Alternative Positioning, Navigation, and Timing Initiative

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The Need for *Robust Radionavigation*

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What is ***Robust*** Radionavigation?

ro·bust, *adj,* [rō-ˈbəst, ˈrō-(ˌ)bəst]

***a*: strong and healthy; having or exhibiting strength or vigorous health.**

***b*: (of an object) strongly formed or sturdy in construction.**

c: (of a process, system, organization, etc.) able to withstand or overcome adverse conditions.

. . . so let's agree to define *Robust* Radionavigation as the provision of position, navigation, and timing (PNT) services that are *strong, sturdy, and able to withstand or overcome adverse conditions*.

What are Adverse Conditions?

- **Interference**
  - Intentional/Unintentional
  - Predictable/Unpredictable
  - Manmade/Environmental
  - Crude/Sophisticated (Jamming/Spoofing)
  - Widespread/Localized
- **Dependent on the PNT System (both xmtr and rcvr)**
  - High power/low power
  - Line-of-sight/ground wave
  - Designed robustly/Engineered for a sunny day
- **Both suppliers and users of PNT services should recognize the potential for real-world adverse conditions and plan and design accordingly**

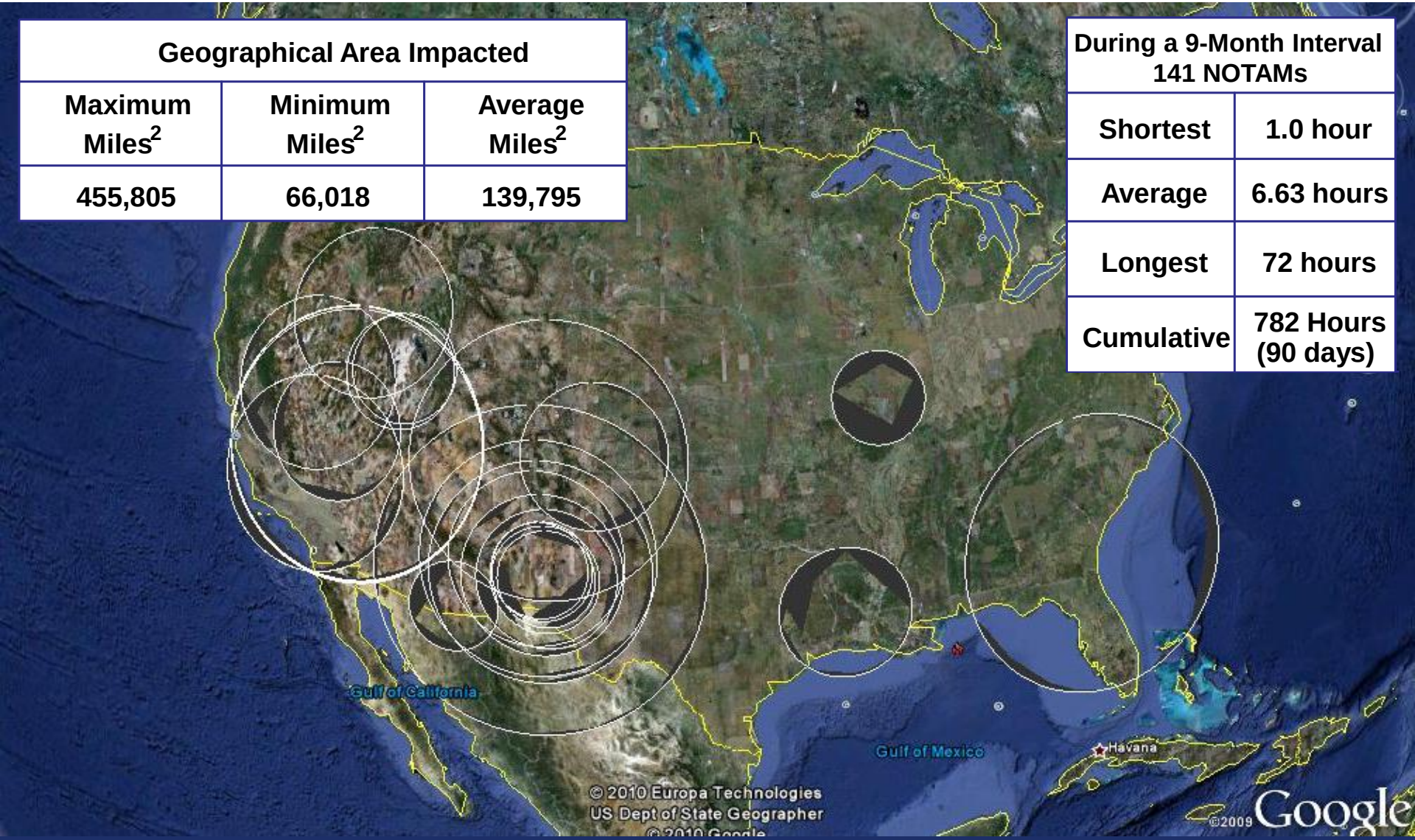
The world is changing…

…The world has changed

Adverse Conditions: GPS Testing by DOD

Geographical Area Impacted		
Maximum Miles^2	Minimum Miles^2	Average Miles^2
455,805	66,018	139,795

During a 9-Month Interval 141 NOTAMs	
Shortest	1.0 hour
Average	6.63 hours
Longest	72 hours
Cumulative	782 Hours (90 days)



Commercially Available GPS Jammer
(so called "Personal Privacy Device")

Portable GPS Jammer GJ02

Specifications*

- Cover interface: GPS L1
- Isolating range: GPS L1 1575.42MHz
- Output power: 0.5 Watt
- Antennas: External, omnidirectional
- Power supply: Car cigarette lighter
- Humidity: 5%-80%
- Effective range: Radius 2-10 meters
- Dimension: 70mm x 20mm x 20mm
- Weight: 25g

~ $33

Certainly much, much further!!!

* Information provided on internet website

… and a few more “Personal Privacy Devices”

$110 Ebay

$335 Ebay

$40 GPS&GSM
www.chinavasion.com

$55 Ebay

$83 GPS&GSM
www.Tayx.co.uk

$152 Ebay

“Super HOT New Cigarette Case Cell Phone Jammer”

- **Features**
  Power supply: **Rechargeable Li-battery**
  Effective Radius: **5m**
  Dimension: **90x50x15mm**
  Energy Consumption: **33dbm**
  Accessories: **AC Adapter/Car Adapter**

- **Specifications**
  Jamming Signal Frequency:
  *** CDMA: 869-880MHZ**
  *** GSM: 925-960MHZ**
  *** DCS: 1805-1930MHZ**
  *** 3G: 2110-2170MHZ**

In Harm's Way: LAAS Antenna Location

Step 1: Know you're in Harm's Way. Step 2: Take the appropriate actions.

Step 3: Don't forget Step 1.

Why Alternate PNT?

- **The Federal Aviation Administration (FAA), in compliance with national policy, needs to maintain aviation operations indefinitely in the event of a Global Positioning System (GPS) interference event or outage.**
  - Maintain safety and security
  - Minimize economic impact
- **<u>Waiting for the source of the interference to be located and turned off is not an acceptable alternative.</u>**

