Satellite Navigation Program Status

Presented To: CGSIC

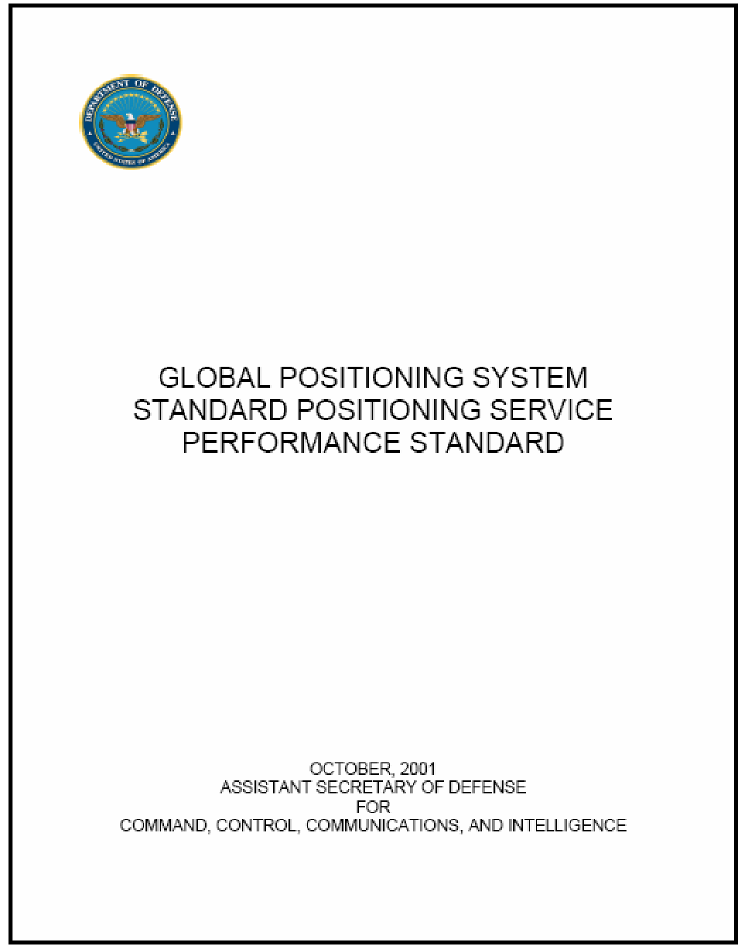
Leo Eldredge, GNSS Program Manager
Federal Aviation Administration (FAA)

Overview

- Wide Area Augmentation System (WAAS) Status
- GNSS Evolutionary Architecture Study (GEAS)
- Local Area Augmentation System (LAAS) Status

USG Commitment to GPS

- **Based on a Constellation With 24 Nominal Plane/Slot Positions**
- **24 Operational Satellites 95% (averaged over any day)**
  - All 24 may not be operating
  - Not All SVs May Be Located in Primary Orbit Slots
- **21 of 24 Plane/Slot Positions Must Be Set Healthy and Transmitting a Navigation Signal With 98% Probability (averaged yearly)**
- **6 Meter User Range Error (URE)**



