Alternative Positioning, Navigation, and Timing (APNT)

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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

• *Waiting for the source of the interference to be located and turned off is not an acceptable alternative!*
What are “Disruptions”?  

- For GNSS “Disruptions” = “Interference”  
- GNSS Interference can be:  
  - Intentional/Unintentional  
  - Predictable/Unpredictable  
  - Manmade/Environmental  
  - Crude/Sophisticated (Jamming/Spoofing)  
  - Widespread/Localized  

- Applies to all GNSS provided services  
  - Position  
  - Navigation  
  - Timing
Today’s Alternate PNT

- The FAA currently relies on existing legacy systems for GPS alternative navigation which does not fully support RNAV, RNP, or TBO.
- Today’s ATC system cannot simply be scaled up to handle twice the traffic
- Today’s Legacy PNT services cannot support many NextGen Operational Improvements (OIs) or meet performance requirements necessary to maintain adequate capacity and efficiency
  - Continued reliance on current APNT infrastructure will significantly impact:
    - NAS capabilities and capacities
    - Pilot and controller workload
    - Economic and environmental benefits (fuel, carbon footprint, etc.)
    - Capital budget (Continuation of Current State Requires Recapitalization of VORs: a very large investment for a non-PBN solution)
## Legacy Case – DDI and VOR

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description</th>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Risk / Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Sustain the current DME infrastructure&lt;br&gt;• Sustains the VOR Network&lt;br&gt;• Users must equip with DME/DME/IRU to fly RNAV procedures without GNSS</td>
<td>• No new MOPS/TSO/ICD required&lt;br&gt;• 97% of air carriers already have DDI or DD avionics&lt;br&gt;• Rulemaking not required&lt;br&gt;• Meets minimum RNAV coverage for Air Carrier Operations</td>
<td>• 30% of air carriers (Regional Jets) do not have IRU&lt;br&gt;• Accuracy limited to RNAV-1.0&lt;br&gt;• No RNP backup, RNP IFPs will be GNSS only&lt;br&gt;• Loss of GNSS may cause unacceptable workload for pilots and controllers as they revert to VOR and radar vectors&lt;br&gt;• Will require retention of additional SSRs&lt;br&gt;• No RNAV backup for GA</td>
<td>Technical -Low&lt;br&gt;Cost – Low&lt;br&gt;Schedule – Low</td>
</tr>
</tbody>
</table>

### Performance Summary

<table>
<thead>
<tr>
<th>Aircraft Equipage Capability</th>
<th>RNP-0.3</th>
<th>ADS-B-0.05 nm</th>
<th>RNP-1.0/2.0 Backup</th>
<th>No PBN Backup</th>
<th>No PBN Backup</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Carrier</td>
<td>No</td>
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NextGen Alternate PNT

• The Alternative Positioning, Navigation, and Timing (APNT) project is investigating alternatives for providing higher precision back-up for Global Positioning System (GPS)-based position, navigation, and timing (PNT) services.

• GPS PNT services are the enablers of performance-based navigation (PBN) and Automatic Dependent Surveillance Broadcast (ADS-B) services that, in turn, enable Trajectory-Based Operations (TBO), area navigation (RNAV), Required Navigation Performance (RNP), and other NextGen improvements.

• NextGen APNT will provide a means for users to seamlessly continue RNAV and RNP operations.
CONOPS Overview – Backup to GPS

Primary PNT Service
GNSS meets all PBN levels and ADS-B performance throughout the NAS and TBO requirements

Alternate PNT Service:
Enables RNAV & RNP for enroute and terminal, excluding approach & landing. Provides positioning information for ADS-B

- RNP 0.3 in Climb
- RNP 0.3 in Arrival
- RNP 0.1 in Approach
- RNP-1.0 in Cruise

Takeoff

+ ROTG – RNAV off the ground
+ RNP – Required Navigation Performance
+ TBO – Trajectory Based Operations
+ ADS-B – Automatic Dependent Surveillance Broadcast
+ PBN – Performance Based Navigation
+ NAS – National Airspace System
The Road to APNT

**APNT Today**
- VOR, DME, TACAN, and ILS Receivers
- VHF/UHF Ranging and Azimuth Signals

**NextGen APNT**
- Ground-Based Infrastructure
- Signals-in-Space
- Avionics
The development of APNT requires the identification of multiple solution sets that can serve diverse NAS users.

