Alternative Positioning, Navigation, and Timing (APNT)

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The Need for *Resilient Radionavigation in the US National Airspace System (NAS)*

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Stanford PNT Symposium

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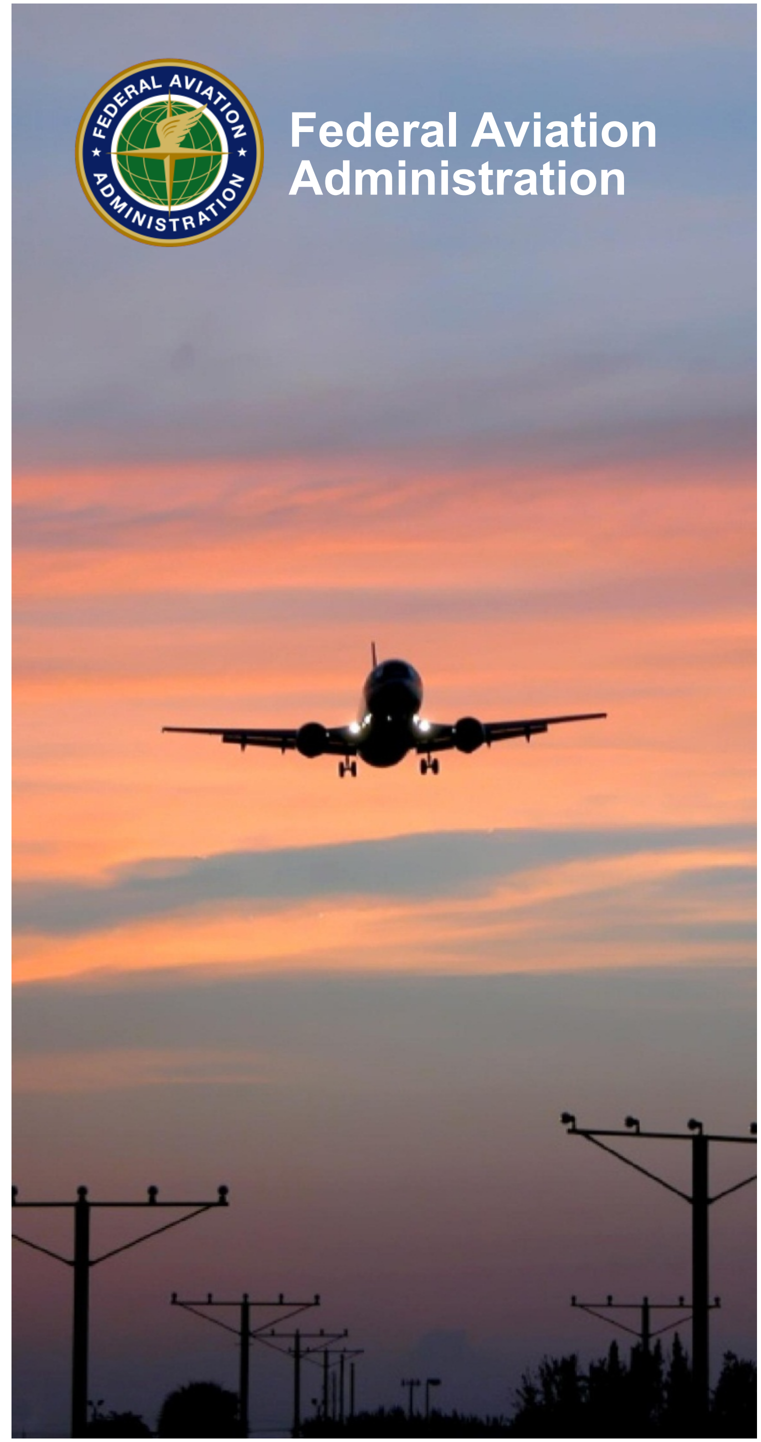


The Definition of ***Resilient***

re·sil·ient, *adj,* [ri' zilyent]

***a*: the ability of a material to absorb energy when it is deformed and release it upon unloading.**

***b*: (of an object) the capability to regain its original shape or position after bending, stretching, compression, or other deformation.**

c: (of a process, system, organization, etc.) the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions – including from deliberate attacks or naturally occurring threats or incidents.*

***Presidential Policy Directive 21**
February 12, 2013

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!***

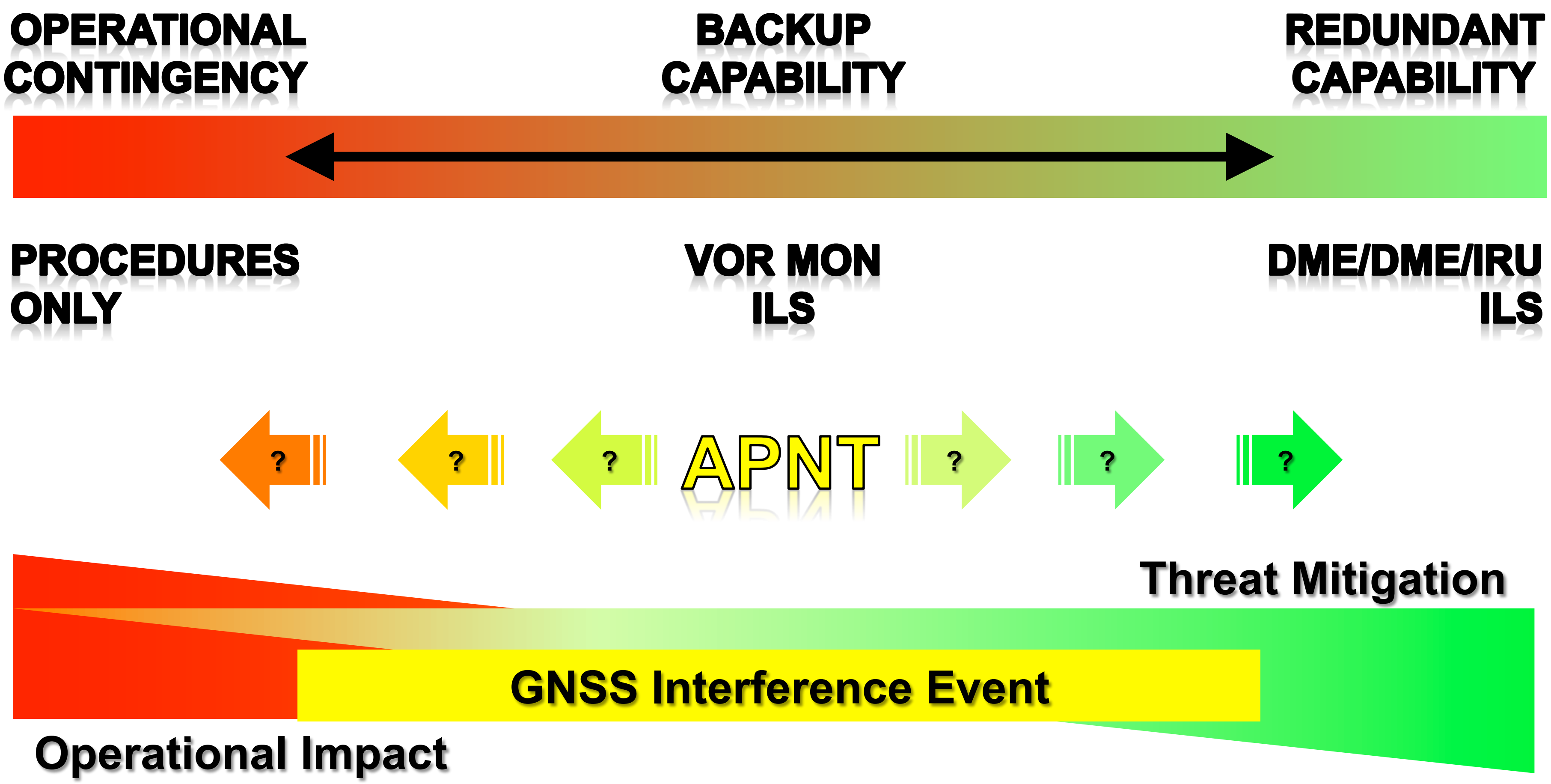
What are “Disruptions”?