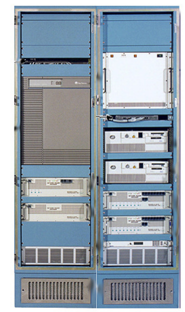
GLOBAL POSITIONING SYSTEM
STANDARD POSITIONING SERVICE
PERFORMANCE STANDARD

OCTOBER, 2001
ASSISTANT SECRETARY OF DEFENSE
FOR
COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE

FAA Satellite Navigation Program

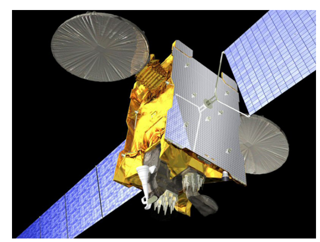
WAAS Architecture

38 Reference Stations

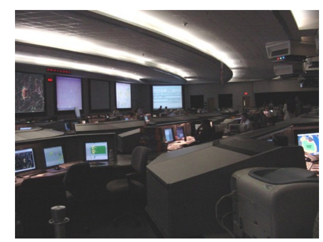


3 Master Stations

4 Ground Earth Stations

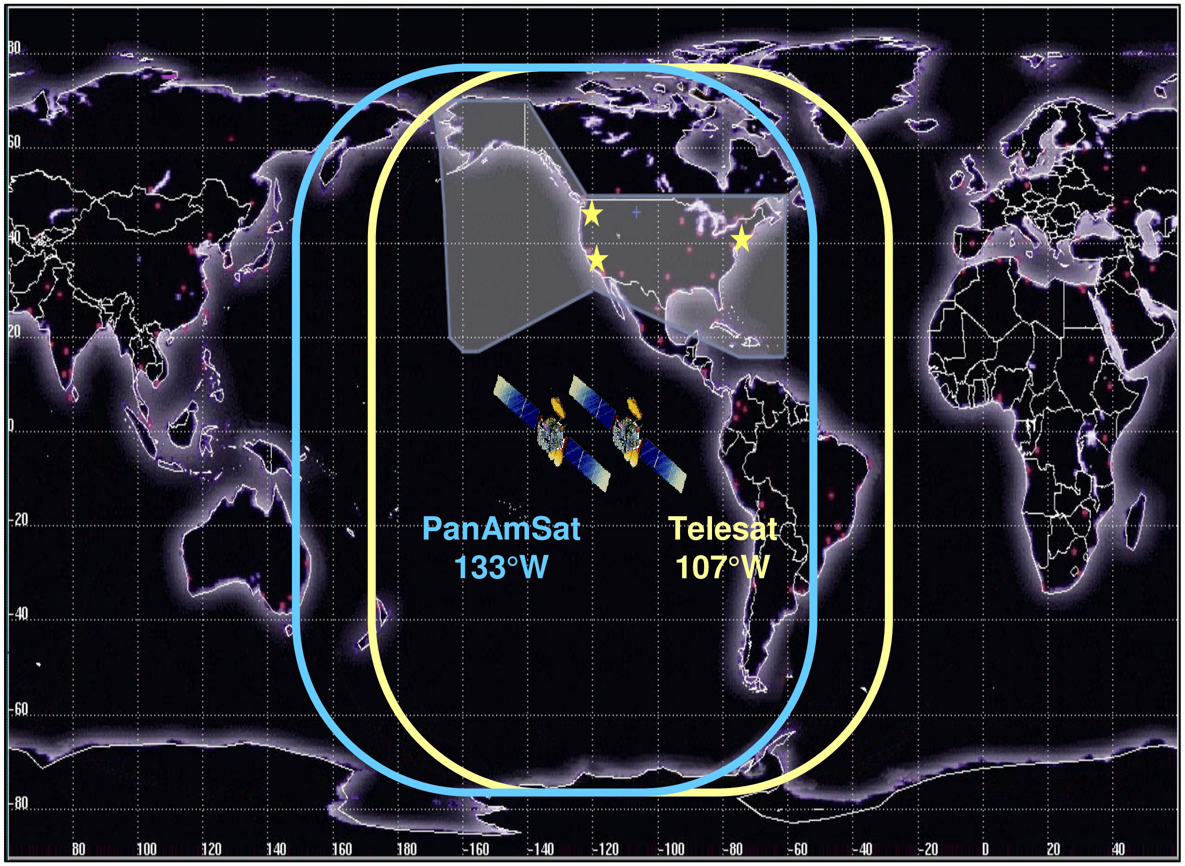


2 Geostationary Satellite Links

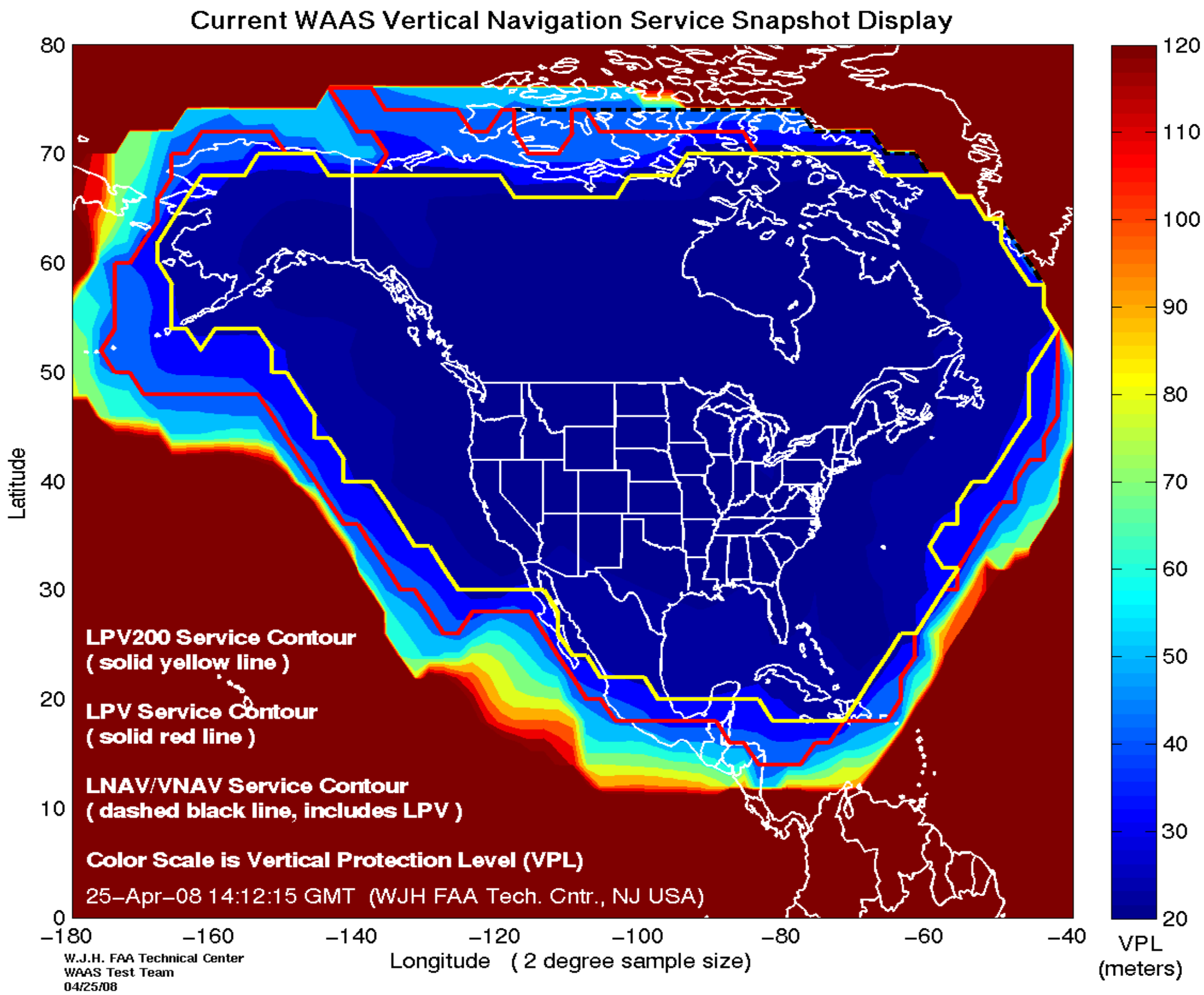


2 Operational Control Centers

Geostationary Satellites (GEO)



