Navigation Programs Update

Presented by: Deborah Lawrence
Presented to: Stanford PNT Symposium
Date: October 2014
Topics

• GPS Intentional Interference and Spoofing - Threats & Recommendations
• Alternate Positioning, Navigation, and Timing (APNT) Update
• Complementary Positioning, Navigation, and Timing Tiger Team (CPNT3)
• Instrument Landing System (ILS) Drawdown Decision
• VHF Omni-directional Range (VOR) Minimum Operational Network (MON)
• Questions
GPS Intentional Interference and Spoofing - Threats & Recommendations Update
Background

• FAA is dependent on GPS for navigation, surveillance, and network/infrastructure timing
• Majority of NextGen benefits currently rely on GPS, and this reliance will increase in the future
• GPS is a very weak signal and therefore vulnerable to unintentional or intentional interference
  – The GPS signal is almost a billion times weaker than other navigation signals (DMEs, VORs, ILS, etc)
• Inexpensive jamming and spoofing equipment, as well as tactics are widely available on the internet
Operational Mitigations

• **Loss of GPS**
  - ATC vectors
  - Reversion to backup navigation (if available)
  - Procedural separation if ADS-B is lost in non-radar coverage

• **Undetected spoofing**
  - ATC should detect erroneous position in radar airspace (pilot may not sense change in trajectory)

• **Infrastructure use of GPS and impacts not well known**
  - NSPD-39, PPD-21, and E.O. 13636 require back-up capability and resiliency against GPS disruption and cyber attack
Recommendations in the short term, within FY14 (1 of 2)

• Require future aircraft equipment to cease GNSS use when intolerable interference or spoofing is detected
  – Develop a plan to address spoofing detection provisions within relevant domestic and international standards
  – Focus on low-cost techniques

• Engage Department of State in its update of ITAR to explore an adaptive GPS antenna exemption for civil aircraft

• Accelerate the Alternative PNT (APNT) program as a mitigation for GNSS intentional interference and spoofing to
  – Enable continuity and capacity
  – Enable cross-checks between GNSS PNT and APNT

• Update pilot and controller training materials to address interference and spoofing
Recommendations in the short term, within FY14 (2 of 2)

• Determine whether enhancements to the ADS-B network are required to:
  – mitigate intentional interference and spoofing
  – enable the identification and annunciation of geographical areas impacted by jamming or spoofing in real time

• Update interagency GPS interference procedures to include spoofing

• Review SC-216 products to ensure adequate information security guidance is available for installed aircraft GNSS equipment

• Provide guidance on use of GNSS for air traffic control system timing
  – A non-GNSS alternative or backup timing source should be provided for critical systems
  – This guidance might include a standard for time receiver autonomous integrity monitoring for GNSS-dependent timing systems in the NAS

• Promote legal prohibition on owning GNSS jammers
Recommendations in the Long Term

• Provide guidance to aircraft manufacturers and navigation equipment integrators stressing the importance of cross-checks of GPS sensor data against other position sources, and on the optional use of higher cost spoofing mitigation solutions

• Continue to develop standards for aviation use of the third civil GPS frequency (L5) and additional GNSS signals

• Implement digital signatures within the satellite-based augmentation system (SBAS) messages on L5
  – Encourage the inclusion of digital signatures within the GPS L5 navigation data
Why Alternate PNT?

