GPS Augmentation Systems Status

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Federal Aviation Administration (FAA)
September 2009

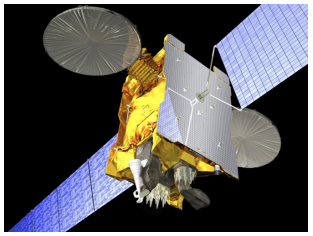
FAA GPS Augmentation Programs

WAAS Architecture

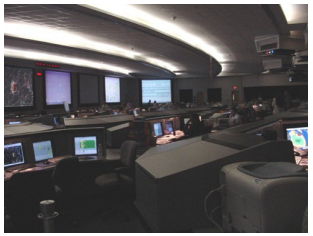
38 Reference Stations

3 Master Stations

4 Ground Earth Stations

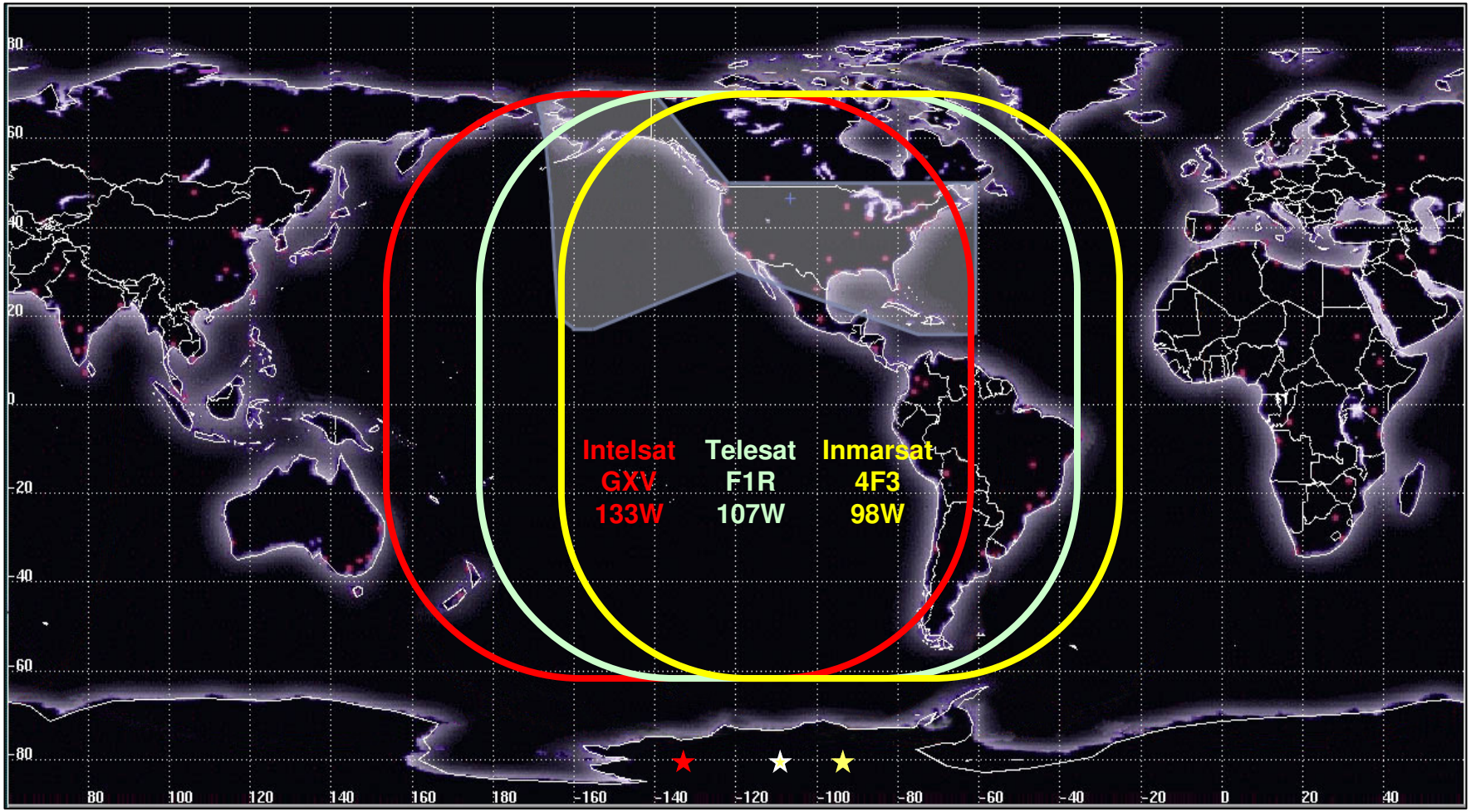


2 Geostationary Satellite Links

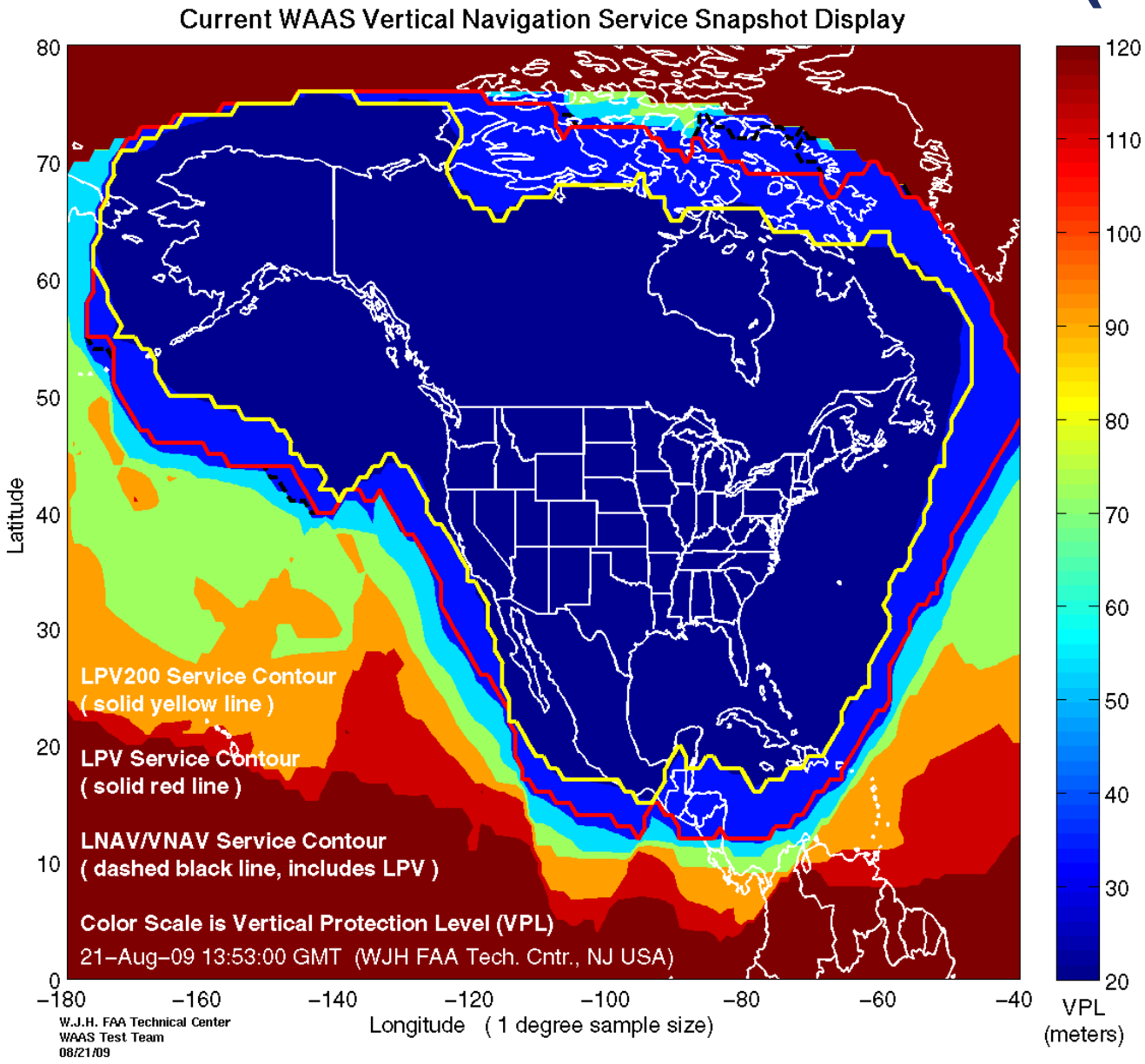


2 Operational Control Centers

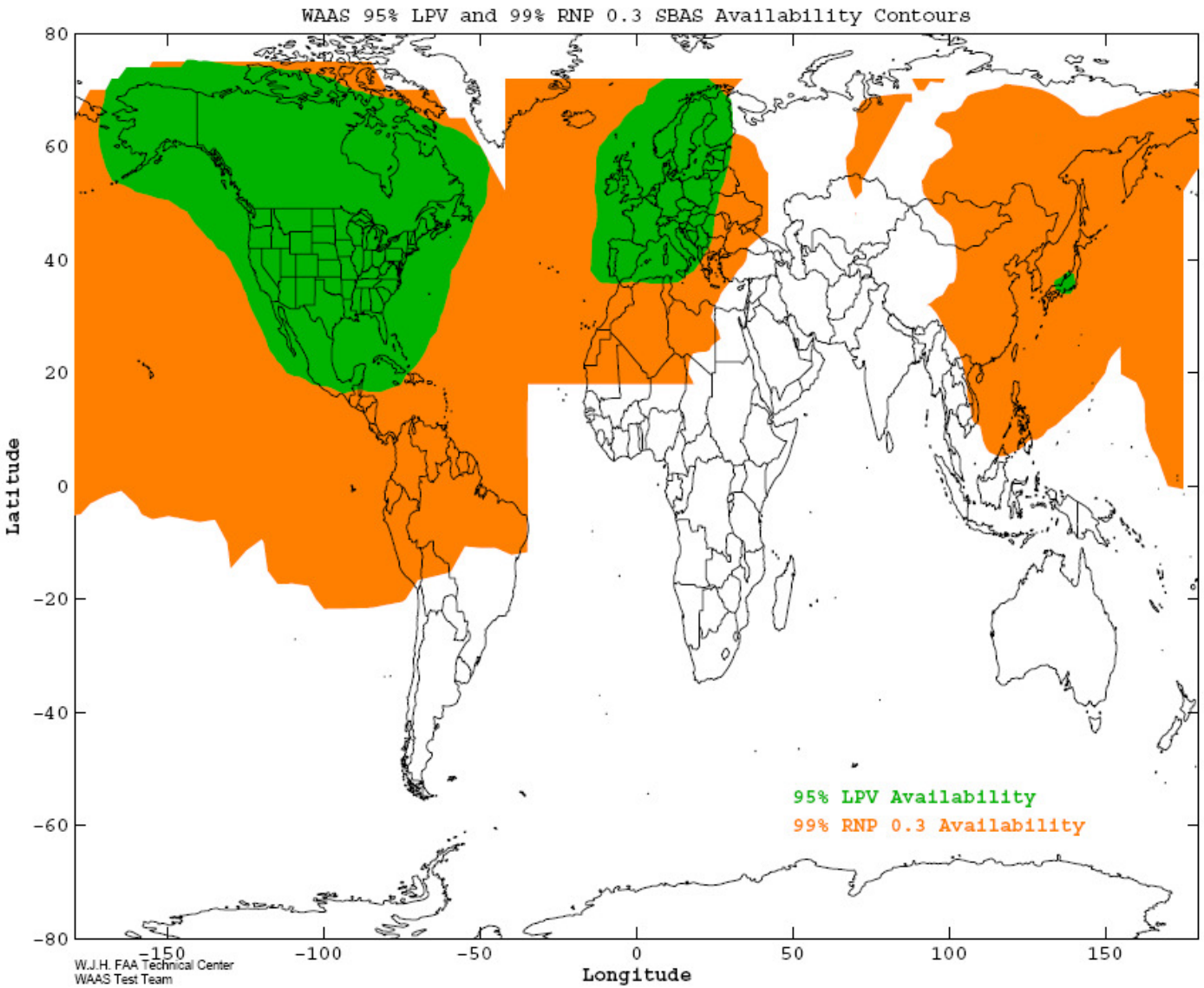
GEO Satellite Coverage Plot



Localizer Performance Vertical (LPV)



