ADS-B Benefits to General Aviation and Operational Barriers to Implementation

Fabrice Kunzi
kunzi@mit.edu

Advisor: Professor R. John Hansman
rjhans@mit.edu

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Introduction

- **Automatic Dependent Surveillance – Broadcast (ADS-B)** is a fundamental technology for future air transportation\(^1\)
  - Being implemented by the FAA (NextGen) as well as around the world
  - ADS-B represents a shift from ground based surveillance to aircraft “Dependent Surveillance”

- The research presented analyzes how this transition affects General Aviation (Business Jets, recreational aircraft, flight training, etc)
Automatic Dependent Surveillance – Broadcast (ADS-B)

**ADS-B Out:** Position and intent broadcast to ground or other aircraft

**ADS-B In:** Information transmitted from ground or other aircraft to aircraft

**ATC Integration**

**Aircraft Capability/Avionics Equipage**

**Operating Procedures**

**Ground Infrastructure/ATC Integration**

Motivation: ADS-B has unique Benefit Distribution Mechanisms

- Overall system efficiency depends on the system wide level of aircraft ADS-B equipage\(^2,3\)
  - Ensuring equipage across all stakeholders is crucial
- However, after initial FAA stakeholder reviews, ADS-B appeared to provide insufficient benefit for General Aviation (GA)
  - Solution: Provide low cost equipment with free link to weather information in cockpit (FIS-B) to incentivize equipage
  - Caveat: Initially proposed ADS-B frequency (1090) has insufficient bandwidth
- The FAA decided to implement a dual link strategy
  - UAT (Universal Access Transceiver) for General Aviation (978 MHz)
  - 1090ES for mostly commercial operators

\(^2\) Weibel and Mozdzanowska (MIT, 2008), \(^3\) Marais and Weigel (MIT, 2006)
Motivation:
Concerns exist about GA Cost/Benefit Case

- GA is big part of population (96%) and a critical stakeholder
  - If GA were not to equip, the system would be much less efficient

- Benefit and Equipage Incentives for GA differ from those for Commercial Aviation and other stakeholders
  - Increased Safety, Situation Awareness
  - Difficulty arises when trying to place monetary value on these benefits

- Research Question:
How does General Aviation benefit from ADS-B and how can incentives for voluntary equipage in General Aviation be created?

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4 Xiaojie Hu, “Technology Transition in the National Air Transportation System: Market Failure and Game Theoretic Analysis with Application to ADS-B”, MIT 2008
ADS-B as a Multiple-Stakeholder System

To ensure successful system transition, the cost/benefit case needs to resolve for as many stakeholders as possible.
Focus on General Aviation: Benefits

**Capabilities**
- Aircraft Equipage
- Operating Procedures
- ATC Ground Infrastructure

**Applications**
- Application 1
- Application 2
- ... Application x

**Aggregate Cost/Benefits**

First Step: Understand how ADS-B delivers benefit to GA

Benefit from ADS-B is achieved through “ADS-B Applications”
A study of ADS-B Literature identified 41 unique ADS-B Applications

- Identified 41 unique ADS-B Applications based on a review of ADS-B literature
  - Next Generation Implementation Plan
  - ADS-B Technical Documentation
  - ADS-B Integrated Working Plan (AIWP) Spiral 1

- Each application reviewed and benefit ranked from the perspective of different GA user groups
  - User groups were: Recreational Use, Business Users, Flight Training and Functional/Other
  - Ranking: 3 = High Benefit
    2 = Medium Benefit
    1 = No/Insignificant Benefit
  - Ranking based on input from review literature, pilot survey (Lester), AIWP, Center for General Aviation Research (CGAR), expert feedback
  - An activity-weighted average was then created for each application (based on hours of activity)
## Sample Application Rankings

<table>
<thead>
<tr>
<th>Application</th>
<th>GA User Group</th>
<th>Ranking</th>
<th>Activity Percentage</th>
<th>Weighted Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced Visual Acquisition</td>
<td>Recreational Use</td>
<td>3</td>
<td>37.10%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Business Use</td>
<td>2</td>
<td>26.48%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flight Training</td>
<td>3</td>
<td>15.97%</td>
<td>2.74</td>
</tr>
<tr>
<td></td>
<td>Functional/Other</td>
<td>3</td>
<td>20.45%</td>
<td></td>
</tr>
</tbody>
</table>
### Sample Application Rankings

