

# Wide Area Augmentation System (WAAS) – Program Overview

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**Federal Aviation  
Administration**



# Overview

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

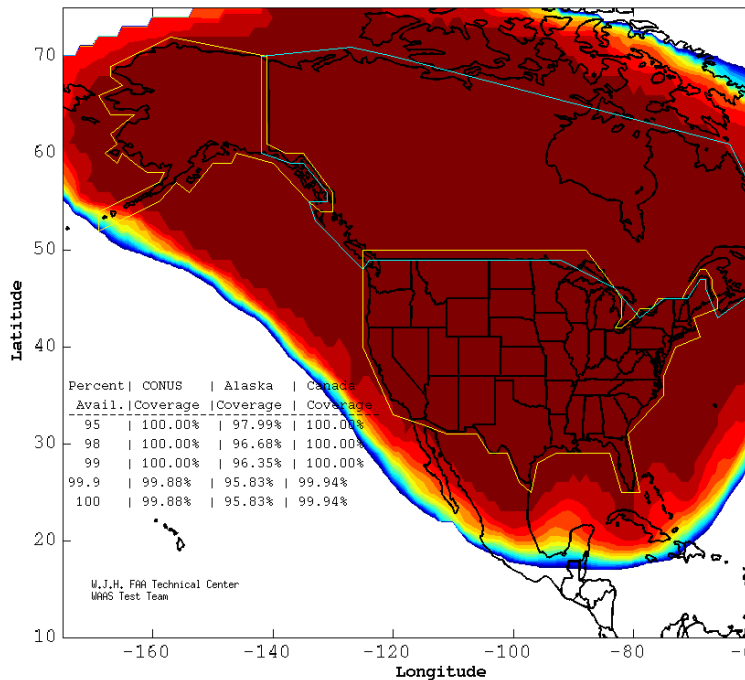


# Coverage and Performance

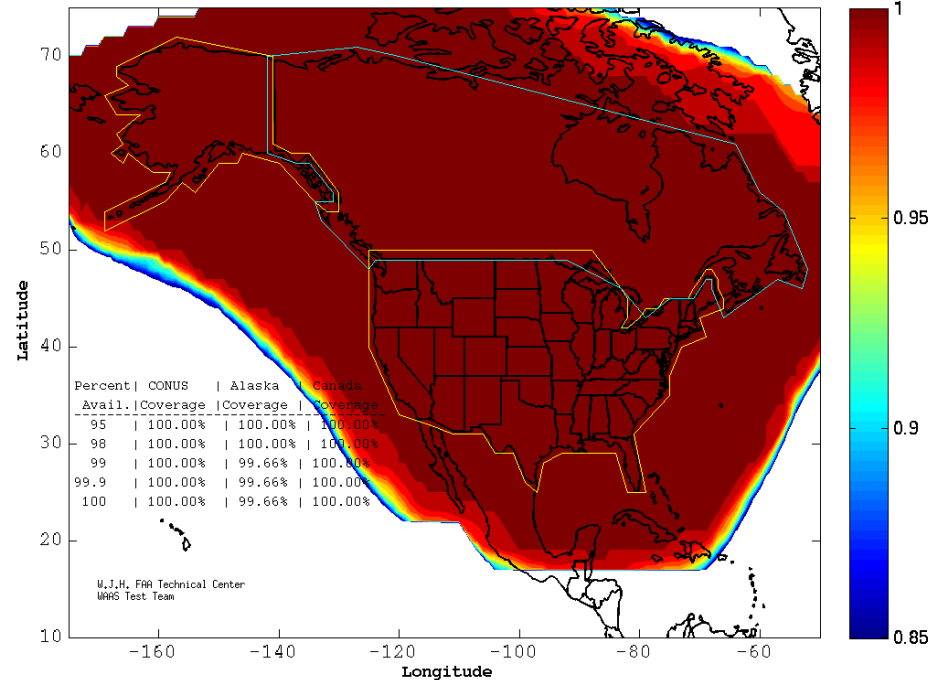


# Current WAAS LPV/LPV-200 Performance

WAAS LPV200 Coverage Contours  
06/08/21  
Week 2161 Day 2



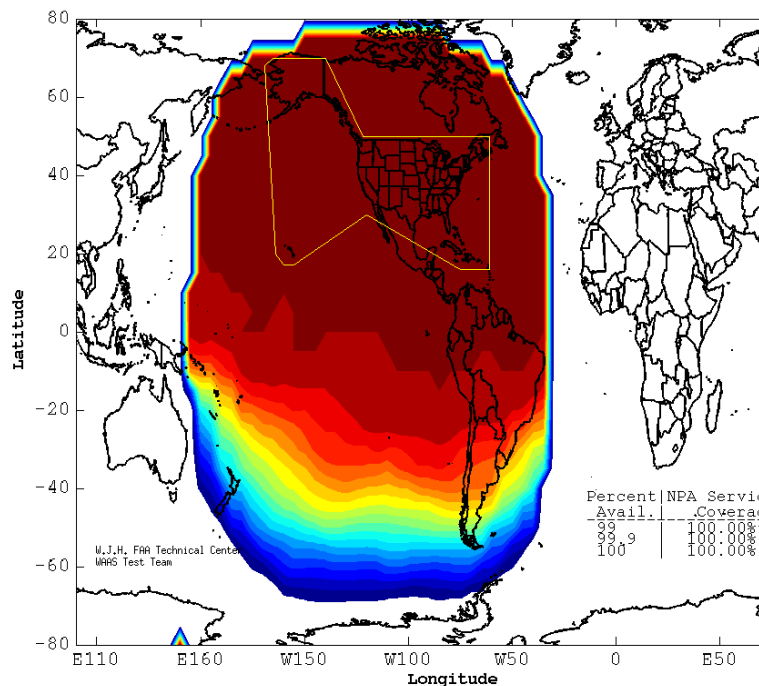
WAAS LPV Coverage Contours  
06/08/21  
Week 2161 Day 2