APNT solution sets will be comprised of ground-based infrastructure transmitting non-GNSS signals-in-space to avionics that may vary by user.

The signals-in-space must support legacy users as well as emerging user communities (e.g., UAS).

Robustness/resilience is paramount, i.e., safety of operations must be maintained and operations must continue at or near nominal levels.
APNT Objectives

Alternative Positioning, Navigation, and Timing

- Safe Recovery (landing) of Aircraft
- No Significant Increase in Pilot/Controller Workload
- Strategic Modification of Trajectories
- Continued Dispatch To/From Affected Areas

Safety → Resilience ← Capacity/Efficiency
## Benefits

### NET Benefits: FAA

| Efficiency/Productivity | Yes | Sustains RNAV/RNP – TBO during GPS outages |

### NET Benefits: User

| Safety | Yes | Users avoid disruptions for transitions from 3nm separation to 5nm during GPS outage |
| Operator Cost | Yes | Avoid impacts to fuel burn during GPS outage transition |
| Passenger Value of Time (PVT) | Yes | Minimizes time lost during GPS outages and limits discomfort and cost people experience when traveling |
| Capacity | Yes | Sustains departure and arrival traffic flow to the Core 30 (minus Hawaii) airports plus the next ~*100 busiest airports in CONUS (*Depending on the business case) |
Notional APNT Coverage

Note: This diagram is not for use in airspace design and is not to scale.

1. **Zone-1**: En Route High
   - FL-600
   - 18,000 Feet MSL
   - 5,000 Feet AGL

2. **Zone-2**: En Route Low
   - CONUS

3. **Zone-3**: Terminal Candidate Airports
   - 2° Slope
   - 10 nm Radius From Airport Reference Point
   - 2.5 nm from Runway End Sloping Upward At 200 Feet/nm To 1,500 Feet AGL
   - 1,500 Feet AGL
   - 500 Feet AGL At High Density Airports

Note: 1,500 foot AGL floor covers arrivals while the 500 foot AGL floor is for departures. The departure coverage starts at 2.5 nm from the runway end and extends upward to cover the climb out and may not be a conical surface around the airport.
Initial Alternatives Evaluated

- Time-difference of arrival (TDOA) of a signal between several known and carefully surveyed observation points
- Uses TIS-B as a data link for navigation
- Precise synchronization of the ground stations

- Leverages Existing DME/DME Technology
  - RNAV Today; Impacts to Avionics to realize RNP
  - Evaluating means to support both IRU and non-IRU aircraft

- New Concept
  - Leverages DME/GBT Infrastructure
  - Provides precise time to aircraft
  - Impact to Avionics
Hybrid APNT Includes DME (two way ranging)
Hybrid APNT Includes GBTs (one way ranging)
Decision Tree

13th National Space-based PNT Advisory Board
June 2014

APNT

- **TRL-5 Enhanced DME/DME**
  - Yes → **GO**
  - No → End
- **TRL-6 Multi-lateration**
  - Yes → **GO**
  - No → End
- **TRL-4 Pseudolite**
  - Yes → **GO**
  - No → End
- **TRL-3 Diverse Ranging**
  - Yes → **GO**
  - No → End
- **TRL-4 Hybrid Ranging (DME/RT)**
  - Yes → **GO**
  - No → End

- **TRL-5 Enhanced DME/DME**
  - End

- **TRL-4 Hybrid (DME/RT)**
  - End

Note: Yes/No TRL – Target Readiness Level

- **Pending:**
  - Down select to an alternative.

- **Combines with Hybrid (DME/RT)**

- **MLAT was eliminated because computing the position on the ground and transmitting the position back to the plane with integrity & authentication could not be determined.**

- **Pseudolite was eliminated due to the lack of ground infrastructure (minimum of 3 ground stations in good geometry) and technical maturity.**

- **Diverse Ranging was eliminated due to congestion on 1090 MHz, uncertainty over the integrity approach, technical maturity, and high cost.**

- **Combines with DME for Hybrid (DME/RT)**
## Enhanced DME (eDME)

