

# Navigation Programs Update

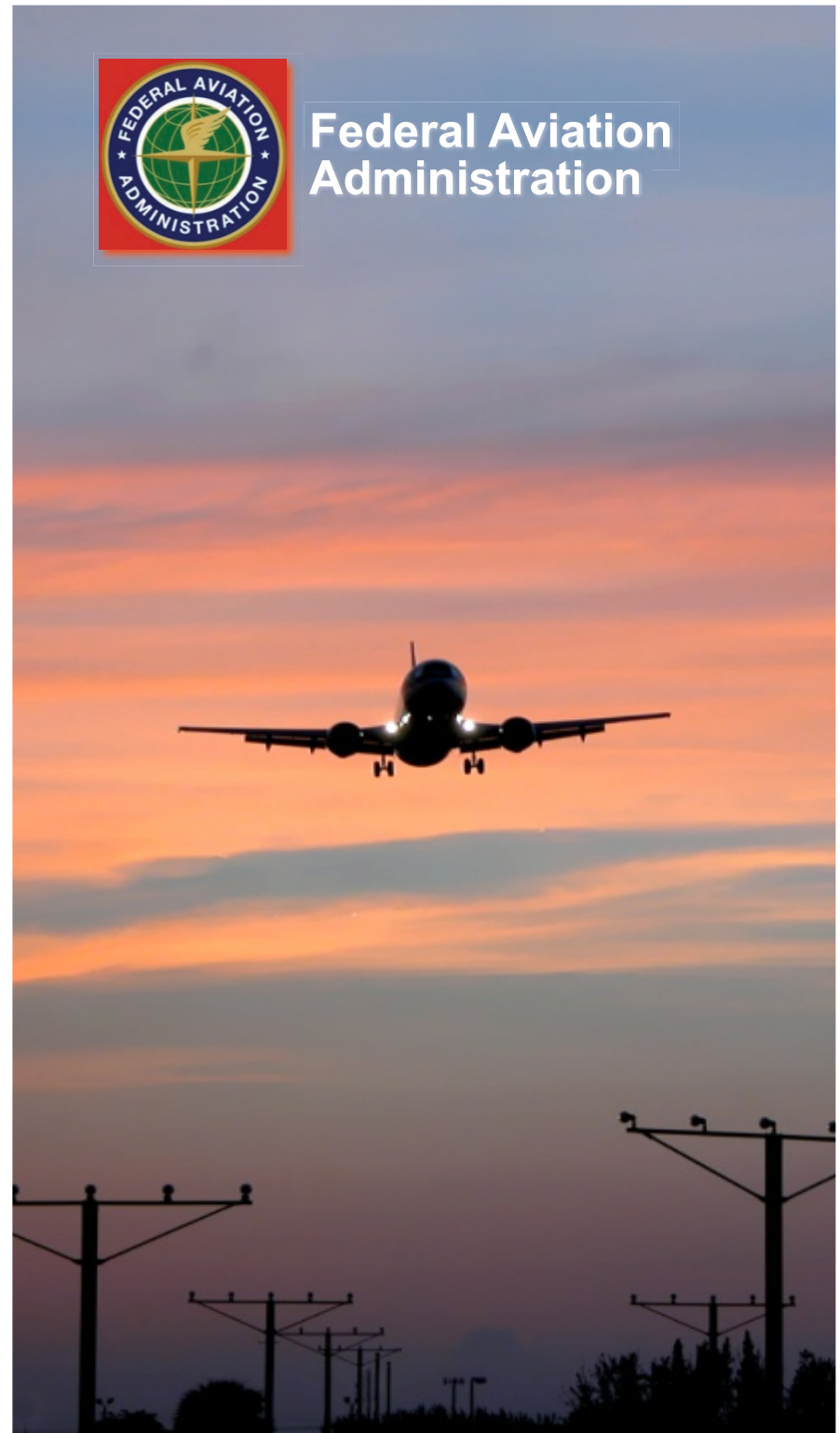
**Presented by: Deborah Lawrence**

**Presented to: Stanford PNT Symposium**

**Date: October 2014**



**Federal Aviation  
Administration**



# 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**





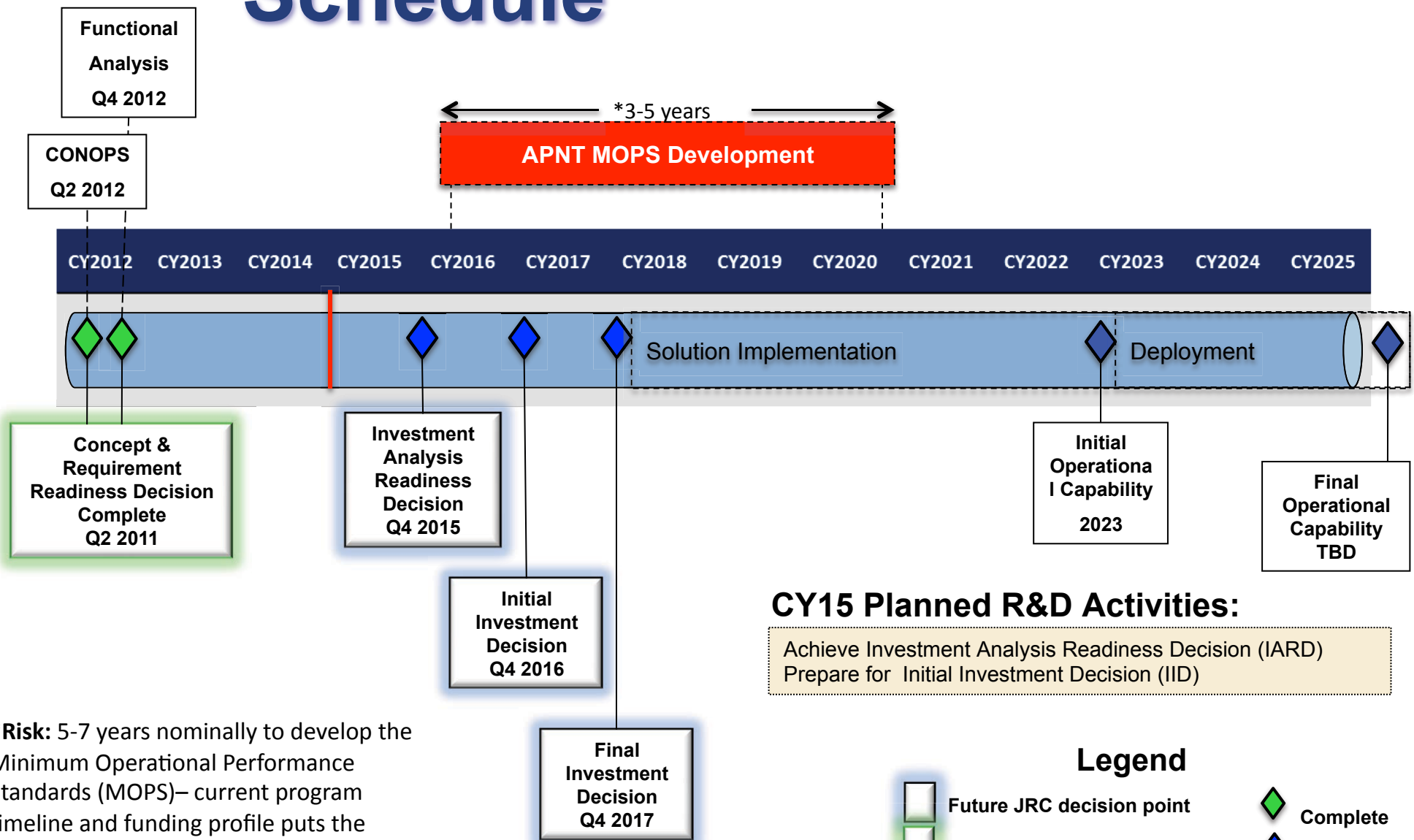
# APNT Update



# 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



## CY15 Planned R&D Activities:

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

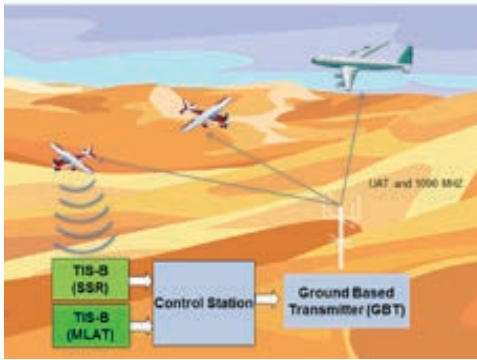
**\*Risk:** 5-7 years nominally to develop the Minimum Operational Performance Standards (MOPS)— current program timeline and funding profile puts the program at risk in accomplishing NextGen 2025 objective.