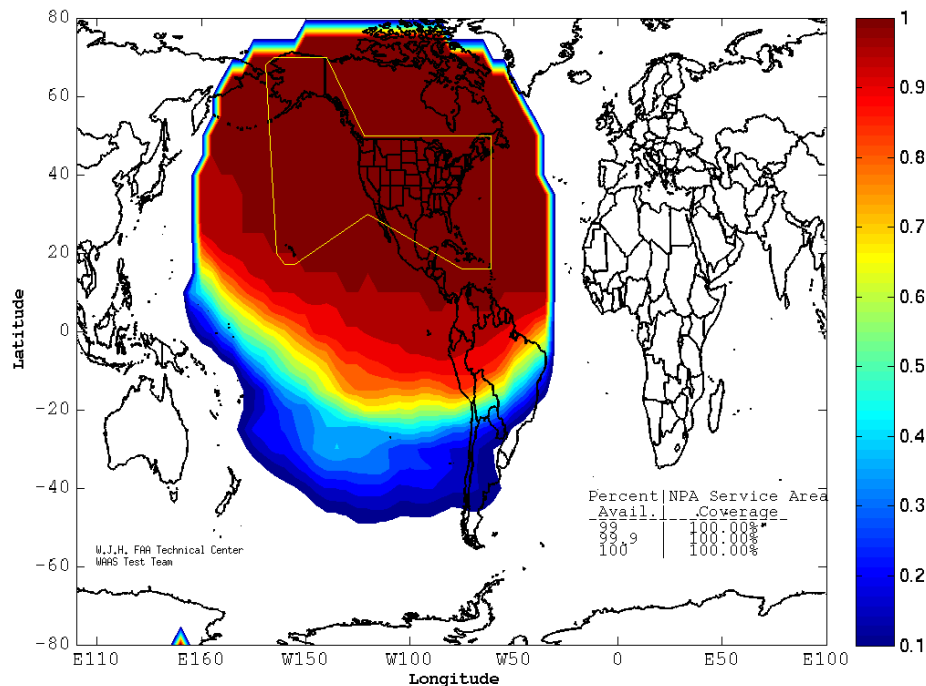
Throughout the Continental US WAAS LPV and LPV-200 remains above 99%

# Current WAAS RNP 0.3/0.1 Performance

WAAS RNP 0.3 Coverage Contours  
06/08/21  
Week 2161 Day 2



WAAS RNP 0.1 Coverage Contours  
06/08/21  
Week 2161 Day 2



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 NTSB stations**
  - Precision approach
    - Daily results documented at <http://www.ntsb.tc.faa.gov/pasummary/>
  - Non-Precision approach
    - Daily results documented at [http://www.ntsb.tc.faa.gov/npa\\_sps\\_summary/](http://www.ntsb.tc.faa.gov/npa_sps_summary/)
  - GPS Standard Positioning Service (SPS)
    - Daily results documented at [http://www.ntsb.tc.faa.gov/spa\\_summaryDB3/](http://www.ntsb.tc.faa.gov/spa_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.ntsb.tc.faa.gov/AirportSchedules/>



# WAAS Performance Jan 1 – Mar 31 2021

Parameter	CONUS Site/Maximum	CONUS Site/Minimum	Alaska Site/Maximum	Alaska Site/Minimum
95% Horizontal Accuracy (HPL <= 40 meters)	Arcata 1.515 meters	Memphis 0.532 meters	Juneau 0.664 meters	Bethel 0.511 meters
95% Vertical Accuracy (VPL <= 50 meters)	Miami 1.722 meters	Salt Lake City 0.688 meters	Barrow 1.253 meters	Cold Bay 1.054 meters
LP Availability (HPL <= 40 meters)	Multiple Sites 100%	Albuquerque 99.95%	Anchorage 99.95%	Anchorage 99.95%
LPV Availability (HPL <= 40 meters & VPL <= 50 meters)	Multiple Sites 100%	Albuquerque 99.95%	Anchorage 99.95%	Barrow 99.94%
LPV200 Availability (HPL <= 40 meters & VPL <= 35 meters)	Atlantic City-a 100%	Miami 99.90%	Anchorage 99.95%	Barrow 99.61%
99% HPL	Miami 16.985 meters	Dallas 11.011 meters	Cold Bay 20.251 meters	Fairbanks 13.220 meters
99% VPL	Arcata 30.055 meters	Kansas City 19.818 meters	Barrow 31.843 meters	Anchorage 21.639 meters

