GPS Augmentation Systems Status

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Federal Aviation Administration (FAA)
September 2009
FAA GPS Augmentation Programs

WAAS

Enroute Oceanic
Enroute Domestic
Terminal
Approach
Surface

LAAS

Institute of Navigation (ION)
September 2009
WAAS Architecture

- 38 Reference Stations
- 3 Master Stations
- 4 Ground Earth Stations
- 2 Geostationary Satellite Links
- 2 Operational Control Centers
GEO Satellite Coverage Plot
Airports with WAAS Supported Instrument Approaches with Vertical Guidance

As of Aug 27th, 2009
- 1,822 LPVs serving 970 Airports
- 1,049 LPVs to non ILS Runways
- LPVs to 678 non-ILS Airports
- 773 LPVs to ILS runways
WAAS Enterprise Schedule

Phases:
- FLP Segment (Phase II)
- LPV-200 Segment (Phase III)
- Dual Frequency (Phase IV)

GPS Modernization:
- GPS L5
- WAAS
- WAAS Avionics

GEO:
- GEO #3 – Intelsat
- GEO #4 – TeleSat Gap
- Filler GEO
- GEO #5 – TBD
- GEO #6 – TBD
- GEO #7 - TBD

Approach Development:
- WAAS Procedure Development

Key Dates:
- FOC Launch: 10/05
- Operational Launch:
  - 9/05
  - 09/08
  - 09/14
  - 09/16
  - 09/18

Total Count: ~5,218
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)

COMPASS

GLONASS

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”)

38 US WRS IFOR Threshold

38 US WRS 13 SA WRS IFOR Threshold

0.9999 ≤ 1.0000
0.9995 ≤ 0.9999
0.9990 ≤ 0.9995
0.9950 ≤ 0.9990
0.9900 ≤ 0.9950
0.9750 ≤ 0.9900
0.9400 ≤ 0.9750
0.8000 ≤ 0.9400
0.7500 ≤ 0.8000
0.0000 ≤ 0.7500
0.0000 = 0.0000

Institute of Navigation (ION)
September 2009
Current International Signal Plans

- GPS (US)
- GLONASS (Russia)
- Galileo (Europe)
- COMPASS (China)
- IRNSS (India)
- QZSS (Japan)
- SBAS (US Europe India Japan)

Future CDMA signal

Compass & IRNSS in S-band
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

For VAL = 35m, NDP & Acc: 97.77% coverage at 99.5% availability

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

<table>
<thead>
<tr>
<th></th>
<th>Navigation (≥ 99.0% Availability)</th>
<th>Surveillance (≥99.9% Availability)</th>
<th>Positioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy (95%)</td>
<td>Containment (10^-7)</td>
<td>Separation</td>
<td>NACp (95%)</td>
</tr>
<tr>
<td><strong>En Route</strong></td>
<td>*10 nm</td>
<td>5 nm</td>
<td>1 nm (95%)</td>
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<td></td>
<td>*4 nm</td>
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<td></td>
<td>*2 nm</td>
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<tr>
<td><strong>Terminal</strong></td>
<td>*1 nm</td>
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<tr>
<td>LNAV</td>
<td>*0.3 nm</td>
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<tr>
<td><strong>RNP (AR)</strong></td>
<td>*0.1 nm</td>
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<td></td>
<td>**0.1 nm</td>
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<tr>
<td><strong>LPV</strong></td>
<td>16m/4m</td>
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<td>40m/50m</td>
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<td><strong>LPV-200</strong></td>
<td>16m/4m</td>
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<td>40m/35m</td>
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<td><strong>GLS Cat-I</strong></td>
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*Operational requirements are defined for total system accuracy, which is dominated by flight 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) | Surveillance Integrity Level (SIL) | Navigation Accuracy Category for Position (NACp)