Transforming the NAS to NextGen

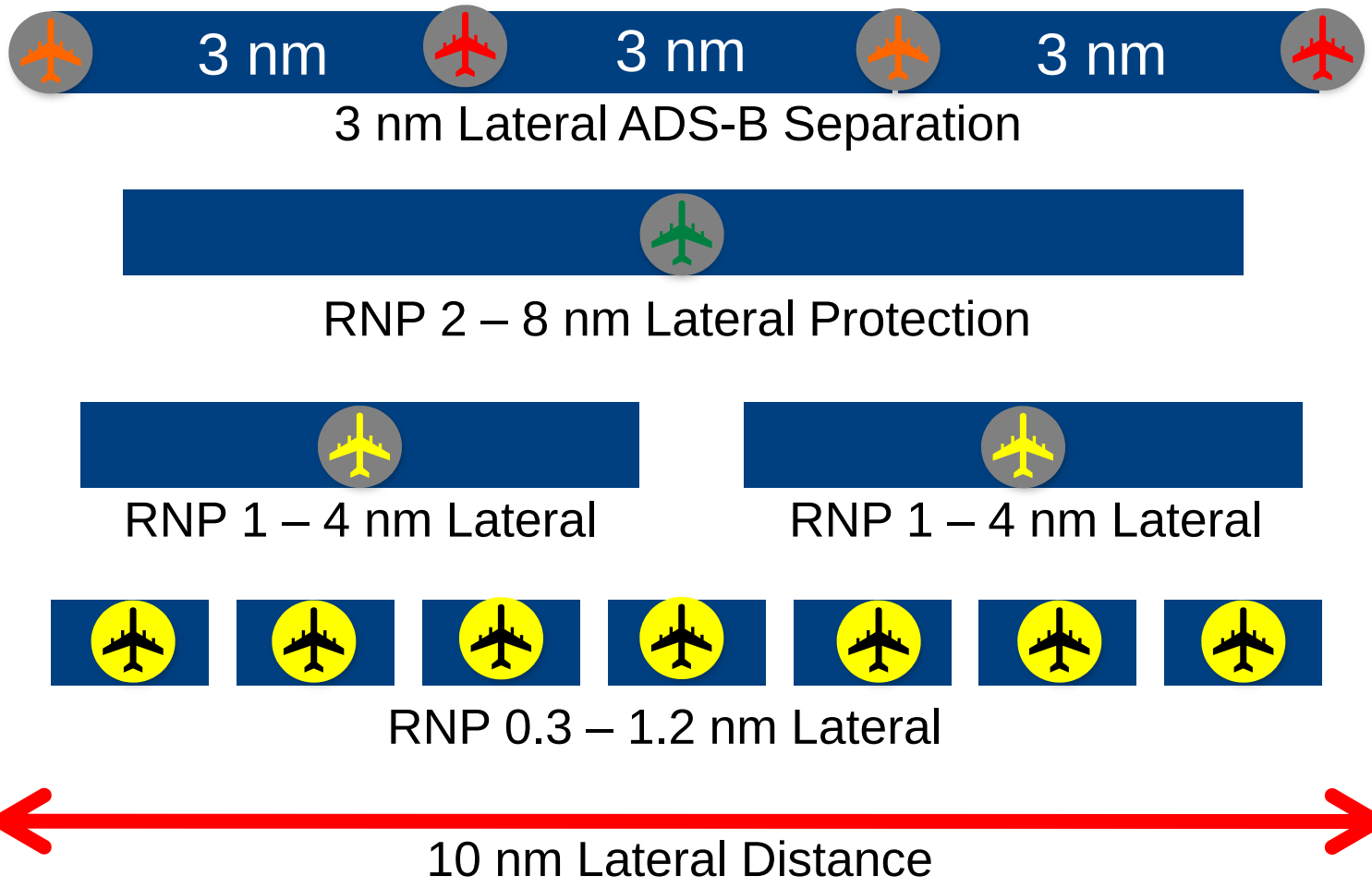
- **NextGen is, in part**
  - ***"An evolution from a ground-based system of air traffic control to a satellite-based system of air traffic management …"***
  - ***"The development of aviation-specific applications for widely-used technologies, such as the Global Positioning System (GPS)"***
  - ***The means by which more aircraft will safely fly closer together on more direct routes, reducing delays and providing unprecedented benefits for the environment and the economy …"***
- **The transformation of the NAS to the NextGen is driving new requirements and increased reliance on GNSS-based PNT services.**
  - **APNT needs to address these requirements.**

Alternate PNT and NextGen

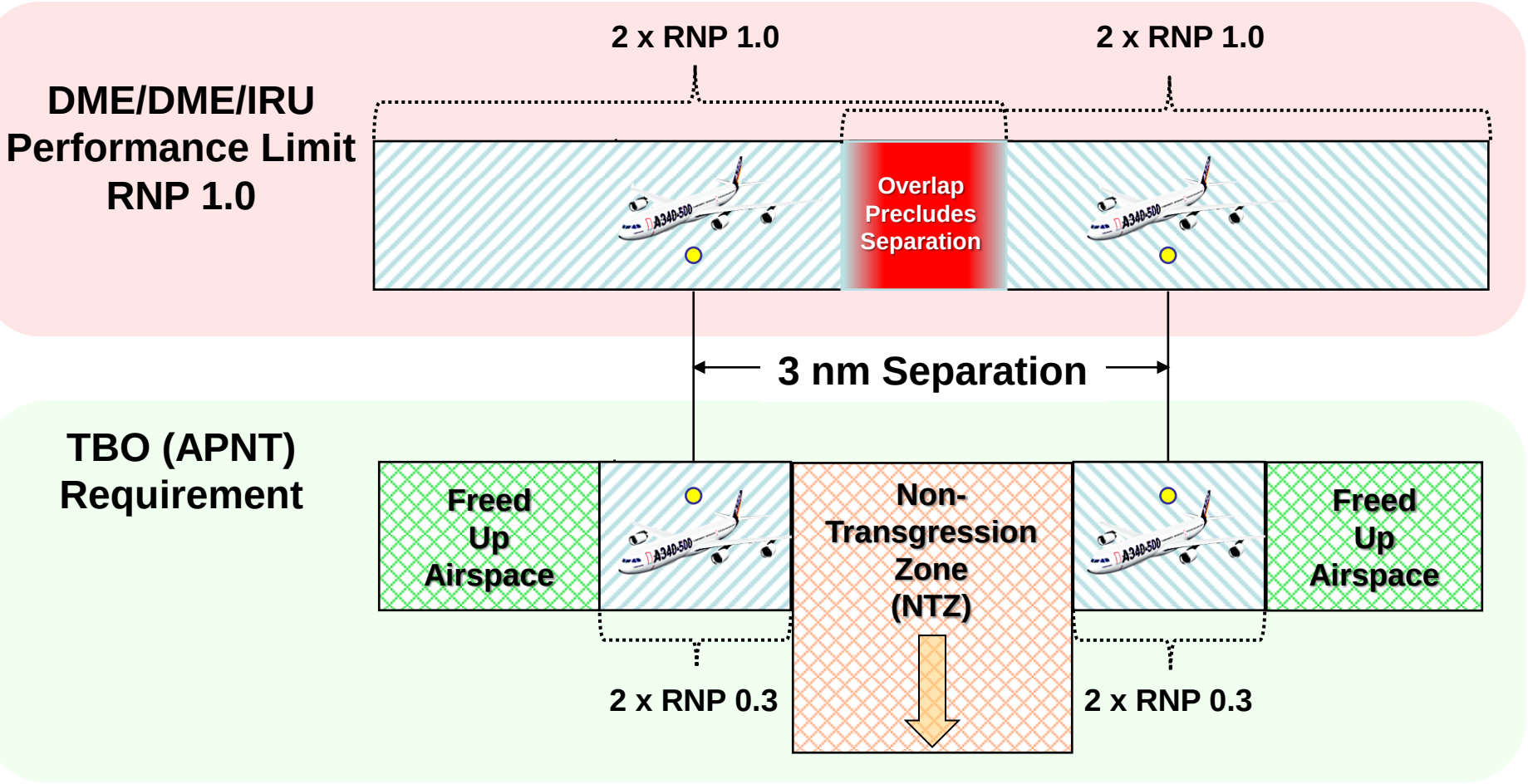
- **Today's ATC system cannot simply be scaled up to handle twice the traffic**
  - **Twice today's traffic is more than a controller can handle using radar vectors**
  - **Automation will need to separate aircraft performing trajectory based operations (TBO) based on RNAV and RNP routes**
  - **Controllers will need to intercede to provide "control by exception"**
- **TBO Trajectories require PNT performance that exceeds DME/DME/IRU (D/D/I)**

Airspace and Arrival Gains with RNP

(Containment zone = 2 x RNP value)