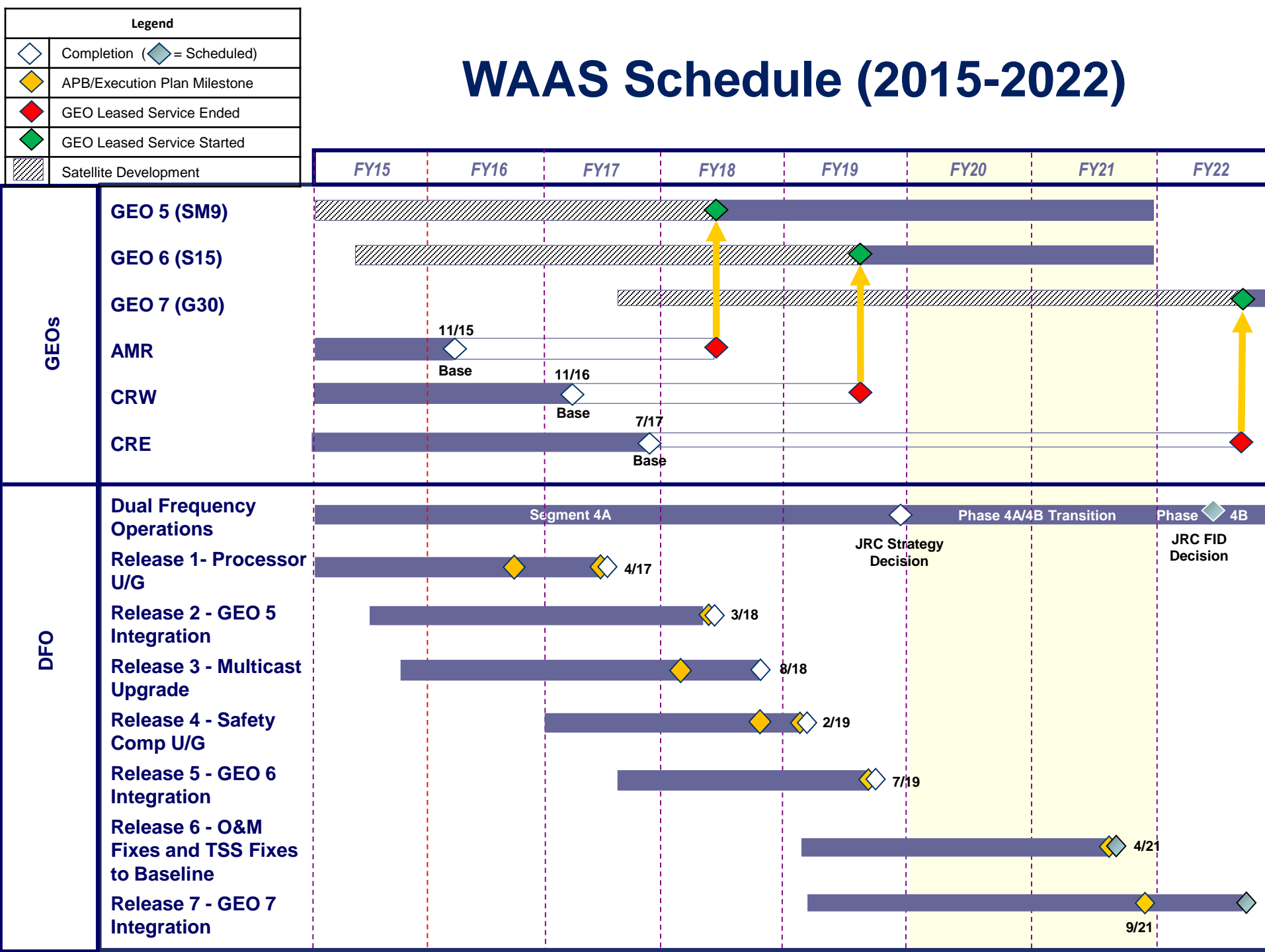
Localizer Performance (LP) service is available when the calculated Horizontal Protection Level (HPL) is less than 40 meters. Localizer Performance with Vertical Guidance (LPV) service is available when the calculated HPL is less than 40 meters and the Vertical Protection Level (VPL) is less than 50 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)



# GEO System



# WAAS GEOs

Current Operational WAAS GEOs		
		
<b>Telesat Anik F1R</b> Launched: 9/2005 Operating: 107.3°W	<b>Eutelsat Satmex-9</b> Launched: 6/2016 Operating: 117 °W	<b>SES SES-15</b> Launched: 5/2017 Operating: 129 °W <i>Operational: 6/2019</i>

- **Anik F1R (CRE)**
  - On contract through July 2022
- **Eutelsat 117 WB [ex SatMex 9] (GEO 5)**
  - Completed WAAS integration on March 27, 2018, on contract through 2028
- **SES-15 (GEO 6)**
  - Completed WAAS integration on June 15, 2019, on contract through 2029
- **Intelsat Galaxy 30 (GEO 7)**
  - Launched August 2020, integration mid-2022