Localizer Precision Vertical (LPV) Coverage

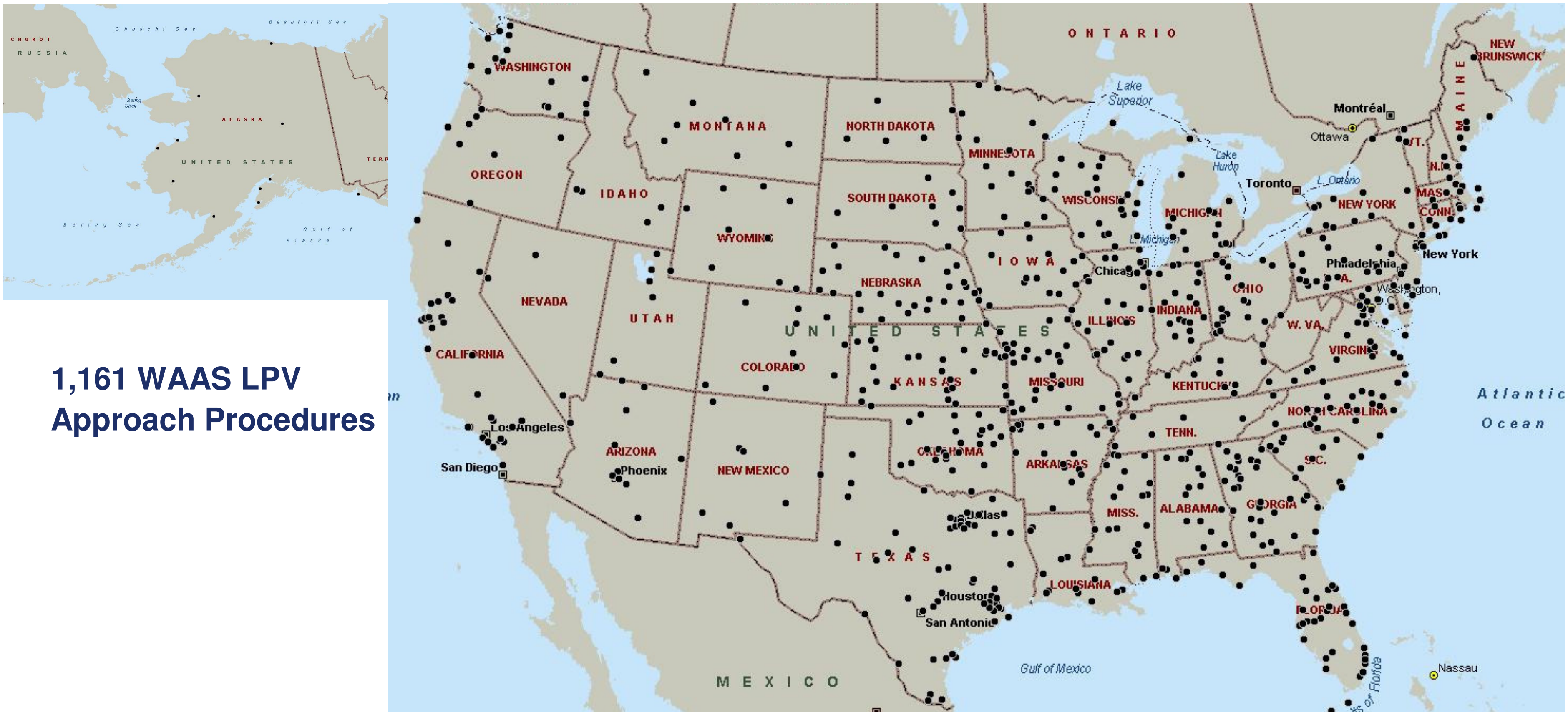


WAAS Avionics Status

- **General Aviation**
  - Over 33,000 Units Sold
  - Increasing at ~1000 Units Per Month
  - New Products Coming to Market in Late 2008
- **Business & Regional Aircraft**
  - Over 500 Units Sold Since 2007
  - Two Additional Products Coming to Market in Late 2008
  - Cessna CJs Delivering with WAAS Avionics in 2009
  - Acceptance Rates Should Increase Significantly in 2009
- **Air Carrier & Cargo Aircraft**
  - Southwest Airlines Equipping 200 Boeing 737s
  - Federal Express Has Equipped 253 Caravan Aircraft
  - Horizon Airlines Equipping 48 Bombardier Aircraft
- **Helicopter Aircraft Implementing WAAS**
  - Significant Growth Projected for First Responders
- **WAAS Avionics are Interoperable with Other SBASs**