- **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

Alternate PNT and NextGen

- Today's Air Traffic Control (ATC) system cannot be scaled up to handle twice the traffic in the future
- 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)
- The NextGen NAS will require the NextGen APNT

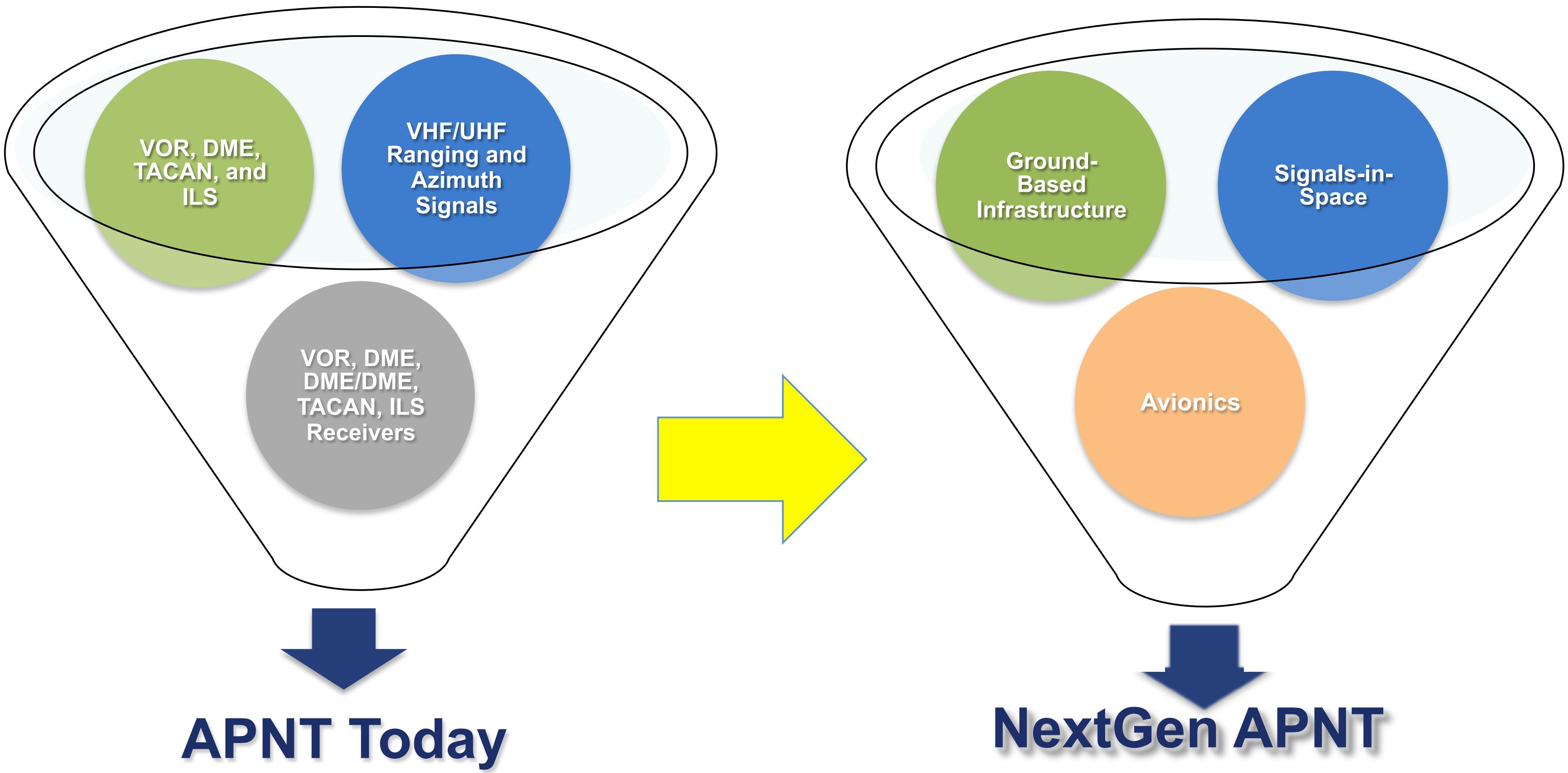
NextGen APNT Trade Space



Transforming the NAS to NextGen

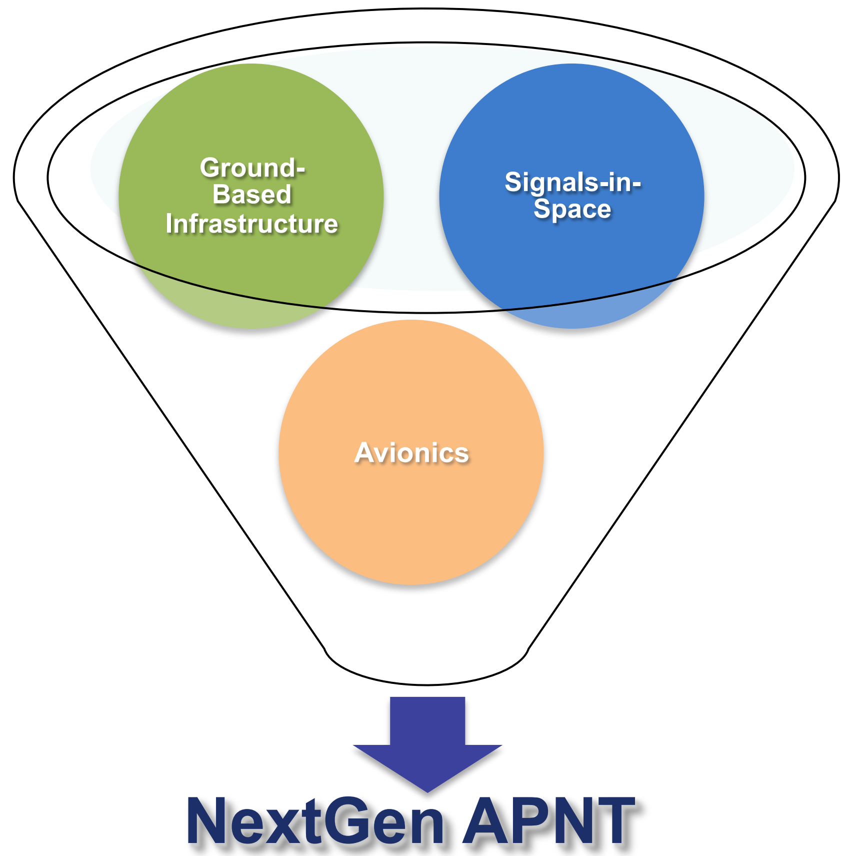
- NextGen APNT needs to support:
  - The safe and efficient transition from "NAS ***Normal***" (i.e., based to a large extent on GNSS services) to "NAS ***Nominal***" (i.e., relying on robust and resilient APNT backup solutions)
  - Performance-based Navigation (PBN)
    - Area Navigation (RNAV) everywhere
    - Required Navigation Performance (RNP) where required for safety or necessary to derive economic benefits
  - Dependent Surveillance Operations (ADS-B Out and In)
  - Trajectory-Based Operations (TBO)
  - Four Dimensional Trajectories (4DT)