Achieving and Maintaining 3-mile Separation

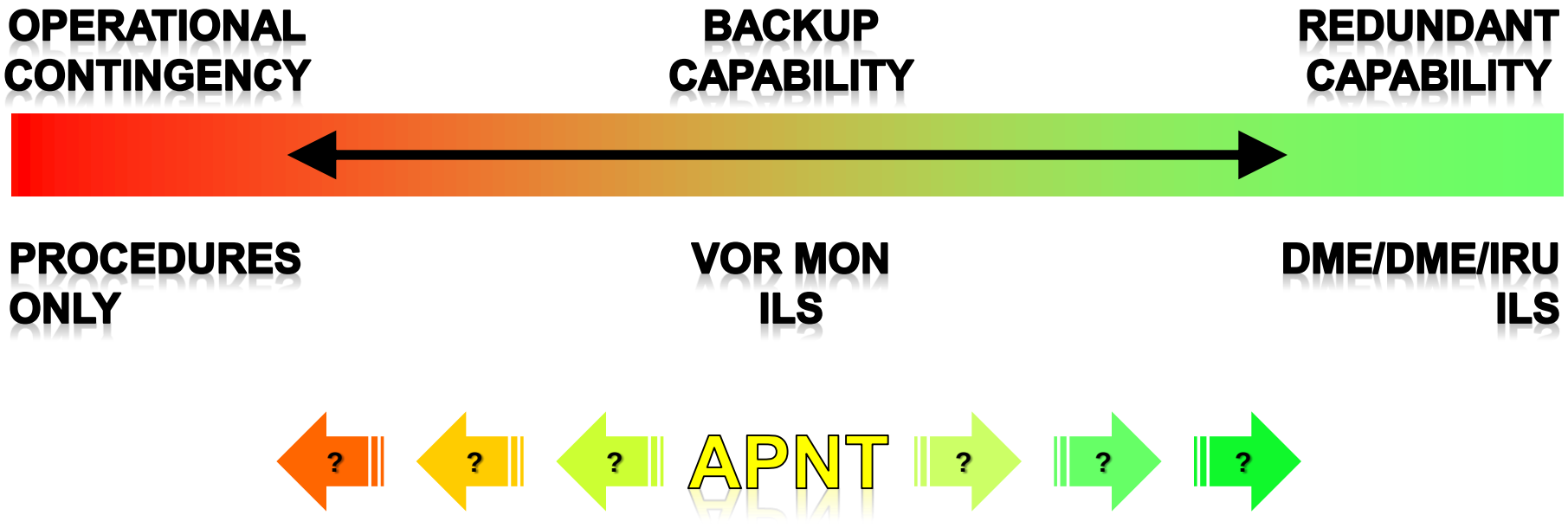


Current Alternative Positioning

- **ADS-B Surveillance**
  - **GNSS for primary positioning**
  - **Secondary Surveillance Radar (SSR) Backup**
    - **Only a subset of existing SSRs will be retained over the longer term**
  - **Multi-Lateration also used to validate GPS Position**
- **Performance Based Navigation (PBN) Backup**
  - **Transport Category Aircraft rely on DME/DME/INS + ILS**
    - **Optimized DME retained to support enroute and terminal PBN**
    - **ILS retained for final approach guidance**
  - **General Aviation aircraft rely on VORs, (not DME equipped)**
    - **VOR not an optimum solution for PBN**
- **Continuation of Current State Requires Recapitalization of VORs - ~$1.0B Investment**

APNT
Challenges

APNT Trade Space



Potential Actions/Impacts Associated with Loss of GNSS Service

- Get aircraft from 3-mile to 5-mile separation en route and on arrivals outside of 40 nm
- Implement procedures to sustain separation at reduced throughput
- Support flights through the area of GNSS interference
- Reroute aircraft around GNSS interference area to reduce demand
- Throttle back demand to compensate for loss of capabilities like parallel runway approaches
- Limit RNAV/RNP arrivals and departures and reduce options to handling arrivals
- Shift some aircraft to radar vectors – significant implications
- Recover aircraft in weather
- Continue to dispatch aircraft
- Operate at reduced capacity and efficiency

APNT
Assumptions and Alternatives

APNT Research and Development Goals

- **Provide a *Cost Effective* Alternative PNT service that:**
  - **Ensures continuity of operations in NextGen:**
    - **Performance Based Navigation (PBN) – RNAV/RNP**
    - **Dependent Surveillance Operations (ADS-B Out and In)**
    - **Trajectory-Based Operations (TBO)**
    - **Four Dimensional Trajectories (4DT)**
  - **Supports all users (GA, Business, Regional, Air Carrier, Military)**
  - **Minimizes Impact on User Avionics Equipage by**
    - **Leveraging existing or planned equipage as much as possible**
    - **Supporting backward compatibility for legacy users**
    - **Minimizing need for multiple avionics updates for users**
    - **Providing long lead transition time (circa 2020 transition)**
  - **Avoids Recapitalization Costs for VORs ~$1.0B**
    - **Potentially Disestablish all VORs and NDBs by 2025**

GNSS Enables PBN and ADS-B

		Navigation (≥ 99.0% Availability)		Surveillance (≥99.9% Availability)			Positioning
		Accuracy (95%)	Containment (10^{-7})	Separation	NACp (95%)	NIC (10^{-7})	GNSS PNT (99.0 – 99.999%)
APNT	En Route	*10 nm	20 nm	5 nm	308m (7)	1 nm (5)	GPS
		*4 nm	8 nm				
		*2 nm	4 nm				
	Terminal	*1 nm	2 nm	3 nm	171m (8)	0.6 nm (6)	DME Only Gap
	LNAV	*0.3 nm	0.6 nm				
	RNP (AR)	*0.1 nm	**0.1 nm	2.5 nm DPA	171m (8)	0.2 nm (7)	SBAS
	LPV	16m/4m	40m/50m	2.5 nm DPA	171m (8)	0.2 nm (7)	
	LPV-200	16m/4m	40m/35m				
	GLS Cat-I	16m/4m	40m/10m	2.0 nm IPA	121 m (8)	0.2 nm (7)	GBAS
	GLS Cat-III	16m/2m	40m/10m				

* Operational requirements are defined for total system accuracy, which is dominated by fight 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.

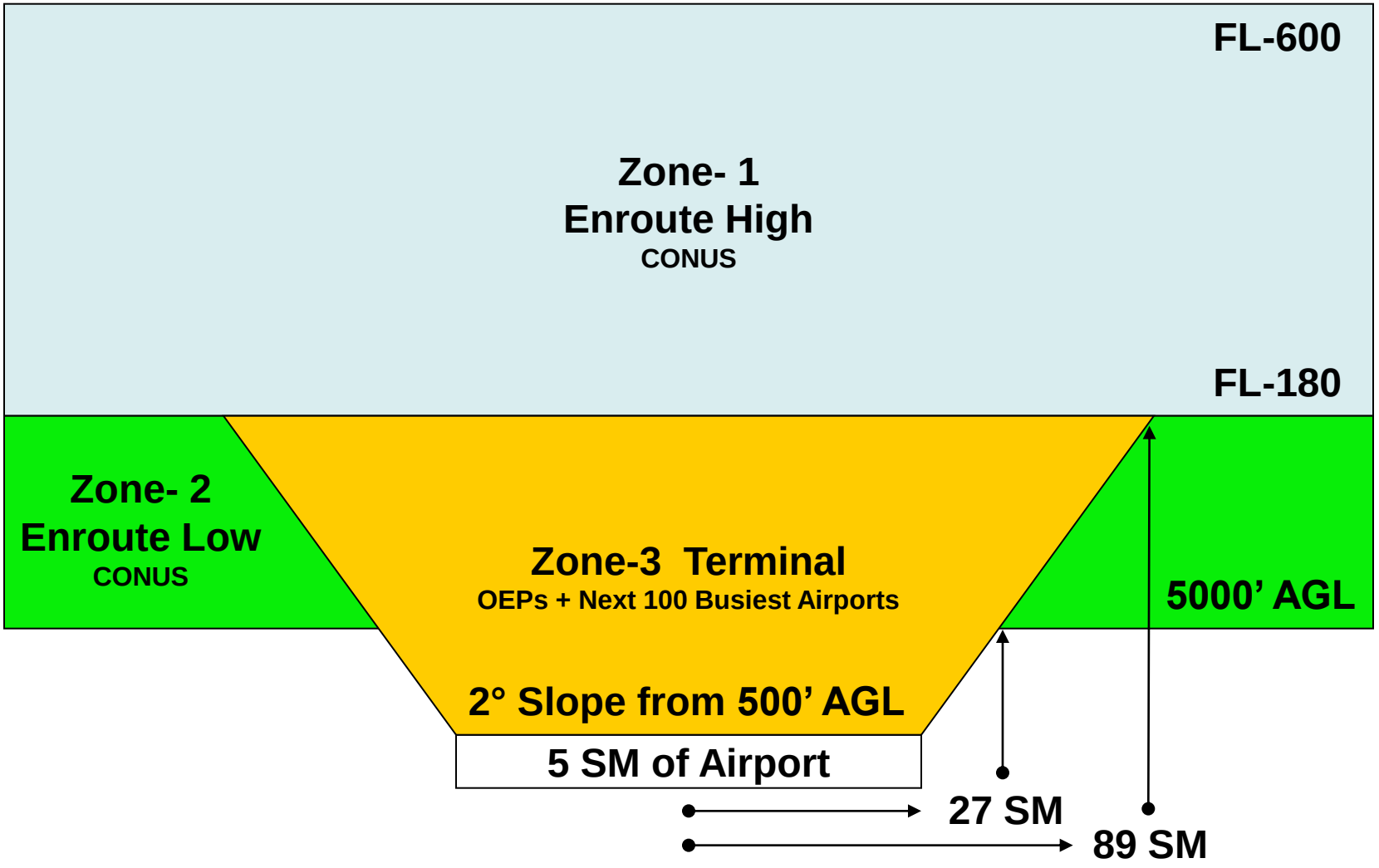
The APNT Initiative within the FAA's Lifecycle Management System

