Modernizing the NAS Surveillance and Navigation Infrastructures

Presented at NEXTOR's
NAS Infrastructure Management Conference

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CAASD MITRE

Topics

- Today's infrastructures
- Why modernize?
- Potential future infrastructures
- Aircraft equipage requirements
- Cost impacts

NAS Surveillance Today

709 Radars in CONUS

319 Skinpaint

338 Beacon

45 ASDE

7 PRM

Unit F&E Costs	$7.9M	$2.4M	$4.4M	$26.4M

Beacon Radars are the Backbone

- 206 Terminal radars
- 132 En route radars

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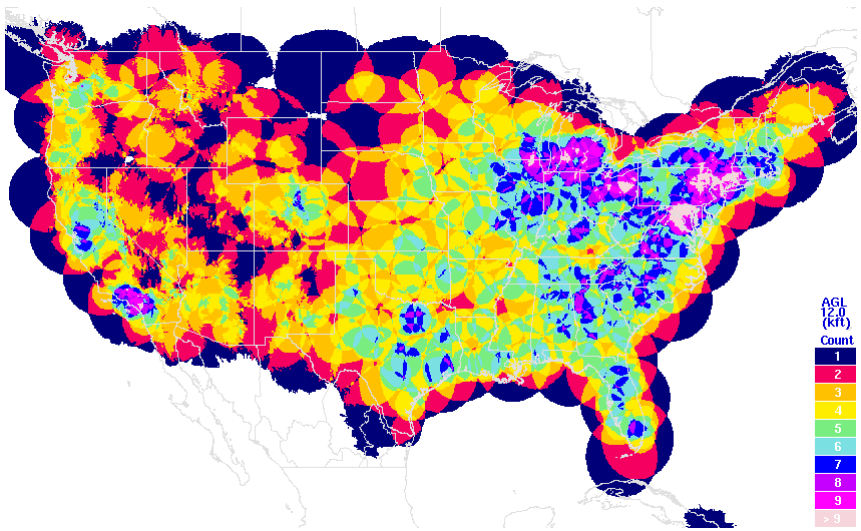
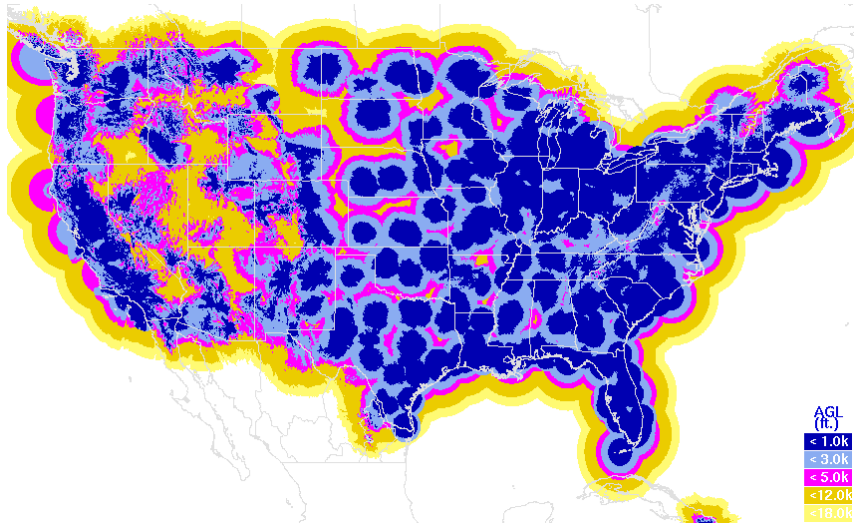
Today's Surveillance System Coverage

338 Backbone Beacon Radars



Coverage Overlap at 12K ft Above Ground Level



Coverage at 1, 3, 5, 12, 18K ft Above Ground Level

The coverage is excellent, but is also very costly!

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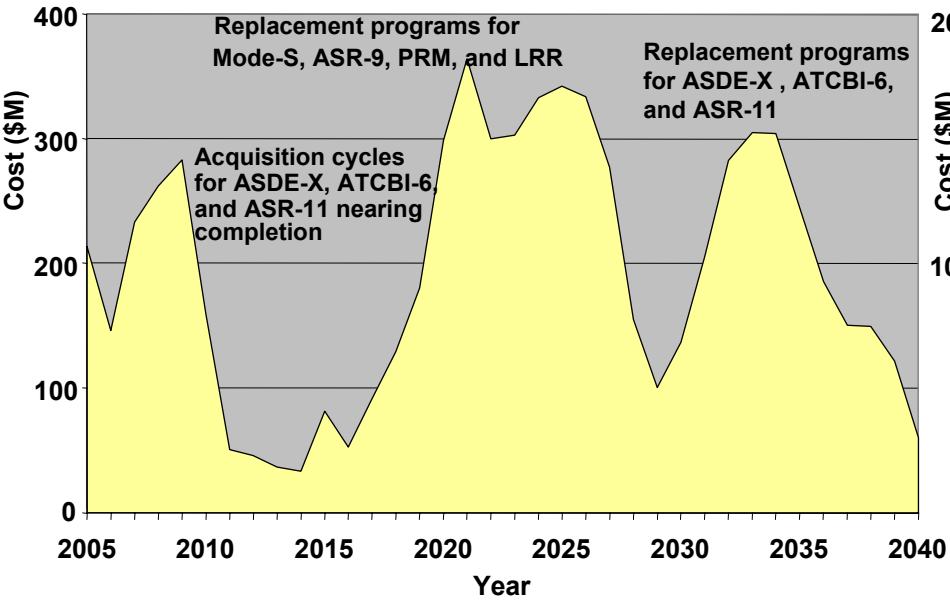
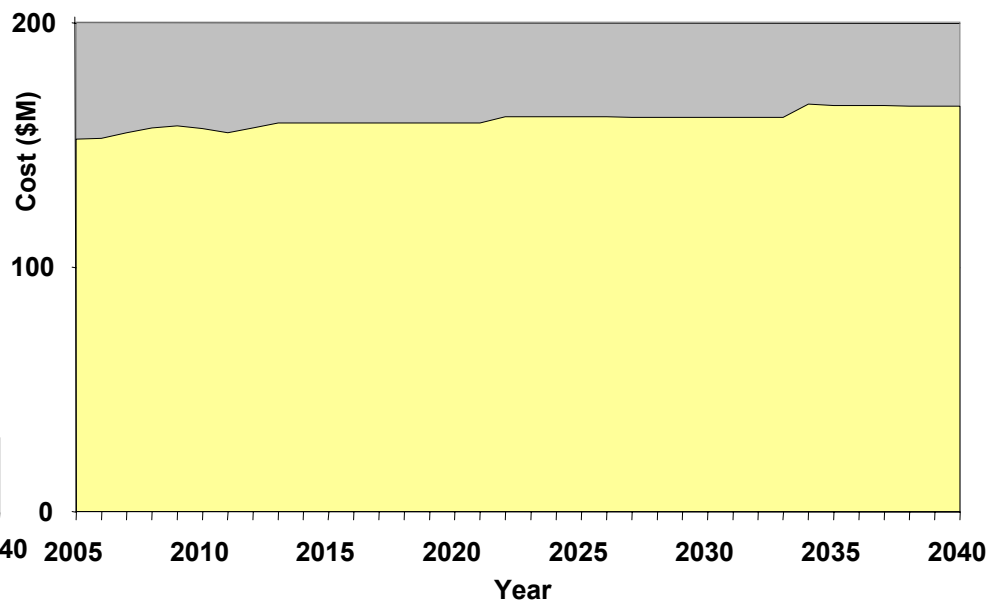
Operating and Maintaining Today's Surveillance Infrastructure