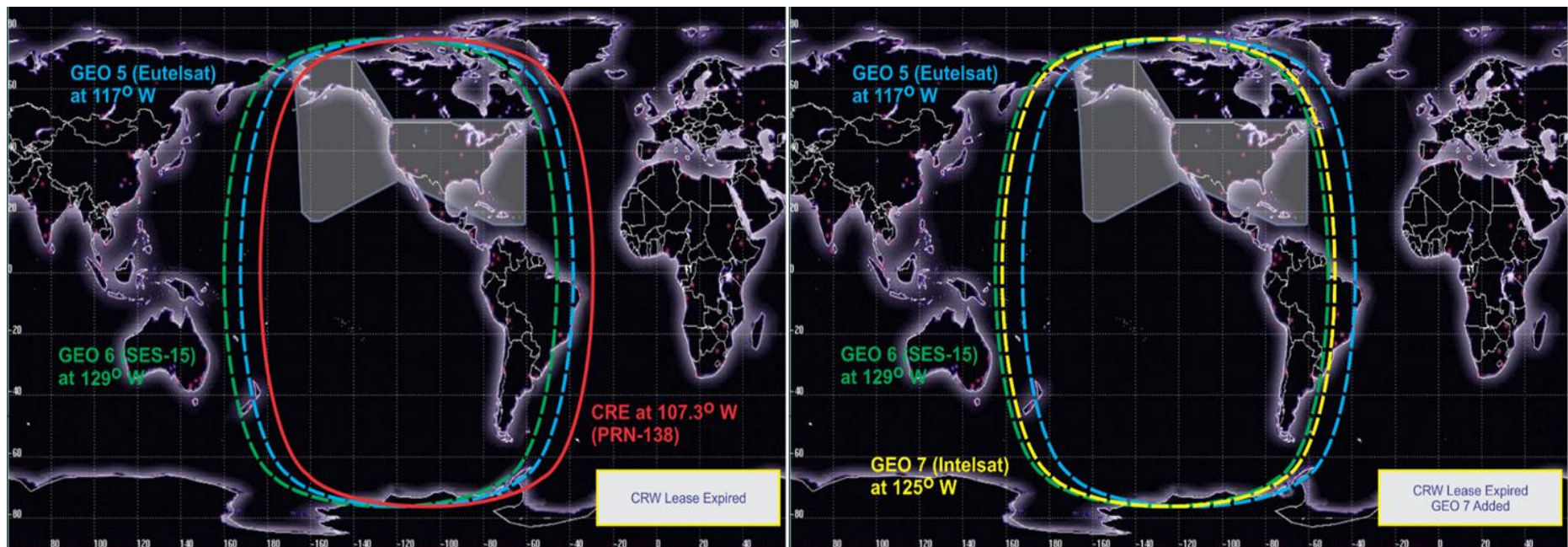
# GEO Sustainment (GEO 7)

- **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 7 Launch occurred on August 15, 2020
- GSP IOT completed January 2021
- Phase 1 Testing (Milestone 1A) completed June 2021
- Undergoing system testing with WAAS Integration projected for June 2022

# WAAS GEO Coverage

## Current and Future GEO Coverage



# WAAS Phase 4A/4B Transition

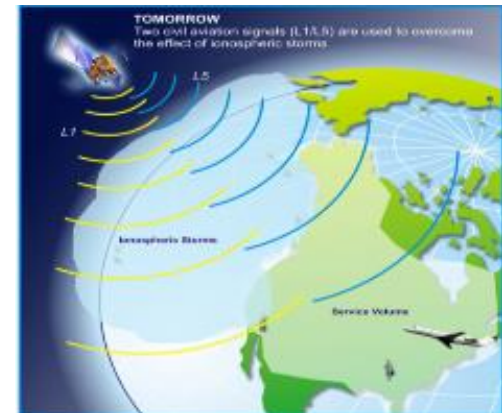
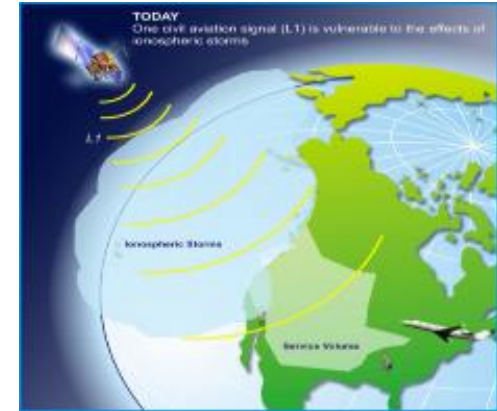




# WAAS Phase 4A – 4B Transition

- **FY20/21**

- Two year continuation of the WAAS program prior to Phase 4B
- Two releases to focused on 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 3<sup>rd</sup> Quarter FY2022
- 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



# Release 6/7 Status

- **Release 6 (WAAS Performance and Enhancement Tasks - O&M & TSS Fixes)**
  - Complete in April 2021
- **Release 7A (SIGGEN and Default L5 Compliant MT-0 Message)**
  - Completed development – March 2021
  - Complete validation testing – July 2021
  - Cutover expected Q4 2021
- **Release 7B (GEO 7 Integration)**
  - GEO 7 IOT Complete – January 2021
  - Commenced test and integration activities in June 2021



# WAAS Broadcast L5 message changes

- **Release 7A changes WAAS L5 broadcast**

- Currently WAAS broadcasts a copy of the L1 message on L5
  - This signal is not representative of DFMC SBAS L5 messages and the data should not be used for prototyping efforts
- Release 7A changes WAAS to send an MT-0 message with correct 4x6 L5 preamble and 216-bit data field
  - Designed to the proposed DFMC SBAS L5 message with data field of alternating 1s and 0s. This is a test message and may be changed without prior notification.