WAAS Approach Procedures

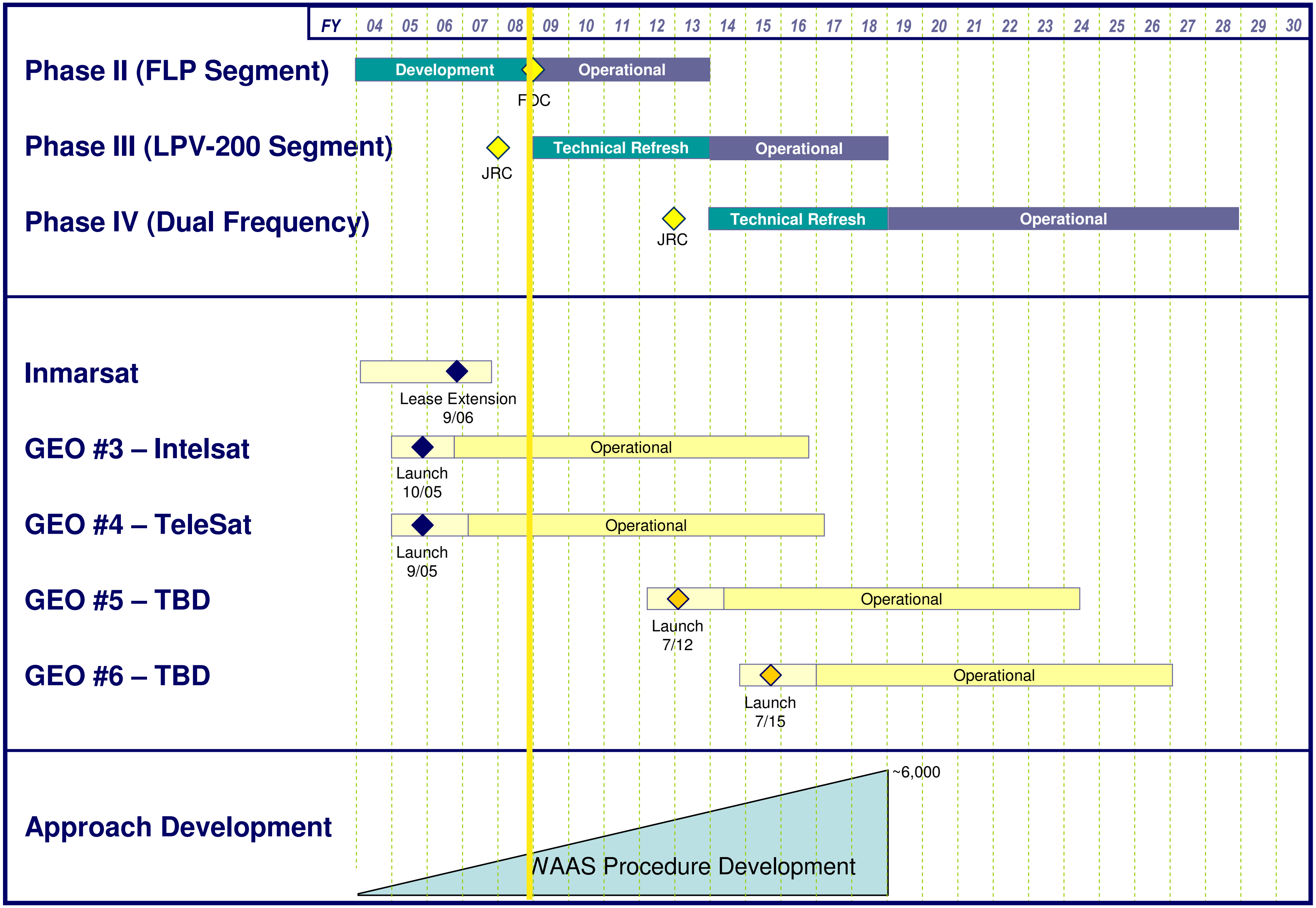
- Projected to Exceed Legacy Systems, eg. ILS By Sep 2008 -



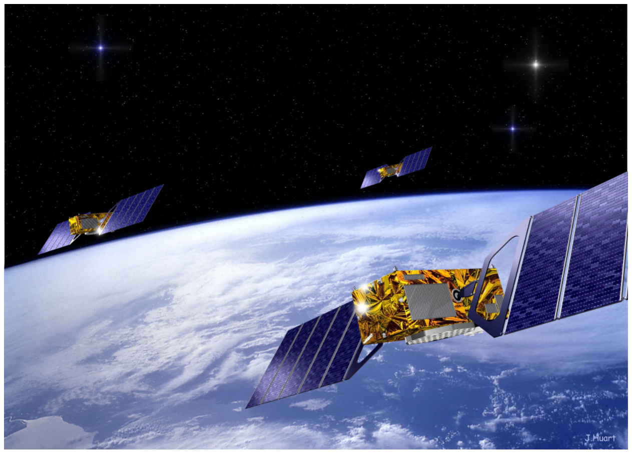
1,161 WAAS LPV Approach Procedures

WAAS Procedures to be Published to All Instrument Runways in the NAS by 2018

WAAS Enterprise Schedule

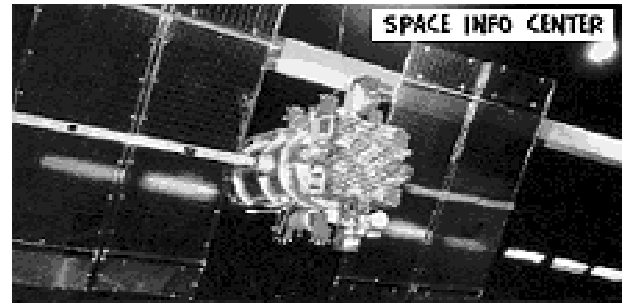


Future Considerations



Galileo (EU)

Other?



