Automatic Dependent Surveillance-Broadcast (ADS-B) Costs, Benefits, Applications, and Implementation Challenges

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Airline Advisory Board Meeting
November 6, 2008
Automatic Dependent Surveillance-Broadcast (ADS-B)

**Air Vehicle Component**

- ADS-B Out: Position & intent broadcast from aircraft to ground or other aircraft
- ADS-B In: Information transmitted from ground or other aircraft to the aircraft

**Ground Component**

- ATC Integration

**Cockpit-Based Applications**
- Self-separation
- Equivalent VFR operations
- Traffic & runway awareness
- Airspace, weather, terrain awareness
- Precision Navigation

**ATC-Based Applications**
- Surveillance
- Separation procedures
- Trajectory-based operations

**Global Navigation Satellite System**

**Coverage Volume**

**ATC**

**Air Traffic Control**
ADS-B As Global ATM Modernization Enabler

Canada
USA
Europe
Russia
China
Iceland
India
S. Africa
Australia & New Zealand
Indonesia & Singapore
Japan

Hudson Bay: 2010 implementation of ground infrastructure

US: 2020 Mandated ADS-B out, ground contract award

EU: 2015 Mandated ADS-B out, follow-on to enhanced surveillance

Australia: ADS-B Separation services provided

Implemented
Committed
Expected
Evaluated
Motivation

- **US (2020) and Europe (2015) mandating ADS-B airborne equipage for ATC surveillance**
  - Mandates perceived as cost shifting from ANSP to users

- **Desire to stimulate early equipage prior to mandate**
  - Many ADS-B benefits require minimum threshold of equipage
  - Multiple working groups examining ADS-B applications
  - Ground infrastructure deployed early, desire to achieve benefit

- **Need to examine cost and benefit distributions to understand and effect equipage dynamics**
  - Benefits come from implemented applications
  - Costs depend on types of equipment and infrastructure costs

- **MIT active in multiple aspects of ADS-B program**
  - Magnitude & categories of benefits
  - Infrastructure “rollout”
  - Equipage requirements
  - Implementation challenges
Multi-Stakeholder Value Distribution

Adapted from: (Dr. Karen Marais & Prof. Annalisa Weigel (MIT) “Encouraging and Ensuring Successful Technology Transition in Civil Aviation”
Operational Benefits Driven by ADS-B Applications

Operational Capabilities

- Operating Procedures
- Aircraft Operational Capability
- ATC Operational Capability
- Ground Infrastructure

Applications

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

Aggregate Cost/Benefits

- stk₁
- stk₂
- stk₃

Benefits
- b₁(t)
- b₂(t)
- b₃(t)

Costs
- c₁(t)
- c₂(t)
- c₃(t)

Legend

Level of Benefit/Cost

- Significant
- Some/Indirect
- None/Insignificant

Legend icons
Fundamental Challenges in Safety Approval of ADS-B Capabilities

- Safety approval will be key barrier to achieving operational benefits: especially for fundamentally new concepts
  - Substantial time & resources in decision-making
  - Approval process produces uncertainty in delivery of benefits

- Specific concerns in ADS-B system requirements
  - Requirements Stability
  - Airborne vs. ground assurance standards
  - Assessment to target level of safety

- Majority of high benefit applications fundamentally different and therefore require significant effort in safety approval to implement
Integrated Air/Ground Operational Capability

Steps
Application Categories

- Environmental Situation Awareness
  - Weather Information
  - Airspace Information

- Traffic Situation Awareness
  - Cockpit Display of Traffic Information (CDTI)

- Conflict Detection

- Merging & Spacing
  - In-Trail Procedures
  - En-Route Spacing
  - Arrival Spacing (CDA, CSPR, Paired..)

- Improved Airspace Use
  - Flow Corridors
  - Closely Spaced Routes

- Conflict Resolution

- Trajectory Planning
  - Route or Flight Level Optimization

- Separation Responsibility
  - Delegated Separation
  - Self-Separation
MIT Pilot Survey (Ted Lester 2007)
- A web based survey of pilot perception of
  ADS-B benefits.
- 1136 Valid responses were obtained between
- Participant type of operation:
  - Part 91 Recreational 57%
  - Part 91 Business Travel 17.9%
  - Part 91 Flight Training 7.6%
  - Part 121 4.8%
  - Part 135 4.8%
  - Part 91 Commercial 3.9%
  - Other Government 1.2%
  - Military 1.1%
  - Law Enforcement 0.3%

MIT Airline Survey (Jenny Hu 2008)
- An interview based survey of Managers and
  technical experts.
- 14 airline responses were obtained in 2007.
- Airline type of operation:
  - Domestic Nationals 54%
  - Regional 23%
  - Cargo 15%
  - Business Jets 8%
## Comparison of Survey Conclusions