The Road to APNT



The Road to APNT

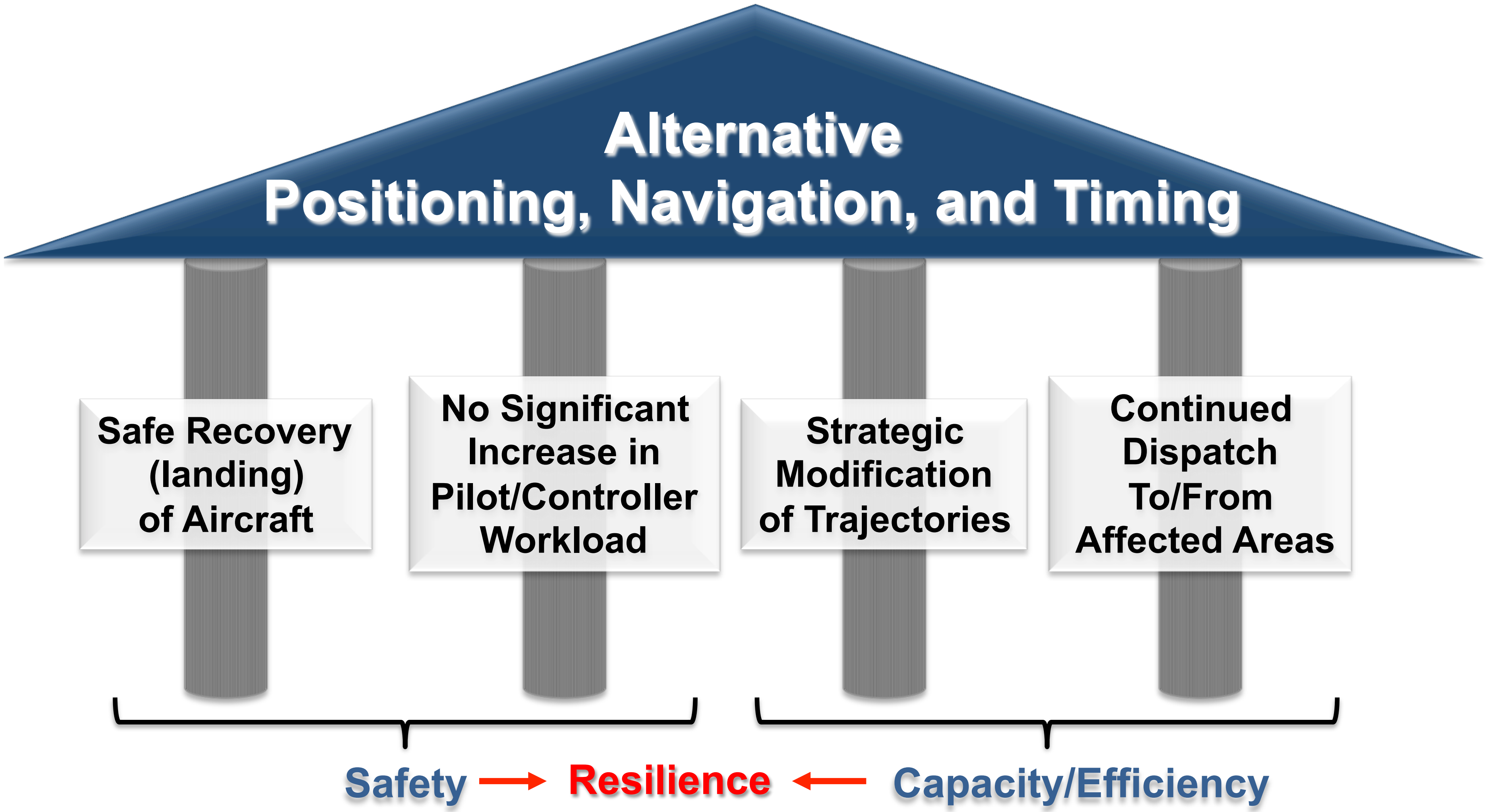
- The development of APNT requires the identification of multiple solution sets that can serve diverse NAS users
- APNT solution sets will be comprised of ground-based infrastructure transmitting non-GNSS signals-in-space to avionics that may vary by user
- The signals-in-space must support legacy users 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 nominal levels



APNT Objectives

- Provide an alternative means of positioning, navigation, and timing to support the broadest segments of aviation
  - Leverage existing or planned equipage/infrastructure to the extent possible
  - Support backward compatibility for legacy users
  - Minimize the need for multiple avionics updates for users
  - Provide long lead transition time
- Deliver position information sufficient to support required separation services
- Continue to support the dispatch and recovery of aircraft
- Provide positioning and navigation functions to other integrated Communications/Navigation/Surveillance (ICNS) functions to sustain NextGen operations, and specifically TBO
- Reduce, and potentially eliminate, the need for many VORs

APNT Objectives

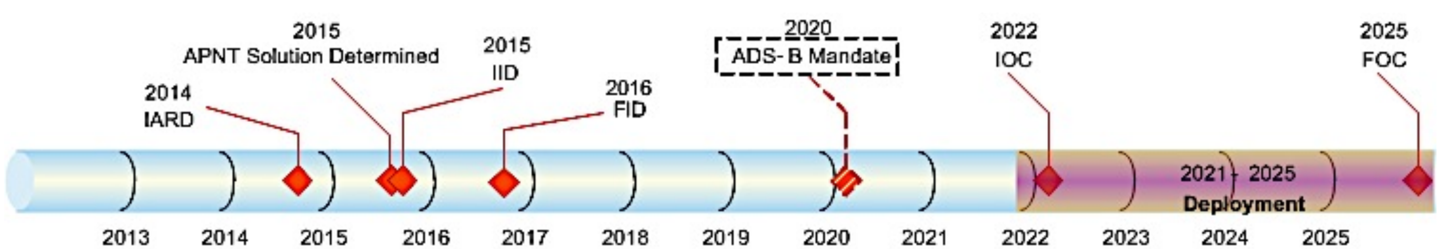


Benefits

- Continue aircraft en route operations throughout the Conterminous United States (CONUS) during GPS outages
  - Includes terminal/TBO operations (dispatch and arrivals) at high density MetroPlex airports without requiring excessive pilot or controller workload
  - Sustain arrival and departure rates at the Core 29 (i.e., minus HNL) plus ~100 next busiest airports in CONUS when GPS is unavailable
    - Final list of airports dependent on the business case
  - Maintain 3 nautical mile (nm) high density airspace separation to sustain capacity without unacceptable risk
  - Sustains RNAV en-route flight paths
  - Sustain navigation capability for precision or non-precision approach to a safe landing
- Maintain reduced user fuel costs/carbon emissions; avoid delays that GNSS outages would otherwise trigger