GLONASS

GPS

Future Considerations

- **GNSS Modernization**
  - GPS Dual Frequency (L1/L5) Service Provides Foundation
  - Potential for Larger GNSS or Use of Multiple GNSS Constellations
  - User Equipment Standards Development for New Signals
- **WAAS Dual Frequency Upgrade**
  - Determine Appropriate Level of Dual Frequency Integration Required to Maximize Benefit With Minimum Impact
- **Established GNSS Evolutionary Architecture Study (GEAS) to Investigate Long Range Planning for Dual Frequency GPS**
  - Develop Architectural Alternatives to Provide Worldwide LPV-200 Service in the ~2020-2030 Timeframe
  - Leverage Lessons Learned on WAAS/LAAS to Identify the Best Architecture Alternative to Meet Aviation Integrity Requirements
  - Participation With The GPS Wing, DoD National Security Space Office (NSSO), DOT Research & Innovative Technology Administration (RITA), and the Joint Planning & Development Office (JPDO) for NextGen

GEAS Panel

Deane Bunce (Co-Chair)	FAA ATO-W
Per Enge (Co-Chair)	Stanford University
Leo Eldredge	FAA ATO-W
Deborah Lawrence	FAA ATO-W
Calvin Miles	FAA ATO-W
Kevin Bridges	FAA AVS
Hamza Abduselam	FAA AVS
Tom McHugh	FAA ATO-P
Bill Wanner	FAA ATO-P
David Schoonenberg	NSSO
Mike David	NSSO
Karen Van Dyke	RITA/Volpe
Ed Sigler	GPS TAC
Tim Murphy	Boeing Aircraft

Geoff Harris	G-Wing/Aerospace
Karl Shallberg	GREI
Boris Pervan	IIT
John Dobyne	G-WIng/ARINC
Karl Kovach	G-Wing/Aerospace
Eric Atschuler	Sequoia Research
Chris Hegarty	MITRE
Young Lee	MITRE
JP Fernow	MITRE
Frank Van Graas	Ohio University
Juan Blanch	Stanford University
Todd Walter	Stanford University
Pat Reddan	Zeta Associates
AJ Van Dierendonck	Zeta Associates

Determination of Integrity

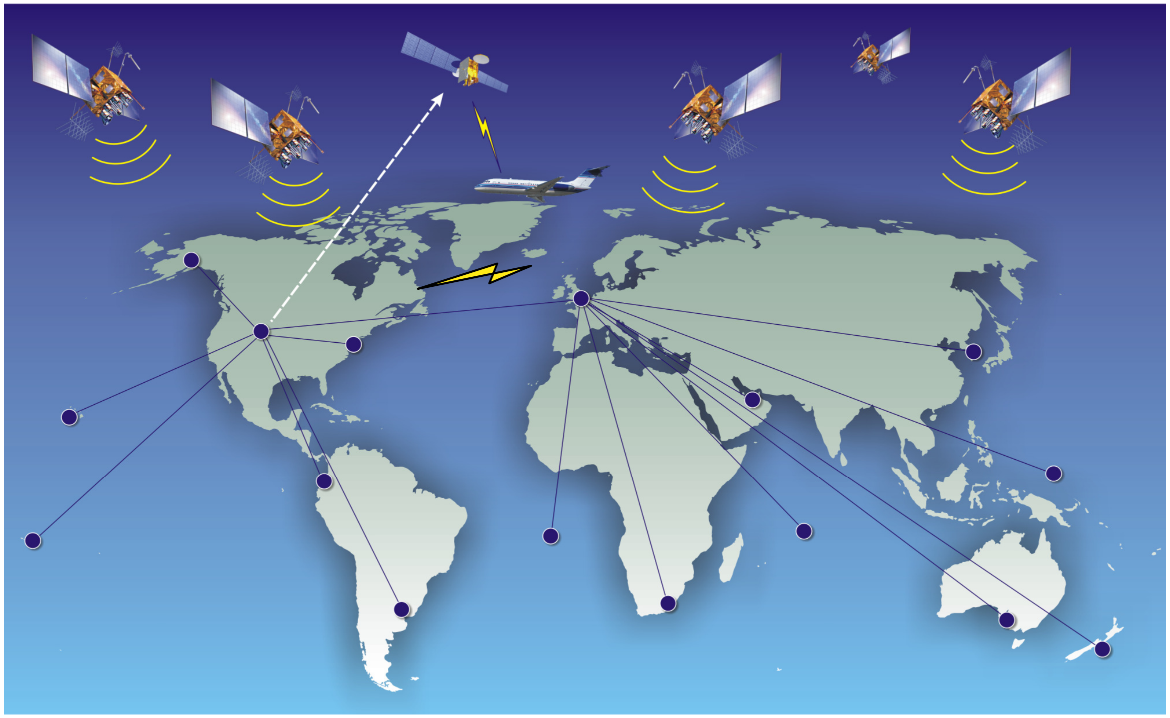
- **Aircraft Based**
  - Integrity is determined on board the aircraft using redundant ranging sources or sensors
  - e .g. RAIM, AIME, …
- **Ground Based**
  - Integrity determined external to User
  - e.g. SBAS, GBAS, GRAS, GNSS Monitoring, …
- **Satellite Based**
  - Determination of integrity is made on board the satellite using redundant components
  - e.g. Clock Monitoring (TKS), Signal Deformation Monitoring (SDM)

Layered Approach

- **Ultimate integrity architecture will combine threat detection at all elements**
  – Satellite
    - Best time to alarm (TTA) for rapid clock & digital errors
  – Ground
    - Necessary for absolute accuracy
  – Aircraft offers
    - Direct integrity monitoring by user
    - Mitigating ionosphere delays and local errors
- **Alternatives trade the degree of aircraft based augmentation (ABAS), constellation geometric robustness, user range accuracy, and augmentation**
- **Need to find best trade for cost, TTA, integrity performance and constellation dependency**