Global SBAS Coverage

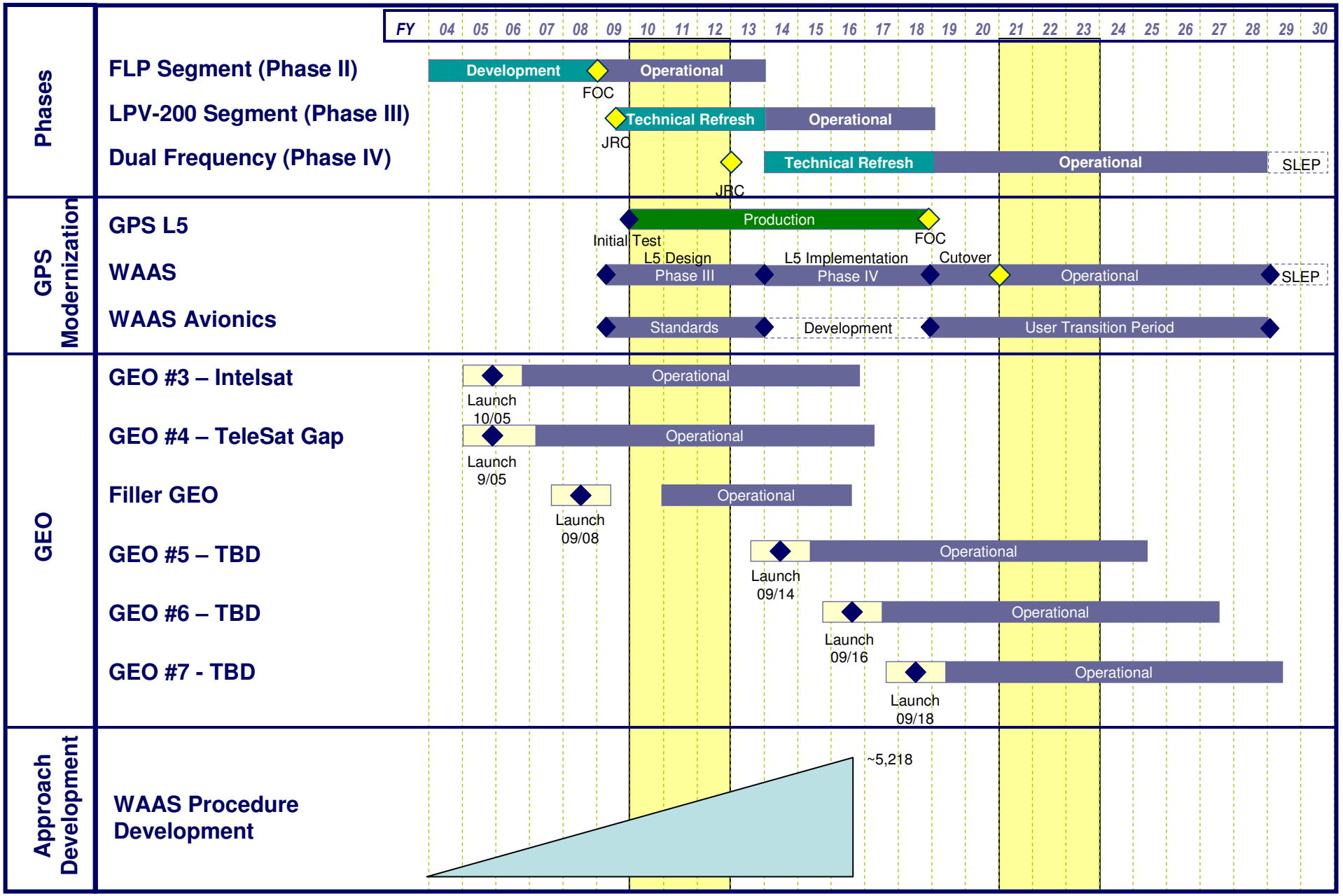


Airports with WAAS Supported Instrument Approaches with Vertical Guidance

As of Aug 27th, 2009