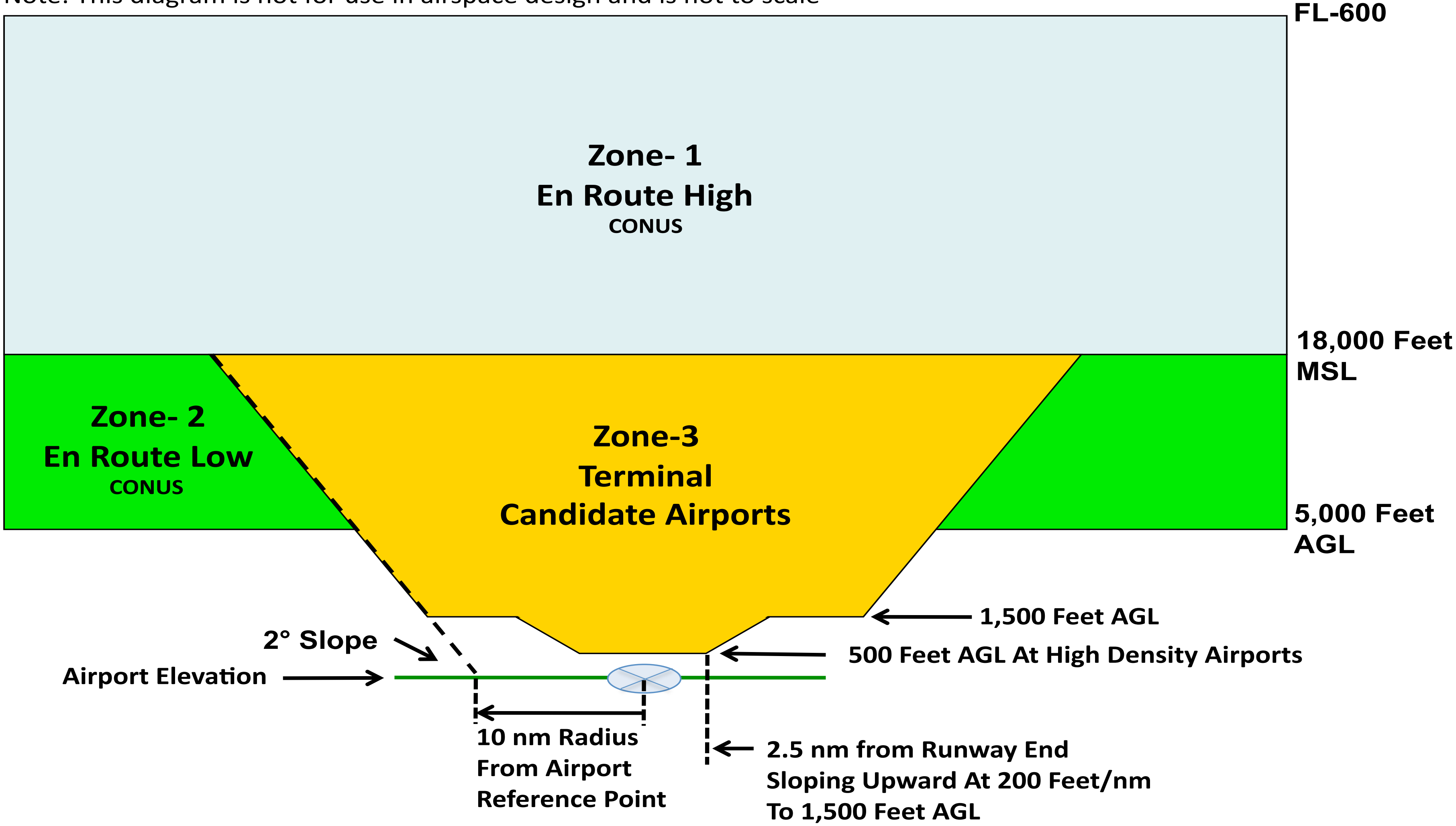
Alternate Position, Navigation, and Time (APNT)

- The FAA is investigating technologies to maintain safety and ensure continuity of PBN operations in the NextGen operating environment in the event of a GPS interference event or outage
- APNT is coordinating with the ADS-B IN mandate to minimize cost to the operator for equipage
- FY14 Activities: Preliminary Requirements, Shortfall Analysis, Operational Safety Assessment (OSA), and an initial Rough Order of Magnitude (ROM) Budget



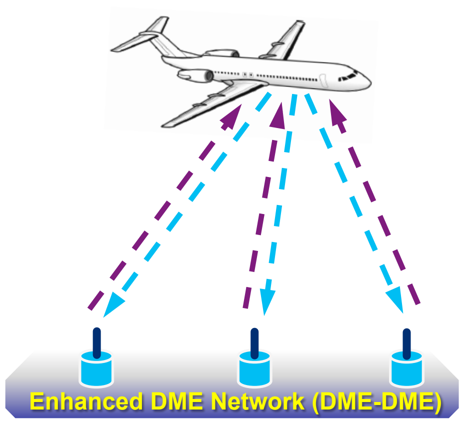
Notional APNT Coverage

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

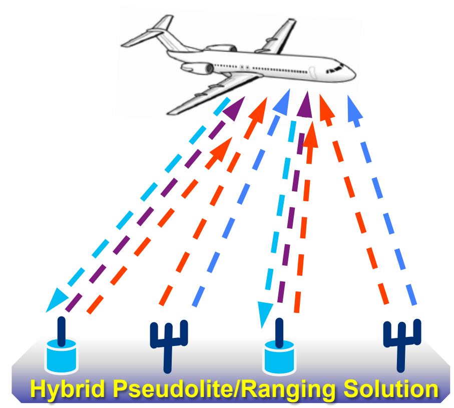


Note: 1,500 foot AGL floor covers arrivals while the 500 foot AGL floor is for departures. The departure coverage starts at 2.5 nm from the runway end and extends upward to cover the climb out and may not be a conical surface around the airport.

