will improve WAAS performance enhancements by correcting anomalies to the O&M, Test Support Software (TSS) and network critical message logging capabilities
 - Release 7 will integrate GEO 7 into WAAS and upgrade with new Signal Generator including the retrofitting of new
 - SIGGENs at the GEO 5 and GEO 6 legacy GUS sites. GEO 7 projected to be operational by September 2021
- Continued definition of DFO Phase 4B requirements and alignment with GPS modernization schedule
- Demonstration of alternatives to transition the communications network from Time Division Multiplexing (TDM) to Internet Protocol (IP)
- Additional work will include:
 - Completion of L5 Dual Frequency (DF) signal analysis and support Minimal Operational Performance Standards (MOPS) development to facilitate requirements definition
 - Resolution of WAAS Operations & Maintenance software reliability and maintainability issues
 - Integration of GEO 7
 - Replacement of obsolete Signal Generator (SIGGEN)
 - Generation of WAAS Phase 4B FID Artifacts



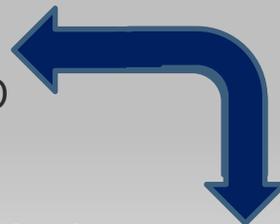
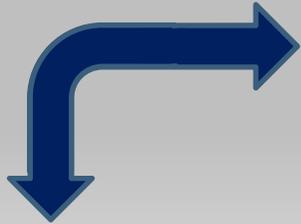
WAAS Dual Frequency Operations (DFO)