GNSS integrity Channel (GIC)

- **Key Feature:**
  - Integrity Determination External to the User
- **Key Enabler**
  - Rapid Messaging Rate
  - TTA of 6.2 Sec
- **Key Benefit**
  - Redundant Ranging Signals Not Required
- **Key Challenge**
  - Meeting TTA

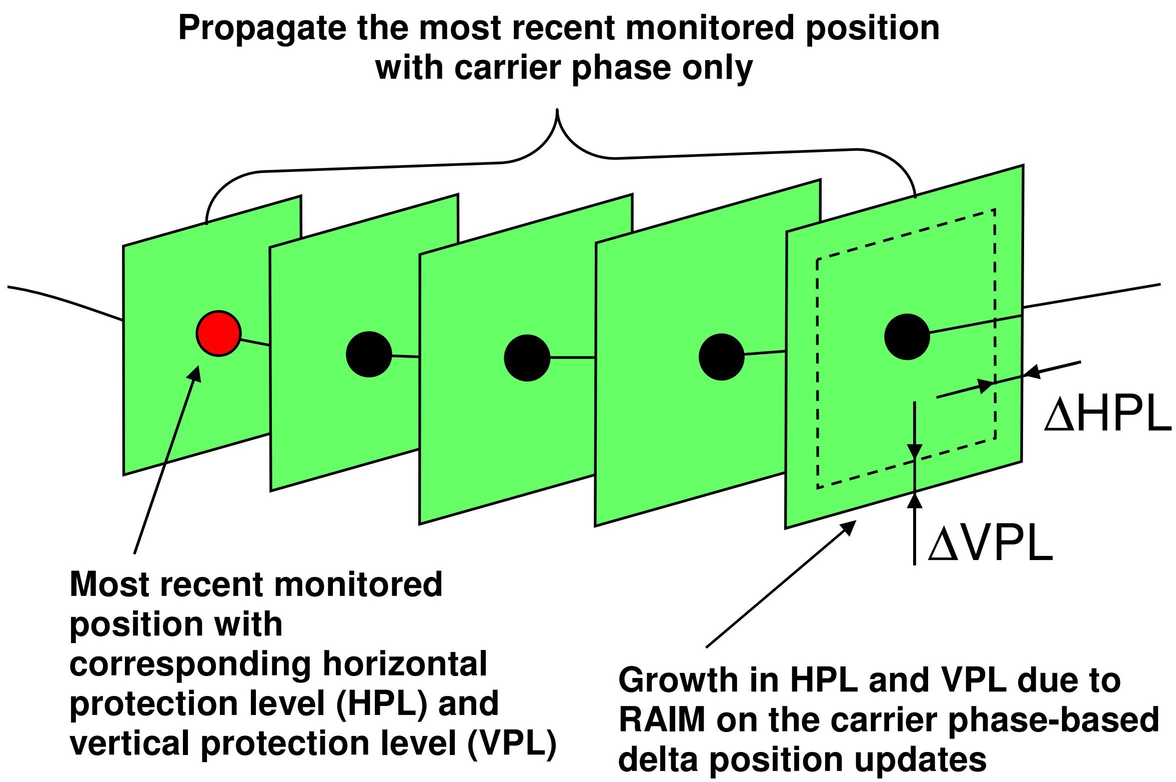


Time-To-Alert (TTA)

- A significant challenge with a worldwide system (i.e., Galileo or GPS-IIIC integrity) is meeting the 6.2 second TTA requirement
- WAAS is just able to meet TTA with its North American network
- A different approach is required for worldwide system
- Allocate the TTA requirement to the aircraft or satellite fault detection

