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)
FAA Satellite Navigation Program

WAAS

LAAS

Federal Aviation Administration
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

<table>
<thead>
<tr>
<th>Phase II (FLP Segment)</th>
<th>Development</th>
<th>Operational</th>
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</thead>
<tbody>
<tr>
<td>Phase III (LPV-200 Segment)</td>
<td>Technical Refresh</td>
<td>Operational</td>
</tr>
<tr>
<td>Phase IV (Dual Frequency)</td>
<td>Technical Refresh</td>
<td>Operational</td>
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#### Inmarsat

- **GEO #3 – Intelsat**
  - Lease Extension: 9/06
  - Launch: 10/05
  - Operational

- **GEO #4 – TeleSat**
  - Launch: 9/05
  - Operational

- **GEO #5 – TBD**
  - Launch: 7/12
  - Operational

- **GEO #6 – TBD**
  - Launch: 7/15
  - Operational

#### Approach Development

- NAAS Procedure Development
  - ~6,000
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

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Deane Bunce (Co-Chair)</td>
<td>FAA ATO-W</td>
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<tr>
<td>Per Enge (Co-Chair)</td>
<td>Stanford University</td>
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<td>Leo Eldredge</td>
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<td>Deborah Lawrence</td>
<td>FAA ATO-W</td>
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<td>Calvin Miles</td>
<td>FAA ATO-W</td>
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<tr>
<td>Kevin Bridges</td>
<td>FAA AVS</td>
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<tr>
<td>Hamza Abduselam</td>
<td>FAA AVS</td>
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<tr>
<td>Tom McHugh</td>
<td>FAA ATO-P</td>
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<td>Bill Wanner</td>
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<td>David Schoonenberg</td>
<td>NSSO</td>
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<td>Mike David</td>
<td>NSSO</td>
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<tr>
<td>Karen Van Dyke</td>
<td>RITA/Volpe</td>
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<td>Ed Sigler</td>
<td>GPS TAC</td>
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<tr>
<td>Tim Murphy</td>
<td>Boeing Aircraft</td>
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<td>Geoff Harris</td>
<td>G-Wing/Aerospace</td>
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<td>Karl Shallberg</td>
<td>GREI</td>
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<td>Boris Pervan</td>
<td>IIT</td>
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<td>John Dobyne</td>
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<td>Karl Kovach</td>
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<tr>
<td>Eric Atschuler</td>
<td>Sequoia Research</td>
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<td>Chris Hegarty</td>
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<td>Young Lee</td>
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<td>JP Fernow</td>
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<tr>
<td>Frank Van Graas</td>
<td>Ohio University</td>
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<tr>
<td>Juan Blanch</td>
<td>Stanford University</td>
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<tr>
<td>Todd Walter</td>
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<tr>
<td>Pat Reddan</td>
<td>Zeta Associates</td>
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<tr>
<td>AJ Van Dierendonck</td>
<td>Zeta Associates</td>
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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-III C 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

<table>
<thead>
<tr>
<th>Constellation</th>
<th>24 minus 1</th>
<th>24</th>
<th>27 minus 1</th>
<th>27</th>
<th>30 minus 1</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GIC</strong></td>
<td>86.6%</td>
<td>100%</td>
<td>97.8%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
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<tr>
<td><strong>RRAIM with 30 s coasting</strong></td>
<td>81.2%</td>
<td>99.4%</td>
<td>96.8%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>RRAIM with 60 s coasting</strong></td>
<td>74.4%</td>
<td>98.5%</td>
<td>92.8%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>RRAIM with 300 s coasting</strong></td>
<td>28.0%</td>
<td>76.1%</td>
<td>52.3%</td>
<td>99.6%</td>
<td>93.9%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>ARAIM</strong></td>
<td>7.80%</td>
<td>44.7%</td>
<td>30.6%</td>
<td>94.1%</td>
<td>90.5%</td>
<td>100%</td>
</tr>
</tbody>
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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](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

Rio De Janeiro, Brazil

Agana, Guam

Malaga, Spain

Sydney, Australia

Frankfurt, Germany

Bremen, Germany
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