WAAS Phase 4B

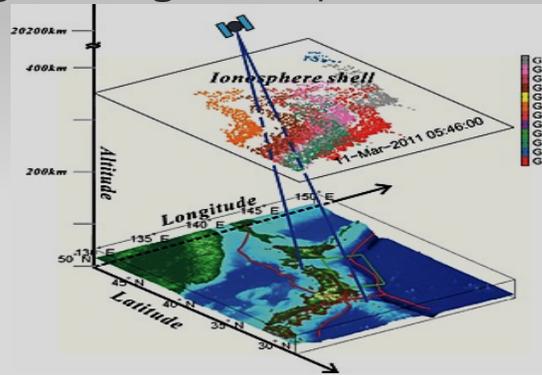
Dual Frequency Operations

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



- GEO 7 Integration
- GEO 8 Acquisition & Integration

H-ARAIM



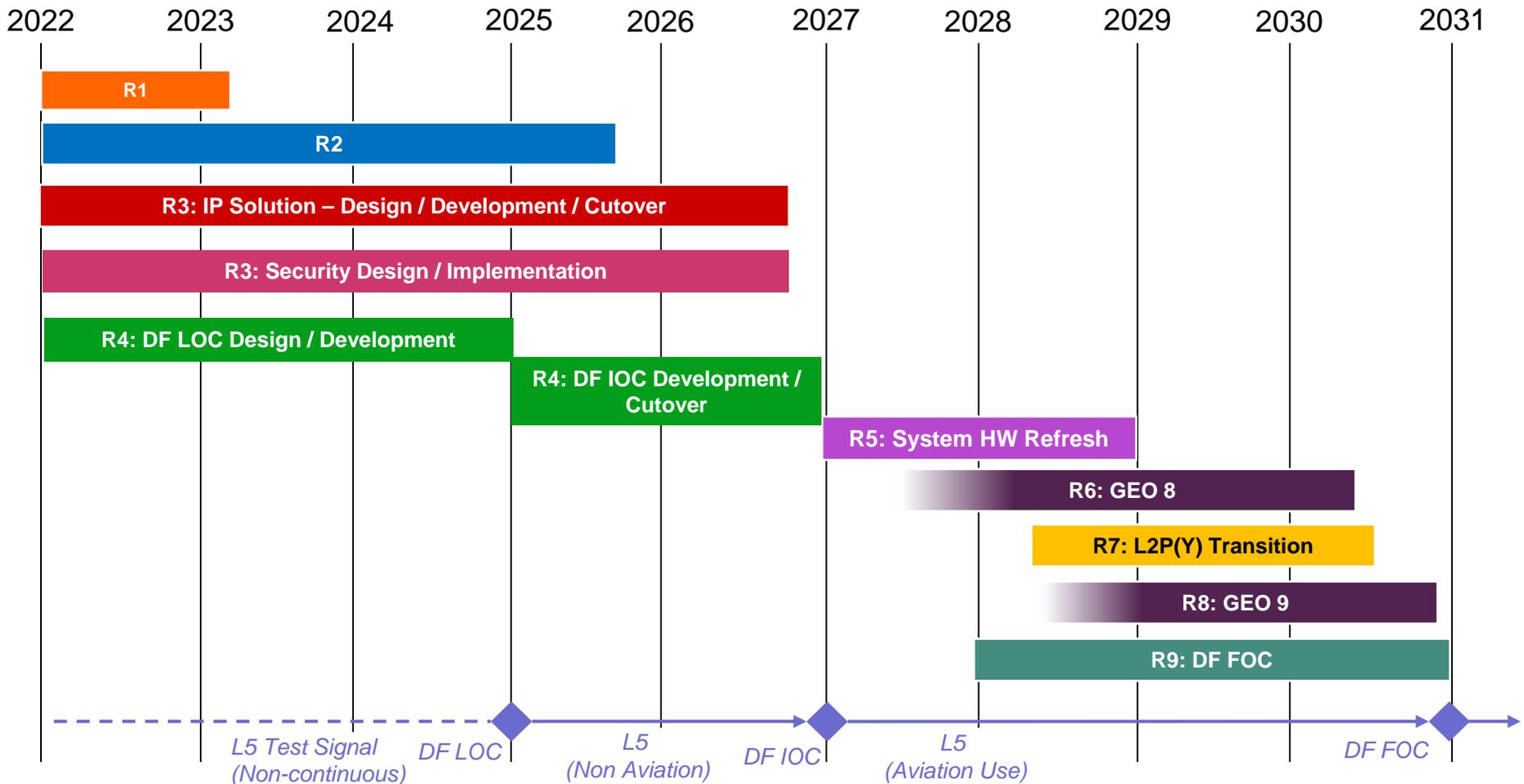
Evaluation & testing of Horizontal Advanced Receiver Autonomous Integrity Monitoring Capabilities

TDM-IP Transition



Design, testing, and implementation of TDM-IP transition

Phase 4B Release timeframe



WAAS Phase 4 DFO, began in 2014 to leverage improvements the Department of Defense (DoD) will make as part of its GPS modernization program, specifically the introduction of the second civil frequency (L5). Current US Air Force GPS plans predict declaration of GPS L5 Initial Operational Capability (IOC) in FY2022 and Full Operational Capability (FOC) in late FY 2028. FAA plans are for a 24-month transition leading to a WAAS DFO FOC in FY2030.



DFO Expected Deliverables

- **DFO development work**
 - Re-baseline Dual Frequency (DF) Prototype
 - Develop DF capability from Single Frequency (SF) Code base
 - Separate Correction and Verification (C&Vs) for SF and DF services
 - Develop a shadow environment DF approach
 - Integrate Covariance User Differential Range Error (UDRE) algorithm
 - Modify G-III to track higher GPS PRNs
 - Hardware updates to meet new FAA-E-2892e DF requirement standards
- **The WAAS System requires continual modification and updates to meet the safety standards set forth by the FAA. In support of the new DF capability the program office will make updates to the Wide Area Master Stations (WMS) C&V subsystem, Operations and Maintenance (O&M) and the GUS Processor (GPT)**
- **Further critical DFO work will be identified during the next two years and integrated into the new WAAS DFO Prime Contract projected to be awarded by 2022**