Relative RAIM: *Range Rate Residuals*

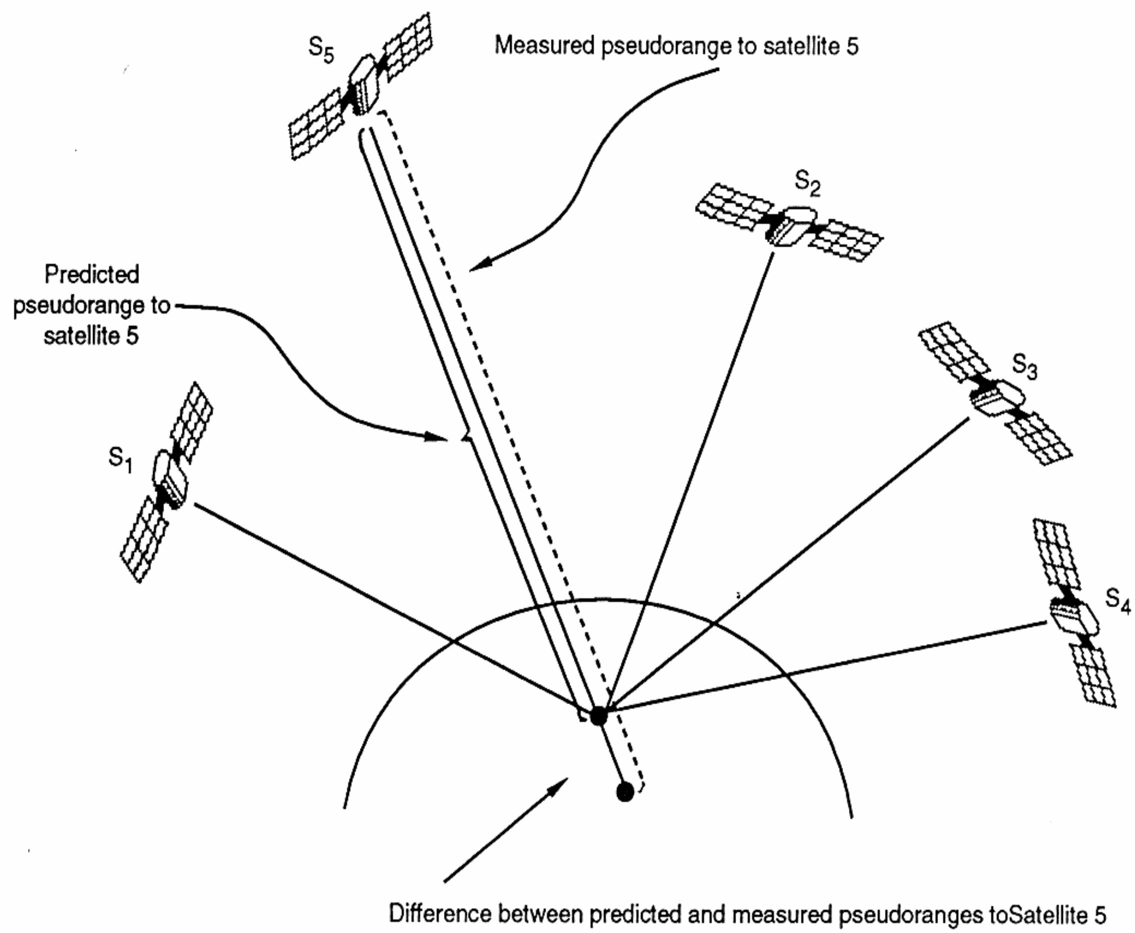
- **Key Feature:**
  - Real-Time Integrity Determination By User Using Carrier Phase Approach
- **Key Enabler**
  - External Monitoring
  - Redundant Geometry
- **Key Benefit**
  - TTA Latency Relaxed to Minutes



From Prof. van Graas, Ohio University

Absolute RAIM

- **Key Feature:**
  - Real-Time Integrity Determination by the User (ABAS)
- **Key Enabler:**
  - Redundant Ranging Sources
  - 30 or More SVs
- **Key Benefit**
  - Latency Relaxed to Hours



Preliminary Results

	Constellation					
Architecture	24 minus 1	24	27 minus 1	27	30 minus 1	30
GIC	86.6%	100%	97.8%	100%	100%	100%
RRAIM with 30 s coasting	81.2%	99.4%	96.8%	100%	100%	100%
RRAIM with 60 s coasting	74.4%	98.5%	92.8%	100%	100%	100%
RRAIM with 300 s coasting	28.0%	76.1%	52.3%	99.6%	93.9%	100%
ARAIM	7.80%	44.7%	30.6%	94.1%	90.5%	100%

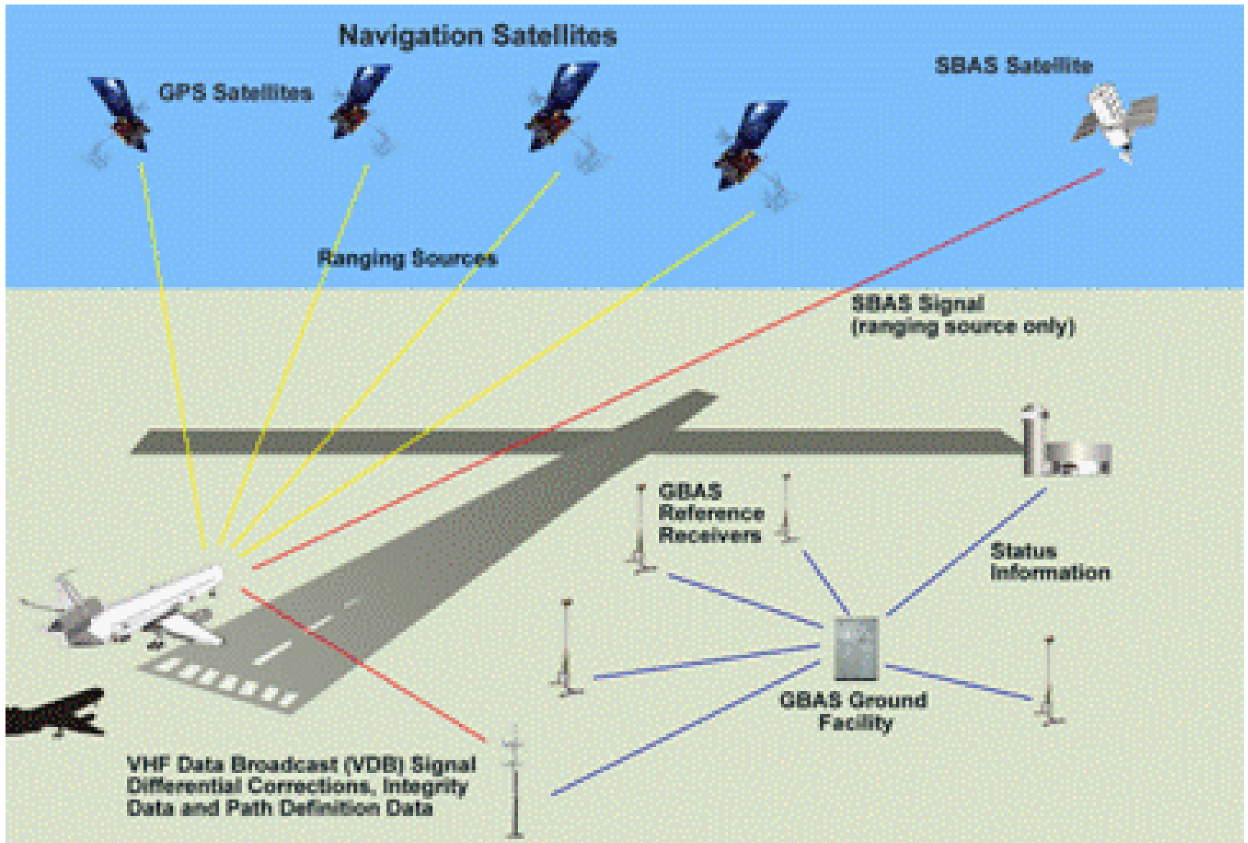
Note: Predictions Valid for WAAS-Like Integrity Assured URA's of 1 Meter or Less