<table>
<thead>
<tr>
<th>Level of Benefit</th>
<th>Airlines</th>
<th>Pilots</th>
</tr>
</thead>
</table>
| **High** (>66% Indicated Significant Benefits) | Reduced Separation Standards or Buffer  
Improved Arrival & Departure Procedures | Improved Pilot Situation Awareness |
| **Medium** (33%-66% Indicated Significant Benefits) | More Efficient Use of Non-Radar Airspace  
Enhanced Flight Tracking by Airlines  
More Even Task Distribution between ATC & FD | More Even Task Distribution between ATC & FD  
Improved ATC Situation Awareness  
More Efficient Use of Non-Radar Airspace  
More Efficient Use of Radar Airspace  
Reduced Separation Standards or Buffer  
Improved Arrival & Departure Procedures |
| **Low** (<33% Indicated Significant Benefits) | Improved ATC Situation Awareness  
More Efficient use of Radar Airspace  
Improved Pilot Situation Awareness | Enhanced Flight Tracking by Airlines |
### ADS-B Application Benefits

<table>
<thead>
<tr>
<th>Environmental Situation Awareness</th>
<th>Traffic Situation Awareness</th>
<th>Conflict Detection</th>
<th>Merging &amp; Spacing</th>
<th>Conflict Resolution</th>
<th>Improved Airspace Use</th>
<th>Trajectory Planning</th>
<th>Separation Responsibility</th>
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</thead>
<tbody>
<tr>
<td>Terrain Awareness</td>
<td>TIS-B</td>
<td>Dynamic Conflict Alerting</td>
<td>Enhanced Visual Acquisition</td>
<td>Static Conflict Resolution</td>
<td>Pared Closely-Spaced Routes</td>
<td>Taxi Instructions</td>
<td>Radar En-Route Self-Separation</td>
</tr>
<tr>
<td>Static Airspace Boundaries</td>
<td>ADS-R</td>
<td>Static Conflict Alerting</td>
<td>Enhanced Instrument Acquisition</td>
<td>Collision Avoidance, 4d</td>
<td>Independent Closely Spaced Routes</td>
<td>Flight Path Instructions</td>
<td>Non-Radar En-Route Self-Separation</td>
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<tr>
<td>Dynamic Airspace Boundaries</td>
<td>Surface Traffic Awareness</td>
<td>Separation Violation Alerting</td>
<td>Pared Closely Spaced Parallel Departures</td>
<td>Dynamic Conflict Resolution</td>
<td>Flow Controls</td>
<td>Route Optimization</td>
<td>Radar Terminal Self-Separation</td>
</tr>
<tr>
<td>Frequency Outages</td>
<td></td>
<td>Non-Radar: Taxi-Out Spacing</td>
<td>Non-Radar: Departure, Spacing</td>
<td>Separation</td>
<td></td>
<td></td>
<td>Non-Radar Terminal Self-Separation</td>
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<tr>
<td>Weather Reports (FIS-B)</td>
<td></td>
<td>ITP: Follow</td>
<td>ITP: Climb &amp; Descent</td>
<td>Separation Violation</td>
<td></td>
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<td>Weather Alerts, Bulletins, Warnings</td>
<td></td>
<td>ITP: Crossing &amp; Passing</td>
<td>ITP: Merge &amp; Spacing</td>
<td>Separation</td>
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<td>Weather Forecasts (FIS-B)</td>
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<td>Non-Radar: CDA</td>
<td>Non-Radar CSPR: Paired Approaches</td>
<td>Separation</td>
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<td>Radar: CDA</td>
<td>Radar En-Route Merging &amp; Spacing</td>
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- **Reduced Separation Standards or Buffer**
- **Improved Arrival and Departure Procedures**
- **More Efficient Use of Non-Radar Airspace**
- **Enhanced Flight Tracking by Airlines**
- **More Even Task Distribution between ATC and FD**
- **Improved ATC SA**
- **More Efficient Use of Radar Airspace**
- **Improved Pilot SA**
Aircraft Equipage

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<thead>
<tr>
<th>Trade Space</th>
<th>Old</th>
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<tr>
<td>DO</td>
<td>260</td>
<td>260A</td>
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<tr>
<td>SA ON/OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
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<td>Display</td>
<td>Side</td>
<td>Forward</td>
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<tr>
<td>GPS Augmentation</td>
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<td>Software Cert. Level</td>
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Navigation System

SA ON/OFF, GPS Augmentation

Display Requirements

High Criticality requires Forward Displays

ADS-B Transmit/Receive

DO-260 vs. DO-260A

Other Systems

Software Cert Level
Application Packages - Preliminary Results

### Package A

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- Current Equipage
- Significant Benefits with Current Equipage
  - Enhanced ATC Surveillance
  - Improved Use of Non-Radar Airspace (ADS-B OUT)
  - Air Traffic Awareness

### Package B

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- Significant Benefits with DO-260A with Forward Field of View
  - Package A Applications
  - Advanced In-Trail Procedures
  - Conflict Detection & Resolution
  - Basic Approach Applications
  - Surface Traffic Awareness
  - Delegated Separation (TBD)
  - Self-Separation (TBD)

### Package C

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- Increased Benefit with 260A, Forward Display and GPS Augmentation.
  - Package A & B Applications
  - Advanced Approach Applications
  - Delegated Separation
  - Self-Separation
Conclusions

- **Global Implementation of ADS-B is in-work.**
  - FAA: 2020 Mandate
  - Europe: 2015 Mandate

- **ADS-B OUT benefits are available with current aircraft equipage (DO-260).**

- **Significant benefits for ADS-B IN applications require DO-260A with Forward displays.**

- **Certification & Operational Approval is a major obstacle.**