WAAS Procedures and Avionics

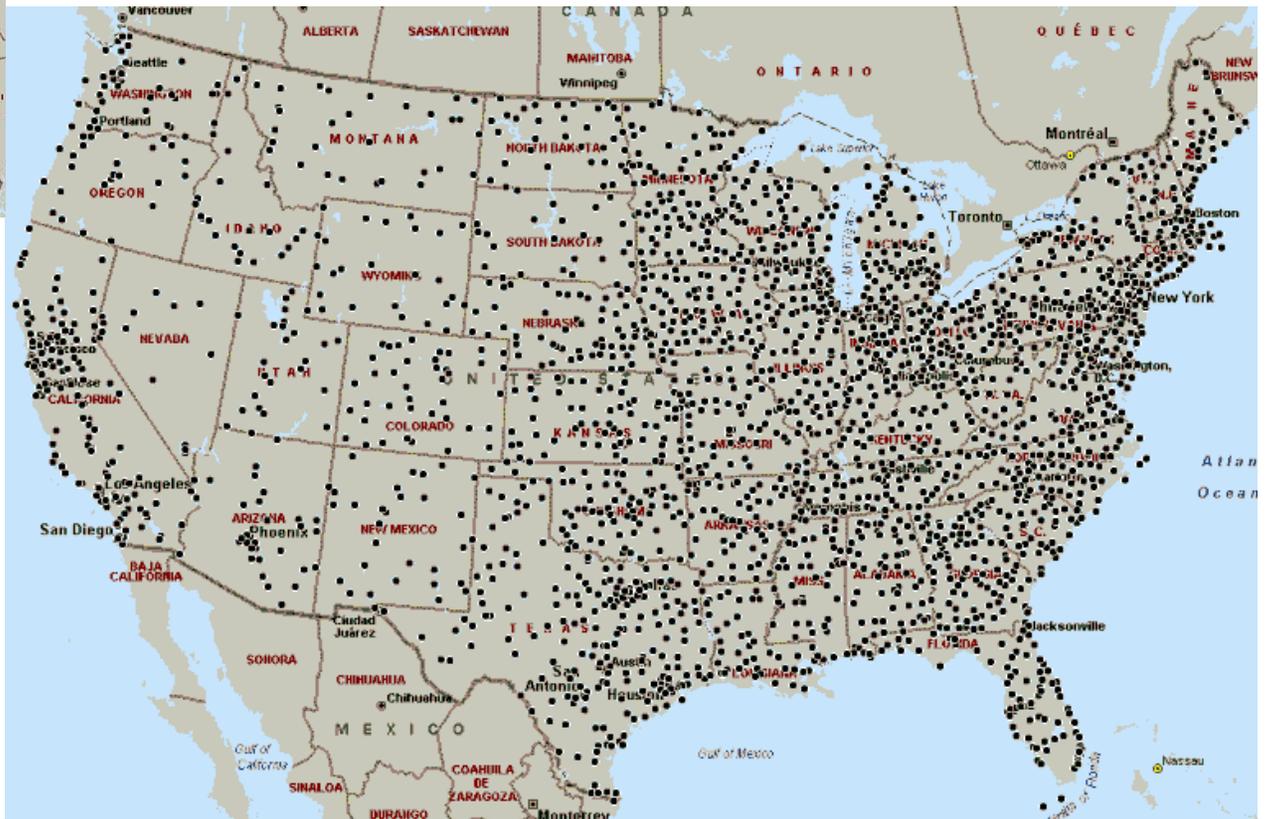


WAAS LPV/LP Instrument Approaches



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

- As of January 2020 there are currently 1,546 ILS procedures while WAAS has 4,764 LPV/LP procedures published



WAAS Avionics Equipage Status

- **Over 131,000 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 have 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)



Future Development



WAAS Phase 4B Investigations

- **Dual-Frequency Multi-constellation Capability (DFMC)**
 - 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 completed drafted SARPS Nov 2018
 - SARPS currently out for review and validation to be approved by October 2020
 - SBAS Interoperability Working Group (IWG) has proposed preliminary DFMC requirements and a SBAS interface control standard
 - ICAO NSP, RTCA and EUROCAE are developing draft standards
 - Aircraft equipage is expected no earlier than 2026
 - EU is 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>