Legacy Surveillance Cost (F&E)



Legacy Surveillance Cost (O&M)



Legacy Investment Replacement Cost
$7B F&E / $6B O&M (35 years)

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Motivation for Modernizing the Surveillance Infrastructure

Budget shortfalls

- **Reduce cost**
  - Equipment
  - Maintenance

Increased air traffic & complexity

- **Improve service**
  - Increased target accuracy
  - Increased target update rate
  - More robust surveillance data distribution

Increased controller workload

- **Add new services**
  - Cockpit display of traffic information
  - Down linking of aircraft information, e.g., intent

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A Potential Future Surveillance Infrastructure

Automatic Dependent Surveillance – Broadcast (ADS-B)

Primary System

SENSIS UAT GBT

Thales Antenna

Backup System

47 Terminal

114 En route

566 ADS-B Ground Stations

161 Radars

A significant reduction in equipment complexity and cost!

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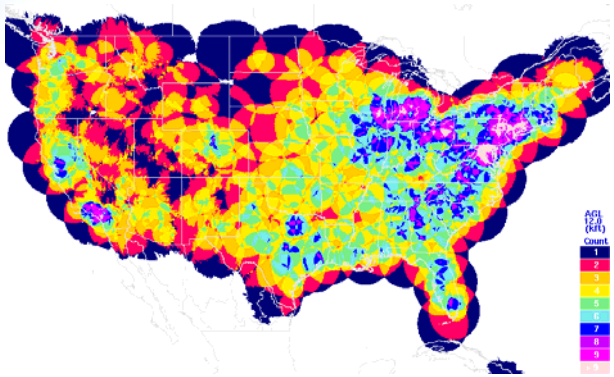
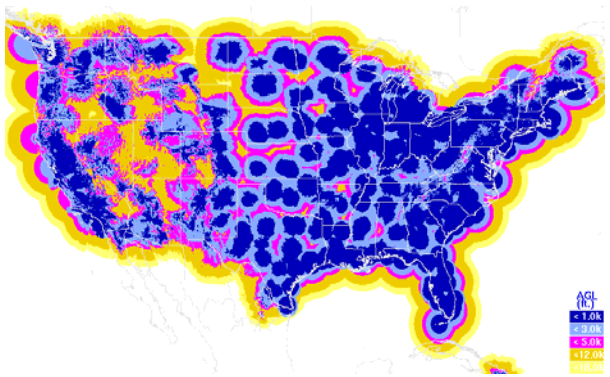
Surveillance Coverage Comparison