Research and Systems Analysis

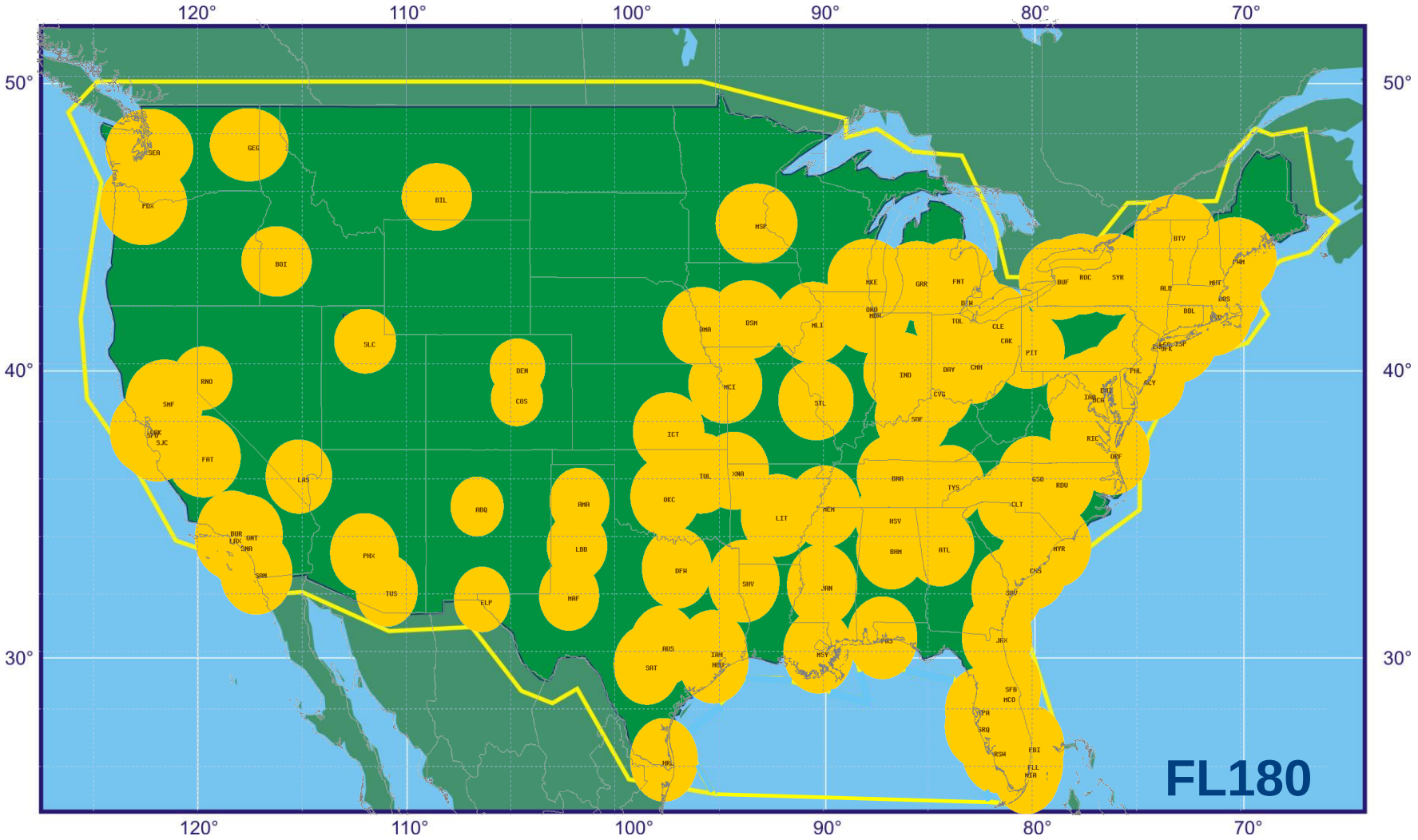
Service Analysis → Concept Requirements Definition → Initial Investment Analysis → Final Investment Analysis → Solution Implementation → In-Service Management