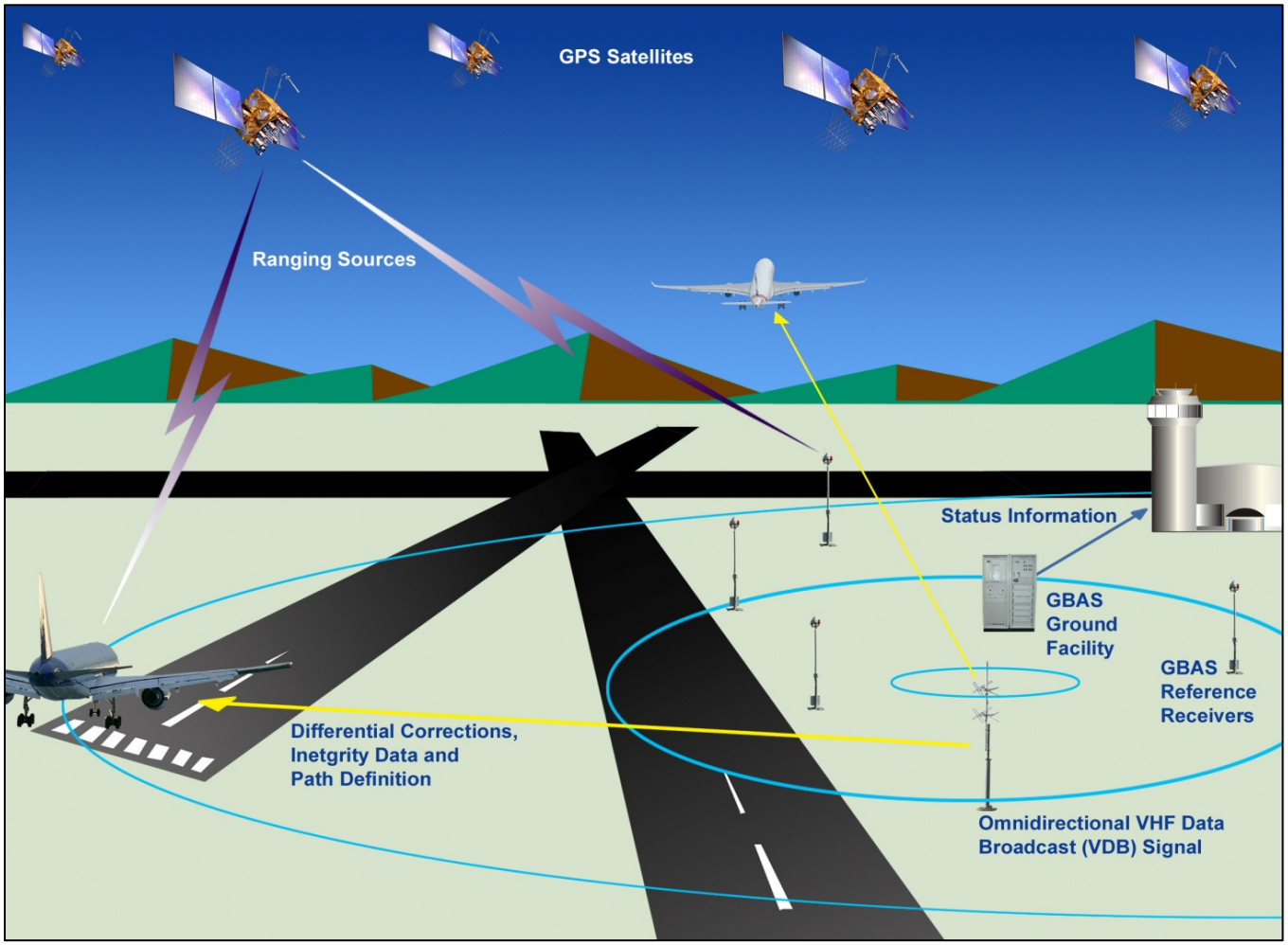
- -1,822 LPVs serving 970 Airports
- 1049 LPVs to non ILS Runways
- LPVs to 678 non-ILS Airports
- 773 LPVs to ILS runways