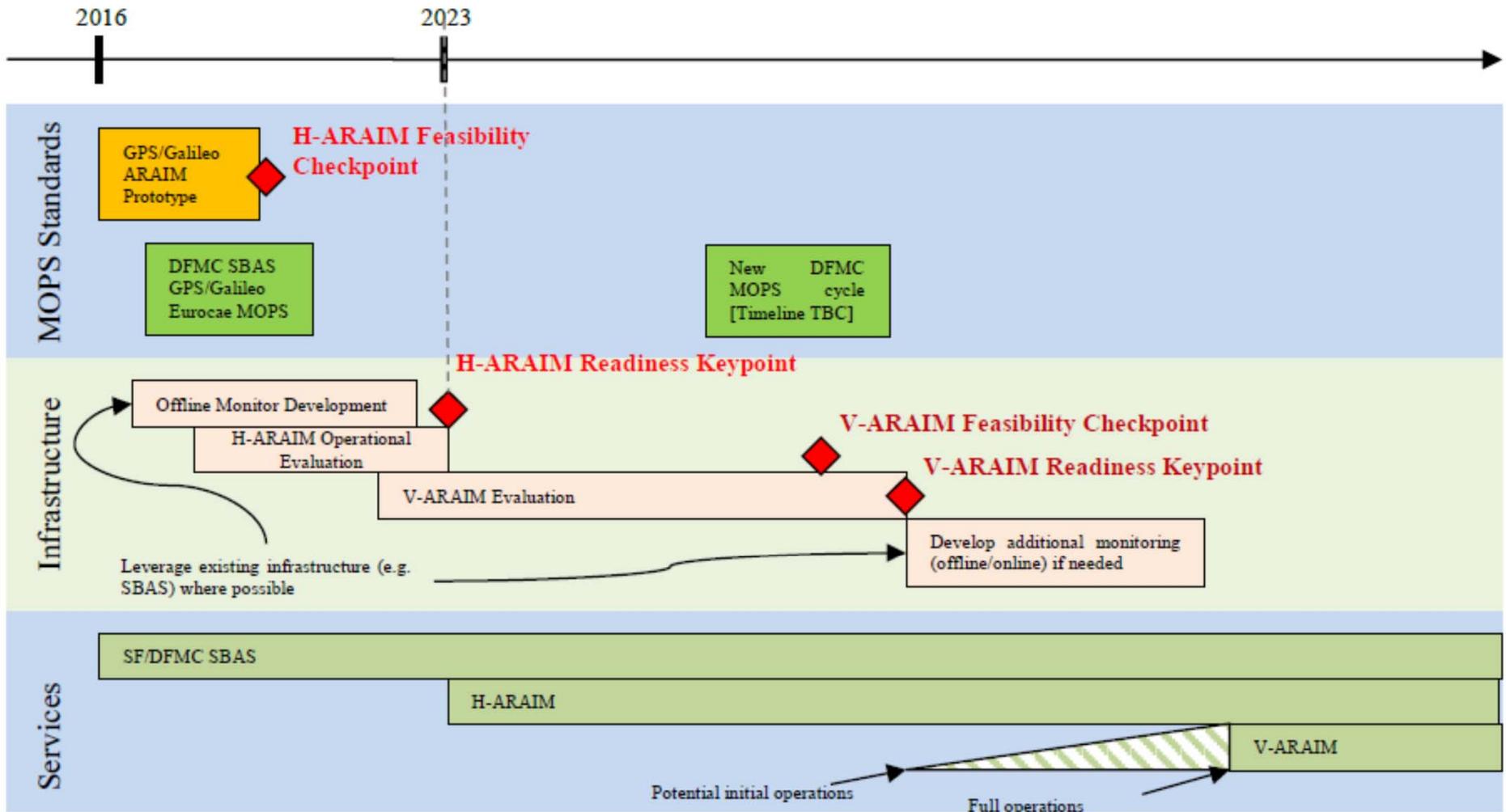
WAAS Phase 4B Investigations (cont.)

- **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 in 2018
 - Safety Documentation – Completed Sep 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
 - Gain approval for SARPS changes in 2020
 - Add material to DFMC MOPS to incorporate ARAIM function

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



Aviation Long-term Timeline



WAAS Phase 4B Investigations (cont.)