WE ARE HERE

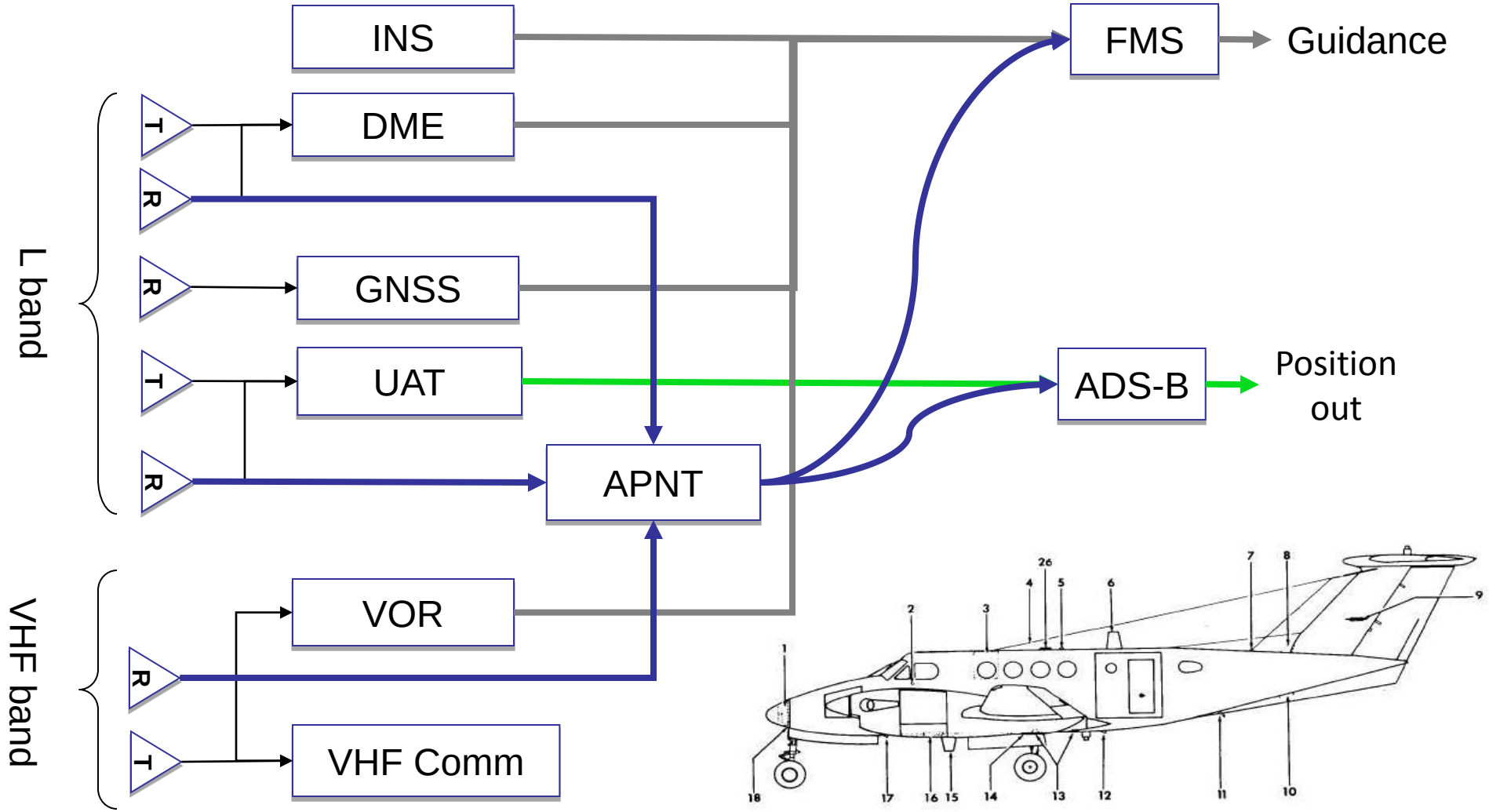
PNT Performance Zones



Zone 1, 2, and 3 Geographic Areas

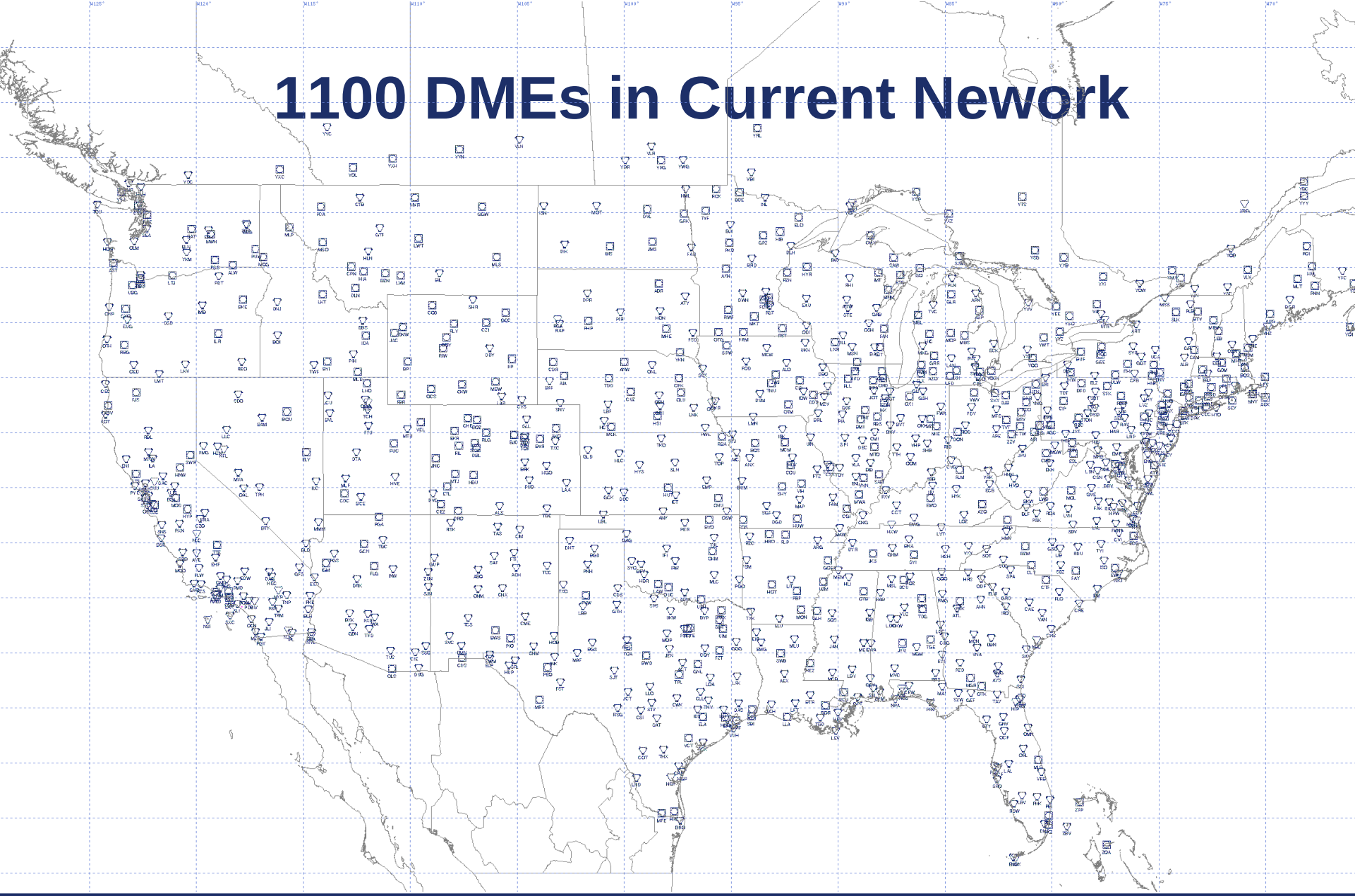


Aviation Signals of Opportunity



APNT Alternative 1
Optimized DME Network

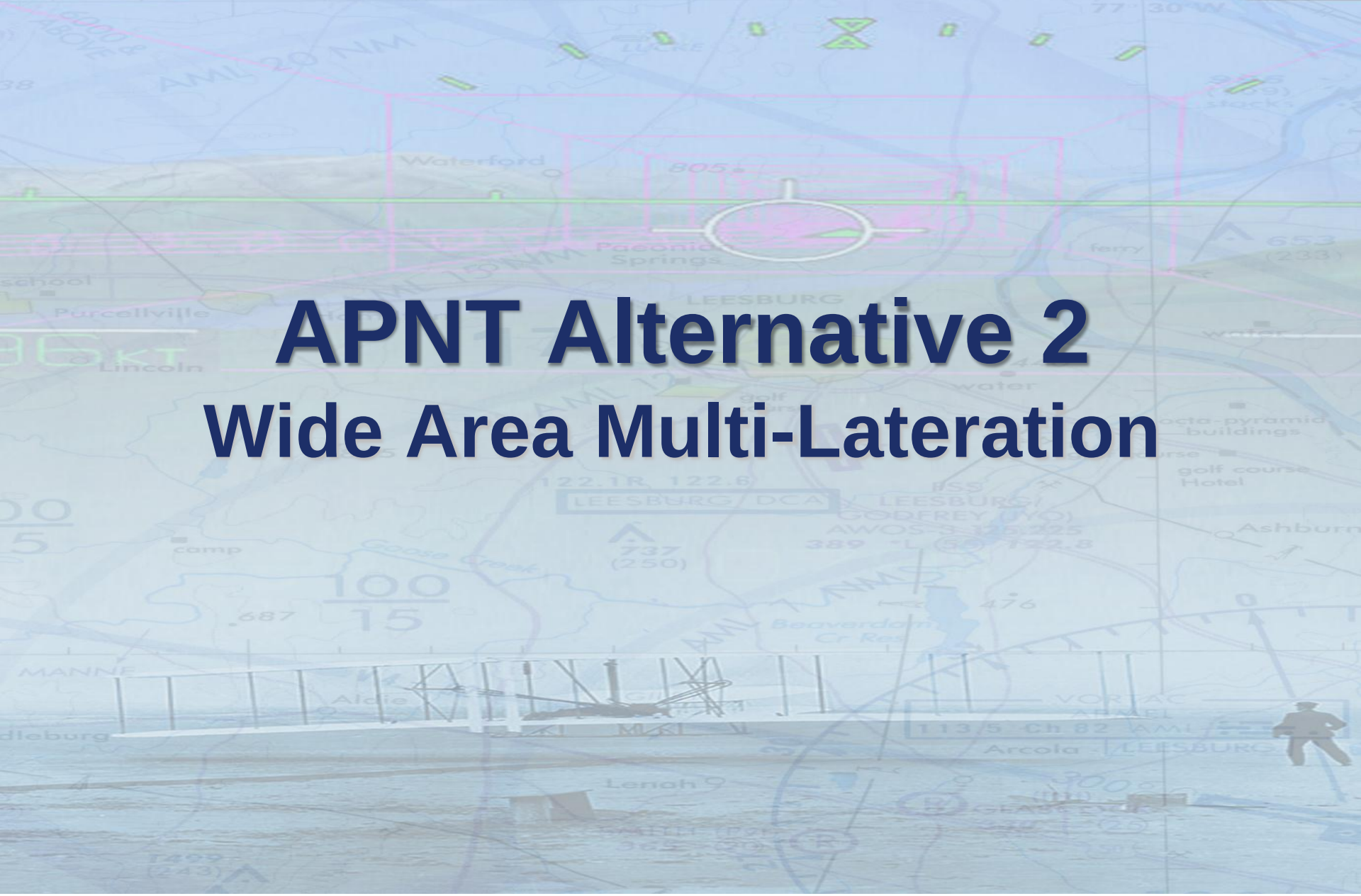
1100 DMEs in Current Nework



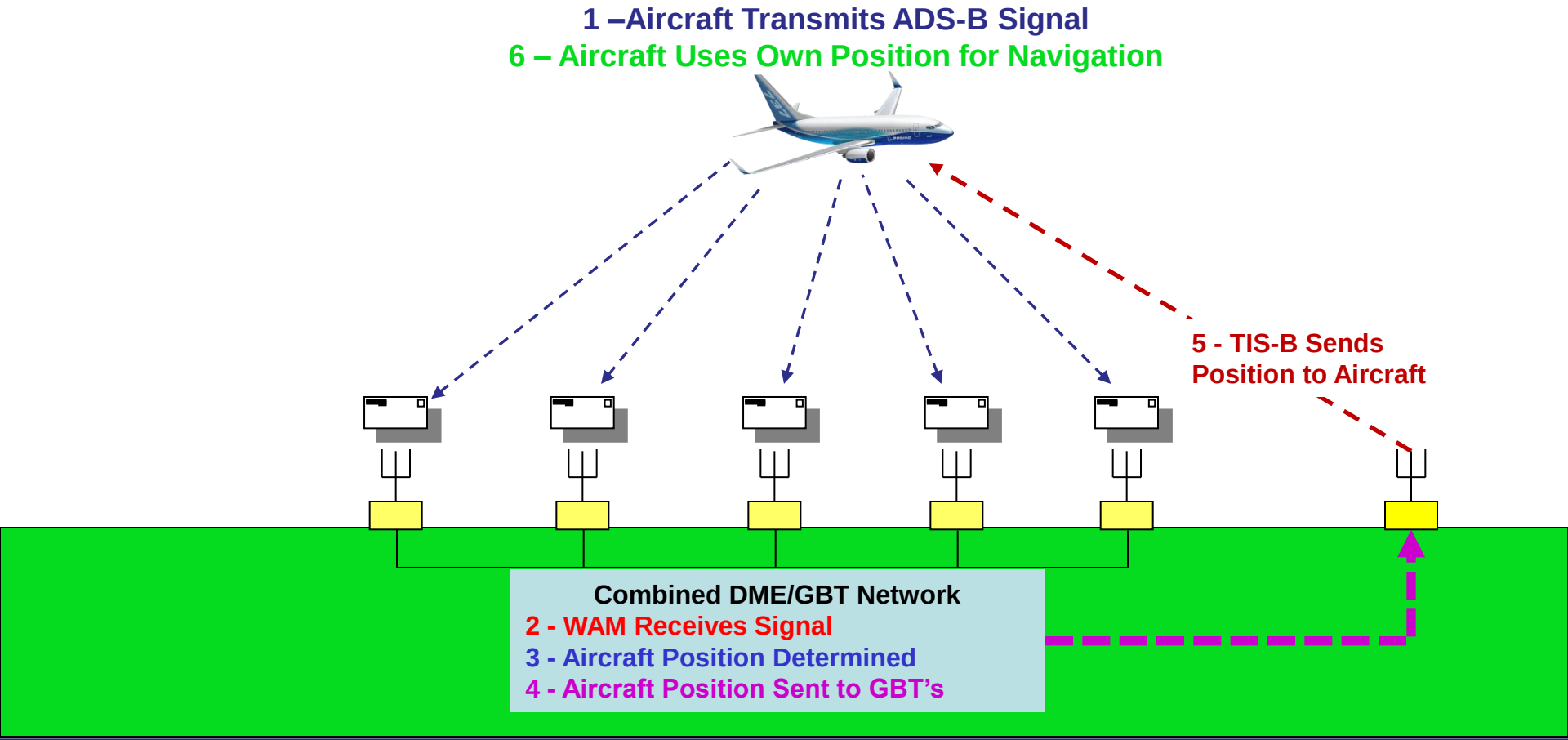
DME-DME Alternative

- **Strengths**
  - Leverage existing technology and systems
  - Least Impact on Avionics for Air Carriers
- **Weaknesses**
  - Significant Impact on Avionics for General Aviation