Today

338 SSR Backbone
(206 Terminal, 132 En Route)



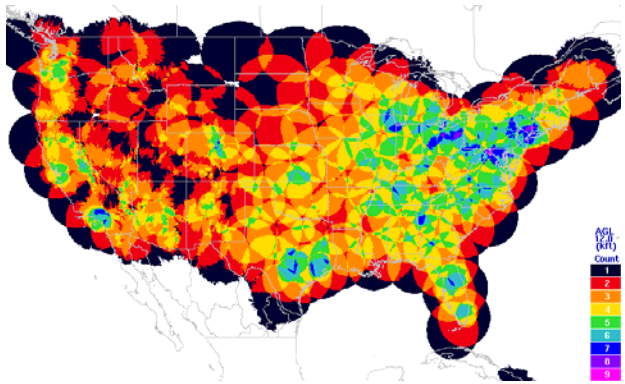
AGL Coverage Overlap at 12K ft



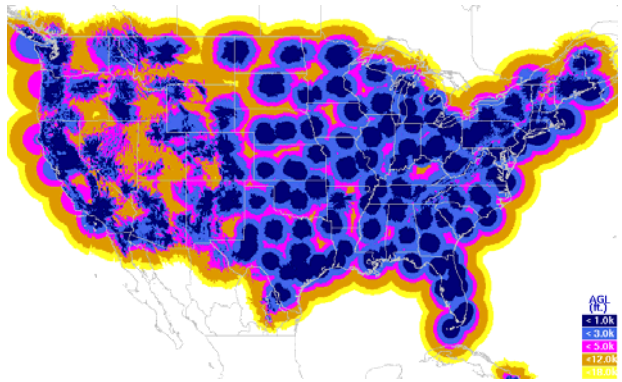
AGL Coverage at 1, 3, 5, 12, 18K ft

Potential Future

161 Radars
(47 Terminal, 114 En Route)

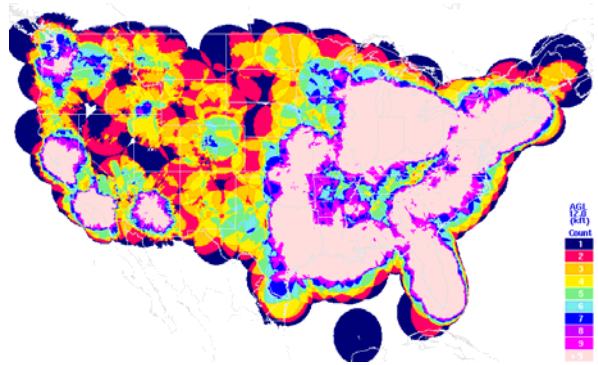


AGL Coverage Overlap at 12K ft

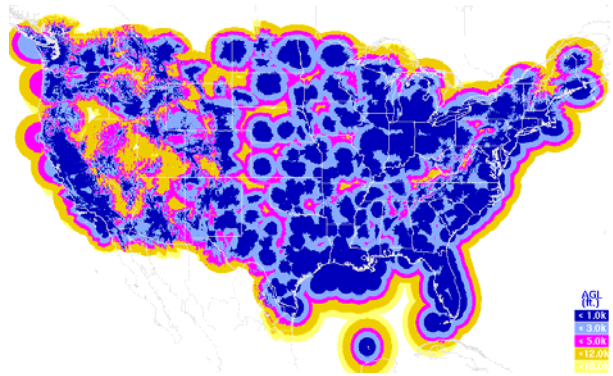


AGL Coverage at 1, 3, 5, 12, 18K ft

566 GBTs
(497 Terminal + 69 En Route)



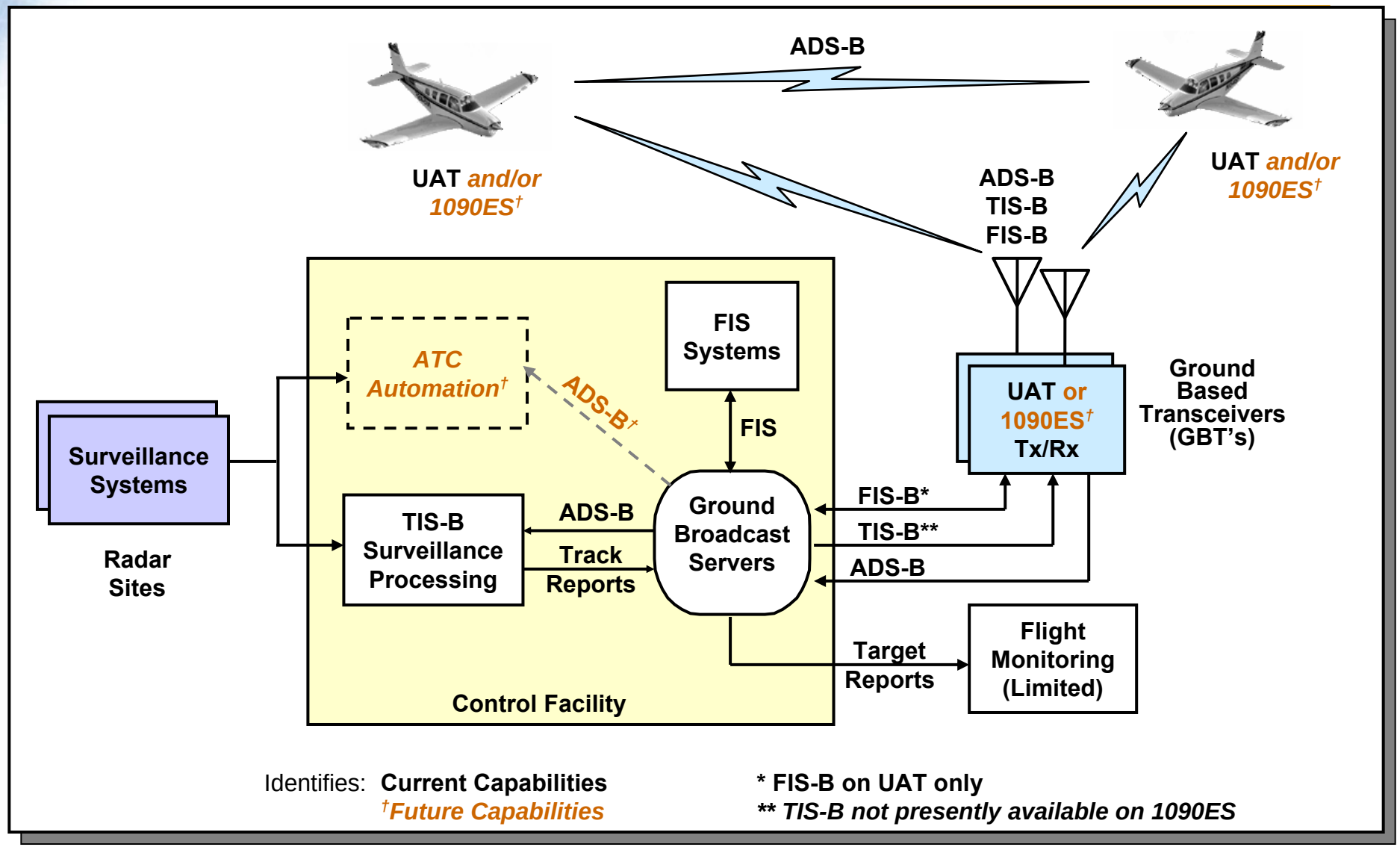
AGL Coverage Overlap at 12K ft



AGL Coverage at 1, 3, 5, 12, 18K ft

AGL = Above Ground Level

Automatic Dependent Surveillance-Broadcast (ADS-B) Architecture

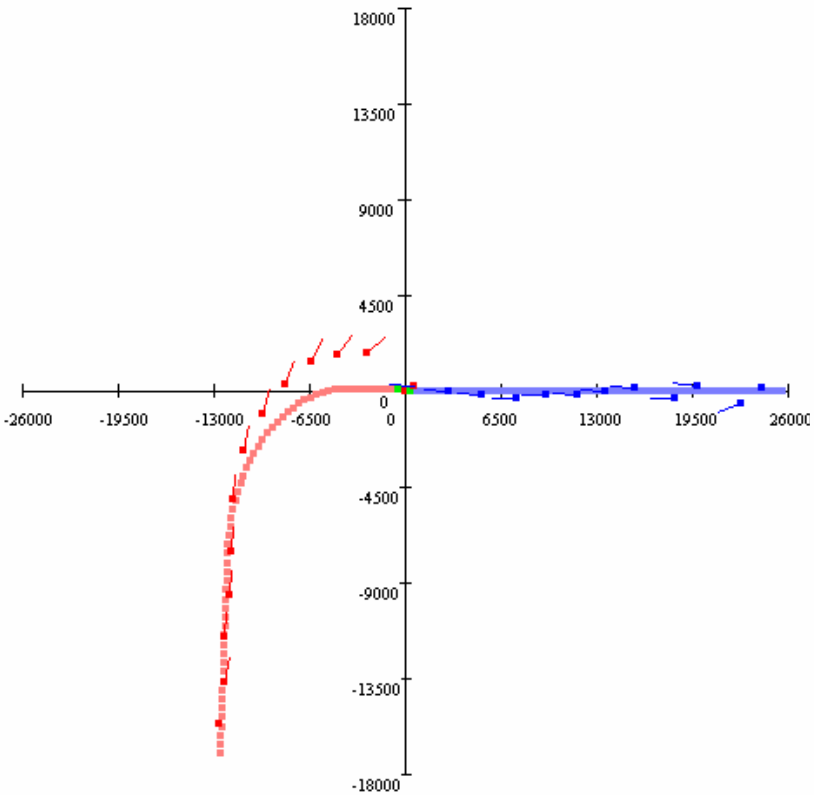


Identifies: **Current Capabilities**
†Future Capabilities