- **Time-Division Multiplexing to Internet Protocol (TDM-to-IP)**
 - TDM-to-IP project is an agency-wide initiative for transitioning of existing Time Division Multiplexing (TDM) based point-to-point communication circuits into a NAS Operational Internet Protocol (OPIP) or Private Ethernet Virtual Local Area Network (VLAN)(PEV)
 - WAAS Program Office is in coordination with the FAA Communications, Information & Network Programs (CINP) group and FAA Authorizing Official Designated Representative (AODR) on requirements
 - Completed the TDM-IP Transition Study to select the best System Architecture for WAAS, and Demonstration tests have begun
 - OPIP demo tests began August 2019
 - PEV demo tests scheduled to begin March 2020



Websites



Informational Sites

- **For further detailed information please visit:**
 - <https://www.gps.gov/>
 - Instrument Flight Procedures (IFP) Inventory Summary:
https://www.faa.gov/air_traffic/flight_info/aeronav/procedures/ifp_inventory_summary/
 - William J. Hughes Technical Center WAAS Test Team:
<http://www.nstb.tc.faa.gov/>
 - FAA TV: The WAAS Experience : <https://www.faa.gov/tv/?mediaId=730>
 - Satellite Navigation WAAS Website:
https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/waas/



Summary

- **Maintaining a three GEO constellation**
- **Currently within Phase 4A-4B Transition Period**
 - DFO follow on Contract
 - Update of SIGGENs
 - WAAS performance enhancements
 - TDM-IP Demo Testing
 - Integration of GEO 7
- **Ongoing Future work with DFMC and ARAIM**

