Development of High User Benefit ADS-B Applications: Conflict Detection for General Aviation

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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

Need to Incentivize GA Equipage

- **Co-dependency of ADS-B benefits**
  - All ADS-B In applications require 2 players
  - ATC mixed equipage concerns imply a minimum equipage level may be required

- **GA is significant part of fleet (96%)**
  - Need equipage of GA
  - Relatively low utilization per year
  - Cost sensitive

- **ADS-B Out mandate for 2020 in the US (2015 in Europe)**
  - To achieve voluntary equipage before 2020, benefit needs to outweigh cost
  - Early equipage = early benefit

- **Most prior ADS-B application efforts have been focused on commercial aviation**
  - Focus on GA

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Bureau of Transportation Statistics, Table 1-11, 2005 Data
ADS-B as a Multiple-Stakeholder System

<table>
<thead>
<tr>
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Dr. Karen Marais & Prof. Annalisa Weigel (MIT) "Encouraging and Ensuring Successful Technology Transition in Civil Aviation"
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**ADS-B Applications**

**Essential Services**

- **Data Applications**
  - TIS-B
  - FIS-B

Source: Marisa Jenkins
ADS-B Applications

Critical Services (ADS-B Out)

- ATC Surveillance Applications (ADS-B Out)
  - ATC Services in Non-Radar Areas
  - Non-Radar Increased IFR Airport Acceptance Rate
  - Enhanced Tower Situational Awareness
  - Improved ATC Traffic Flow Management
  - Improved Search and Rescue
  - etc.

Source: Marisa Jenkins
ADS-B Australia Implementation

Source: Greg Dunstone
ADS-B Program Manager
US Radar Coverage
Elevation of Lowest ETMS Radar Return (AGL)

Source: Fabrice Kunzi
AIWP ADS-B Applications

**ADS-B In**

- Traffic Situation Awareness Applications
  - Traffic Situation Awareness–Basic
  - Traffic Situation Awareness for Visual Approach
  - Traffic Situation Awareness with Alerts
  - Airport Traffic Situation Awareness
  - Airport Traffic Situation Awareness with Indications and Alerts

Source: Bill Richards, Boeing
Marisa Jenkins
Proposed ADS-B Applications

ADS-B In

- **Routing Applications**
  - Independent Closely Spaced Routes
  - Flow Corridors

- **Separation Applications**
  - Delegated Separation–Crossing
  - Delegated Separation–Passing
  - Self Separation

- **Closely Spaced Parallel Approaches**

- **Aircraft to Aircraft Separation Applications**
  - Oceanic In-Trail Procedures
  - Flight Deck Based Interval Management – Spacing or Delegated Separation
  - Flight Deck Based Interval Management – Delegated Separation with Wake Risk Management
## Application Integrated Work Plan (AIWP) Applications

<table>
<thead>
<tr>
<th>No</th>
<th>Application</th>
<th>Air Carrier</th>
<th>High-End GA</th>
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Source: AIWP, Final Release, v2
Barriers to Implementation of High Value ADS-B Applications

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Level of Benefit/Cost
- Significant
- Some/Indirect
- None/Insignificant

Dr. Karen Marais & Prof. Annalisa Weigel (MIT) “Encouraging and Ensuring Successful Technology Transition in Civil Aviation”
Barriers to Implementation of High Value ADS-B Applications

- **Aircraft Equipage:**
  - Technical standards and final rule for ADS-B Out have been published
  - Cost appears to be a significant barrier to equipage

- **Operating Procedures:**
  - Applications need to be described before procedures can be developed
  - Procedure Development appears to be starting but is not as mature as others

- **ATC Infrastructure:**
  - Various “Key Sites” are already operating the ADS-B ground infrastructure (Florida, Gulf of Mexico, etc.)
  - The FAA is committed to have nationwide ground infrastructure fielded by 2013
## AIWP Applications Under Active Development

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New Effort in ATSA-AIRB
Focused on GA Benefits

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Traffic Situation Awareness with Alerts (ATSA-AIRB)

• ATSA-AIRB provides flight crews of non-TCAS equipped aircraft with traffic alerts
  – Conflict Detection, not Conflict Avoidance

• Collaborative Project
  – MIT (encounter scenarios, algorithms, human factors)
  – Avidyne (ConOps, hardware development and flight testing)

• Develop and test ATSA-AIRB demonstration system focused on GA operations
  – Capability demonstration
  – MOPS acceleration
Traffic Situation Awareness with Alerts

- **Six Tasks over 3 years**
  - Identify and develop a list of representative encounter scenarios
  - Develop an AIRB with Alerting Concept of Operation (ConOps)
  - Develop a set of algorithms
  - Develop a simulation for initial functionality and human factors testing
  - Develop a working prototype and conduct flight test and evaluation
  - Provide documentation and support interaction with standards and regulatory efforts (RTCA, ConOps, MOPS, etc.)