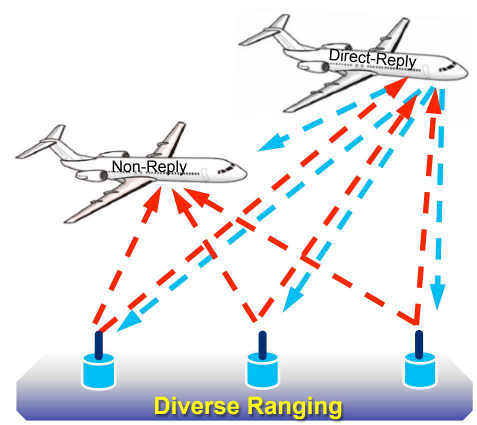
Alternatives Being Evaluated



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

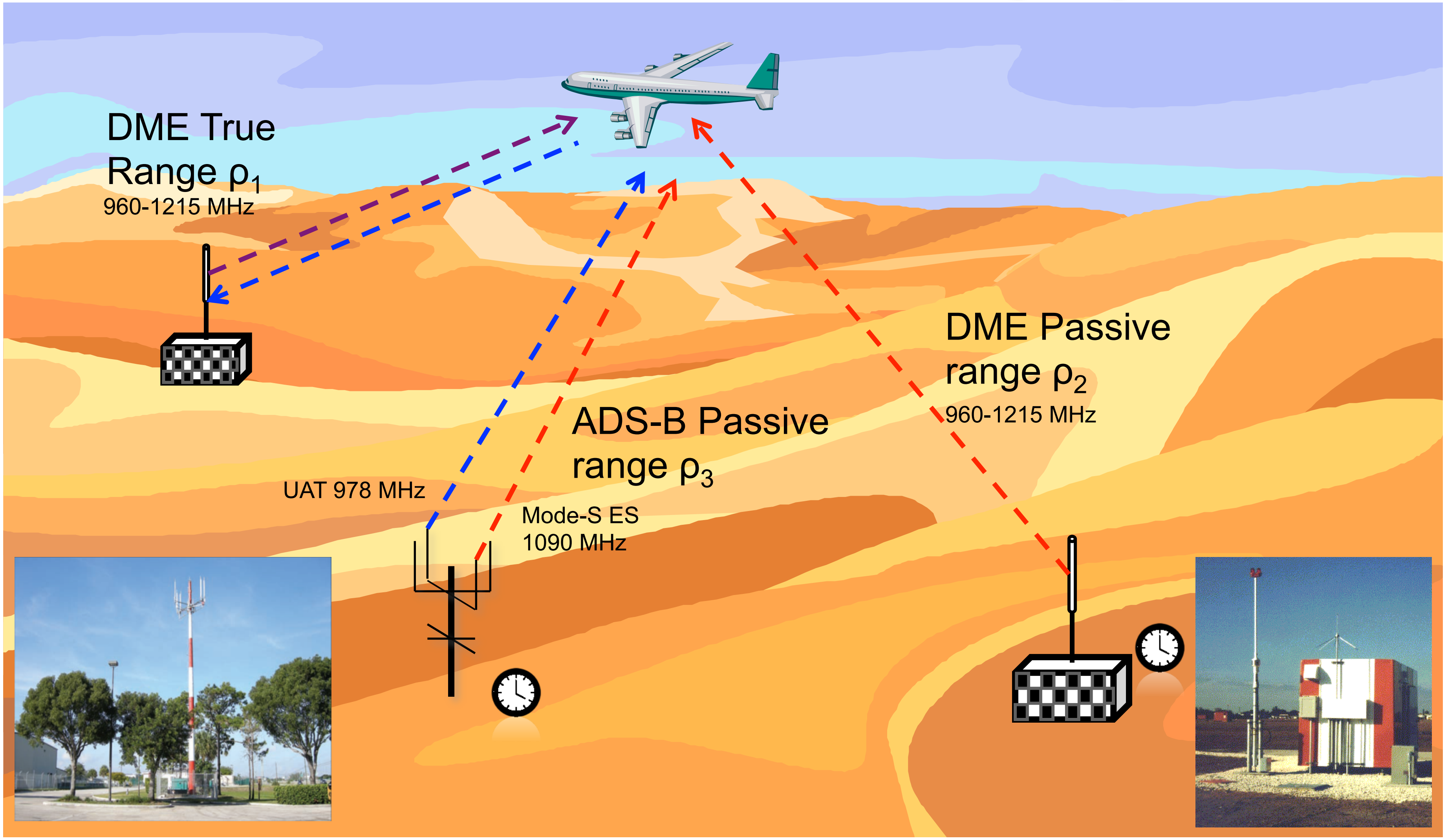


- New Concept
- Leverages DME/Ground Based Transmitter Infrastructure
- Leverages Planned and Existing Automate Dependent Surveillance-Broadcast (ADS-B) Technology and Air/Ground Infrastructure
- Provides precise time to aircraft
- Impact to Avionics

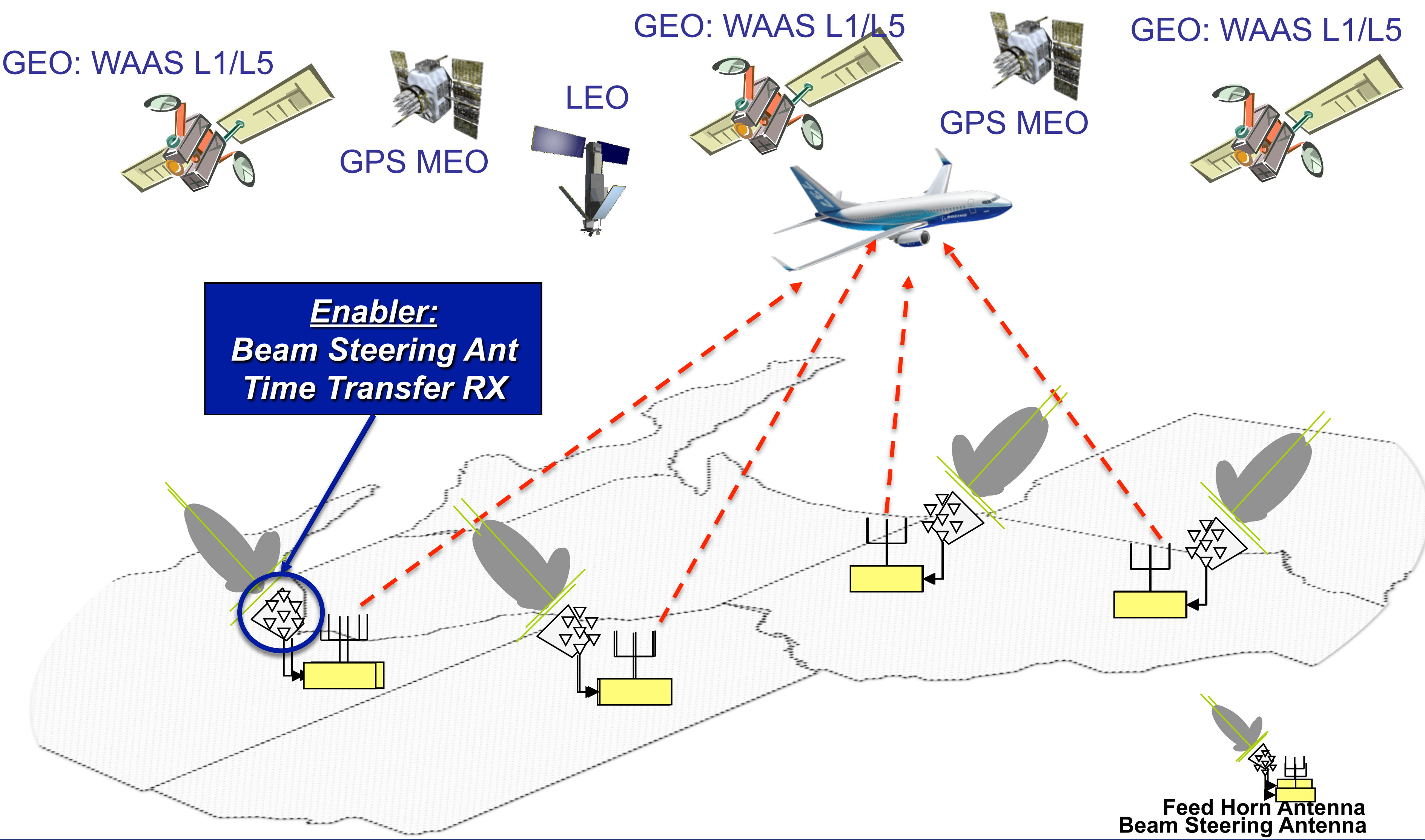


- New Concept
- Uses Ground and Aircraft-based emitters for coverage
- Leverages Planned and Existing Automate Dependent Surveillance-Broadcast (ADS-B) Technology and Air/Ground Infrastructure
- Provides precise time to aircraft
- Impact to Avionics