## Legend

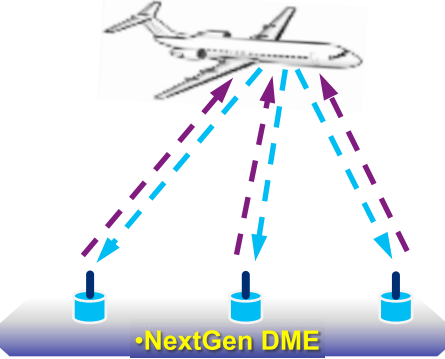
- Future JRC decision point
- Complete JRC decision point
- Complete
- Planned



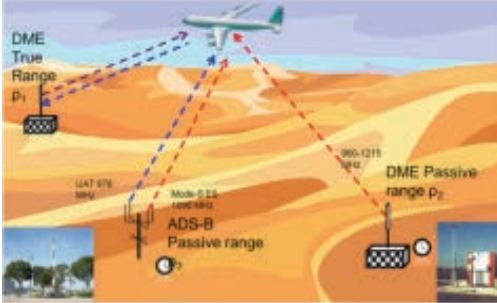
# APNT Alternative: TIS-B

Alternative	Description		Strengths	Weaknesses	Risk				
 <p>The diagram illustrates the TIS-B system architecture. It shows two aircraft in flight: one equipped with TIS-B (SSR) and another with TIS-B (MLAT). These aircraft communicate with a ground-based transmitter (GBT) via a control station. The control station also receives data from the GBT. The system is designed to provide advisory services to non-ADS-B aircraft.</p>	<ul style="list-style-type: none"> <li>Provides ADS-B- In equipped aircraft with position reports from SSR of non-ADS-B reporting aircraft (with in proximity)</li> <li>Provides an advisory service using a communications uplink on 1090MHz and 978MHz</li> <li>Aircraft are intended to navigate using its own ship position as computed and transmitted by the ground system.</li> <li>Need to complete evaluation of TIS-B as an alternative</li> </ul>		<ul style="list-style-type: none"> <li>Existing ground infrastructure</li> <li>Existing signal</li> <li>Aligns with ADS-B IN Plan</li> </ul>	<ul style="list-style-type: none"> <li>Safety assurance for navigation requires validation</li> <li>May require TIS-B interference monitor</li> <li>Navigation and Surveillance both rely on 1090MHz – Common mode failure</li> <li>May have limited radar coverage at low altitudes in remote areas</li> <li>Concerns on update rate and variable latency</li> </ul>	<p><b>Technical - Medium</b></p> <ul style="list-style-type: none"> <li>New interface with Navigation/FMS (software)</li> </ul> <p><b>Cost / Schedule– Medium</b></p> <ul style="list-style-type: none"> <li>Program may retire TIS-B (under discussion)</li> <li>Safety assurance process                             <ul style="list-style-type: none"> <li>Converting an advisory service into a safety critical service</li> </ul> </li> <li>Aircraft: FMS integration</li> </ul>				
<p><b>Services provided:</b></p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Position</li> <li><input checked="" type="checkbox"/> Navigation</li> <li><input type="checkbox"/> Time</li> </ul>									
<p><b>Performance Summary</b></p>	<p>RNAV 1</p>	<p>ADS-B 0.05 nm</p>	<p><b>Existing Aircraft Equipage</b></p>			<p>Air Carrier</p>	<p>Regionals &amp; Business</p>	<p>GA</p>	<p>MOPS Changes</p>
	<p>~Yes</p>	<p>~No</p>	<p>No, ~2%</p>	<p>No, ~2%</p>	<p>No, ~2%</p>	<p>Yes</p>			