WAAS Enterprise Schedule



Local Area Augmentation System (LAAS)

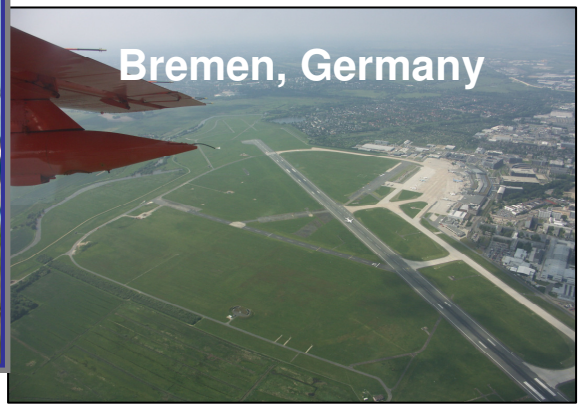
- Precision Approach For CAT- I, II, III
- Multiple Runway Coverage At An Airport
- 3D RNP Procedures (RTA), CDAs
- Navigation for Closely Spaced Parallels
- Super Density Operations



GBAS Pathway Forward

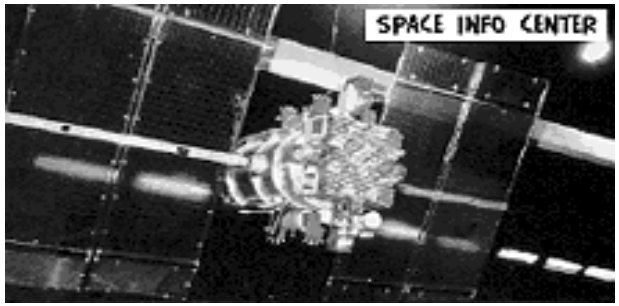
- **Cat-I System Design Approval at Memphis – Complete**
- **Cat-III Validation by - 2010**
- **Cat-III Final Investment Decision by - 2012**

LAAS/GBAS International Efforts



Future Considerations

Galileo (EU)