<table>
<thead>
<tr>
<th>Application</th>
<th>Rank</th>
<th>Description</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS-B Enabled Portable Devices for Airport or FBO Employees</td>
<td>2.10</td>
<td>Enhanced Visual Acquisition</td>
<td>2.74</td>
</tr>
<tr>
<td>ADS-B Flight Following</td>
<td>2.53</td>
<td>Final Approach and Runway Occupancy Awareness</td>
<td>2.06</td>
</tr>
<tr>
<td>ADS-B Traffic Situational Awareness on the Surface (ATSA-SURF)</td>
<td>2.80</td>
<td>Flow Corridors</td>
<td>1.90</td>
</tr>
<tr>
<td>Airborne Conflict Management</td>
<td>3.00</td>
<td>Flight Information Service - Broadcast (FIS-B)</td>
<td>3.00</td>
</tr>
<tr>
<td>Airline Based En-Route Sequencing and Spacing</td>
<td>1.53</td>
<td>Improved ATC Traffic Flow Management</td>
<td>2.06</td>
</tr>
<tr>
<td>Airport Surface Surveillance and Routing Service</td>
<td>2.27</td>
<td>Improved Search and Rescue</td>
<td>3.00</td>
</tr>
<tr>
<td>Approach Spacing for Instrument Approaches (ASIA)</td>
<td>2.06</td>
<td>ITP Climb and Descend</td>
<td>1.53</td>
</tr>
<tr>
<td>Automatic Flight Plan Cancellation</td>
<td>2.22</td>
<td>ITP Crossing and Passing</td>
<td>1.53</td>
</tr>
<tr>
<td>ATC Surveillance for En-Route Airspace (ADS-B-ACC)</td>
<td>1.90</td>
<td>ITP Follow</td>
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</tr>
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<td>2.06</td>
<td>Non-Radar Airspace Delegated Separation</td>
<td>2.84</td>
</tr>
<tr>
<td>ATC Surveillance in Terminal Areas (ADS-B-TMA)</td>
<td>2.06</td>
<td>Non-Radar Airspace Self-Separation</td>
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<tr>
<td>CDTI Continuous Descent Approach</td>
<td>1.26</td>
<td>Non-Radar Increased IFR Airport Acceptance Rate</td>
<td>3.00</td>
</tr>
<tr>
<td>CDTI VFR-like Separation in All Weather Conditions (IMC and VMC)</td>
<td>2.64</td>
<td>Obstacle Awareness Application</td>
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<td>CDTI-Based Visual-Like Approaches in All Conditions</td>
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<td>Radar Airspace Self-Separation</td>
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<tr>
<td>Emergency Locator Transmitter (ELT) Application</td>
<td>2.58</td>
<td>Traffic Aware Strategic User Requests with Limited Delegation</td>
<td>2.04</td>
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<tr>
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<tr>
<td>ADS-B Enhanced Parallel Approaches/ADS-B PRM</td>
<td>1.26</td>
<td>Wake Visualization and Avoidance</td>
<td>2.43</td>
</tr>
<tr>
<td>Enhanced Tower Situational Awareness in Reduced Visibility</td>
<td>2.26</td>
<td>Weather Reporting to Ground</td>
<td>2.10</td>
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</tbody>
</table>
Overall Ranking of 2.5 was used to identify high user benefit applications.

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High GA Benefit ADS-B Applications

- **Data Link Applications**
  - Provide Weather data, Airspace Information, Traffic Maps, etc.

- **ADS-B Out Applications**
  - Based solely on ADS-B Out messages

- **ADS-B IN Applications**
  - Require ADS-B In for functionality

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### ELT Application
- **Obstacle Awareness Application**
ADS-B system components need to be capable of supporting applications. Performing a certain application levies requirements onto the system components.

- Aircraft Equipage
- Operating Procedures
- ATC Ground Infrastructure

Applications:
- Application 1
- Application 2
- Application x

Aggregate Cost/Benefits:
- \( b_1(t) \)
- \( b_2(t) \)
- \( b_3(t) \)
- \( c_1(t) \)
- \( c_2(t) \)
- \( c_3(t) \)

Costs:
- \( \text{stk}_1 \)
- \( \text{stk}_2 \)
- \( \text{stk}_3 \)

Benefits:
- \( \text{stk}_1 \)
- \( \text{stk}_2 \)
- \( \text{stk}_3 \)
Little attention has been given to ADS-B Operating Procedures

- **Aircraft Equipage:**
  - Technical Standards are in the process of being developed
  - Prototype Equipment has been evaluated on a large scale (Alaska Capstone Project)