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<th>Weaknesses</th>
<th>Risk / Rationale</th>
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<tbody>
<tr>
<td></td>
<td>• Modify DME facilities to enable RNP with Monitoring &amp; Alerting</td>
<td>• Air carriers are equipped with DDI</td>
<td>• MOPS Changes will be needed to enable RNP accuracy and monitoring &amp; alerting</td>
<td>Technical - High</td>
</tr>
<tr>
<td></td>
<td>• Modify DME facilities to Improve ranging accuracy to achieve RNP-0.3</td>
<td>• MOPS/TSO already exist (RTCA/SC-227)</td>
<td>• RTCA/SC-227 does not support</td>
<td>Enabling RNP Monitoring &amp; Alerting - High Risk</td>
</tr>
<tr>
<td></td>
<td>• Modify DME avionics to enable Monitoring &amp; Alerting and improved accuracy</td>
<td>• Global Air Navigation Plan compatible</td>
<td>• GA does not have DME</td>
<td>RNP-0.3 accuracy - High Risk</td>
</tr>
<tr>
<td></td>
<td>• Assumes NextGen DME will eliminate critical facilities and fill coverage</td>
<td></td>
<td>• Performance may be limited to RNAV-0.6 at best.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>gaps for DD-only users</td>
<td></td>
<td>• Does not meet ADS-B positioning requirements (SSRs still needed)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Will need to retain more VORs</td>
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<th>Genral Aviation</th>
<th>MOPS Changes</th>
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<tr>
<td></td>
<td>TBD</td>
<td>No</td>
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## Hybrid Ranging

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|             | • Modify DMEs to add a pseudolite ranging signal  
• Modify ADS-B RTs to enable 1090/UAT ranging  
• New Avionics to compute position solution  
• Provide backup positioning for PBN and ADS-B  
• Assumes NextGen DME will eliminate critical DMEs and fill coverage gaps. | • Achieves the accuracy required for RNP-0.3  
• Provides RNP Monitoring & Alerting  
• Signal and site diversity | • Requires new MOPS/TSO/ICD  
• No user equipage base  
• Long term solution  
• Most costly alternative | **Technical** - Medium  
**Achieving RNP Monitoring & Alerting** – Medium Risk  
**Meeting accuracy for RNP-0.3** – Low Risk  
**User acceptance** – Medium Risk |

### Technical Summary

- **Achieving RNP Monitoring & Alerting** – Medium Risk
- **Meeting accuracy for RNP-0.3** – Low Risk
- **User acceptance** – Medium Risk

### Schedule - High

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Summary

• **GNSS is vulnerable!**
• Today’s status quo may not be an acceptable alternative in the future as GNSS services continue to proliferate and support more and more critical operations
• There are robust and resilient alternatives – but there is a need to identify and incorporate them into operations that ensure safety and security and to mitigate significant economic impact
• NextGen is addressing the need for robust and resilient alternative position, navigation, and timing services
Questions
Back Up
Legacy Infrastructure Description

• **VOR MON ~ 500 VORs**
  – 30 to 40 years old

• **DME Service**
  – DME ~400
    • 30 to 40 years old
  – TACAN ~537
    • 40 to 50 years old

• **Aging infrastructure will require sustainment activities**
  – Technical refresh required
### Legacy Case

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<tr>
<td><strong>Class A Airspace FL180-FL600 (with gaps)</strong></td>
<td>Current: VOR Airways Q/T Routes (RNAV-2.0)</td>
<td>Primary: GNSS or VOR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GNSS Backup: 70% of air carriers can use DDI for en route above FL240 and terminal RNAV at approximately 135 Airports</td>
</tr>
<tr>
<td><strong>Class B - 36 Airports 1000’ AGL up to 10,000 AGL</strong></td>
<td>Current: Conventional SID/STAR RNAV SID/STAR (RNAV-1.0)</td>
<td>Primary: GNSS or VOR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All others revert to VOR/DME for en route &amp; terminal Navigation</td>
</tr>
<tr>
<td><strong>Class C – ~99 Civil Airports 1000’ AGL up to 4000 AGL</strong></td>
<td>Current: RNAV Approach Conventional Approach</td>
<td>Primary: GNSS or VOR/ILS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOR/DME/ILS for approach &amp; landing</td>
</tr>
<tr>
<td><strong>Class E Airspace 5000 AGL up to FL180</strong></td>
<td>Current: VOR Airways Q/T Routes (RNAV-2.0)</td>
<td>Primary: GNSS or VOR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOR navigation for en route &amp; terminal VOR/ILS for approach &amp; landing</td>
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1100 DMEs in Current Network
Combined Network of DMEs and GBTs