APNT Hybrid Solution
Passive and True Ranging



Resilient Pseudolite Time Synchronization



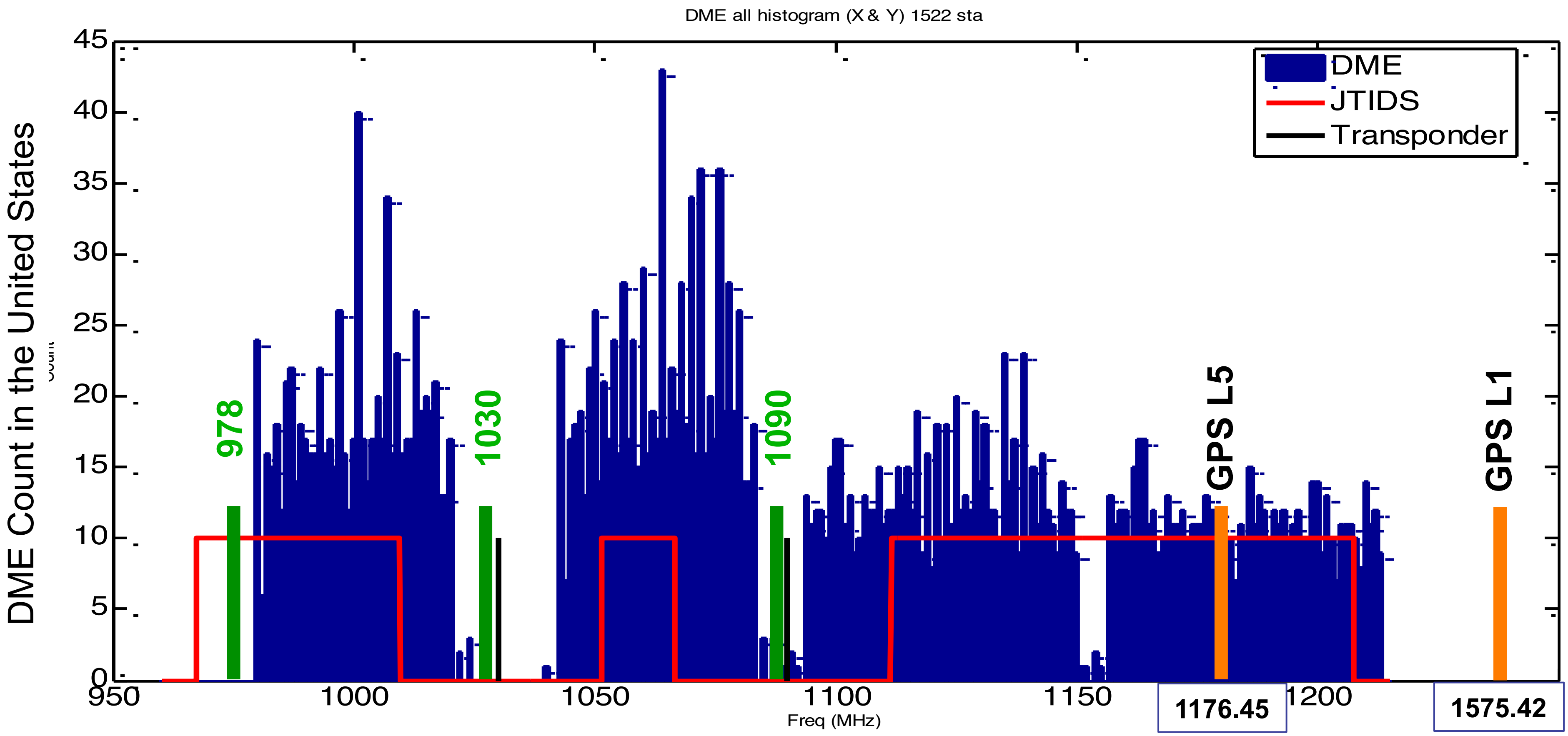
All Alternatives Use Robust and Resilient High Power Ground-Based Systems

Distance Measuring Equipment (DME)
1000 W

Automatic Dependent Surveillance – Broadcast
500 W

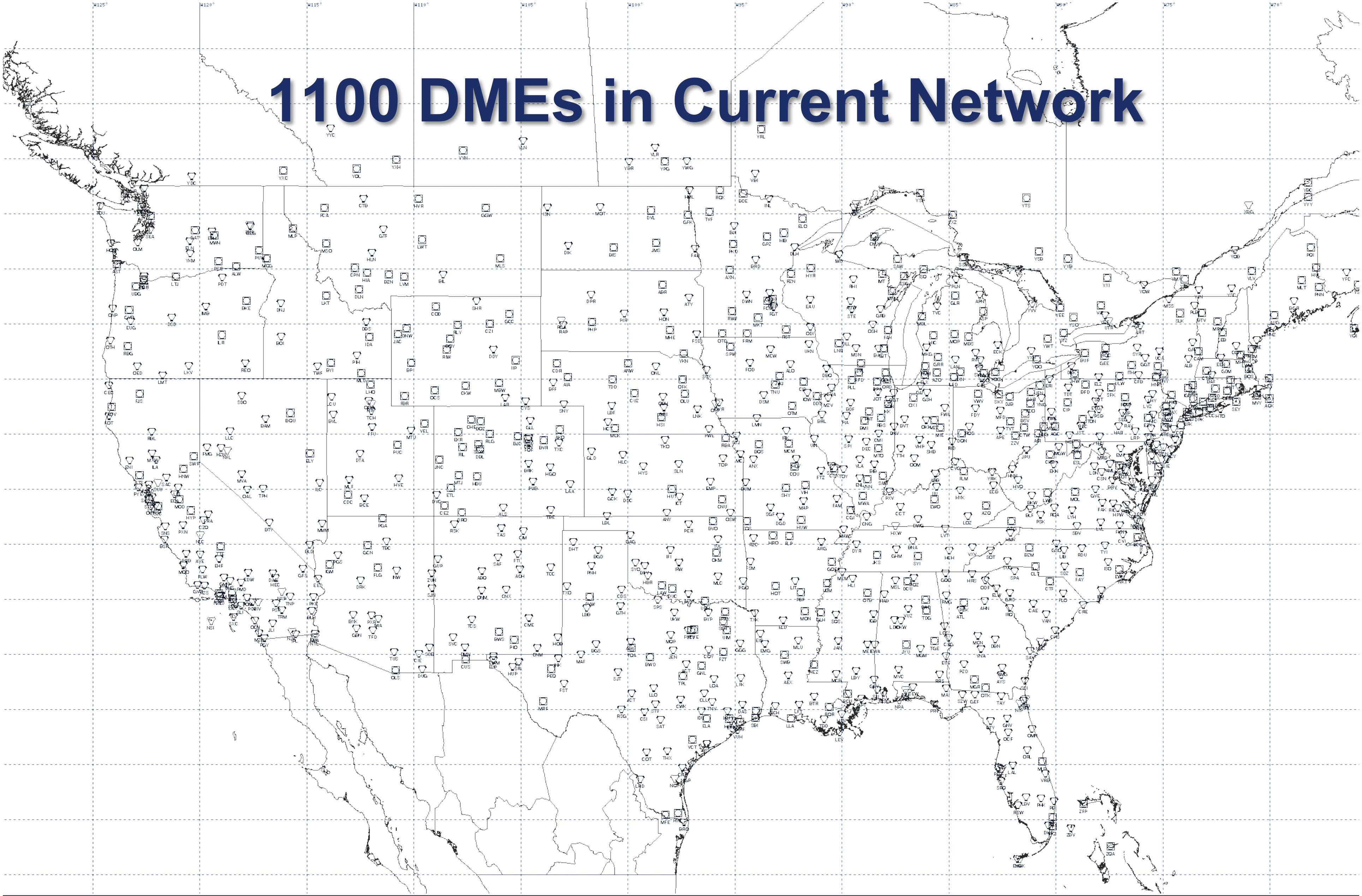
L-Band Aeronautical Radionavigation Services