- **Timeframe**

- Initially only on GEO-7 (Galaxy 30 (G30)) during integration and test activities for Release 7B
  - Started June 2021
  - Expect to set operational mid 2022.
- Will change GEO-5 and GEO-6 broadcast as part of Release 7A
  - Approximately Q4 CY 2021
- Dates are planned dates and subject to change

# WAAS Dual Frequency Operations (DFO)



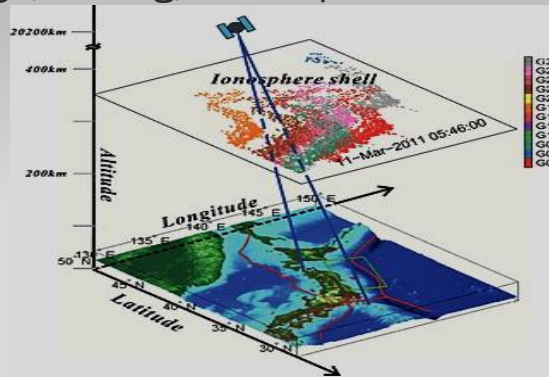
# WAAS Phase 4B

## Dual Frequency Operations

Design, testing, and implementation of DFO

### Software

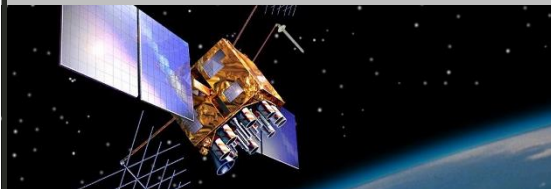
- L5 Message Generation
- Correction & Verification
- AIX to Linux
- L2 to L5



### Hardware

- C&V Hardware
- Obsolete Processor Upgrade
- SIGGEN
- GUS Receivers

## GEO Acquisition & Integration



- GEO 7 Integration
- GEO 8 Acquisition & Integration

## H-ARAIM



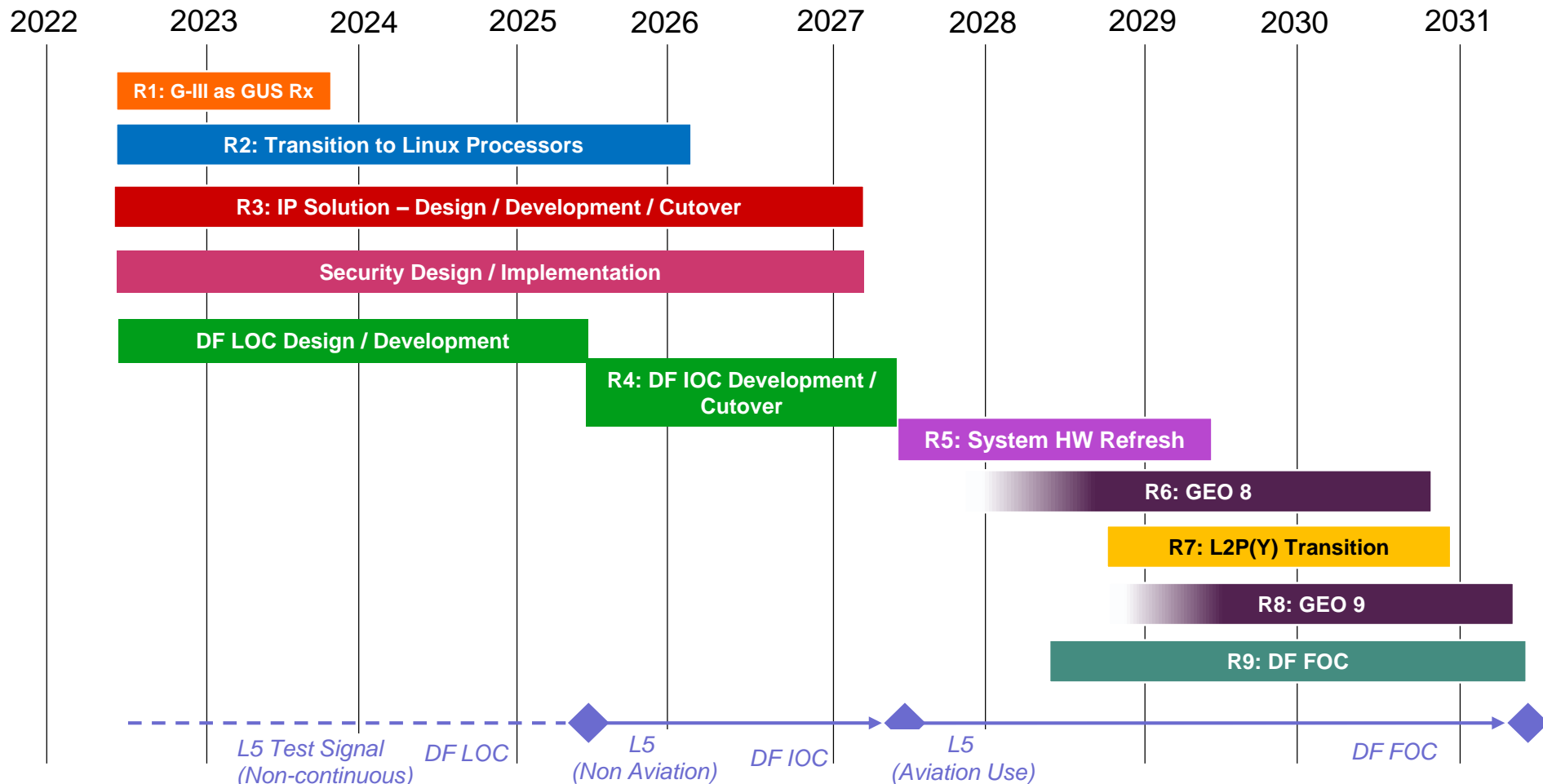
Evaluation & testing of  
Horizontal Advanced Receiver  
Autonomous Integrity  
Monitoring Capabilities