• Presidential Policy Directive 21 (PPD-21), *Critical Infrastructure Security and Resilience*
  – Advances a national unity of effort to strengthen and maintain secure, functioning, and resilient critical infrastructure

• FAA needs to maintain aviation operations in the event of a Global Navigation Satellite System (GNSS) interference event or outage
  – Maintain safety and security
  – Maintain a reasonable level of capacity and efficiency
  – Minimize economic impact
**Schedule**

- **Initial Operational Capability 2023**
- **Investment Analysis Readiness Decision Q4 2015**
- **Initial Investment Decision Q4 2016**
- **Final Investment Decision Q4 2017**
- **Concept & Requirement Readiness Decision Complete Q2 2011**
- **CONOPS Q2 2012**
- **Functional Analysis Q4 2012**
- **APNT MOPS Development**
- **Solution Implementation**
- **Deployment**

**Legend**
- Future JRC decision point
- Complete JRC decision point
- Planned

**CY15 Planned R&D Activities:**

- Achieve Investment Analysis Readiness Decision (IARD)
- Prepare for Initial Investment Decision (IID)

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**Risk:** 5-7 years nominally to develop the Minimum Operational Performance Standards (MOPS)—current program timeline and funding profile puts the program at risk in accomplishing NextGen 2025 objective.
### APNT Alternative: TIS-B

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description</th>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Provides ADS-B-equipped aircraft with position reports from SSR of non-ADS-B reporting aircraft (with in proximity)</td>
<td>• Existing ground infrastructure</td>
<td>• Safety assurance for navigation requires validation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Provides an advisory service using a communications uplink on 1090MHz and 978MHz</td>
<td>• Existing signal</td>
<td>• May require TIS-B interference monitor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Aircraft are intended to navigate using its own ship position as computed and transmitted by the ground system.</td>
<td>• Aligns with ADS-B IN Plan</td>
<td>• Navigation and Surveillance both rely on 1090MHz – Common mode failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Need to complete evaluation of TIS-B as an alternative</td>
<td></td>
<td>• May have limited radar coverage at low altitudes in remote areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Concerns on update rate and variable latency</td>
<td></td>
<td></td>
</tr>
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</table>

#### Services provided:
- **Position**
- **Navigation**
- **Time**

#### Performance Summary

<table>
<thead>
<tr>
<th>Performance Summary</th>
<th>RNAV 1</th>
<th>ADS-B 0.05 nm</th>
<th>Existing Aircraft Equipage</th>
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<tbody>
<tr>
<td>Air Carrier</td>
<td></td>
<td></td>
<td>Regionals &amp; Business</td>
</tr>
<tr>
<td>~Yes</td>
<td>~No</td>
<td>No, ~2%</td>
<td>No, ~2%</td>
</tr>
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#### Existing Aircraft Equipage:

- **RNAV 1**
- **ADS-B 0.05 nm**

- **Air Carrier**
  - ~Yes
  - ~No

- **Regionals & Business**
  - No, ~2%

- **GA**
  - No, ~2%

- **MOPS Changes**
  - Yes

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**October 2014**
## APNT Alternative: NextGen DME

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<th>Weaknesses</th>
<th>Risk/CNS Benefits</th>
</tr>
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<tr>
<td>Current DME criteria based on AC90-100A</td>
<td>MOPS/TSO already exist (RTCA/SC-227)</td>
<td>DME locations require optimization</td>
<td>Cost /Schedule Risk</td>
<td></td>
</tr>
<tr>
<td>All en route and Class B terminal area coverage supported, without IRU requirements</td>
<td>Current air carriers and regionals are currently equipped</td>
<td>GA is not equipped</td>
<td>• Ground system – Low</td>
<td></td>
</tr>
<tr>
<td>Elimination of all critical DMEs</td>
<td>Leverages existing airborne and ground infrastructure</td>
<td>Provides navigation only backup</td>
<td>CNS Bundle Pros</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proof of concept not required</td>
<td>Updated MITRE DME analysis may determine if additional DME’s are needed</td>
<td>• No MOPS required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Updated MITRE DME analysis may determine if a reduction in DME’s is feasible</td>
<td></td>
<td>• No cost to user</td>
<td></td>
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October 2014
## APNT Alternative: Hybrid Ranging

