GNSS Backup Navigation Initiative

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FAA GPS Augmentation Programs
## GNSS Enabled RNP and ADS-B

<table>
<thead>
<tr>
<th>En Route</th>
<th>Terminal</th>
<th>LNAV</th>
<th>RNP (AR)</th>
<th>LPV</th>
<th>LPV-200</th>
<th>GLS Cat-I</th>
<th>GLS Cat-III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy (95%)</td>
<td>Containment (10⁻⁷)</td>
<td>Separation</td>
<td>NACp (95%)</td>
<td>NIC (SIL=10⁻⁷)</td>
<td>GNSS PNT (99.0 – 99.999%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*10 nm</td>
<td>20 nm</td>
<td>5 nm</td>
<td>0.1 nm (7)</td>
<td>1 nm (5)</td>
<td>GPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*4 nm</td>
<td>8 nm</td>
<td>3 nm</td>
<td>0.05 nm (8)</td>
<td>0.6 nm (6)</td>
<td>SBAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*2 nm</td>
<td>4 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*1 nm</td>
<td>2 nm</td>
<td>3 nm</td>
<td>0.05 nm (8)</td>
<td>0.2 nm (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*0.3 nm</td>
<td>0.6 nm</td>
<td>3 nm</td>
<td>0.05 nm (8)</td>
<td>0.2 nm (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*0.1 nm</td>
<td>**0.1 nm</td>
<td>2.5 nm</td>
<td>0.1 nm (7)</td>
<td>0.2 nm (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16m/4m</td>
<td>40m/50m</td>
<td>2.5 nm</td>
<td>0.05 nm (8)</td>
<td>0.2 nm (7)</td>
<td>GBAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16m/4m</td>
<td>40m/35m</td>
<td>2.5 nm</td>
<td>0.05 nm (8)</td>
<td>0.2 nm (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16m/4m</td>
<td>40m/10m</td>
<td>2.0 nm</td>
<td>121 m (8)</td>
<td>0.2 nm (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16m/2m</td>
<td>40m/10m</td>
<td>2.0 nm</td>
<td>121 m (8)</td>
<td>0.2 nm (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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)**

**Independent Parallel Approach (IPA)**  **Navigation Integrity Category (NIC)**
Federal Airways – Circa 1930’s
Backup Positioning

• **ADS-B Surveillance**
  – GNSS for primary positioning
  – Secondary Surveillance Radar (SSR) Backup
  – Multi-Lateration Used to Validate GPS Position

• **Performance Based Navigation (PBN)**
  – GPS/WAAS/LAAS Primary Enablers
  – Retain Legacy Systems for Backup
  – General Aviation aircraft rely on VORs, (not equipped with DME)
    • VOR not an optimum solution for PBN
  – Transport Category Aircraft rely on DME/DME/INS + ILS
    • Optimized DME can support enroute and terminal but not final approach
    • ILS final approach only
Objective

• **Provide a Cost Effective Backup PNT service**
  – Enable Performance Based Navigation (PBN)
    • RNAV/RNP for enroute, terminal, and approach (RNP-0.3)
  – All users (GA, Business, Regional, Air Carrier)
    • Avoid Recapitalization Costs for VORs
  – Minimize Impact on User Equipage Costs
    • Leverage existing equipment as much as possible
    • Backward compatibility for Legacy Users
    • Minimize need for multiple avionics updates for users
    • Provide long lead transition time (Circa 2020 transition)
Multilateration Overview
Surveillance and Broadcast Service Descriptions
Concept to use TIS-B to provide ADS-B equipped aircraft with backup positioning for navigation using MLAT
800 GBT’s Provide National Coverage
Current DME Network

- Redundant coverage (no critical facilities)
- Single critical facility
- Two critical facilities
- No coverage

Stanford PNT Symposium
21 October 2009
MLAT Backup Concept

ADS-B Positioning Service
- GNSS (Primary)
- SSR (Backup)
- MLAT (Validation)

Navigation Service
- GNSS (Primary)
- MLAT (Backup)

• GNSS (Primary)
• SSR (Backup)
• MLAT (Validation)
MLAT Backup Block Diagram

Other Aircraft/Vehicles

ADS-B Out

AIRCRAFT

GPS Aircraft Position
FIS-B Own Position

Transponder (MLAT)

GPS/WAAS Navigation

1090/UAT TDOA

MLAT Network

GBT/MLAT

Dilution of Precision Integrity Monitoring
Network Time Synchronization

ADS-B Out
ADS-B In

1090
UAT Radio

ATS System

SSR Network

ADS System

ADS-B
ADS-R
TIS-B
FIS-B

DME/MLAT

Network Time Synchronization

CPU

UAT

DME

1090 Radio

UAT Receive
1090 Receive

DME T/R
Pseudolite Concept

- 1 Hz Pseudolite Message
- Station ID & Time of Transmit
- From DMEs and/or GBTs

- Aircraft Calculates Position
- RAIM Based Integrity Solution
- Included in ADS-B In Avionics
- Interface to Navigation Avionics

GPS-Independent
Common Time Reference
DME/GBT Pseudolite Backup

**Avionics**
- ADS-B Positioning
  - GNSS (Primary)
  - Pseudolite (Validation/Backup)

**Navigation Positioning**
- GNSS (Primary)
- Pseudolite (Backup-RNP-0.3)
- RAIM Based Integrity

**GBT/DME MLAT Sites**
- 1Hz Broadcast
- Station ID
- Time of Transmit
- Broadcast from DME/GBT
DME/GBT Pseudolite Block Diagram

**AIRCRAFT**
- GPS/WAAS Navigation
- Transponder (MLAT)
  - GPS Aircraft Position
  - FIS-B Own Position

**DME/MLAT Station**
- DME
- 1090 Radio
- CPU
- Network Time Synchronization

**MLAT Network**
- 1090/UAT Pseudolite
- DME/GBT Pseudolite Transmit
- DME/GBT

**ADS System**
- ADS-B
- ADS-R
- TIS-B
- FIS-B

**SSR Network**

**ATS System**

**MLAT Functions**
- Aircraft Position Determination
- Dilution of Precision Integrity Monitoring
- Network Time Synchronization

**ADS-B**

**ADS-B Out**

**ADS-B In**
- PL Aircraft Position
- RAIM Integrity
Next Steps

• Develop the Project Plan for Full Investigation
• Develop and Validate Backup Requirements
• System Engineering Analysis
  – Potential to provide RNP-0.3 approach service with MLAT/Pseudolite
  – Coverage for Enroute Operations
  – Terminal (RNP-1.0) and Approach (RNP-0.3) at Busiest Airports
  – Communications Latency and Throughput
  – Infrastructure Impacts and Transition Issues
• R&D Prototyping
  – Establish a Test Bed with Modified DME/GBT Stations
  – Prototype Avionics
  – Conduct Flight Evaluations
• Develop Cost & Schedule Estimates
• Complete Analysis of Alternatives (AoA)
Questions