GEAS Next Steps

- **Phase 1 Report – Completed**
  - http://gps.faa.gov
- **Future Work Plan**
  - WAAS Dual Frequency Architecture
    - Detailed Analysis and Design Leading to Implementation of the Dual Frequency Architecture for WAAS by 2018
  - Dual Frequency GNSS
    - Continued Investigation of ARAIM and RRAIM
  - Support to GPS-III/OCX Integrity & Continuity Assurance Activities
    - Provide Assistance to GPS Wing Program Office Team

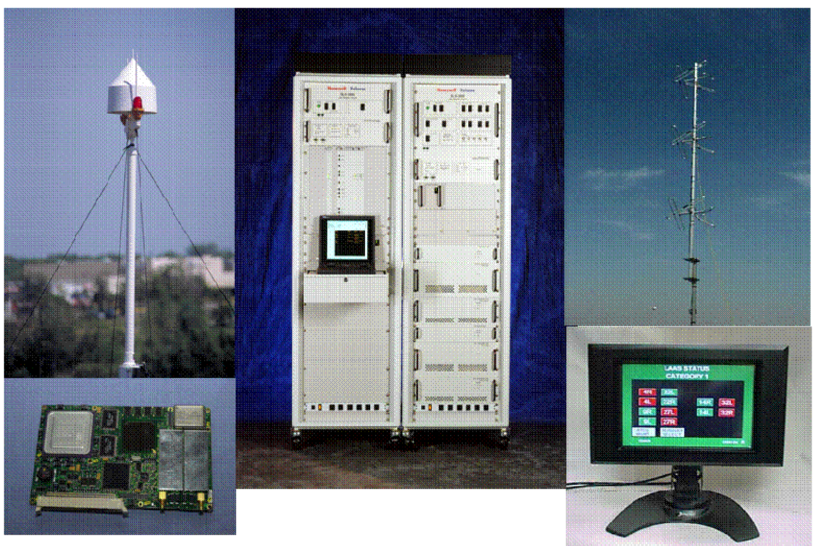
Local Area Augmentation System (LAAS)

- 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

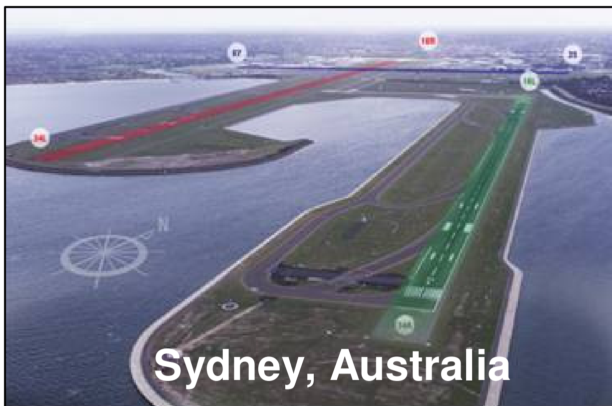


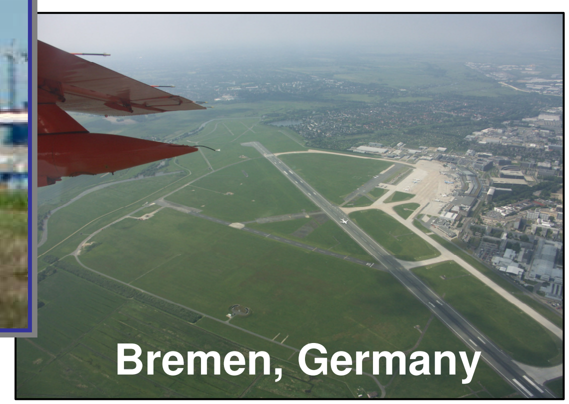
GBAS Pathway Forward

- **Cat-I System Design Approval (SDA) at Memphis - 2008**
- **Cat-III Prototype Validation by - 2010**
- **Cat-III SDA Approval by - 2012**
- **Evaluating Potential to Leverage Resources with DoD Joint Precision Approach Landing System (JPALS)**



LAAS/GBAS International Efforts





Summary

- The WAAS Program Has Matured Through Development and is Rapidly Progressing Through Operational Implementation
- GEAS Investigating Future Architecture Alternatives for WAAS and GNSS
- The First Certified LAAS is Expected In Late 2008
- LAAS is Expected to Achieve Cat-III By 2012
- Combined LAAS/JPALS Opportunities are Being Investigated

Questions

http://gps.faa.gov