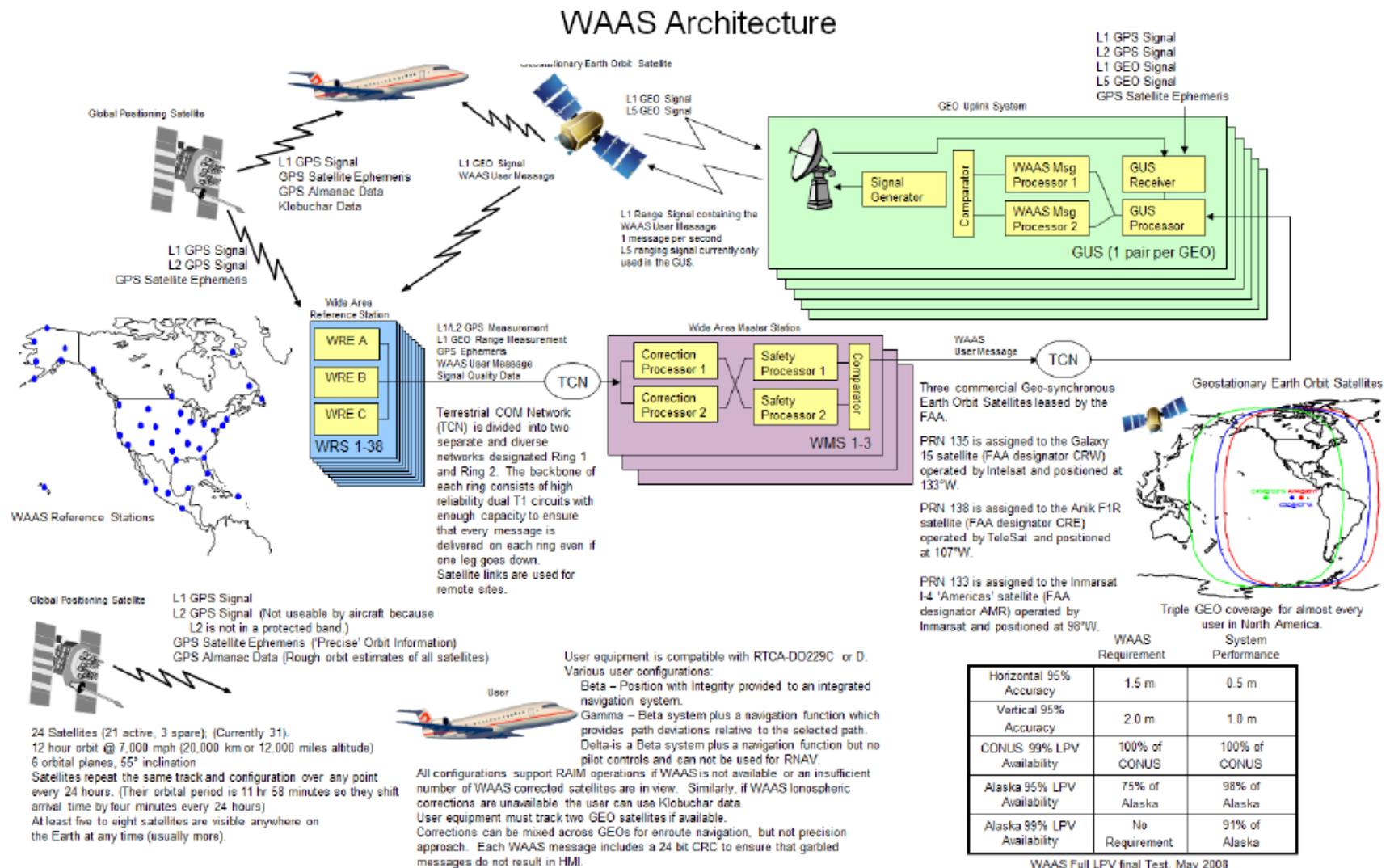
BACKUP



Infrastructure and Requirements



WAAS System Architecture



WAAS System Architecture Wide-Area Reference Station (WRS)



- **Collects Data from GPS and GEO Satellites**
- **Screens Data for ‘Outliers’**
- **Forwards Data to WMS’s**
- **Triple Redundant**

WAAS System Architecture Wide-Area Master Station (WMS)



- **Receives Data from WRS's**
- **Calculates Satellite and Ionospheric Corrections**
- **Defines Ionospheric Grid Points (IGP's)**
- **Ensures Satellite and IGP Integrity**
- **Generates WAAS Messages**
- **Sends Data to GUS's**

WAAS System Architecture GEO Uplink Subsystem (GUS)