## TDM-IP Transition



Design, testing, and  
implementation of TDM-IP  
transition

# Phase 4B Notional 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 2023 and Full Operational Capability (FOC) in late 2027. FAA plans are for a 24-month transition leading to a WAAS DFO FOC by FY30.**

# 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**

# DF SBAS Ranging

- **WAAS now planning to implement DF SBAS services with DF SBAS ranging**
  - WAAS only augments GPS
  - DF SBAS ranging to ensure DF WAAS meets performance goals at GPS constellation minimum commitment
- **WAAS impact**
  - Preliminary indication that existing WAAS L1 and L5 broadcast signals are sufficient for ranging
  - Some algorithms beyond DF WAAS minimum required to enable DF SBAS ranging capability
    - GEO ephemeris generation for L5 messages
    - Integrity monitoring of the DF GEO range

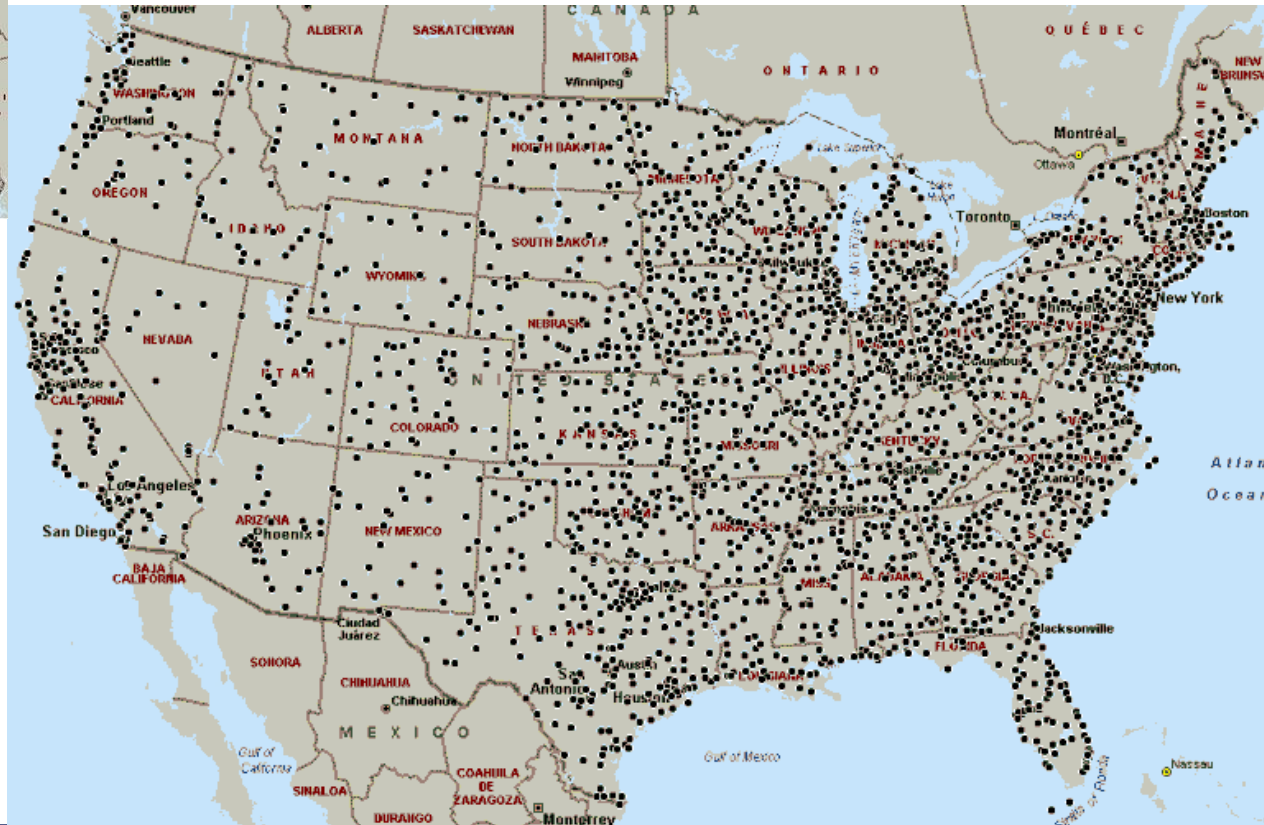
# WAAS Procedures and Avionics



# WAAS LPV/LP Instrument Approaches



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



- As of January 2020 there are currently 1,612 ILS procedures while WAAS has 4,808 LPV/LP procedures published



# WAAS Avionics Equipage Status

- **Over 140,000 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



# GNSS Modernization Status

- **Dual-Frequency Multi-constellation Capability (DFMC)**
  - DFMC SBAS SARPS approved by NSP during Nov 2020 meeting. They will be effective late 2022.
  - RTCA/EUROCAE continue joint meetings for the DFMC MOPS
    - Mar 2022 – planned SC-159 approval of the initial DFMC SBAS MOPS (FDE, no ARAIM capability)
    - Oct 2023 – tentative date for second DFMC SBAS MOPS approval (may include ARAIM, authentication)
- **Advanced RAIM (ARAIM)**
  - Holding bi-weekly safety meetings with EU counterparts
    - Meetings are raising good issues which can be fed back in to requirements development and safety analysis work
  - Developing Functional Hazard Assessment to document consensus on key assumptions
  - Supporting development of SARPs, with technical baseline planned for Nov '21
  - RFC-413 change for GPS CNAV ISM passed engineering review. No clear timeframe when DoD may implement changes.