- **Operating Procedures:**
  - Applications need to be described before procedures can be developed
  - There is currently little attention on procedure development

- **ATC Infrastructure:**
  - The FAA is committed to have nationwide ground infrastructure fielded by 2013
  - Various “Key Sites” are already operating the ADS-B ground infrastructure (Florida, Gulf of Mexico, etc.)
First Conclusion: Development of Operational Procedures for ADS-B needed

- Based on a review of current procedures, identified three procedure categories of increasing complexity and benefit
  - 1. Data Link Applications
  - 2. Applications as Enhancements for already existing Procedures
  - 3. Applications using ADS-B specific functionality (do not currently exist)
    - These procedures are needed to achieve a major component of ADS-B benefit

- Conclusion: Operational Procedures need to be developed for ADS-B
  - The lack of procedures may pose a large barrier for GA to achieve benefit and therefore be a disincentive

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</tr>
</tbody>
</table>

1st Category

Center/Company/Online Flight Tracking
Improved Search and Rescue
ELT Application

2nd Category

Airborne Conflict Management
CDTI VFR-like Separation in All Weather Conditions

3rd Category

Obstacle Awareness Application
Focus on General Aviation: Cost

Capabilities

- Aircraft Equipage
- Operating Procedures
- ATC Ground Infrastructure

Applications

- Application 1
- Application 2
- ....
- Application x

Aggregate Cost/Benefits

\[
\begin{align*}
\text{stk}_1 & \quad \text{stk}_2 & \quad \text{stk}_3 \\
b_1(t) & \quad b_2(t) & \quad b_3(t) \\
\text{benefits} & \quad & \\
\text{stk}_1 & \quad \text{stk}_2 & \quad \text{stk}_3 \\
c_1(t) & \quad c_2(t) & \quad c_3(t) \\
\text{costs} & \quad & \\
\end{align*}
\]

Second Step:
Understand cost to GA to achieve benefits
Currently Required Surveillance Equipment

- Currently required surveillance equipment is an ATC Transponder
  - Replies to radar interrogations
- Mode C: Transmits an ATC assigned squawk code and Altitude
  - Altitude encoding altimeter is required
- Mode S: Same as Mode C with the capability of modifying the transmission with additional data
  - Allows for specific interrogation by ATC radar
Two different ADS-B Avionics Architectures

1090ES Upgrade from Mode S

- Top Antenna
- GPS
- Bottom Antenna

1090ES Transponder/ADS-B Trans.

UAT Upgrade from Mode C

- Top Antenna
- UAT ADS-B
- Bottom Antenna
- Diplexer
- Antenna

Transponder with Antenna Diversity

Altitude Encoder

ATC Transponder

Altimeter
Conducted preliminary cost analysis for different starting conditions

- Cost to equip with ADS-B depends on starting equipment
  - Some aircraft have more advanced equipment than others
  - Used FAA data on Avionics Equipage
  - Created six typical levels of starting equipment and determined upgrade costs
- Used current market prices to price individual components

<table>
<thead>
<tr>
<th>Level of GPS</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 5</th>
<th>Level 6</th>
</tr>
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<tbody>
<tr>
<td>No cert. GPS</td>
<td>Certified GPS</td>
<td>No cert. GPS</td>
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<td>Certified GPS</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Antennas</th>
<th>Single Antenna</th>
<th>Single Antenna</th>
<th>Single Antenna</th>
<th>Single Antenna</th>
<th>Antenna Div</th>
<th>Antenna Div</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transponder</td>
<td>Mode C</td>
<td>Mode C</td>
<td>Mode S</td>
<td>Mode S</td>
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<td>Mode S</td>
</tr>
</tbody>
</table>

~ 87% of GA Fleet
~ 12% of GA Fleet

Second Conclusion: Cost Exceeds Willingness-to-Pay

- Cost to equip with 1090 ES ADS-B cost:
  - $4,200 to $18,100

- Cost to equip with UAT ADS-B:
  - $11,500 to $25,400
  - UAT is more expensive than 1090ES

- Unless it is lowered, cost will be a major barrier for GA equipage
  - Survey data shows cost exceeding willingness-to-pay by ~$15,000

MIT Pilots Survey (Lester, 2007)
Summary of Conclusions

The presented results lead to the following overall conclusions:

1. The current trajectory for the ADS-B system deployment may lead to reduced system efficiency due to hesitation by GA to equip.
2. The two major barriers are cost and a lack of procedures to take advantage of ADS-B improvements and benefits.
Future Work: Approaches to lower GA Equipage Costs

- The equipment cost appears to come mostly from Avionics Certification

- The FAA’s certification requirements for ADS-B avionics are very high
  - What ADS-B applications can be operated safely at lower levels certification?