- **Technical Challenges/Opportunities**
  - Operations inside TCAS envelope
  - GA Diversity and Maneuvering potential
  - Dual-Frequency Issues (e.g. latency, system architecture)
  - Antenna shielding
• Reconstructed encounter geometries for 112 NTSB reports from 10 years
  – Analyzed US, non-commercial flights
• Two steps approach
  – Geometry reconstruction
  – Identify emergent trends
• Format of reported horizontal motion of aircraft (drives resolution)
  – Cardinal Directions: 19%
  – Exact radar data: 12%
  – No Radar Data: 7%
  – Implied from description in report: 63%
• Description of vertical motion is less accurate/consistent
  – Climbing/Descending sometimes determined from radar information (primary vs. secondary radar) or implied from phase

Unknown: 8%
MACs by Location

- **In the Pattern**
  - Both aircraft are flying the airport pattern

- **Airport Vicinity**
  - Aircraft are arriving or departing
  - Overflying the airport
  - Parachute/air shows

- **Away from Airport**
  - All other

- The traffic pattern at an airport has the highest percentage of MACs (45%)
Collisions in the Pattern

- Total of 50 cases (45% of 112)
- 84% of them are on Final, Short Final or the Runway
  - Runway may include a departing AC
- 14% of them are between an aircraft in the pattern and another one entering it
- Two cases had aircraft on final to different airports
- Note: TCAS gives no RA’s below 1000ft or TA’s below 500ft
Collisions Away from the Airport

- Total of 46 cases (42% of 112)
- “Maneuvering” includes aircraft performing a mission
  - Aerial Application
  - EMS/News Helicopters
  - Firefighting
- 9 out of the overall 12 Formation MACs are in this category
- No IFR/IFR collisions
- Minden Mid-Air is in this category
Addressing Cost as a Barrier

Dr. Karen Marais & Prof. Annalisa Weigel (MIT) “Encouraging and Ensuring Successful Technology Transition in Civil Aviation”
Cost as a barrier to equipage

- WAAS GPS is major cost driver
- Cost to equip an aircraft with ADS-B depends on currently installed equipment

Source: Garmin
Initial Cost Analysis
GA ADS-B Out Avionics Costs

- Used 2009 current market prices to price individual components
  - UAT: $18,000 (retrofit) to $25,000 (new)
  - 1090ES: $4,200 (retrofit) to $18,000 (new)

1090ES Avionics Architecture
Source: Fabrice Kunzi

UAT Avionics Architecture
Costs Currently Still Exceed Willingness To Pay

- 2010 Current Market Cost under final rule (without antenna diversity)
  - UAT: $8,000 (retrofit) to $12,500 (new)
  - 1090ES: $5,000 (retrofit) to $12,200 (new)

- Recent developments indicate further potential reductions with bundling and integration

Source: Ted Lester
Next Steps

• **Scenarios informed by**
  - GPS flight tracks from Avidyne
  - Lincoln Labs Encounter Models
    - Used for TCAS 7.1 update, UAV, Sense & Avoid
  - Other trajectory data sources (e.g. PDARS)
  - Previous scenarios used for certification of existing TCAS/TAS avionics

• **Define Matrix and Envelop of Encounter Scenarios**
  - Encounter Geometries
  - Own-ship and Intruder Aircraft Types
  - Missions
  - Environments
    - Pattern, Enroute, Other
    - IMC, VMC, Night, Day
Technical Benefits of ADS-B

- **Performance Advantages (vs RADAR)**
  - Higher update rate than radar (1 sec vs 4-12 sec)
  - Higher velocity accuracy
  - Potentially higher position accuracy
  - ADS-B provides heading information
  - ADS-B messages can contain intent information

- **Other Advantages**
  - Potentially greater coverage area
  - Allows for more even task distribution between ATC and pilots
  - Uplink capability
    - TIS-B
    - FIS-B
  - Reduced infrastructure cost

- **User benefits are distinct from technical benefits**
  - Need benefits to users create equipage incentives

- MIT Pilot Survey
  - Web based survey of pilot perception of ADS-B benefits
  - 1136 Valid responses were obtained between 06/06/2007 and 07/31/2007

Source: Lester, MIT 2007

- **MIT Airline Survey**
  - An interview based survey of Managers and technical experts
  - 14 airline responses were obtained in 2007
  - Airline type of operation included Domestic Nationals, Regional, Cargo and Business Jet

### High Benefit Applications - Airlines

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<tr>
<th>Application</th>
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<td>Reduced Separation Standards</td>
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<td>Arrival and Departure Procedures</td>
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<td>Radar-like Separation in Non-Radar Areas</td>
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<td>AOC Tracking: Airport Surface</td>
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<tr>
<td>Self Separation</td>
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<tr>
<td>Improved ATC Situation Awareness</td>
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<tr>
<td>More accurately spaced aircraft</td>
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<td>AOC Tracking: En Route</td>
<td>0</td>
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<tr>
<td>Improved Pilot Situation Awareness</td>
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</table>

Source: J Hue, MIT 2008
Identifying Applications with High Value for Multiple Stakeholders

- Stakeholder Benefit and High Value Application Comparison
  - Based on rankings of applications in the surveys, applications with high value to multiple stakeholders were identified
  - Applications were rated by weighted benefit
Methodology

• Initial work for Task 1: Identification of Representative ADS-B Conflict Detection Encounter Scenarios
  – Will ultimately inform the development of representative encounter scenarios

• Analyzed 10 years of NTSB Mid-Air Collision Accident Reports
  – Starting Jan 2000 until June 2010
  – Total of 112 Reports
  – Flights operated under Parts 91, 135 and 137 (Ag-Flights), excluded non-US accidents and balloons

• Reviewed full reports
  – Reconstructed encounter geometry from narratives
  – Identified external factors that could be contributing factors (such as mode of operation or differences in equipment)

• Analysis of frequency
  – Identified locations where mid-air collisions occur more frequently
  – Analyzed geometries for recurring patterns
Barriers to Implementation of High Value ADS-B Applications

Adopted from Weibel, “Assuring Safety through Operational Approval: Challenges in Assessing and Approving the Safety of Systems-Level Changes in Air Transportation”, MIT 2009