# 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 began in 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/](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/](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



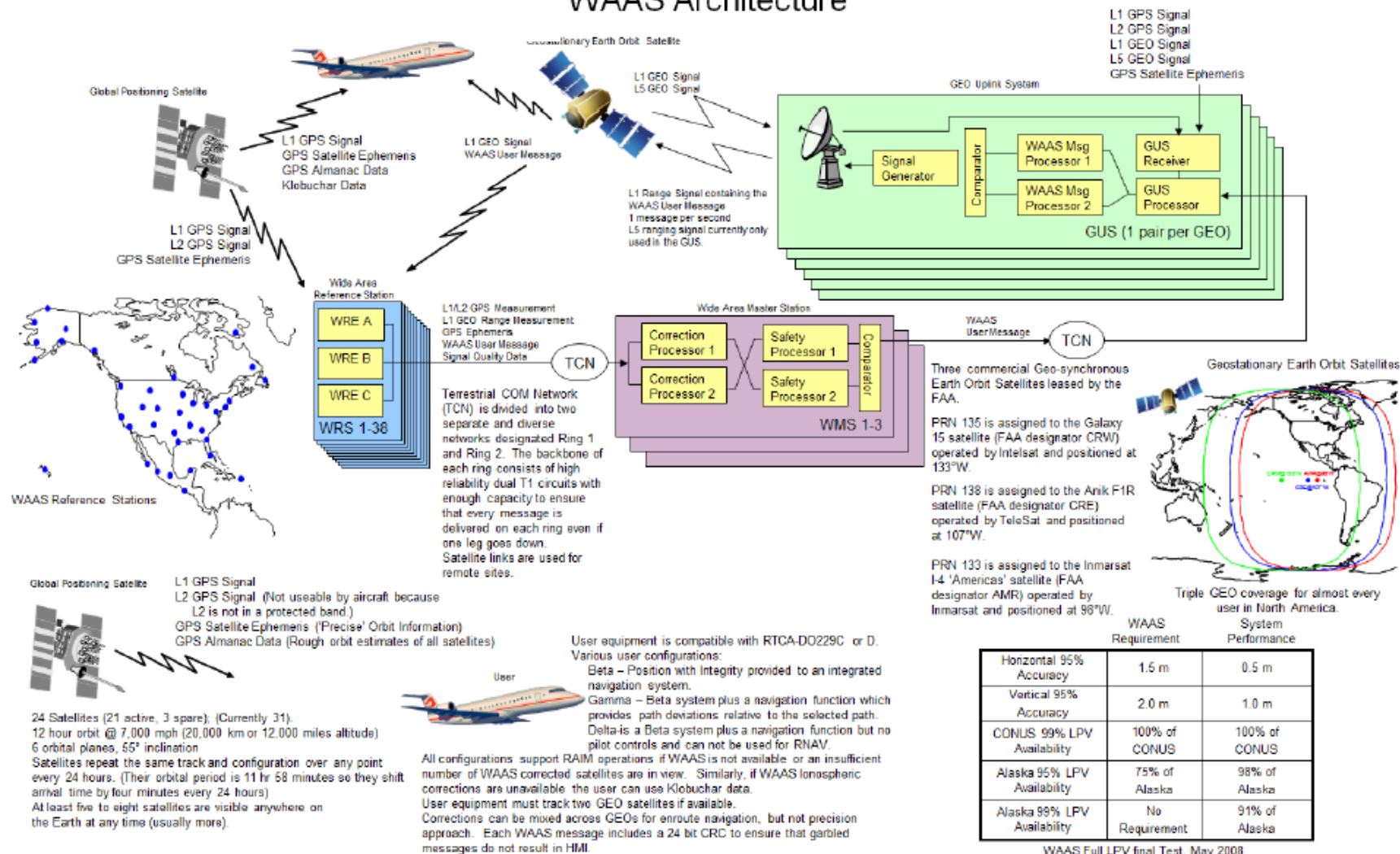


# Infrastructure and Requirements



# WAAS System Architecture

## WAAS 