- Using avionics certified to lower standards may allow for a significantly lower equipment cost
  - The actual equipment components can be the same
Future Work: Lower Cost ADS-B

- **Hypothesis:** Many high benefit ADS-B applications do not require ADS-B avionics certified to high standards
- Currently investigating safety and operational/procedural implications
- Intend to do a formal safety analysis to investigate if lower certification levels may still allow safe operation

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<tr>
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</table>
Relevant Literature

• Academic Contributions

• Other contributions
  7. Strain, DeGarmo and Moody, “A Lightweight, Low-Cost ADS-B System for UAS Applications” (MITRE)

• Government and NextGen Literature
  10. ADS-B and GPS Technical Documentation (available through [www.rtca.com](http://www.rtca.com))
      • MASPS/MOPS, DO-260, DO-289, etc.
  11. FAA Documents and Briefings, received from speakers or Prof. R. J. Hansman
  12. ADS-B Integrated Working Plan (AIWP) Spiral 1, received through membership in working group
  13. AP23 and other Eurocontrol Documentation, available through [www.eurocontrol.int](http://www.eurocontrol.int)
Thank You

Questions?
Backup Slides
FIS-B
Initial study rated user benefit from 19 ADS-B Applications

- **MIT Pilot Survey (Lester, 2007)**
  - 1136 Pilots rated 19 ADS-B applications in an online survey based on perceived benefit
    - No Benefits
    - Some Benefits
    - Significant Benefits

**Closely Spaced Parallel Approach Monitoring**

**Enhanced Visual Acquisition**

<table>
<thead>
<tr>
<th>Non-Radar Airspace ADS-B Out Applications</th>
<th>Operator Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company Flight Tracking in Non-Radar Airspace</td>
<td>Aircraft Owners</td>
</tr>
<tr>
<td>Radar-like IFR separation in non-radar airspace</td>
<td>Part 91 Rec. Airplane</td>
</tr>
<tr>
<td>Increased VFR flight following coverage</td>
<td>Part 91 Biz. Airplane</td>
</tr>
<tr>
<td>ATC airport surface awareness</td>
<td>Part 91 Flight Training Airplane</td>
</tr>
<tr>
<td>ATC final approach and runway occupancy</td>
<td>Part 91 Commercial Airplane</td>
</tr>
<tr>
<td>Better ATC traffic flow management</td>
<td>Part 121 Airplane</td>
</tr>
<tr>
<td>Increase enroute capacity</td>
<td>Part 135 Airplane</td>
</tr>
<tr>
<td>Improved company flight tracking in radar airspace</td>
<td>Helicopter</td>
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</tbody>
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<th>Closely spaced parallel approach monitoring</th>
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<tbody>
<tr>
<td>Reduced separation standards</td>
<td></td>
</tr>
<tr>
<td>More accurate search and rescue response</td>
<td></td>
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<td>Enhance visual acquisition in VFR or MVFR</td>
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<th>ADS-B In Traffic Display Applications</th>
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<tr>
<td>Visual separation in VFR and MVFR conditions</td>
<td>In-Traffic climbs and descents</td>
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<tr>
<td>Merging andSpacing</td>
<td>Real-time cockpit weather display</td>
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<tr>
<td>VFR-like separation in all weather conditions</td>
<td>Real-time cockpit airspace display</td>
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<td>Self-Separation or station keeping</td>
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Preliminary GA Cost Estimation: Assumptions

• Estimates made for different initial equipage levels

• Equipment costs based on Garmin product line
  – If new equipment was to be installed, Garmin equipment and the average price from three different dealers was used
  – If existing equipment was to be upgraded, direct quotes were obtained from Garmin
  – Where no dealer prices were available, a direct quote from Garmin was used
    • Garmin quotes are generally ~$1000 higher than dealer quotes

• Current fleet avionics equipage is based on FAA 2007 survey of GA and Air Taxi

• Encoding altimeter was not included in cost estimates
  – 96% of fleet has at least a Mode C Transponder (or better) implying an altitude encoding altimeter
A project involving MITRE and the Soaring Society of America (SSA) is currently underway.

A low cost, low integrity solution for all of GA would face much opposition because of safety concerns.