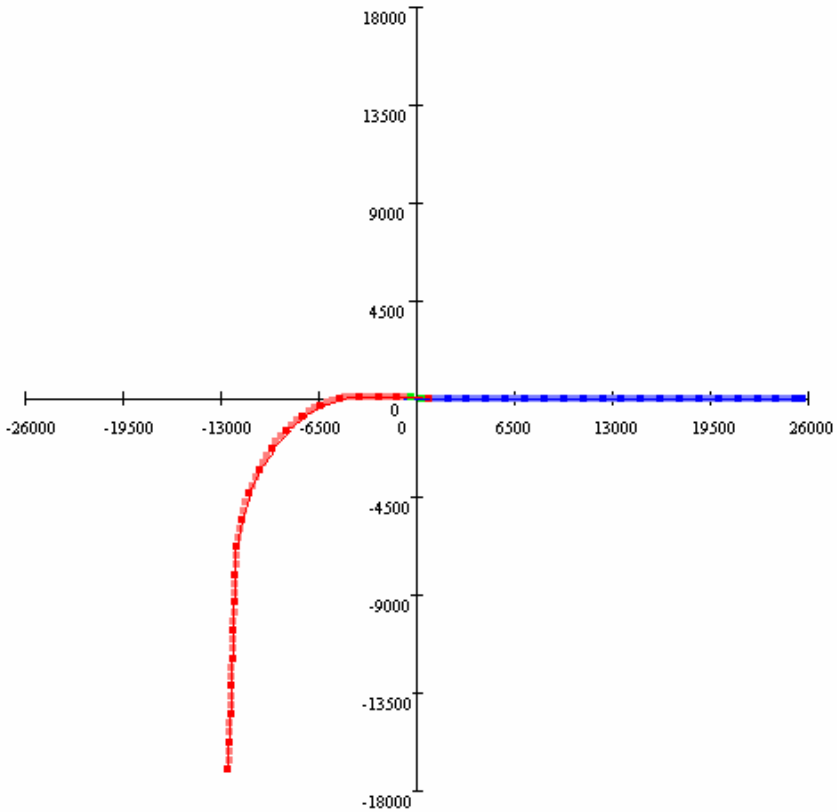
*** FIS-B on UAT only**
***** TIS-B not presently available on 1090ES***

Target Report Comparison

Typical Radar Position and Tracker Estimates

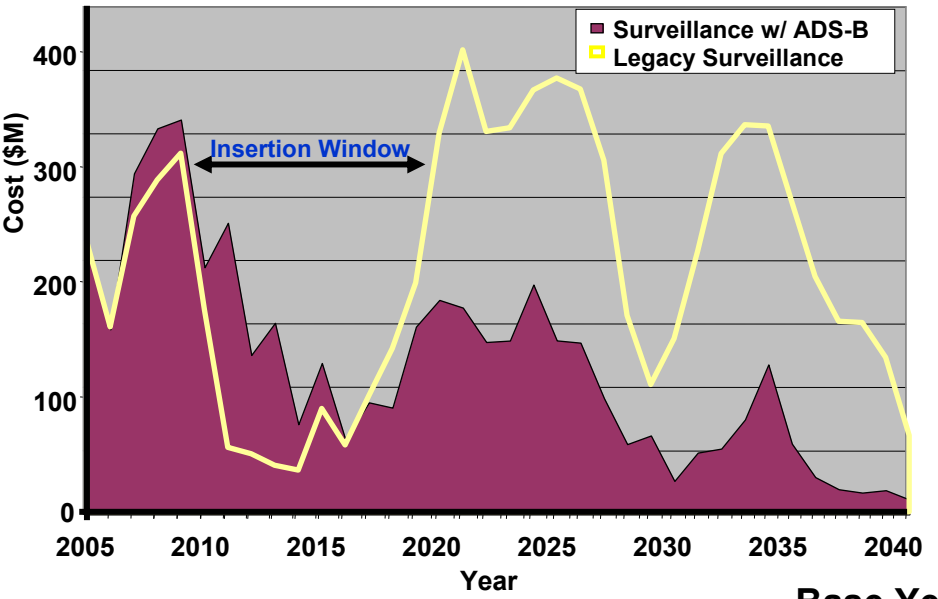


Typical ADS-B Position and Estimates

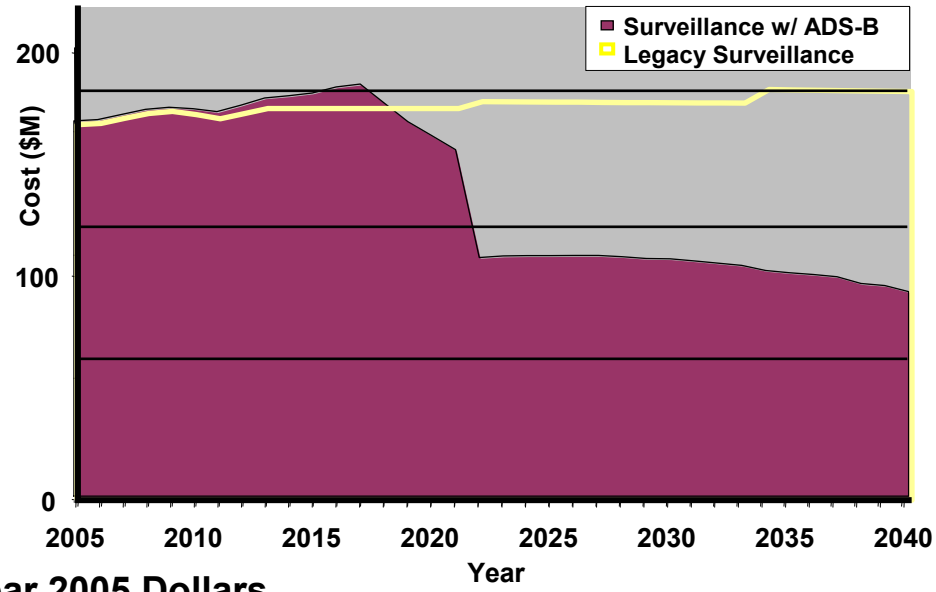


Comparison of FAA Costs

Legacy vs. ADS-B Surveillance Cost (F&E)



Legacy vs. ADS-B Surveillance Cost (O&M)



Base Year 2005 Dollars

Surveillance With ADS-B Investment
$4B F&E / $5B O&M
A Savings of $4B to FAA over 35 Years

**Source: CIP and Radar Program Management Information*
Graph courtesy of SF-21 Program Office

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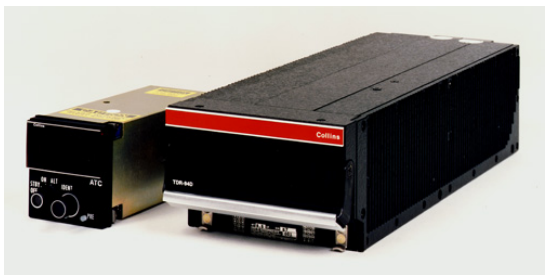
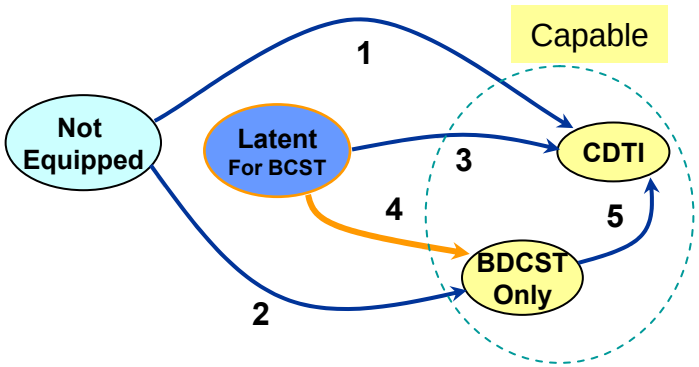
ADS-B Avionics