GLONASS

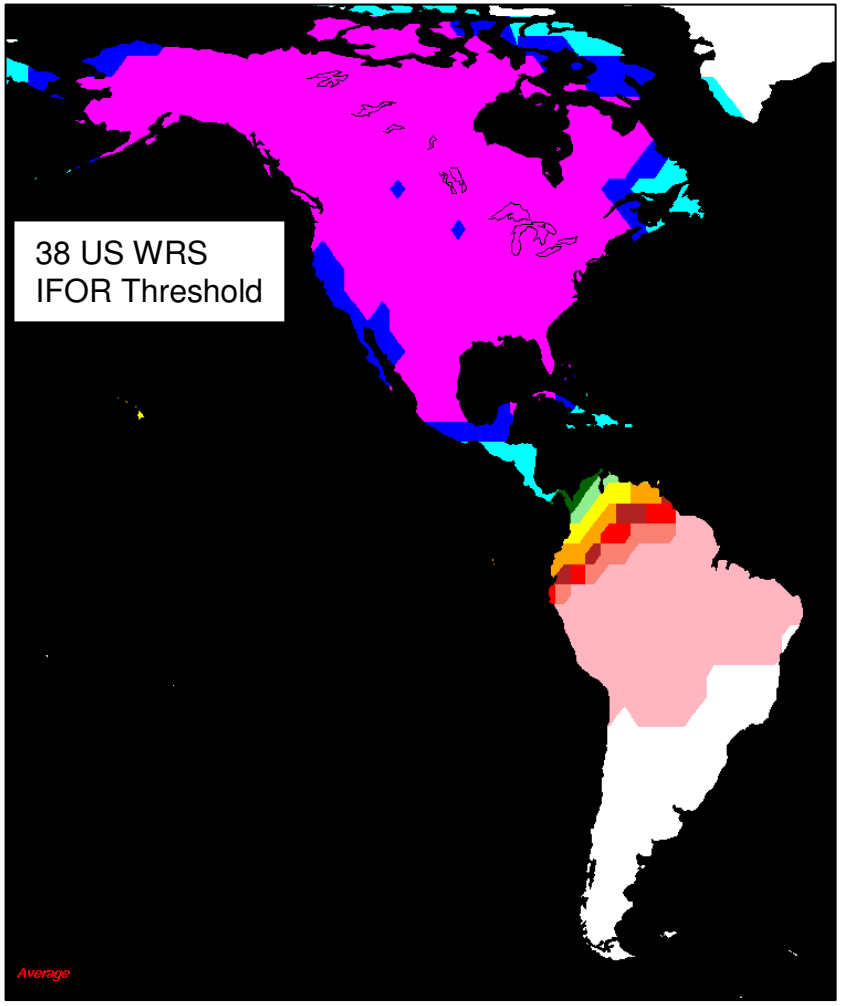
COMPASS

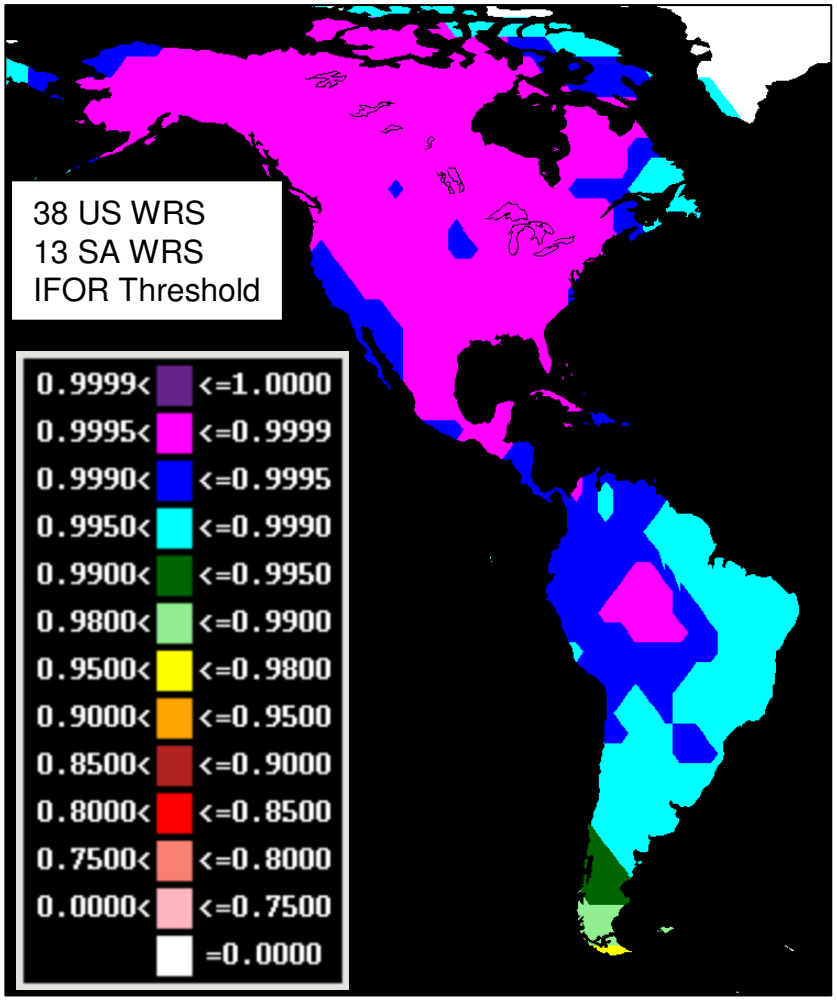
GPS

Two Civil Frequencies

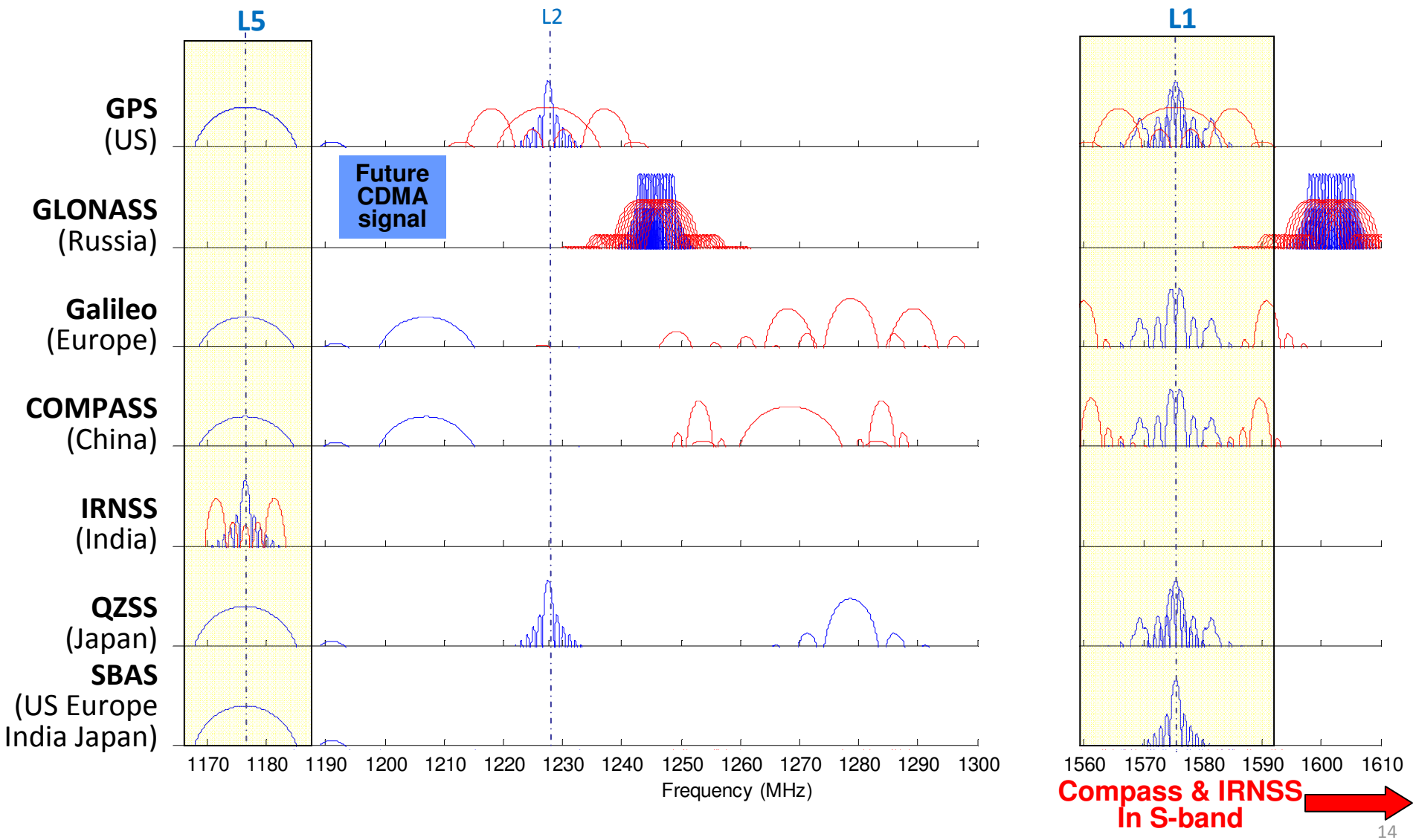
- **The ionosphere creates the largest source of uncertainty affecting today's use of GPS for aviation**
- **When GPS L5 becomes widely available it will be possible for the user receivers to directly remove the ionosphere delay errors**
- **However, the two frequency combination amplifies the effects of other error sources**
  - More satellites tend to reduce the magnitude of the errors

WAAS Dual Frequency User Potential
(No "RDM Constraint")