BUT: Gliders community is a special case
- Non-electric aircraft
- FAA exemption currently allows non-electric aircraft to fly without a Transponder
- Equipping sailplanes with a low-cost, ADS-B Out system could substantially reduce the threat of mid-air collisions with sailplanes and potentially demonstrate benefit for the wider GA community.

It also allows for Procedure Development:
Use Enhanced Visual Acquisition to analyze and understand process required to field an ADS-B Application
- Create and evaluate initial operating procedures for high user benefit applications
- Demonstrate Procedures during the project's phase 1 flight testing in Summer 2010
Integrity and Accuracy of GPS

- GPS position is used for ATC surveillance and other applications, hence it needs to have high Accuracy and high Integrity
  - Accuracy: Ability to match the actual value of the quantity being measured
  - Integrity: The measure of trust in the reported position

- The FAA NPRM requires Accuracy to be $\text{NAC}_p=9$ (R=100ft) and Integrity to be $\text{NIC}=7$ ($R_c=0.2\text{NM}=1000\text{ft}$)

- The high values of NIC and NAC are needed for high end aviation flying in highly congested areas and Instrument Flight (IFR) weather conditions
ADS-B Avionics Architecture
More Detail
Major ADS-B Avionics components are:
- Precision navigation equipment (e.g. GPS)
- ADS-B Transceiver with Antenna Diversity
- Cockpit Display of Traffic Information (CDTI), ADS-B IN only

The cost to GA comes from equipping the aircraft with these ADS-B avionics
- Some existing equipment may be usable for ADS-B resulting in multiple upgrade paths
- A major component is a GPS navigation unit
- Currently not much competition on ADS-B Avionics market
1090 ES ADS-B Out System (per NPRM)

Equipage Percentages: Includes Air Taxi
## Preliminary Cost to equip with a 1090 ES ADS-B Out: $4,200 to $18,000

<table>
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<tr>
<th>Starting Condition:</th>
<th>No cert. GPS</th>
<th>Certified GPS</th>
<th>No cert. GPS</th>
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<tr>
<td>Certified GPS</td>
<td>Mode C</td>
<td>Mode C</td>
<td>Mode S</td>
<td>Mode S</td>
<td>Mode S</td>
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<td>Additional Antenna</td>
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<td>$1,150</td>
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</table>

AD = Antenna Diversity  
ES = Extended Squitter

~ 87% of GA Fleet  
~ 12% of GA Fleet

Equipage Percentages: Includes Air Taxi  
Prices based on currently available equipment  
UAT ADS-B Out System (per NPRM)

Equipage Percentages: Includes Air Taxi
### Preliminary Cost to equip with a UAT ADS-B

**Out:** $11,500 to $25,400

**Note 1:** UAT appears to be more expensive than 1090ES

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#### Equipage Percentages: Includes Air Taxi

Prices based on currently available equipment


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#### Starting Condition:

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<th>Required Equipment</th>
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<tr>
<td>Certified GPS</td>
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<td>Mode C</td>
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<td><strong>$14,600</strong></td>
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</tbody>
</table>

AD = Antenna Diversity  
ES = Extended Squitter

---

\[ ~ 87\% \text{ of GA Fleet} \]

\[ ~ 12\% \text{ of GA Fleet} \]
Financial Cost to Equip with 1090 ES ADS-B Out (per NPRM)

- **NPRM Requirement**
  - Altitude output to NAV source, ADS-B and Transponder equipment
  - Continue use of Transponder

- **Ways of compliance**
  - Ensure altimeter complies with TSO-C10b

- **Big Advantage:**
  - 1090 ES Transponder serves as Transponder and ADS-B, saving space, weight and installation cost

- **NPRM Requirement**
  - Antenna Diversity
  - Compliance with TSO-C166a

- **Ways of compliance:**
  - Replace Mode C with a 1090 ES Transponder and install additional antenna
  - Update Mode S Transponder (Patch)
  - Comply with TSO-C166a

  **Advantages over UAT:**
  - Current 1090 Transponders allow for simple swap
  - Minimal additional weight
  - Disadvantage: NO FIS-B
    - Also, may require 260A update

**NPRM Requirement**
- Certified according to TSO-145b/146b, GSP + WAAS
- RAIM calculations require an altimeter connection

**Ways of compliance:**
- Upgrade existing (current GPS are TSO-145a/146a at best)

**Current Fleet GPS Equipage:**
- GPS but not IFR Cert: 51%
- IFR Cert (LNAV) or better: 21%
Financial Cost to Equip with UAT ADS-B Out (per NPRM)

- **NPRM Requirement:**
  - Altitude output to NAV source, ADS-B and Transponder equipment
  - Continue use of Transponder

- **Ways of compliance:**
  - Ensure altimeter complies with TSO-C10b

- **Problem:**
  - Will the Transponder serve as the squawk code input device? Does that require additional connectivity with the ADS-B unit?