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<tr>
<td>Use a combination of DME and ADS-B ground stations to provide GPS independent PNT to aircraft</td>
<td>• Achieves the highest performance of all the alternatives</td>
<td>• Requires new MOPS/TSO/ICD</td>
<td>Technical - Medium</td>
<td></td>
</tr>
<tr>
<td>Modify DMEs to add a pseudo ranging signal</td>
<td>• Signal and site diversity</td>
<td>• No user equipage base</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modify ADS-B GS-s to enable 1090 Mhz/UAT pseudo ranging</td>
<td>• Provides a system to support positioning for PBN and ADS-B in the event of interference</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo-ranging signal includes precise time of transmission</td>
<td>• The Hybrid alternative supports the current APNT CONOPS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Resistant to interference events</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- The Hybrid alternative supports the current APNT CONOPS</td>
<td></td>
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<td>GA</td>
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<tr>
<td>Yes</td>
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### Technical - Medium
- Spectrum 1090 Mhz
- GS Synchronization (ADS-B and DME)

### Cost – Med/High
- Ground Station Synchronization
- ADS-B Contract Mod
- Avionics and aircraft modifications

### Schedule – High
- Develop APNT MOPS
- Aircraft FMS Integration
CPNT3 Update
Complementary PNT Tiger Team (CPNT3)

• On October 10, 2014 the Space-Based Positioning, Navigation & Timing National Executive Steering Group initiated the CPNT Tiger Team

• The Tiger Team will:
  – Re-explore eLORAN as a back-up GPS technology
  – Evaluate other technologies as a back-up to GPS
  – Investigate the ability to provide P, N & T separately

• The Tiger Team will out brief their findings to the PNT Executive Committee on December 15, 2014
ILS Drawdown Decision
The drawdown decision is scheduled for the 2nd Quarter FY2016

Instrument Landing System (ILS), standalone Localizer (LOC), Simplified Direction Finder (SDF), and Localizer Direction Aide (LDA) facilities installed in the CONUS are considered for removal

Retain all 180 CAT II/III ILSs installed at 92 airports to support International agreements

Retain 129 CAT I ILSs and 12 LOC-only systems at 141 VOR MON recovery airports

ILS will be retained at runways with Precision Runway Monitoring (PRM) radar & Converging ILS operations

At least one ILSs will be retained at the busiest airports where air carriers have not yet equipped with WAAS
There are 1126 CAT I ILS’s in the NAS and 129 are required for VOR MON recovery
   – This leaves approximately 997 for consideration

50% of the ILSs (≈ 498) may need to be retained at the busiest Metroplex airports where air carriers have not yet equipped with WAAS

There are 208 LOC, LDA/SDF procedures in the NAS

75% of the LOC, LDA/SDF (≈ 208) are removal candidates

In total, there are 706 ILS, LOC, LDA/SDF facilities which can be removal candidates

<table>
<thead>
<tr>
<th>ILS</th>
<th>WAAS</th>
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<tbody>
<tr>
<td></td>
<td>Total in NAS</td>
</tr>
<tr>
<td>Category-II/III</td>
<td>180</td>
</tr>
<tr>
<td>Category-I</td>
<td>1126</td>
</tr>
<tr>
<td>LOC, LDA/SDF</td>
<td>290</td>
</tr>
<tr>
<td>Total</td>
<td>1596</td>
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</table>

Preliminary Drawdown Numbers
ILS Drawdown Savings

• WAAS LPV/LP procedures require 1/3rd the cost of ILS to establish and 1/7th the cost to maintain on a per unit basis

• Removal of 706 ILS, LOC, LDA/SDF facilities could reduce recurring maintenance costs by approximately $50M

• ILS removal payback is approximately 4.2 years

• WAAS also enables removal of VOR, NDB, and ADF procedures to accrue additional savings

• A more detailed analysis needs to be performed to refine the ROM estimates
VOR MON Update
VOR MON Program Goals