Where All Performance Based Navigation and ADS-B Originates

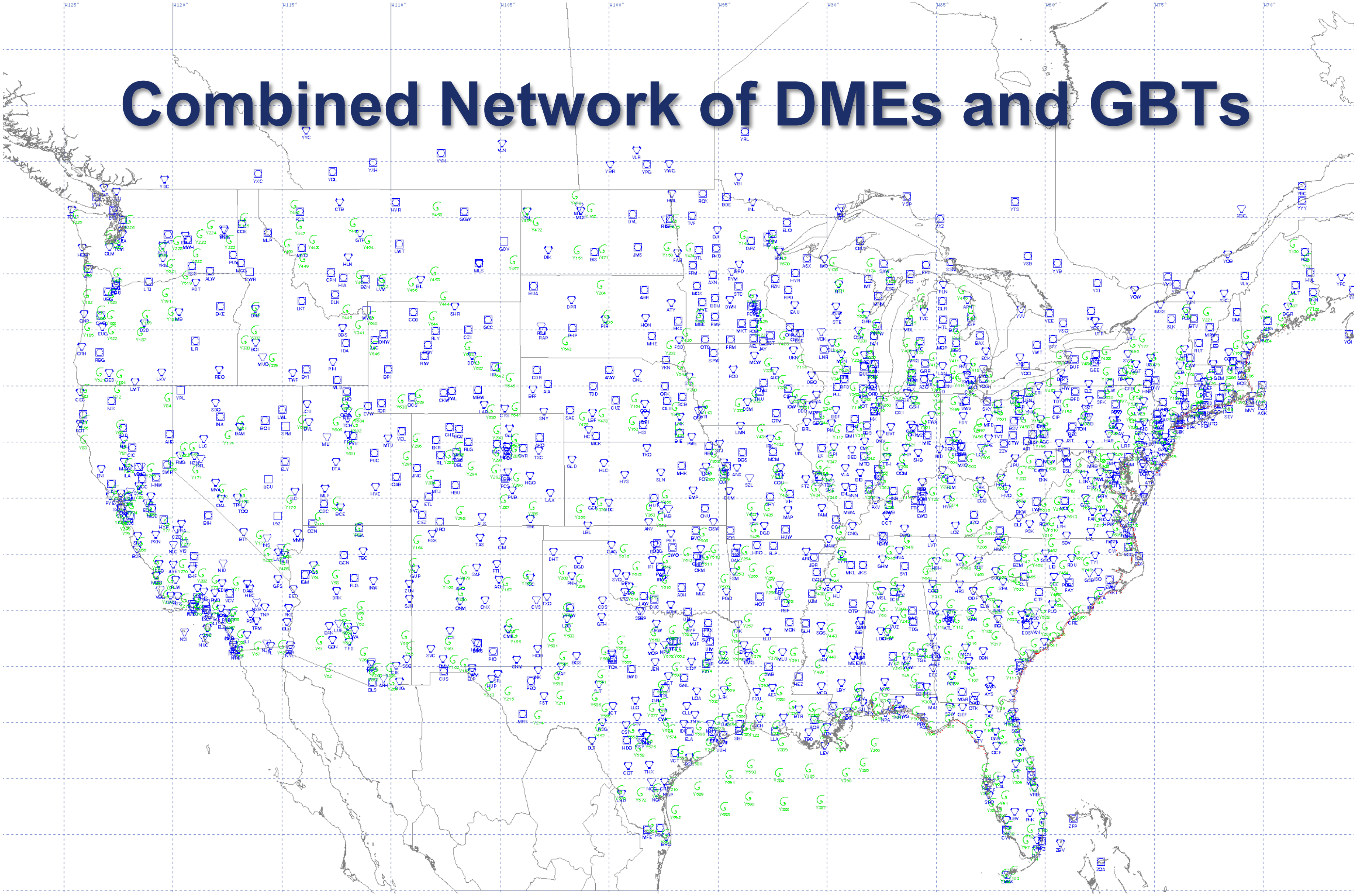


An Opportunity for an Independent, yet Common-Hardware Navigation and Surveillance Avionic Solution without sacrificing performance

1100 DMEs in Current Network



Combined Network of DMEs and GBTs

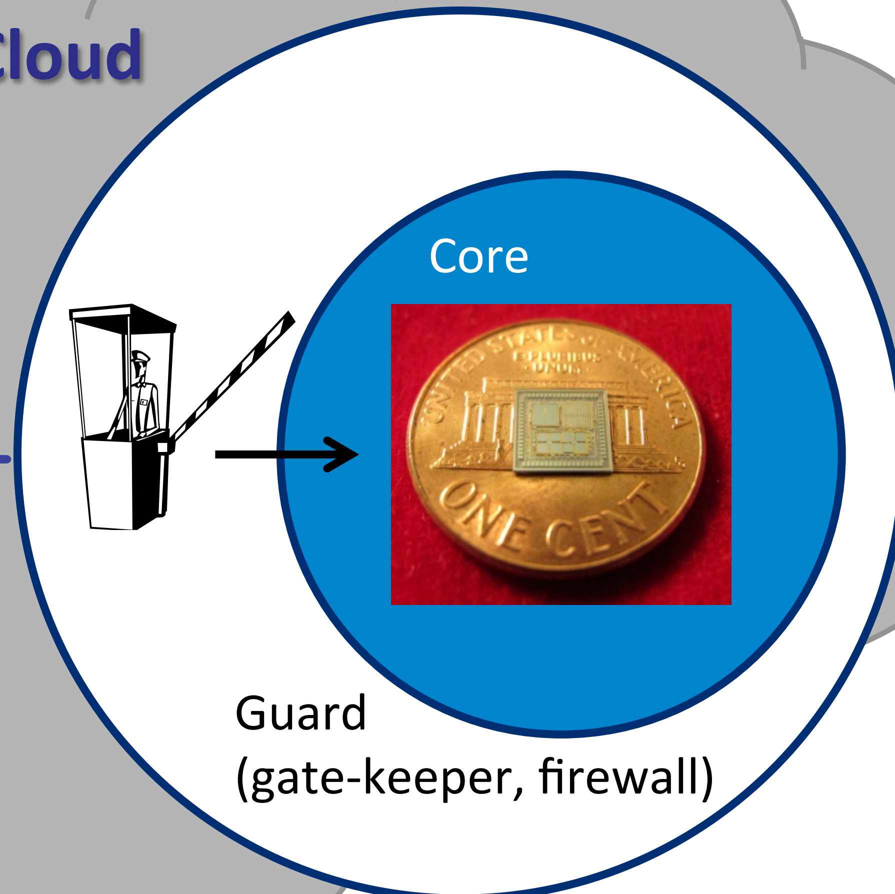


DARPA's Ultimate Navigation Chip (uNavChip)