	"Broadcast Out" (Transmit Only)	"CDTI" (Transmit & Receive)
General Aviation	 Garmin GDL-90 ADS-B UAT	 Garmin MX-20 Multifunction Display
Air Transport	 Rockwell-Collins TDR-94 Transponder	 CDTI on PFD

Air Transport ADS-B Transition Costs

(2004 $)

(Dual Transponder)



Equipage cost depends on:
- Existing equipage
- Upgrade path
- Aircraft type
- Timeframe

Air Transport Aircraft

Constant Year (2004) Unit Cost ($K)	2004 - 2008	2009 - 2012	2013 - 2016	2017 - 2020
Classic				
Path 1 (NE -> CDTI)	$ 251.5	$ 251.5	$ 251.5	$ 251.5
Path 2 (NE -> BCST	$ 169.0	$ 169.0	$ 169.0	$ 169.0
Path 3 (L -> CDTI)	$ 123.4	$ 123.4	$ 123.4	$ 123.4
Path 4 (L -> BCST)	$ 25.5	$ 25.5	$ 25.5	$ 25.5
Path 5 (BCST -> CDTI)	$ 81.2	$ 81.2	$ 81.2	$ 81.2
Neo-Classic				
Path 1 (NE -> CDTI)	$ 564.3	$ 564.3	$ 564.3	$ 564.3
Path 2 (NE -> BCST	$ 143.5	$ 143.5	$ 143.5	$ 143.5
Path 3 (L -> CDTI)	$ 436.2	$ 436.2	$ 436.2	$ 436.2
Path 4 (L -> BCST)	$ 16.6	$ 16.6	$ 16.6	$ 16.6
Path 5 (BCST -> CDTI)	$ 419.6	$ 419.6	$ 419.6	$ 419.6
Modern				
Path 1 (NE -> CDTI)	$ 357.6	$ 357.6	$ 357.6	$ 357.6
Path 2 (NE -> BCST	$ 141.7	$ 141.7	$ 141.7	$ 141.7
Path 3 (L -> CDTI)	$ 231.3	$ 231.3	$ 231.3	$ 231.3
Path 4 (L -> BCST)	$ 16.5	$ 16.5	$ 16.5	$ 16.5
Path 5 (BCST -> CDTI)	$ 214.8	$ 214.8	$ 214.8	$ 214.8
Regional - TurboProp				
Path 1 (NE -> CDTI)	$ 178.8	$ 178.8	$ 178.8	$ 178.8
Path 2 (NE -> BCST	$ 70.9	$ 70.9	$ 70.9	$ 70.9
Path 3 (L -> CDTI)	$ 115.6	$ 115.6	$ 115.6	$ 115.6
Path 4 (L -> BCST)	$ 8.3	$ 8.3	$ 8.3	$ 8.3
Path 5 (BCST -> CDTI)	$ 107.4	$ 107.4	$ 107.4	$ 107.4
Regional - TurboJet				
Path 1 (NE -> CDTI)	$ 178.8	$ 178.8	$ 178.8	$ 178.8
Path 2 (NE -> BCST	$ 70.9	$ 70.9	$ 70.9	$ 70.9
Path 3 (L -> CDTI)	$ 115.6	$ 115.6	$ 115.6	$ 115.6
Path 4 (L -> BCST)	$ 8.3	$ 8.3	$ 8.3	$ 8.3
Path 5 (BCST -> CDTI)	$ 107.4	$ 107.4	$ 107.4	$ 107.4

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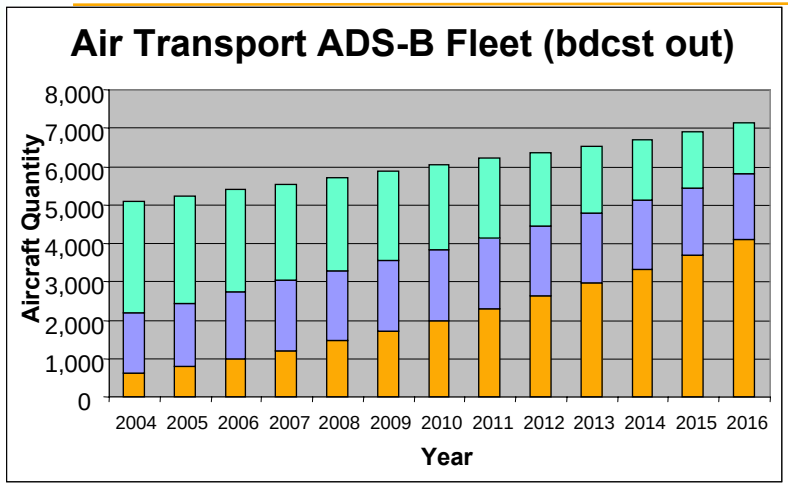
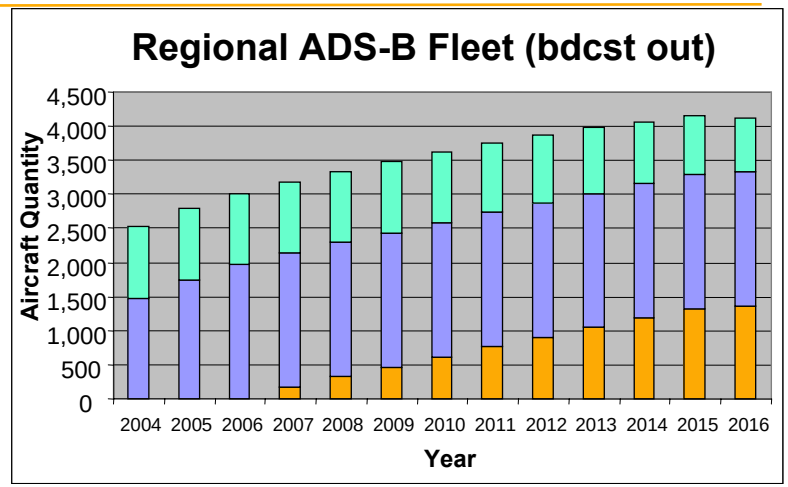
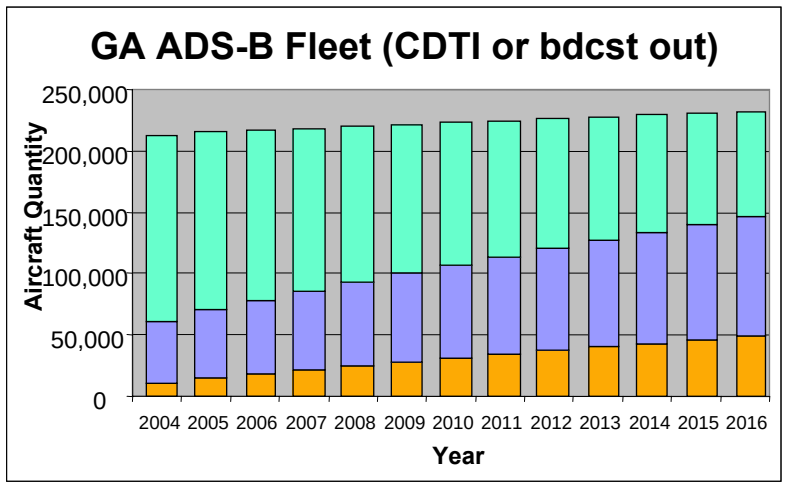
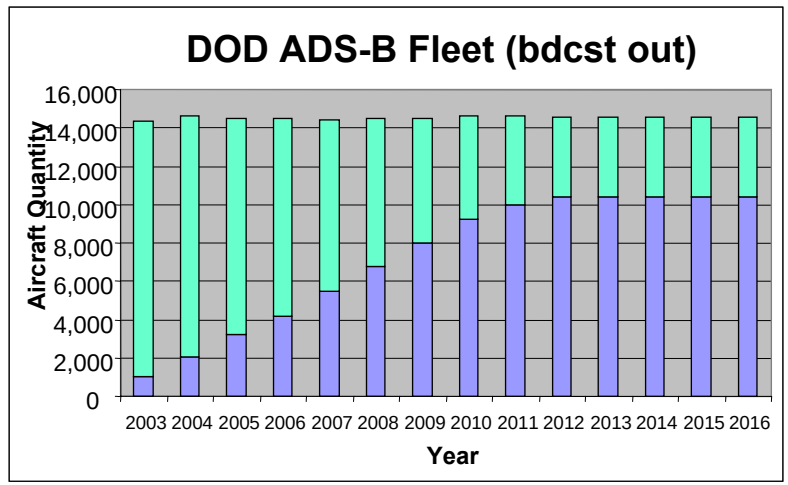
Aircraft Equipage Status