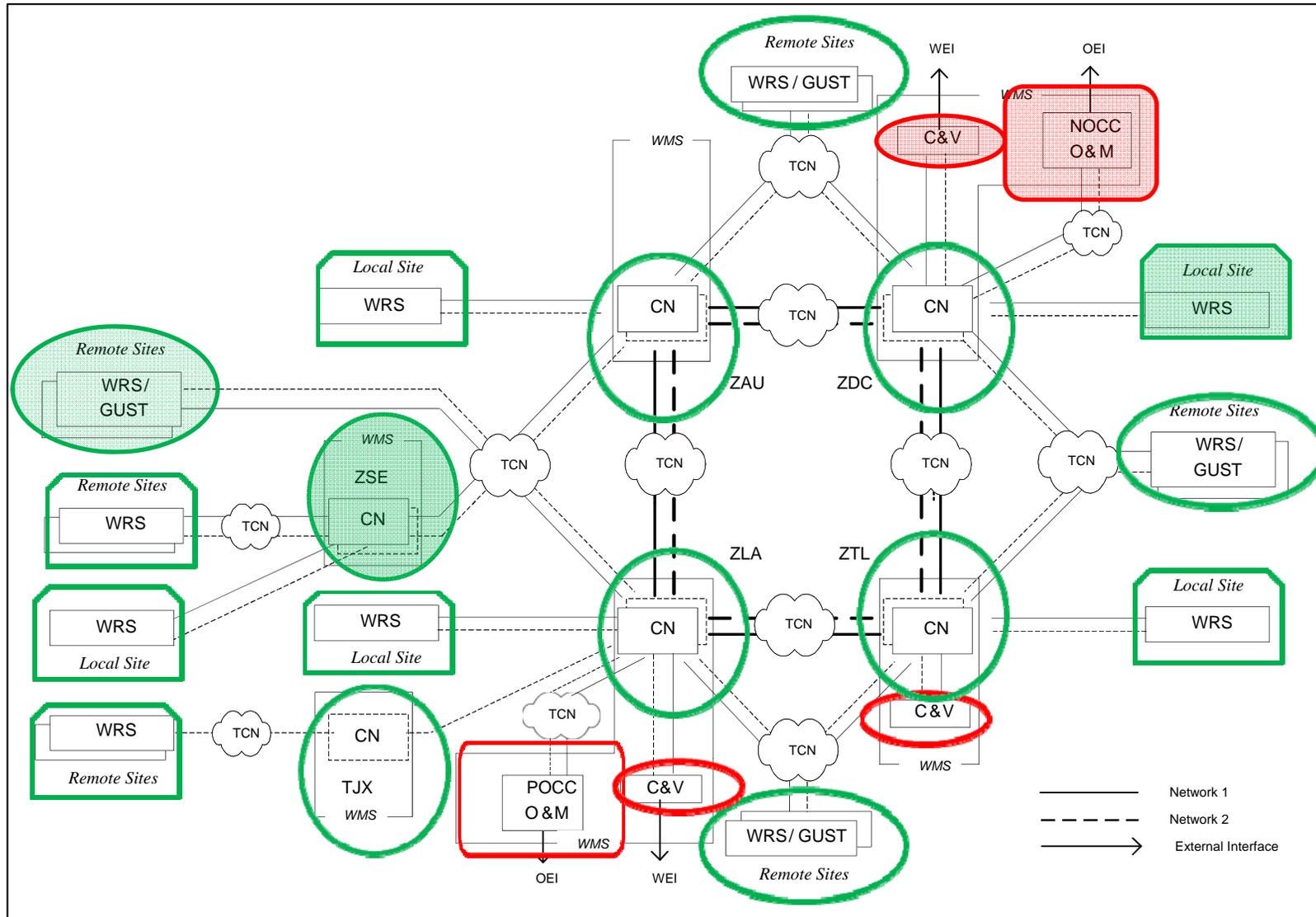
- **Receives WAAS Messages from WMS's**
- **Schedules WAAS Messages**
- **Transfers Scheduled Messages to the RF Uplink Subsystem**
- **RFU Transmits WAAS Messages to GEO**
- **Verifies Integrity of Transmitted Messages**

WAAS System Architecture Operations and Maintenance Subsystem (O&M)

- **Provides Equipment Status for all WAAS Facilities**
- **Monitors WAAS Performance**
- **Allows Control of Equipment States/Modes**
- **Provides Fault Isolation for All WAAS Facilities**



WAAS Terrestrial Comm Network (TCN)



WAAS Requirements



WAAS GPS Requirements

- **Spectrum Requirement**

- The WAAS must receive and process the GPS Signal In Space (SIS) at the L1, L2P(Y) and L5 frequencies through a one-way interface, generated in accordance with the GPS SPS PS, Interface Specification (IS)-GPS-200, IS-GPS-705 and GPS WAAS PS. In the event of conflict between the GPS documents and the GPS WAAS Performance Standard, the GPS WAAS Performance Standard will take precedence
- The GPS L1 and L5 bands used by WAAS are Aeronautical Radio Navigation Service (ARNS) protected. GPS L2, also in use by the WAAS ground system, is Radio Navigation Satellite Service (RNSS) protected
 - WAAS must be consistent with national and international standards for these bands (e.g. Radio Frequency (RF) standards delineated by the International Telecommunication Union (ITU) and Annexes to the International Civil Aviation Organization (ICAO) Convention that establish international Standards and Recommended Practices (SARPs) for aeronautics