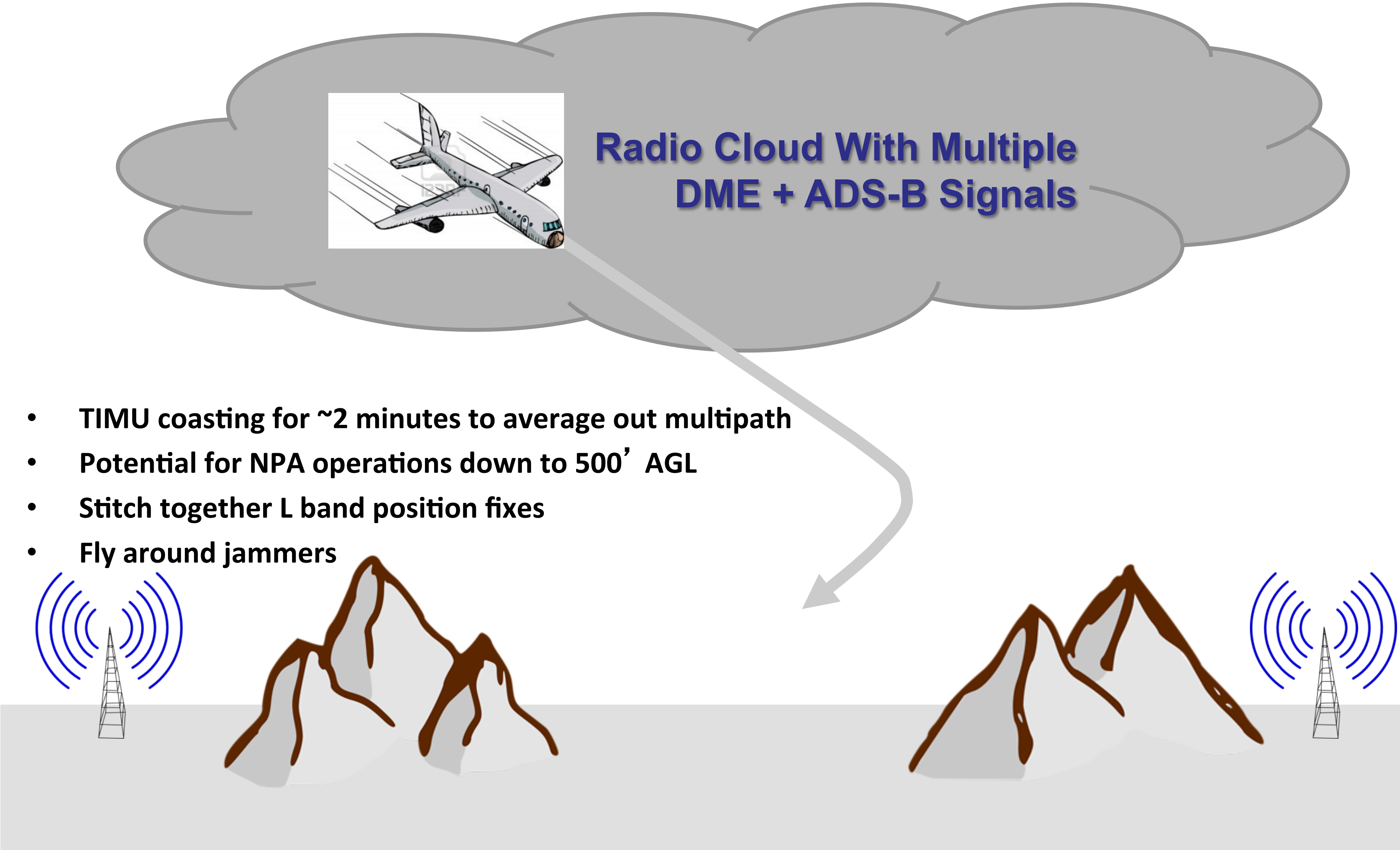
Cloud

DARPA:
- GNSS
- Optical
- Stellar
- Terrestrial radio

APNT
- Civil Nav signals
- 960-1215 MHz
- DME
- ADS-B

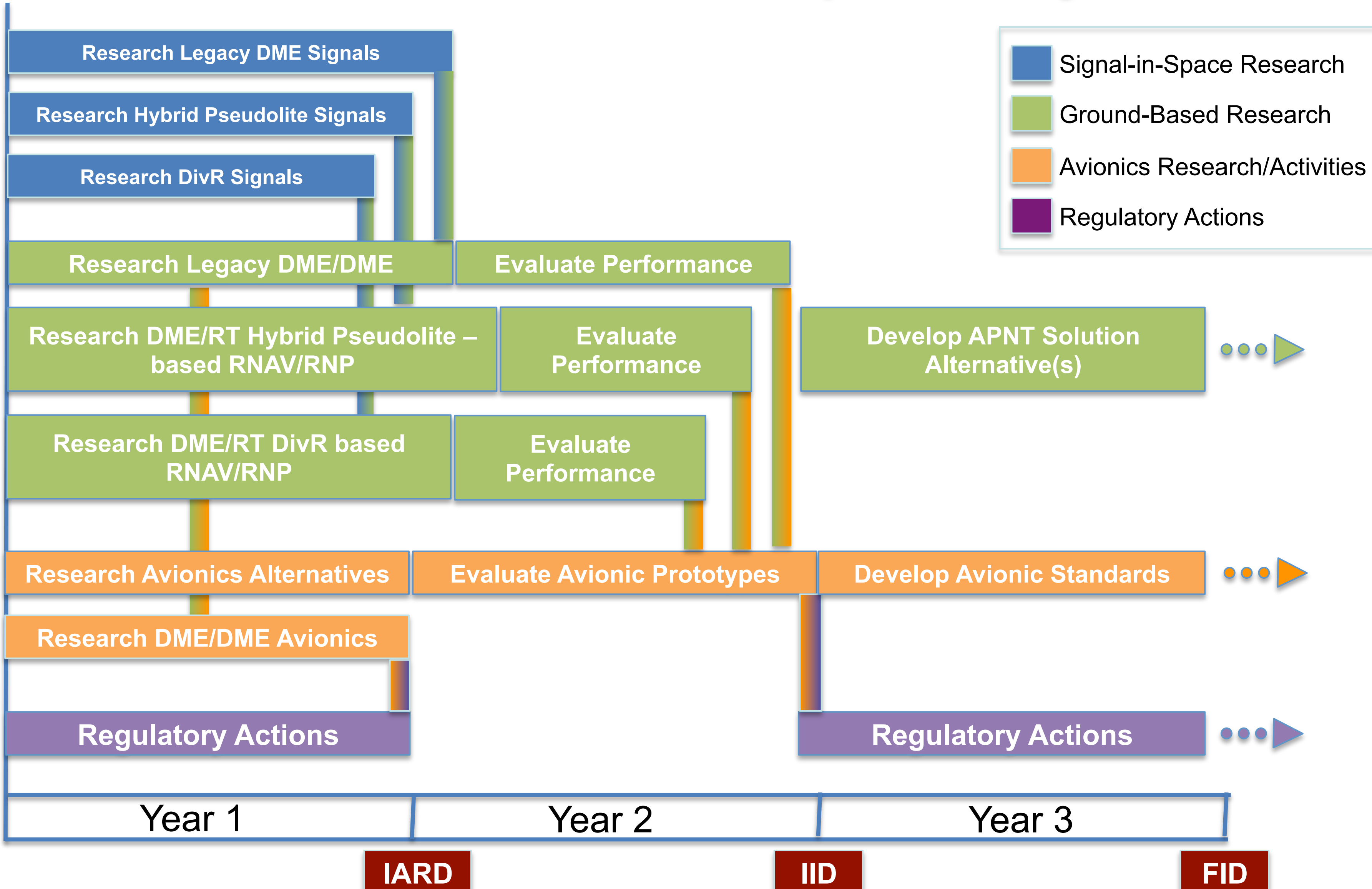


The First and Last Miles
Calibrate at 1500' where DME/ADS-B Coverage is Strong



- TIMU coasting for ~2 minutes to average out multipath
- Potential for NPA operations down to 500' AGL
- Stitch together L band position fixes
- Fly around jammers

Nominal APNT Development Cycle



Next Steps

- Develop and Validate Backup Requirements
- Develop the Project Plan for Full Investigation
- Continue System Engineering Analysis
- Finalize Concept of Operations
- Start R&D Prototyping
- Develop Cost & Schedule Estimates
- Complete Analysis of Alternatives (AoA)

Summary

- ***GNSS is vulnerable because it is so valuable!***
- Today's status quo will 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

Benefits

NET Benefits: FAA		
Cost Savings	Yes	Potential enabler for further reduction of VOR's
Cost Avoidance	Yes	Opportunity to avoid further VOR capital investment
Efficiency/Productivity	Yes	Sustains RNAV/RNP – TBO during GPS outages

NET Benefits: User		
Safety	Yes	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	Minimize time lost during GPS outages and limits discomfort and cost people experience when traveling
Capacity	Yes	Sustain departure and arrival traffic flow to the Core 30 (minus HNL) airports plus the next ~100 busiest airports in CONUS