Capable Latent Not Equipped









Equipage is happening, but mandates will be required!

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Cost of ADS-B Compliance ($M)

	Air Transport	General Aviation	Total
Class A Airspace Mandate	~$ 400	~$ 400	~$ 800
Class B, C, D Airspace Mandate	$ 0	~$ 1,200	~$ 1,200
Total	~$ 400	~$ 1,600	~$ 2,000

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Surveillance Modernization Summary

- **A long-term investment perspective is needed**
  - Must escape from huge recapitalization requirement looming in the relatively near future
- **Moving to an ADS-B-centric system can both:**
  - Improve surveillance service quality
  - Reduce FAA capital and operating costs
- **But a large cost burden would be placed on users**
  - Mostly on General Aviation
- **Even if the FAA covered the avionics cost, it would still obtain a net cost reduction - albeit later**

Is it time to consider the flight deck a mobile NAS facility?

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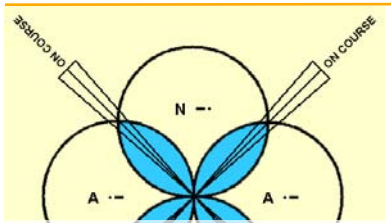
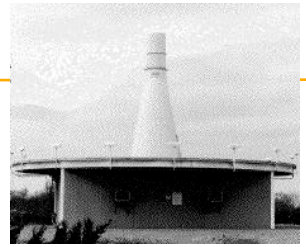
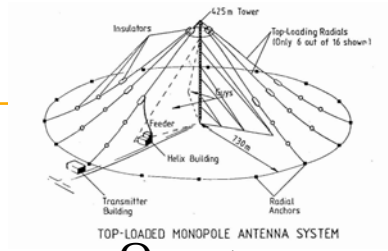
Evolution of NAS Nav/Landing Systems

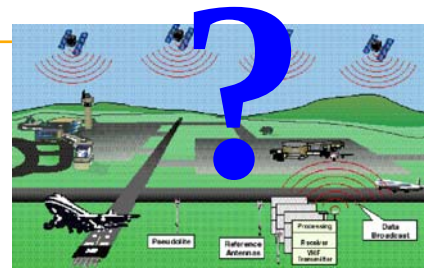




VOR/DME



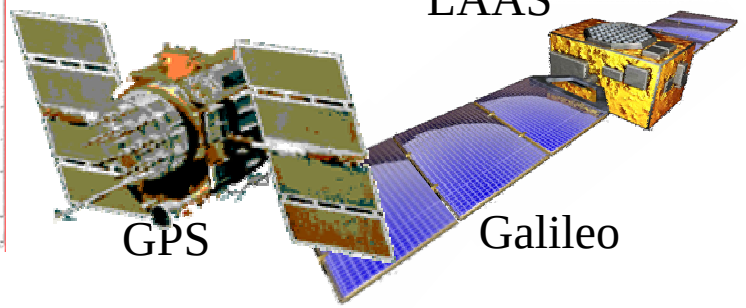
Omega



LAAS

FAA's Transition Strategy

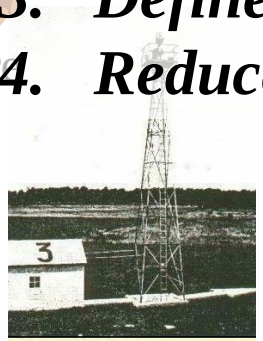
1. ***Introduce GNSS services***
2. ***Allow time for users to equip***
3. ***Define backup systems/services***
4. ***Reduce ground-based navaids***



GPS

Galileo

Bonfi



Beacon lights

Instrument Landing System

WAAS

1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 ?

