GNSS Program Status

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By: Leo Eldredge, Manager
GNSS Group, FAA
FAA Satellite Navigation Program

WAAS

LAAS

Enroute Oceanic
Enroute Domestic
Terminal
Approach
Surface

GNSS Status
8 March 2010
Wide Area Augmentation System - 2003

38 Reference Stations
3 Master Stations
4 Ground Earth Stations
2 Geostationary Satellite Links
2 Operational Control Centers
Three GEO Satellite Coverage

Intelsat
GXV 133W

Telesat
F1R 107W

Inmarsat
4F3 98W
WAAS Approach Procedures Today

As of Feb. 11th, 2010
- 1,975 LPVs serving 1050 Airports
- 1,163 LPVs to non-ILS Runways
- 812 LPVs to ILS runways
- LPVs at 759 Non-ILS Airports
- 246 LPV-200
SBAS Future Considerations

- **Dual Frequency GNSS Services in protected aeronautical bands**
  - Enables direct estimation and removal ionospheric delay errors
  - Single largest source of vertical position uncertainty
- **Most significant remaining threats are satellite failure based**
  - Design a new VPL equation targeting single satellite faults
- **India and Russia are developing SBAS systems**
- **Investigate potential to expand LPV to global coverage**
Current International Signal Plans

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

**Future CDMA signal**

Frequency (MHz):
- L5: 1.170 - 1.300 GHz
- L2: 1.230 - 1.500 GHz
- L1: 1.560 - 1.610 GHz

**Federal Aviation Administration**

8 March 2010
Current Reference Networks
Current LPV-200 Coverage
(Single Frequency GPS)

Availability as a function of user location

WAAS
EGNOS
MSAS

Courtesy of Todd Walter, Stanford University

Availability with VAL = 35, HAL = 40. Coverage(99%) = 7.54%
Future LPV-200 Coverage
(Dual Frequency GPS)

Availability as a function of user location

WAAS
EGNOS
MSAS

Courtesy of Todd Walter, Stanford University

Availiability with VAL = 35. HAL = 40. Coverage (99%) = 28.64%
WAAS, MSAS, EGNOS, GAGAN & SDCM
(Dual Frequency GPS)

Availability as a function of user location

Longitude (deg)

Latitude (deg)

< 50%  > 50%  > 75%  > 85%  > 90%  > 95%  > 99%  > 99.5%  > 99.9%

Availability with VAL = 35. HAL = 40. Coverage(99%) = 36.82%

Courtesy of Todd Walter, Stanford University
Expanded Networks

[Map showing expanded networks globally, courtesy of Todd Walter, Stanford University]
WAAS, MSAS, EGNOS, GAGAN & SDCM
(Dual Frequency GPS + Expanded Networks)

Availability as a function of user location

Longitude (deg)
Latitude (deg)

< 50% > 50% > 75% > 85% > 90% > 95% > 99% >99.5% >99.9%
Availability with VAL = 35. HAL = 40. Coverage(99%) = 67.57%

Courtesy of Todd Walter, Stanford University
WAAS, MSAS, EGNOS, GAGAN & SDCM
(Dual Frequency GPS + Expanded Networks + Two GNSS Constellations)

Availabilty as a function of user location

Availability with VAL = 35.  HAL = 40. Coverage(99%) = 92.65%
Conclusions

• Single frequency coverage is good within the countries fielding SBAS
• Dual frequency extends LPV coverage outside reference networks
• Expanding networks into southern hemisphere could allow global coverage of land masses
• Multi-Constellation SBAS allows even greater coverage with fewer stations
  – Compatible Geodesy and Time Standards are Important
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

Rio De Janeiro, Brazil

Agana, Guam

Malaga, Spain

Sydney, Australia

Frankfurt, Germany

Bremen, Germany
Questions
Universal Navigation Systems (UNS)

Completed Aircraft Approvals

- Astra 1125*
- Beech 400*, Beech 400, B-737-200, B-727-200, B-737
- Bombardier Q-series, Q-300, Q-400
- Bombardier CL-600/60
- Bombardier DHC-8-400 series ‘Q-400’
- Citation 550 Bravo Series,
- Citation V 560 Series, & XL, , 525*, Fleet
- DeHaviland ‘Dash-8’
- Falcon 10, 20D, 50, 50*
- Gulfstream G-II*
- KingAir 200*, 350
- LEAR 31A, 35, 35A,
- LEAR 40, 40XR, 45, 45XR, 60
- MD-87
- S-76, S-76B, S-76C++
- Sabre 65

Projected Aircraft Approvals

- ATR-42
- Beech Be-200, -300
- Boeing B-727-200 C&F, B-737
- Bell 412
- Cessna Citation II
- Cessna Citation 560XL/XLS, 650
- Cessna Citation VII, Encore
- C-9
- Northrop Grumman T-38
- Gulfstream G-II, G-III
- Falcon 20, 2000
- Hawker 125-700B
- King Air 300, RC-12, US Army
- PC-12
- Embraer NB-145
Completed Aircraft LPV STCs:
- Bombardier Challenger CL-604
- Bombardier CRJ-200
- Cessna Citation Jet CJ-1+, 2+, 3
- King Air-300
- Hawker 800XP
- Cessna Citation Encore+

Aircraft LPV STCs in work:
- Estimate completion w/in 6 months:
  - Bombardier CRJ-700/900
  - Beechcraft Premier 1 & 1A
  - Beechcraft King Air 200,200GT,300,350,C90GTi
  - Hawker 400XP, 750, 850/XP, 900XP
  - Beechjet 400A (est. 30 Sep for STC)
- Estimate completion w/in 12 months:
  - Dassault Falcon 20, 50/EX, 2000/EX
  - Piaggio P-180
  - Gulfstream G-150, G-200
  - Bombardier Lear 60XR
- Estimate Completion w/in 18 months:
  - Bombardier Challenger CL-300, CL-605
Honeywell/CMC

Approved Avionics LPV TSOs:
- Primus Epic FMS

Pending Avionics LPV TSOs:
- Primus 2000 (NZ-2000)
- APEX
- EPIC (in other airframes)
- KSN 770 (for GA aircraft)

Approved Aircraft LPV STCs:
- Gulfstream G-450 & -550

Pending LPV STC Approvals:
- Gulfstream G-IV, G-V
- F-900B,-900EXC
- Challenger CL-601
- Hawker 800
- Citation X
- PC-12
- Viking
- Dassault EASy
- Cessna Sovereign