# APNT Alternative: NextGen DME

Alternative	Description		Strengths	Weaknesses	Risk/CNS Benefits	
 <p>NextGen DME</p>	<ul style="list-style-type: none"> <li>• Current DME criteria based on AC90-100A</li> <li>• All en route and Class B terminal area coverage supported, without IRU requirements</li> <li>• Elimination of all critical DMEs</li> </ul>		<ul style="list-style-type: none"> <li>• MOPS/TSO already exist (RTCA/SC-227)</li> <li>• Current air carriers and regionals are currently equipped</li> <li>• Leverages existing airborne and ground infrastructure</li> <li>• Proof of concept not required</li> <li>• Updated MITRE DME analysis may determine if a reduction in DME's is feasible</li> </ul>	<ul style="list-style-type: none"> <li>• DME locations require optimization</li> <li>• GA is not equipped</li> <li>• Provides navigation only backup</li> <li>• Updated MITRE DME analysis may determine if additional DME's are needed</li> </ul>	<p><b>Cost /Schedule Risk</b></p> <ul style="list-style-type: none"> <li>• Ground system – Low</li> </ul> <p><b>CNS Bundle Pros</b></p> <ul style="list-style-type: none"> <li>• No MOPS required</li> <li>• No cost to user</li> </ul> <p><b>CNS Bundle Cons</b></p> <ul style="list-style-type: none"> <li>• Does not support CNS bundle business case</li> </ul>	
<p><b>Services provided:</b></p> <p><input type="checkbox"/> Position</p> <p><input checked="" type="checkbox"/> Navigation</p> <p><input type="checkbox"/> Time</p>						
Performance Summary	RNAV 1	ADS-B 0.05 nm	Existing Aircraft Equipage			
	Yes	No	Air Carrier	Regionals & Business	GA	MOPS Changes
	Yes	No	Yes	Yes	No	No

# APNT Alternative: Hybrid Ranging

Alternative	Description		Strengths	Weaknesses	Risk	
	<ul style="list-style-type: none"> <li>Use a combination of DME and ADS-B ground stations to provide GPS independent PNT to aircraft</li> <li>Modify DMEs to add a pseudo ranging signal</li> <li>Modify ADS-B GS-s to enable 1090 Mhz/ UAT pseudo ranging</li> <li>Pseudo-ranging signal includes precise time of transmission</li> </ul>		<ul style="list-style-type: none"> <li>Achieves the highest performance of all the alternatives</li> <li>Signal and site diversity</li> <li>Provides a system to support positioning for PBN and ADS-B in the event of interference</li> <li>The Hybrid alternative supports the current APNT CONOPS</li> <li>Resistant to interference events</li> </ul>	<ul style="list-style-type: none"> <li>Requires new MOPS/TSO/ICD</li> <li>No user equipage base</li> </ul>	<p><b>Technical - Medium</b></p> <ul style="list-style-type: none"> <li>Spectrum 1090 Mhz</li> <li>GS Synchronization (ADS-B and DME)</li> </ul> <p><b>Cost – Med/High</b></p> <ul style="list-style-type: none"> <li>Ground Station Synchronization</li> <li>ADS-B Contract Mod</li> <li>Avionics and aircraft modifications</li> </ul> <p><b>Schedule – High</b></p> <ul style="list-style-type: none"> <li>Develop APNT MOPS</li> <li>Aircraft FMS Integration</li> </ul>	
<p><b>Services provided:</b></p> <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Position</li> <li><input checked="" type="checkbox"/> Navigation</li> <li><input checked="" type="checkbox"/> Time</li> </ul>						
<p><b>Performance Summary</b></p>	<p>RNAV 1</p>	<p>ADS-B 0.05 nm</p>	<p><b>Existing Aircraft Equipage</b></p>			
	<p>Yes</p>	<p>Yes</p>	<p>Air Carrier</p>	<p>Regionals &amp; Business</p>	<p>GA</p>	<p>MOPS Changes</p>
			<p>No</p>	<p>No</p>	<p>No</p>	<p>Yes</p>

# 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



# Preliminary Drawdown Assumptions

- The drawdown decision is scheduled for the 2<sup>nd</sup> 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

# Preliminary Drawdown Numbers

- There are 1126 CAT I ILS's in the NAS and 129 are required for VOR MON recovery
  - This leave approximately 997 for consideration
- 50% of the ILSs ( $\approx 498$ ) 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 ( $\approx 208$ ) are removal candidates
- In total, there are 706 ILS, LOC, LDA/SDF facilities which can be removal candidates

	ILS		WAAS	
	Total in NAS	Candidates		
Category-II/III	180			
Category-I	1126	498	LPV	3402
LOC, LDA/SDF	290	208	LP	538
<b>Total</b>	<b>1596</b>	<b>706</b>	<b>Total</b>	<b>3943</b>

# ILS Drawdown Savings

- **WAAS LPV/LP procedures require 1/3<sup>rd</sup> the cost of ILS to establish and 1/7<sup>th</sup> 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**