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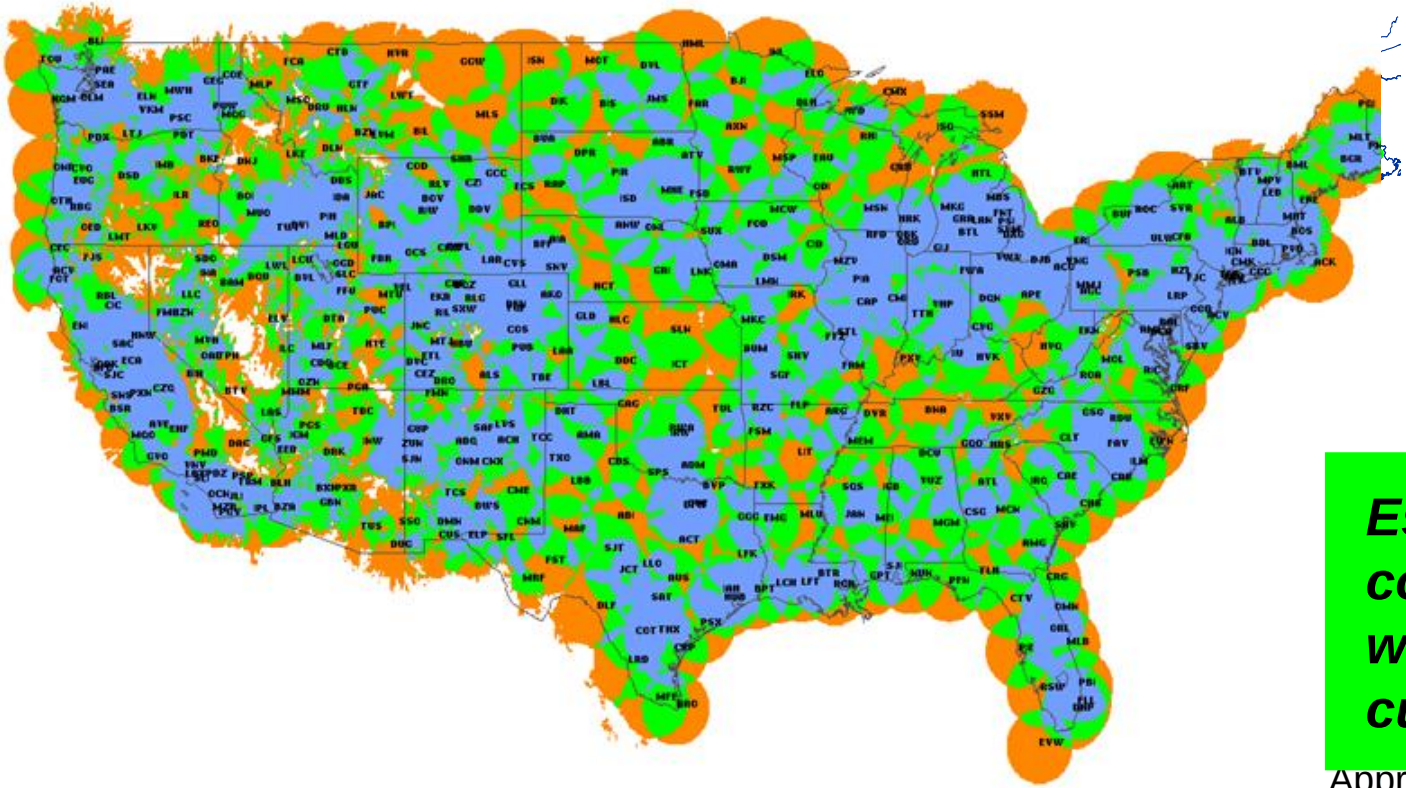
Motivation for Modernizing the Navigation Infrastructure

- **Reduce cost**
  - Ground navaid divestment
  - Procedure termination
- **Improve service**
  - Greater access to more runways
- **Implement performance-based navigation**
  - Fully leverage aircraft capabilities
  - RNAV everywhere; RNP where beneficial
  - Vertically guided approaches for all runways

How Many Ground Navaids Can Be Divested?



Estimated coverage at 5000 ft with about half the current VORs

Approximate Annual O&M Costs
(Technical Refresh costs not shown)

≈600 N
>1500 non-FAA NDBs
(CONUS NDBs)

≈1000 VOR
≈1000 CAT I ILSs
VOR/DME, VORTAC, VOR

Near-term reductions could be made based on today's GPS equipage

Unwillingness to accept "near CAT I" capabilities (WAAS LPV & RNAV) will drive divestiture of the VORs to about half the CAT I ILSs

Navigation Modernization Summary

- **The FAA is moving to Global Navigation Satellite Services (GNSS)**
  - WAAS program continuing to “full LPV” capability
- **The FAA also is moving to Performance-Based Navigation to fully exploit aircraft capabilities**
  - Details in the *Performance-Based Navigation Roadmap*
- **The FAA cannot afford to also sustain the entire ground-based navigation infrastructure**
- **Divestment of some ground navaids and their associated procedures is paramount**
  - A *Navigation Services Evolution Roadmap* is forthcoming
- **The FAA has already begun terminating some NDB procedures**
  - Where other, non-GPS procedures provide equivalent minima

CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT

Questions?

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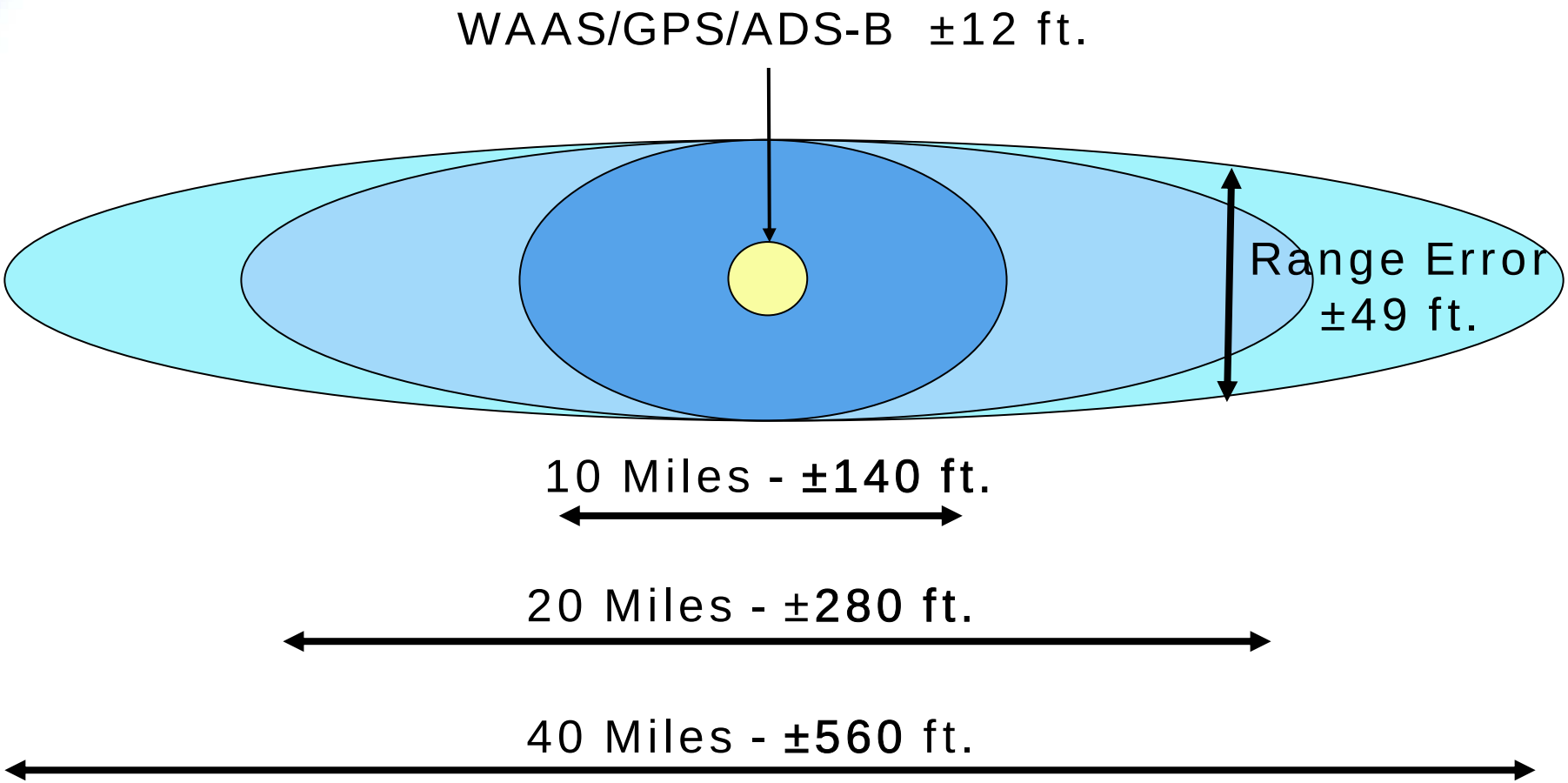
Accuracy Comparison