    - General Aviation avionics are unavailable
  - DME-DME equipped aircraft without Inertial are not currently authorized to fly RNAV/RNP routes
  - DME-DME, even with Inertial, is not authorized for public approach operations less than RNAV/RNP-1.0
  - DME-DME interrogations saturate in very high traffic environments
  - Will require retention and capitalization of nearly half the VORs unless GA equipped with DME/DME/Inertial

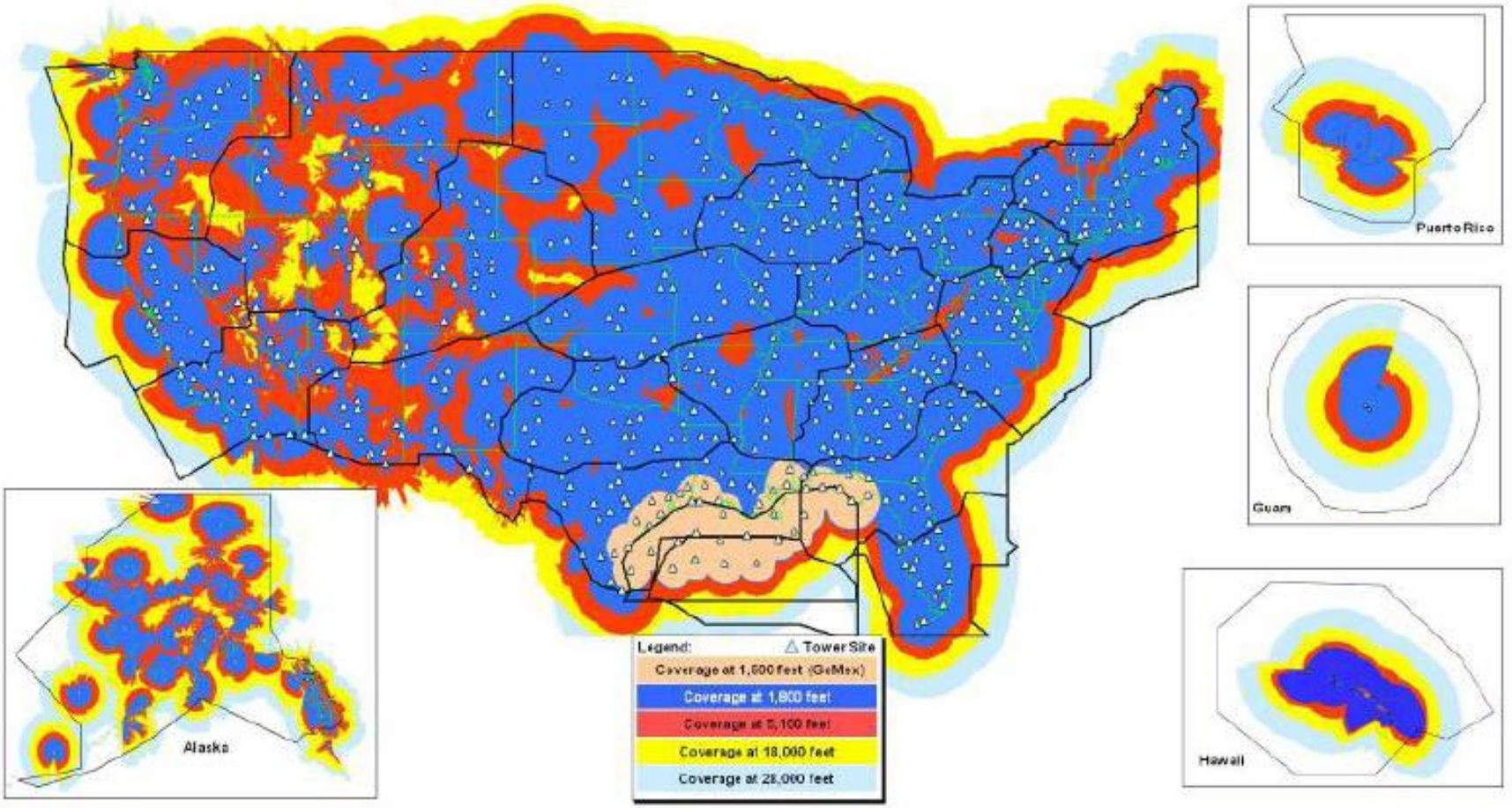
APNT Alternative 2
Wide Area Multi-Lateration



Passive Wide-Area Multi-Lateration (WAM)