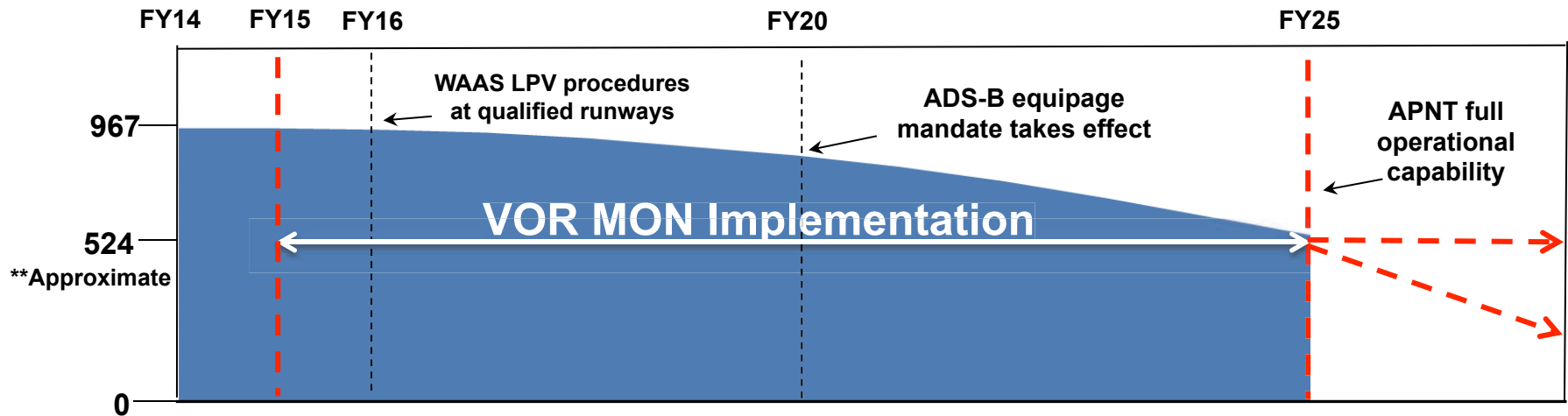
# VOR MON Update



# 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

# VOR MON Strategy and Notional Timeline



\*\* The number of VORs comprising the MON may increase or decrease depending on the requirements for DoD / TOC



# 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, GIISSST, and CPNT Tiger Team
- **The ILS drawdown decision is scheduled for the 2<sup>nd</sup> 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



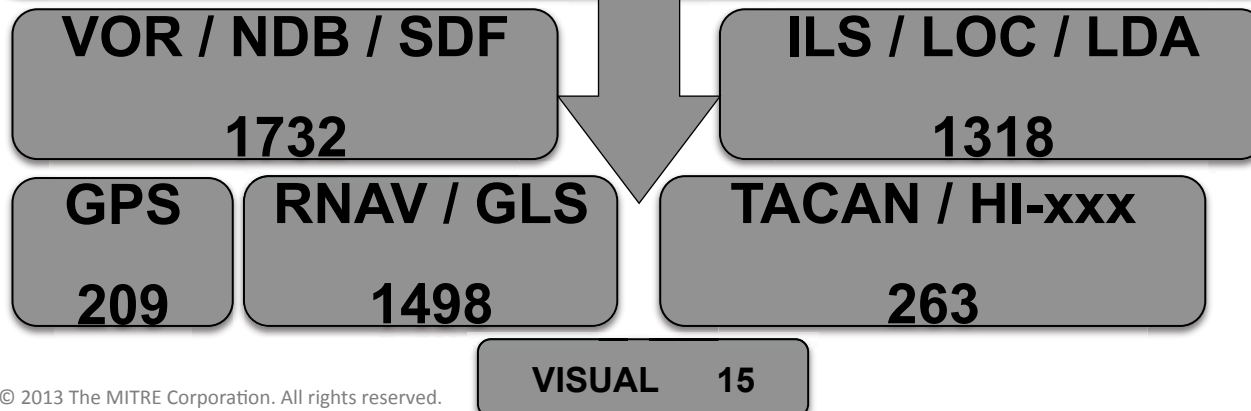
# Back Up

# Overall Instrument Approach Procedure (IAP) Impact Summary

**11798 IAPs identified in CONUS\***

5035 IAPs may be affected by VOR MON

**6763 IAPs are unaffected by VOR MON**



•\*From digital - Terminal Procedures Publication (d-TPP) Volume 1310

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# Affected SIDs/STARs/ODPs

**2084 ODPs/SIDs/STARs identified in CONUS\***

1287 may be affected by VOR MON

**997 are unaffected by VOR MON**

893 SIDs & ODPs

394 STARs\*\*

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

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

Category	Conventional	RNAV
Affected SIDs & ODPs	691	202
Affected STARs	239	155

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