Beacon Radar* vs ADS-B/GPS/WAAS – 95% Error Bounds

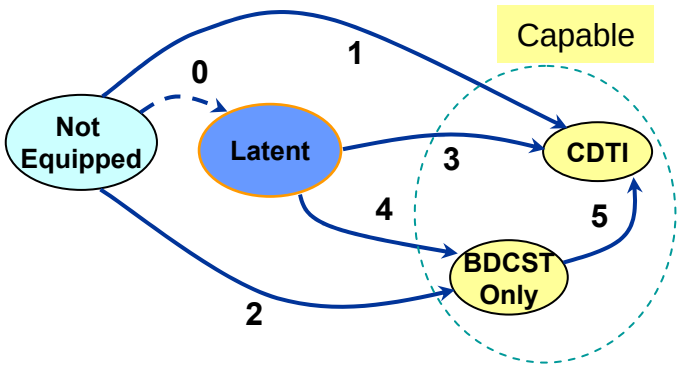


* Radar azimuth measurement error varies with range from sensor. Values reflect performance of ATCBI-6, Mode S, and MSSR subsystem of ASR-11.

General Aviation ADS-B Transition Costs

(2004 $)

(Dual Transponder TP and TJ Only)



General Aviation

Constant Year (2004) Unit Cost ($K)	2004 - 2006	2007 - 2010	2011 - 2020
Turbine Fixed Wing (TurboProp)			
Path 0 (NE -> L)	$ 34.0	$ 30.5	$ 26.9
Path 1 (NE -> CDTI)	$ 147.3	$ 131.4	$ 115.6
Path 2 (NE -> BCST	$ 40.6	$ 36.2	$ 32.2
Path 3 (L -> CDTI)	$ 113.5	$ 101.1	$ 88.5
Path 4 (L -> BCST)	$ 6.6	$ 5.7	$ 5.3
Path 5 (BCST -> CDTI)	$ 109.4	$ 97.4	$ 85.2
Turbine Fixed Wing (Jet)			
Path 0 (NE -> L)	$ 63.4	$ 57.1	$ 50.8
Path 1 (NE -> CDTI)	$ 282.1	$ 253.9	$ 225.7
Path 2 (NE -> BCST	$ 71.7	$ 64.6	$ 57.4
Path 3 (L -> CDTI)	$ 218.1	$ 196.3	$ 174.5
Path 4 (L -> BCST)	$ 8.3	$ 7.5	$ 6.6
Path 5 (BCST -> CDTI)	$ 209.8	$ 188.8	$ 167.8
All Other			
Path 0 (NE -> L)	$ 4.5	$ 3.8	$ 3.0
Path 1 (NE -> CDTI)	$ 12.5	$ 8.8	$ 5.5
Path 2 (NE -> BCST	$ 9.5	$ 7.8	$ 7.0
Path 3 (L -> CDTI)	$ 9.0	$ 6.0	$ 2.5
Path 4 (L -> BCST)	$ 5.0	$ 4.0	$ 4.0
Path 5 (BCST -> CDTI)	$ 9.0	$ 6.0	$ 2.5

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Potential ADS-B Equipage Mandates

- Aircraft using Mode-S manufactured after January 1, 2008 must be DO-260A compliant (no cost allocated)
- Broadcast Out capability required in Class A airspace after January 1, 2014
- Broadcast Out capability required in Class B airspace after January 1, 2016
- Broadcast Out capability required in Class C and D airspace after January 1, 2019

NDB Divestment (CONUS) Example

NDB Procedures

- 1588 NDB approach procedures
  - 669 have non-GPS approach with equivalent minima
    - Immediate divestiture
  - 494 have GPS approach with equivalent minima
    - Divest when sufficient GPS/WAAS equipage (e.g., 2-5 years?)
  - Remainder have no other approach with equivalent minima
    - Divest after RNAV approaches are provided (and sufficient GPS/WAAS equipage)

- Procedure divestment frees resources to develop and maintain new LPV and RNP procedures
  - A necessary step to motivate GPS/WAAS equipage
  - GPS/WAAS equipage necessary to enable future VOR divestiture

NDB Facilities

- 1552 NDB & compass locator facilities
  - Each facility can serve 2 functions:
    - Approach procedure (all)
    - Compass locator for ILS (some)
  - 629 NDBs owned and maintained by FAA (494 are compass locators)
    - Expect only small number that could be divested without loss of the ILS service for non-GPS/WAAS equipped
  - 923 owned & maintained by "other"

- Facility divestment eliminates O&M and life-cycle replacement cost
  - Little near-term savings
  - …but, may be valuable in terms of setting a divestiture precedent

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Possible NDB Divestment (CONUS) Action Plan

- **Part I: Procedure divestment**
  1. **Stop** processing requests for **new procedures** ***(2005)***
  2. **Remove 669** approaches with equivalent VOR, ILS, LOC, SDF approaches ***(2005)***
  3. **Remove 494** approaches when enough users equip with GPS/WAAS ***(2007-2009?)***
  4. For remaining 425 NDB approaches, assess cost-effective choice for each (e.g., keep NDB approach, or replace with LPV or RNAV approach?)

Possible NDB Divestment (CONUS) Action Plan (concluded)

- **Part II: Facility divestment**
  1. **Plan for no further technology refresh *(2005)***
  2. **Identify the procedure/compass-locator use for each of the 629 FAA-owned NDBs**
  3. **Divest non-compass-locator NDBs once procedure is divested**
     - ***Expect very few in 2005* from the 669 procedures (previous slide)**
     - **Most NDBs serving the 494 procedures (above) are not compass locators, and could be divested**
  4. **Assess future need for ILS compass locator function**
  5. **Other steps/issues: charting, pilot test standards, maintenance staffing reduction, public notice & communication of strategy, environmental clean-up**