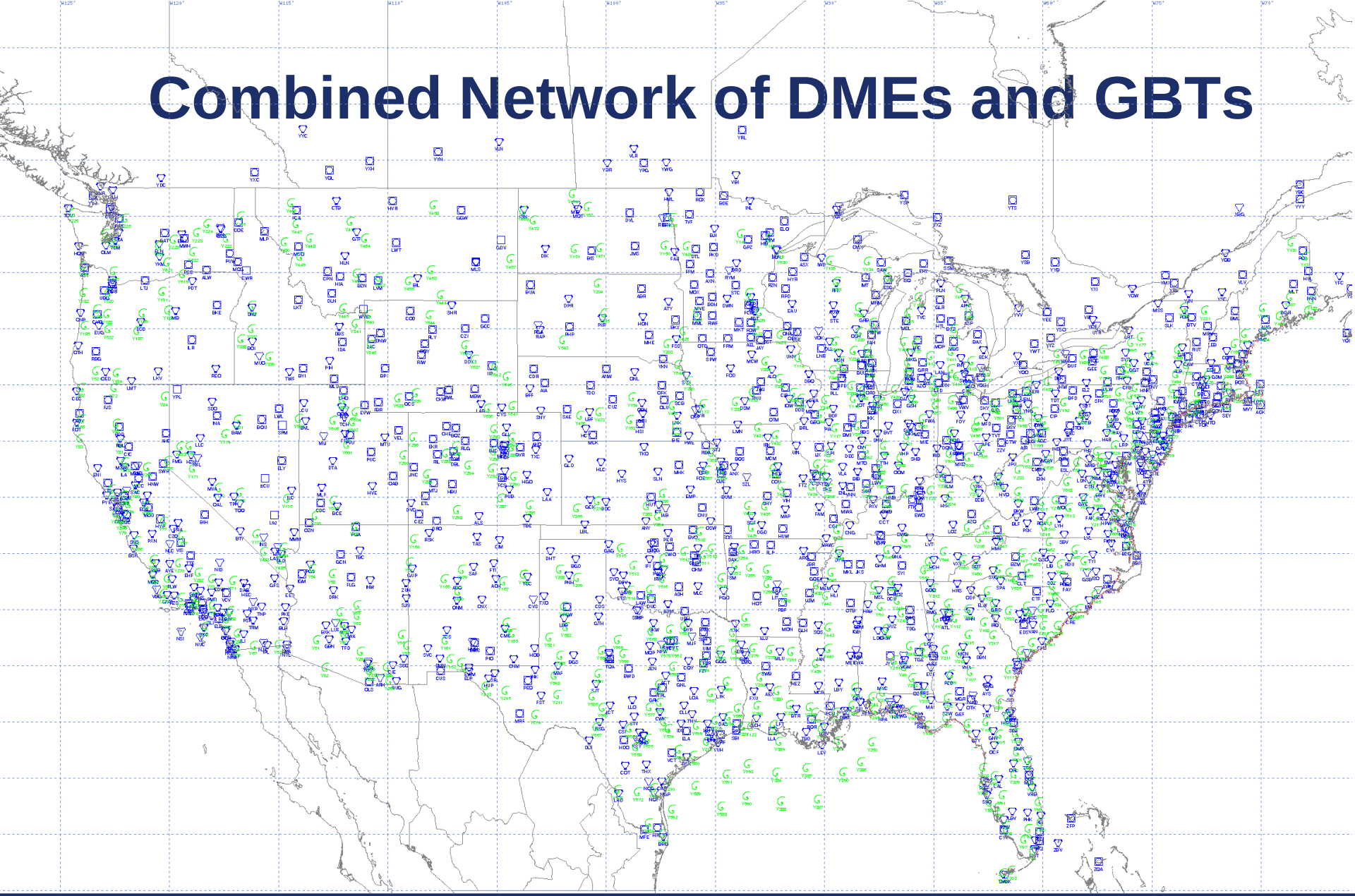


~800 GBT's for National Coverage



Line-of-Site (Communications) Coverage -- *Not* Navigation Service Coverage

Combined Network of DMEs and GBTs

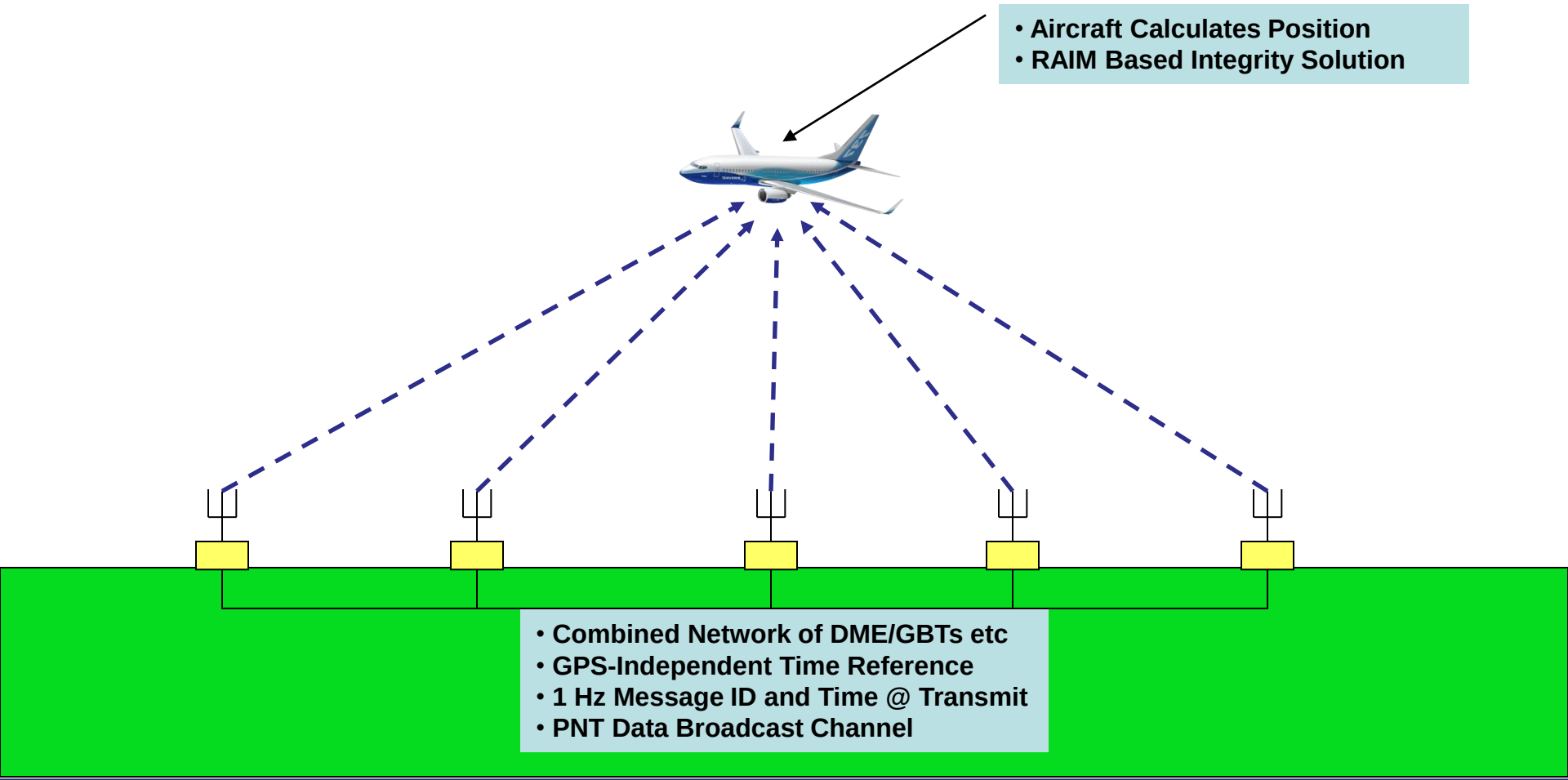


MLAT Alternative

- **Strengths**
  - Minimal Impact on Existing Avionics for Surveillance
  - Accuracy Demonstrated to be within target levels
  - Compatible with existing WAM Systems
- **Weaknesses**
  - Throughput on 1090ES may limit ability of MLAT to meet availability requirements
  - Integrity monitoring and Time to Alert necessary to meet navigation requirements may be very challenging
  - More sites to meet requirements due to limited signal range
  - Capacity limited in high density traffic environments
  - Requires a GPS-Independent common time reference
  - Significant investment in processing facilities and terrestrial communications network may required
  - Use of MLAT for Navigation requires avionics changes

APNT Alternative 3
DME Pseudolites (DMPL)