• The FAA will transition to Performance-Based Navigation (PBN) from the conventional VOR-defined routes and procedures
• PBN provides an opportunity to reduce the aging infrastructure
  – The FAA currently has ~967 federally-owned and operated VORs (including VORTACs and VOR/DMEs)
    • Most are 30+ years old
• The VOR MON Program will implement the MON by targeting the discontinuance of approximately 50% of the VORs in the NAS
  – VOR MON will provide backup coverage during a GPS outage as well as basic navigation capability
  – Support Right Sizing Initiatives
**The number of VORs comprising the MON may increase or decrease depending on the requirements for DoD / TOC**

- FY14
- FY15
- FY16
- FY20
- FY25

0 524 967

- WAAS LPV procedures at qualified runways
- ADS-B equipage mandate takes effect
- APNT full operational capability

**Approximate


VOR MON Implementation Program

2015 - 2025

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VOR MON RTCA Tasking

- In July 2013, the FAA tasked the TOC to establish a VOR MON Task Group
- **Task 1 (Review and Validate Selection Criteria)**
  - Completed November 2013
  - Recommended service volume expansion below 5,000’ AGL
  - Recommended VOR retention around areas of known GPS testing
- **Task 2 (Review and Validate draft MON list)**
  - Completed February 2014
  - Prioritized evaluation criteria for selecting VORs
- **Task 3 (Recommendations to Waterfall Schedule)**
  - Scheduled to start after completion of Task 4
- **Task 4 (Recommendations on Outreach and Education)**
  - Completed September 2014
  - Recommended to release full MON list as information early in process
  - Recommended that the VOR MON overarching theme should relate to the transition to Performance Based Navigation (PBN) and NextGen
VOR MON Challenges

- Instrument Flight Procedure (IFP) Development
- IFP Removal
- Routes
- Engineering Analysis
- Stakeholder Coordination
- Co-Located Facilities (HIWAS, RCO, ATIS, DME)
- Rulemaking
VOR MON Next Steps

• Continue detailed program planning
• Final Investment Decision ~ September 2015
• Finalize coordination with DoD/DHS in identifying necessary VORs for DoD use, expected by December 2014
• Continue stakeholder outreach
Conclusion

• GPS provides several benefits to advancing capabilities in the NAS, however, it is a weak signal and therefore vulnerable to unintentional or intentional interference
  – Short Term mitigations are being implemented

• The FAA needs to maintain aviation operations in the event of a Global Navigation Satellite System (GNSS) interference event or outage
  – Investigating back-up GPS options through the FAA APNT Program, GIISST, and CPNT Tiger Team

• The ILS drawdown decision is scheduled for the 2nd Quarter FY2016
  – Preliminary requirements are being developed

• The VOR MON Program will implement the MON by discontinuing approximately 50% of the VORs in the NAS
  – FID Planned for Sept. 2015
Questions
Back Up
Overall Instrument Approach Procedure (IAP) Impact Summary

11798 IAPs identified in CONUS*

5035 IAPs may be affected by VOR MON

VOR / NDB / SDF 1732
GPS 209
RNAV / GLS 1498
TACAN / HI-xxx 263
ILS / LOC / LDA 1318
VISUAL 15

6763 IAPs are unaffected by VOR MON

*From digital - Terminal Procedures Publication (d-TPP) Volume 1310
Affected SIDs/STARs/ODPs

2084 ODPs/SIDs/STARs identified in CONUS*

- 1287 may be affected by VOR MON
- 893 SIDs & ODPs
- 394 STARs**

997 are unaffected by VOR MON

* From digital - Terminal Procedures Publication (d-TPP) Volume 1405

** Duplicate STAR listings removed as single graphic and textual plate serves multiple airports

<table>
<thead>
<tr>
<th>Category</th>
<th>Conventional</th>
<th>RNAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affected SIDs &amp; ODPs</td>
<td>691</td>
<td>202</td>
</tr>
<tr>
<td>Affected STARs</td>
<td>239</td>
<td>155</td>
</tr>
</tbody>
</table>