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**

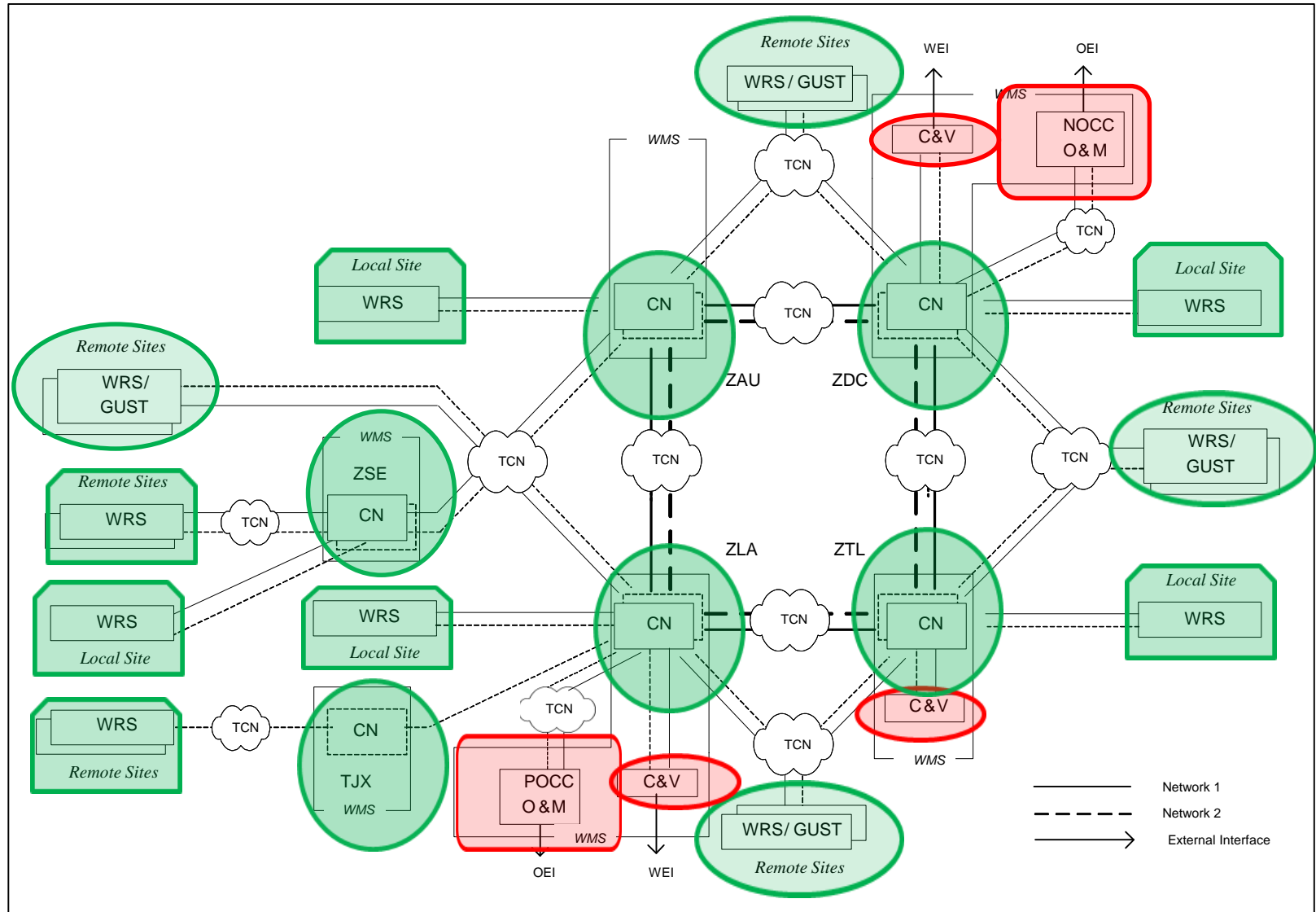


# WAAS System Architecture Operations and Maintenance Subsystem (O&M)

- 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

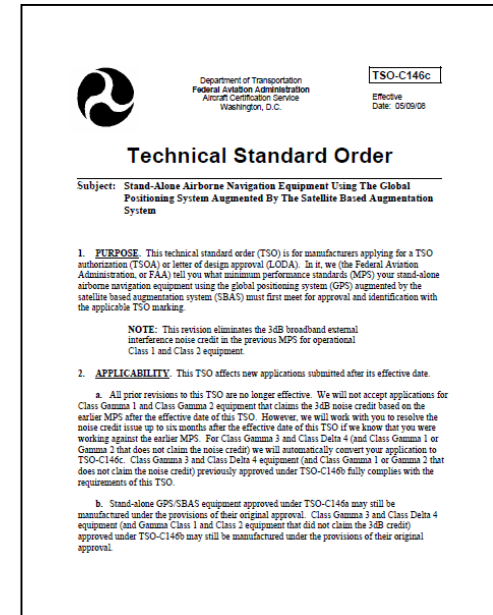
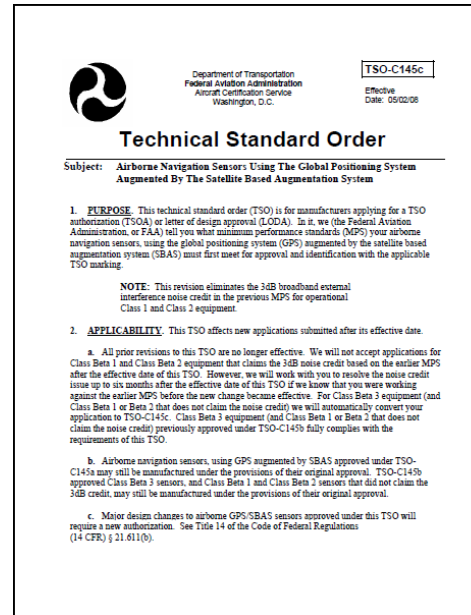
# WAAS GPS Requirements

- **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**