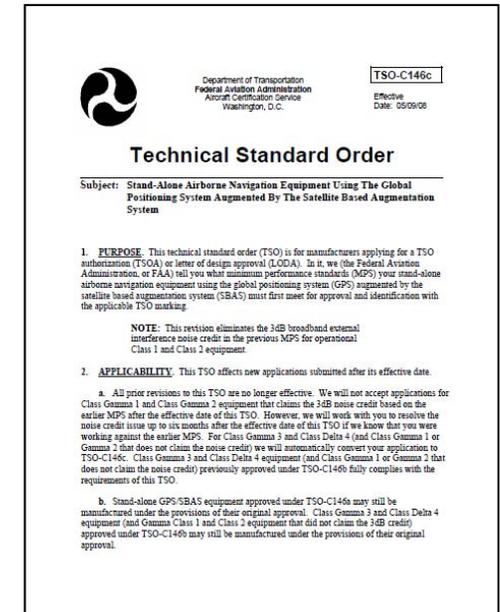
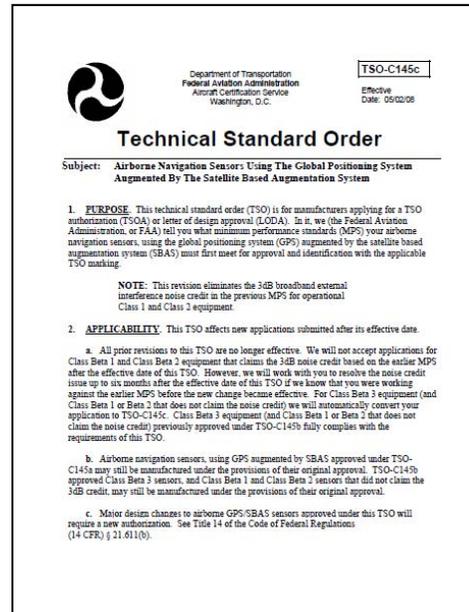
WAAS GPS Requirements

- **Functional Requirement**

- A nominal GPS constellation of 24 operational satellites with an availability of 0.95
- At least 21 healthy satellites in the 24 nominal plan/slot positions with an availability of 0.98
- The GPS constellation must be compliant with the GPS Standard Positioning Service (SPS) Performance Standard (PS)

WAAS User Requirements

- TSO-C145 “Airborne Navigation Sensors Using the GPS Augmented by the WAAS”
- TSO-C146 “Stand-Alone Airborne Navigation Equipment using the GPS Augmented by the WAAS”



WAAS User Requirements

- **TSO-C145/146c**
 - Minimum Performance Standards (MPS) qualification and documentation requirements for functional equipment Class Gamma or Delta in RTCA, Inc. document RTCA/DO-229D, Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment
 - Qualifications
 - Functional Qualification
 - Demonstrate the required performance under the test conditions in RTCA/DO-229D
 - Environmental Qualification
 - Test the equipment according to RTCA/DO-229D, Section 2.4, and RTCA/DO-160E, Environmental Conditions and Test Procedures for Airborne Equipment
 - Software Qualification
 - Develop the software according to RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certification
 - Electronic Hardware Qualification
 - Develop the component to the guidance in FAA Advisory Circular (AC) 20-152, RTCA, Inc. Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware



Benefits



WAAS vs ILS

- **Provides service similar to ILS Category I**
 - Vertical guidance
 - Glidepath more stable than that of ILS
 - Minimums as low as 200 feet
 - which is lower than all Required Navigation Performance (RNP) Authorization Required (AR) approaches and all conventional (e.g. VOR, NDB) non-precision approaches
 - Currently outnumber ILS approaches with a factor of greater than two to one



WAAS in All Areas of Flight

- **WAAS provides benefits over standard GPS for all phases of flight to include Flight Planning, Terminal and Enroute Operations**
 - Allows use of LNAV/VNAV minima without temperature restrictions
 - Provides vertically-guided approach procedures capability at airports that do not have groundbased navigational aides
 - Is not affected by snow reflections that can impact ILS operations
 - Allows RNAV (GPS) approaches to be used for alternate airport flight planning



WAAS in All Areas of Flight (cont.)

- **Increases number of alternate airport options which improves flight planning flexibility**
- **Satisfies equipment requirements for 'T' and 'Q' routes (meets SFAR 97 in Alaska)**
- **Eliminates RAIM check requirement per AC 90-100A**
- **Provides two additional ranging sources (from WAAS GEOs)**
- **Enables extension of terminal mode operations for both departure and**
- **arrival to beyond 30 nautical miles from the airport reference point**
- **Increased accuracy and availability**
- **Eliminates ILS critical areas**
- **Enables ADS-B**