Current International Signal Plans



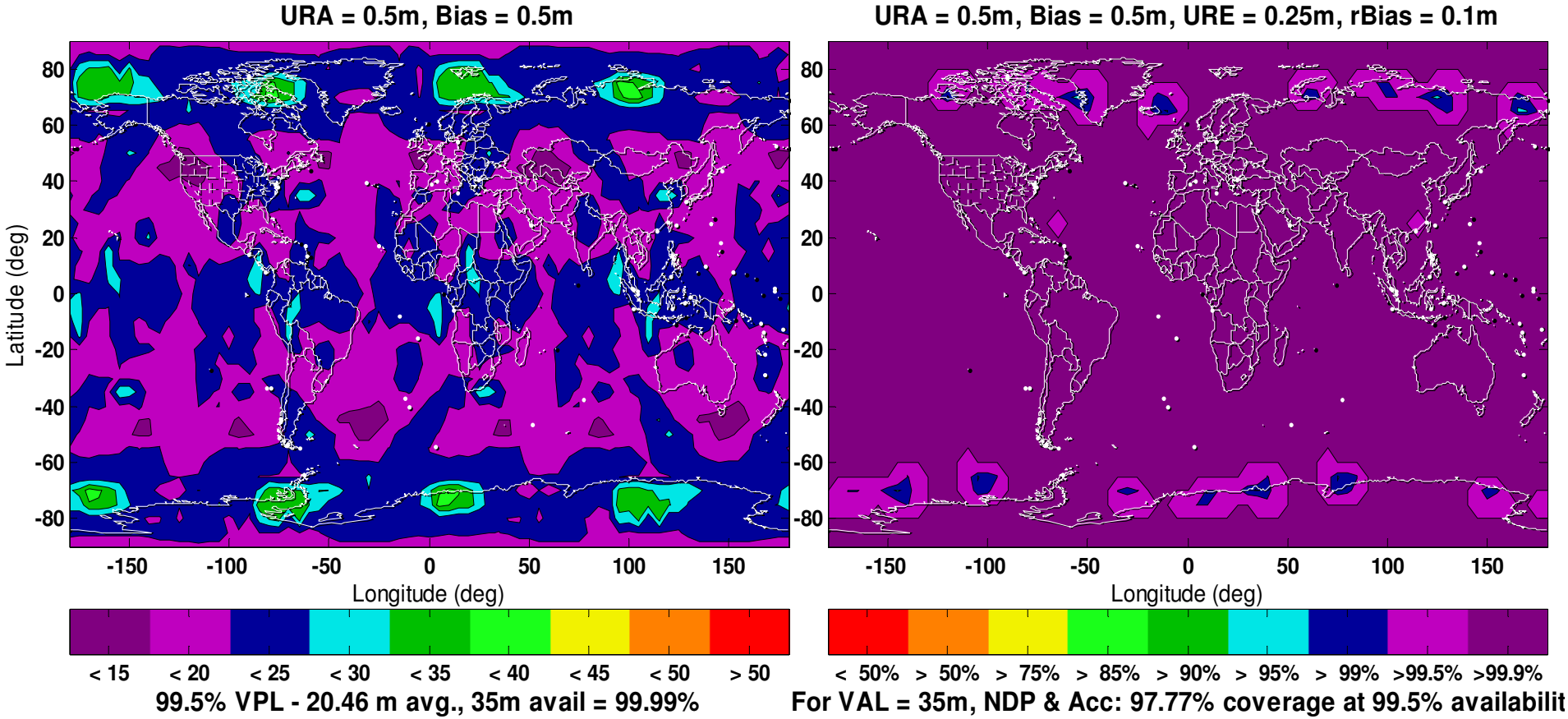
Interoperability of Integrity

- **Interoperability should be a goal not just for GNSS signals, but for integrity provision as well**
  - Augmentation systems already internationally coordinated
- **Different service providers may select different design choices and offer different assurances**
  - However, it is important to establish a common understanding of GNSS performance characteristics and their relationship to provision of integrity
  - Cooperation and transparency are **essential**
- **Combining signals from multiple interoperable constellations can improve performance and availability**
  - Presents opportunity for a truly international solution
  - Not necessarily dependent on any single service provider
  - Seamless global coverage

GNSS Integrity Requirements

- **Assure good nominal signal accuracy**
  - On order 1 m ranging accuracy
- **Assure good availability of signals**
  - Assure most satellites working most of the time
- **Assure good continuity of signals**
  - Less than 10^{-5}/hour probability of unexpected outages
- **Assure low integrity fault rates**
  - On order 10^{-5}/SV/Hour
- **Perform a fault modes and effects analysis**
  - Understand and make transparent potential faults and their effects
  - Assure that multiple satellites do not have consistent errors at the same time
  - Assure limited duration outages (e.g., an hour) of unexpected faults

ARAIM Results for 30 SVs & URA = .5 m



ARAIM currently predicated upon a user update rate of ~ 1hour

Summary

- **WAAS currently providing service to aviation in the U.S. National Airspace System**
- **LAAS system design approval for Category-I completing in September**
- **LAAS activity to continue to Category-II/III**
- **Dual Frequency GNSS Offers Significant Potential for Aviation**

RNP and ADS-B (RAD) Enabled with GNSS PNT

	Navigation (≥ 99.0% Availability)		Surveillance (≥99.9% Availability)			Positioning
	Accuracy (95%)	Containment (10^{-7})	Separation	NACp (95%)	NIC (10^{-7})	GNSS PNT (99.0 – 99.999%)
En Route	*10 nm	20 nm	5 nm	0.1 nm (7)	1 nm (5)	GPS
	*4 nm	8 nm				
	*2 nm	4 nm				
Terminal	*1 nm	2 nm	3 nm	0.05 nm (8)	0.6 nm (6)	SBAS
LNAV	*0.3 nm	0.6 nm				
RNP (AR)	*0.1 nm	**0.1 nm	2.5 nm DPA	0.05 nm (8)	0.2 nm (7)	
LPV	16m/4m	40m/50m	2.5 nm DPA	0.05 nm (8)	0.2 nm (7)	
LPV-200	16m/4m	40m/35m				
GLS Cat-I	16m/4m	40m/10m	2.0 nm IPA	121 m (8)	0.2 nm (7)	GBAS
GLS Cat-III	16m/2m	40m/10m				

*Operational requirements are defined for total system accuracy, which is dominated by fight technical error. Position accuracy for these operations is negligible.

** Containment for RNP AR is specified as a total system requirement; value representative of current approvals.

Dependent Parallel Approach (DPA)
Independent Parallel Approach (IPA)

Surveillance Integrity Level (SIL)
Navigation Integrity Category (NIC)

Navigation Accuracy Category for Position (NACp)