- **NPRM Requirement**
  - Antenna Diversity
  - No higher than FL240
  - Compliance with TSO-C154b

- **Ways of compliance**
  - Install new two antennas or
  - Install one and if possible use existing transponder antenna with a diplexer
  - Upgrade existing UAT ADS-B legacy equipment

- **Problems:**
  - There are currently no UAT ADS-B units for sale under this TSO
  - Requires an interface with transponder or additional panel space
  - Adds weight

- **Ways of compliance:**
  - Upgrade existing GPS but not IFR Cert: 51%
  - IFR Cert (LNAV) or better: 21%
Preliminary Cost to equip with ADS-B IN: $0 to $9,000

- ADS-B IN equipment is in addition to ADS-B Out
  - ADS-B Out Transponder/Transceiver is required to receive ADS-B IN

<table>
<thead>
<tr>
<th>Capability</th>
<th>Receiver</th>
<th>Display</th>
<th>Total:</th>
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<tbody>
<tr>
<td>1090 ES ADS-B IN</td>
<td>TIS-B</td>
<td>Mode S Transponder</td>
<td>GPS</td>
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<tr>
<td>UAT ADS-B IN</td>
<td>FIS-B and TIS-B</td>
<td>UAT Transceiver</td>
<td>MFD: $9000</td>
</tr>
</tbody>
</table>

- Dedicated weather product as alternative to ADS-B IN: XM In-Flight Weather
  - No ADS-B Out or In required
  - Data can be displayed on most Garmin GPS or MFD systems

| XM Weather | In-Flight Weather | XM Receiver: $5,900 | GPS | $5,900 |
Specific Example of ADS-B Application

ADS-B NRA and One-In-One-Out
Example High User Benefit Application: GA Operations out of Radar Coverage

- GA operates in areas with a lack of radar coverage
  - Operations are often below radar coverage – unlike Air Carrier operations over oceanic air space
  - ITT contract *requires* the ADS-B surveillance volume to be equivalent to the existing radar volume although it often has good low altitude coverage
Specific Example: One In One Out Problem

- Most common at non-towered airports
- Due to the lack of radar coverage, only one IFR aircraft is allowed to enter the non-radar airspace, 7110.65 4-8-1 c.
- Unless ATC can use ADS-B as a means to provide separation services, there is little benefit
- Even if ADS-B is allowed to provide separation services, benefit is constrained to very select locations
  - Radar Services are terminated at FAF (switch to CTAF) – 7110.65 4-8-8 and 7110.65 4-8-1 c.
  - Locations receiving most benefit are ones with a large altitude difference between the FAF and the current radar floor
  - Even then, the ITT contract only calls for an ADS-B surveillance volume equivalent to Radar
Low Altitude Surveillance (ADS-B NRA)

- The proposed ADS-B ground infrastructure allows for low altitude surveillance
  - Procedures to use this surveillance need to be in place to create early benefit
  - Surveillance at low altitude would create large incentive for GA

- In order to provide ADS-B separations services at low altitude,
  - ADS-B needs to be accepted as a surveillance source sufficient to provide ATC separation services
    - “Radar equivalency” creates a legal basis for controllers to use ADS-B as a means to provide separation
  - Situations specific to ADS-B surveillance need to be addressed
    - Mixed equipage
    - GPS outage
    - Data Fusion
    - etc.
Methodology

Limitations of ETMS Data:
- Altitudes are only reported in 1NM squares
- Altitudes depend on how the ETMS system changes the reported altitude (+/-350ft)

List of Airports and their Lowest ETMS Tracks

(See Excel Sheet)
ETMS Data with all Airports Displayed
New England ETMS Data up to 8000ft MSL
New England ETMS Data up to 500ft AGL
Radar coverage vs. ADS-B coverage

- ADS-B enables superb low altitude surveillance:
  - Lowest ETMS Track versus predicted New England at 500ft AGL

Lowest ETMS Track (2004-2005) vs. UAT predicted coverage

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Main Point: We know the actual altitudes for locations that actually matter (such as IFR routes).