Pseudolite Alternative Concept

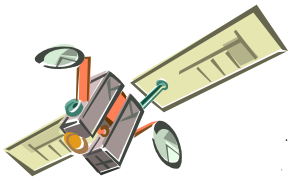


Pseudolite Alternative

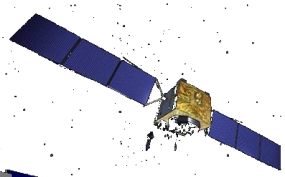
- **Strengths**
  - Unlimited capacity
  - Aircraft based position and integrity solution
  - Potential to leverage use of existing DMEs and GBTs
    - Modified to transmit the PL Signal
  - Potential to use a variety of FAA transmitters to increase coverage.
- **Weaknesses**
  - Minimum of 3 sites required to compute aircraft position
  - Common GPS-independent timing reference needed
  - Greatest Impact to Aircraft Avionics
    - Potential to include position calculation and integrity monitoring functions in ADS-B In avionics
  - Least mature concept, no avionics in development and no standards
  - Will require retention and capitalization of nearly half the VORs unless GA equipped with Pseudolite avionics

APNT
Time Synchronization

Ground-to-Ground Time Synchronization

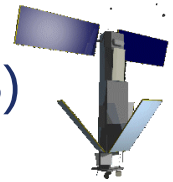


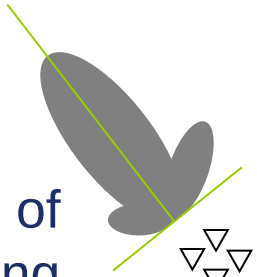
GEO (WAAS L5)



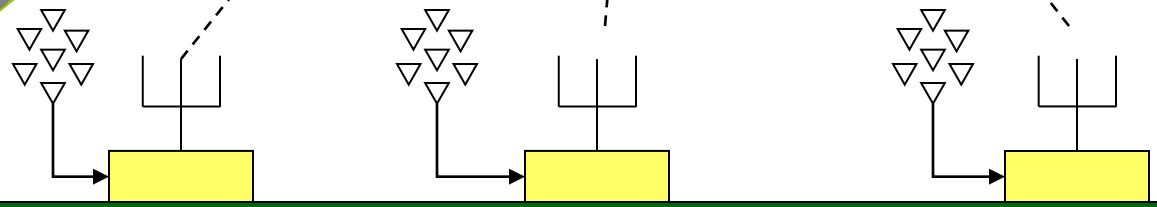
MEO (GNSS)

LEO (MSS)



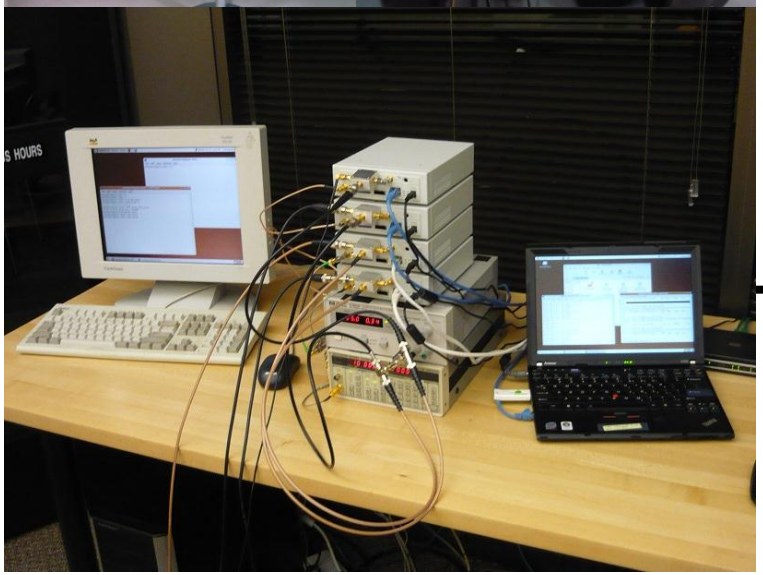


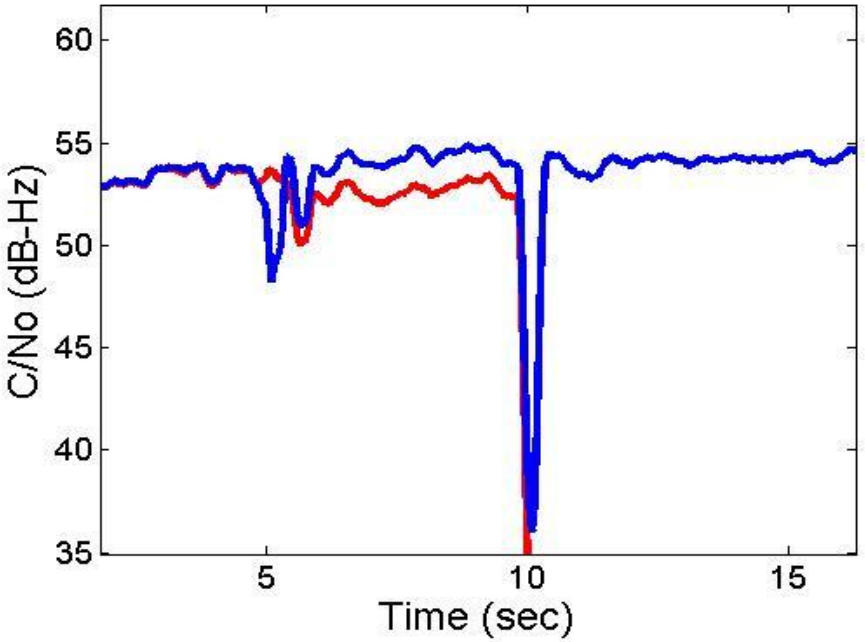
30 dB of processing gain

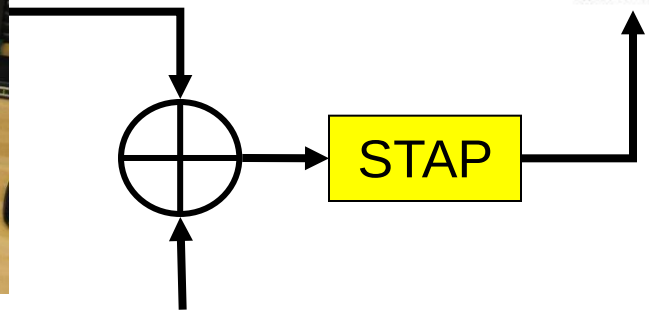


DMEs + Planned DMEs + GBTs

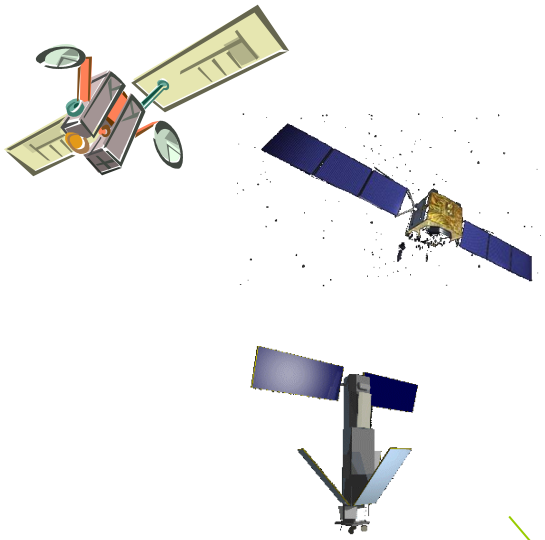
WAAS L5 for Ground-to-Ground Synch.







Ground-to-Air Synchronization



one-way ranging
(aka pseudo-range)

request/reply
(aka two-way ranging
or true range)

DMEs + Planned DMEs + GBTs

Next Steps

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

APNT Life-Cycle Time-Line

Research and Systems Analysis

Service Analysis

Concept Requirements Definition

Initial Investment Analysis

Final Investment Analysis

Solution Implementation

In-Service Management

FY 2011 (Q3)

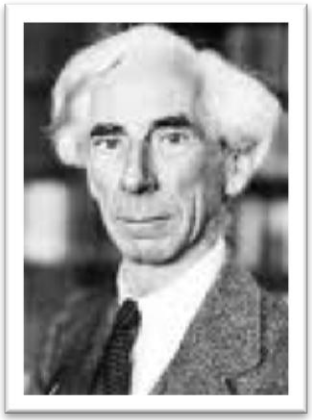
FY 2012

FY 2013

FY 2015

FY 2025

Guiding Principles of Research and Development



"Do not fear to be eccentric in opinion, for every opinion now accepted was once eccentric."

"If we knew what we were doing, it wouldn't be called research."

Questions