Automatic Dependent Surveillance-Broadcast (ADS-B) Costs, Benefits, Applications, and Implementation Challenges
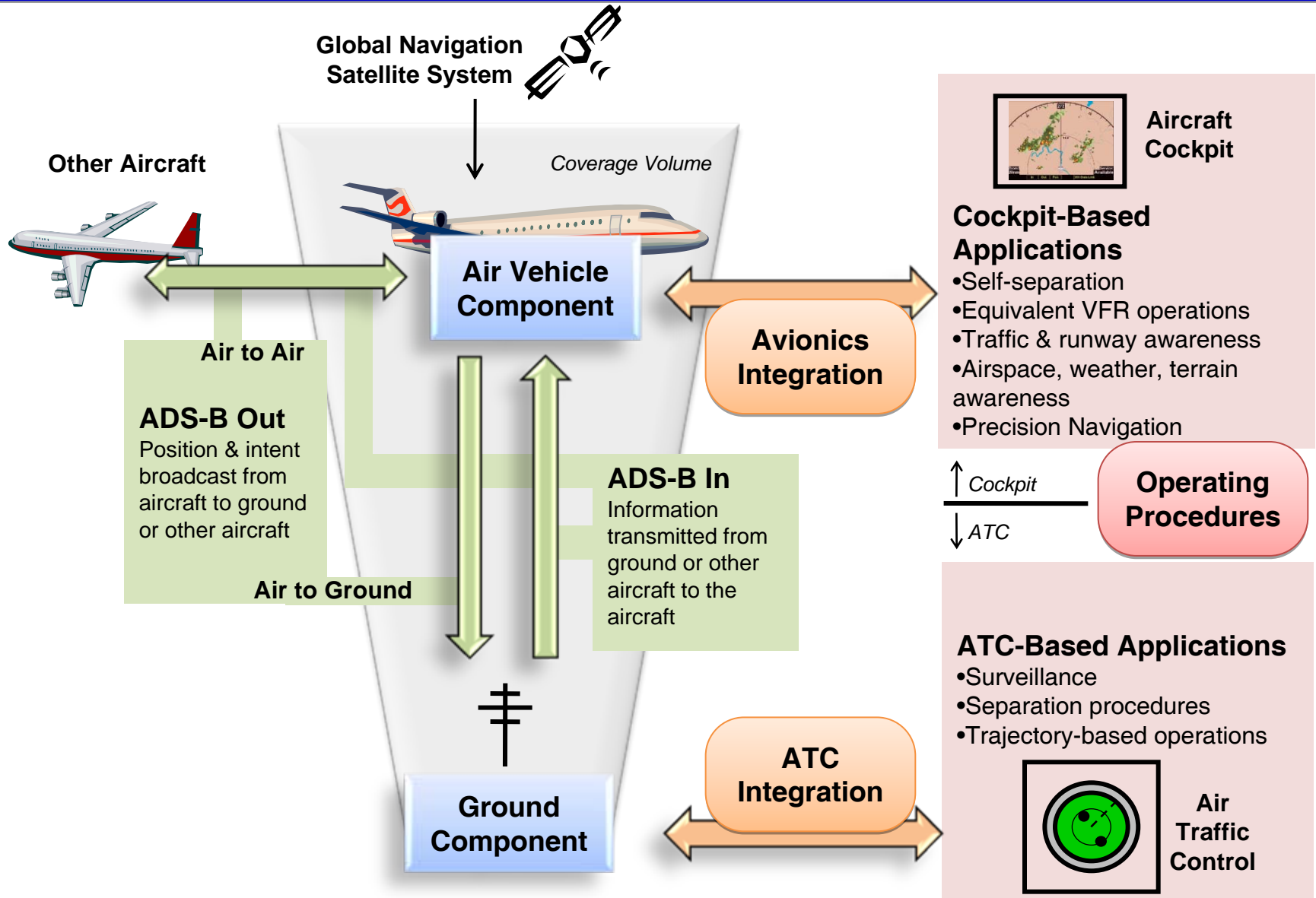
Roland Weibel & Marisa Jenkins
weibel@mit.edu; mjenkins@mit.edu

R. John Hansman
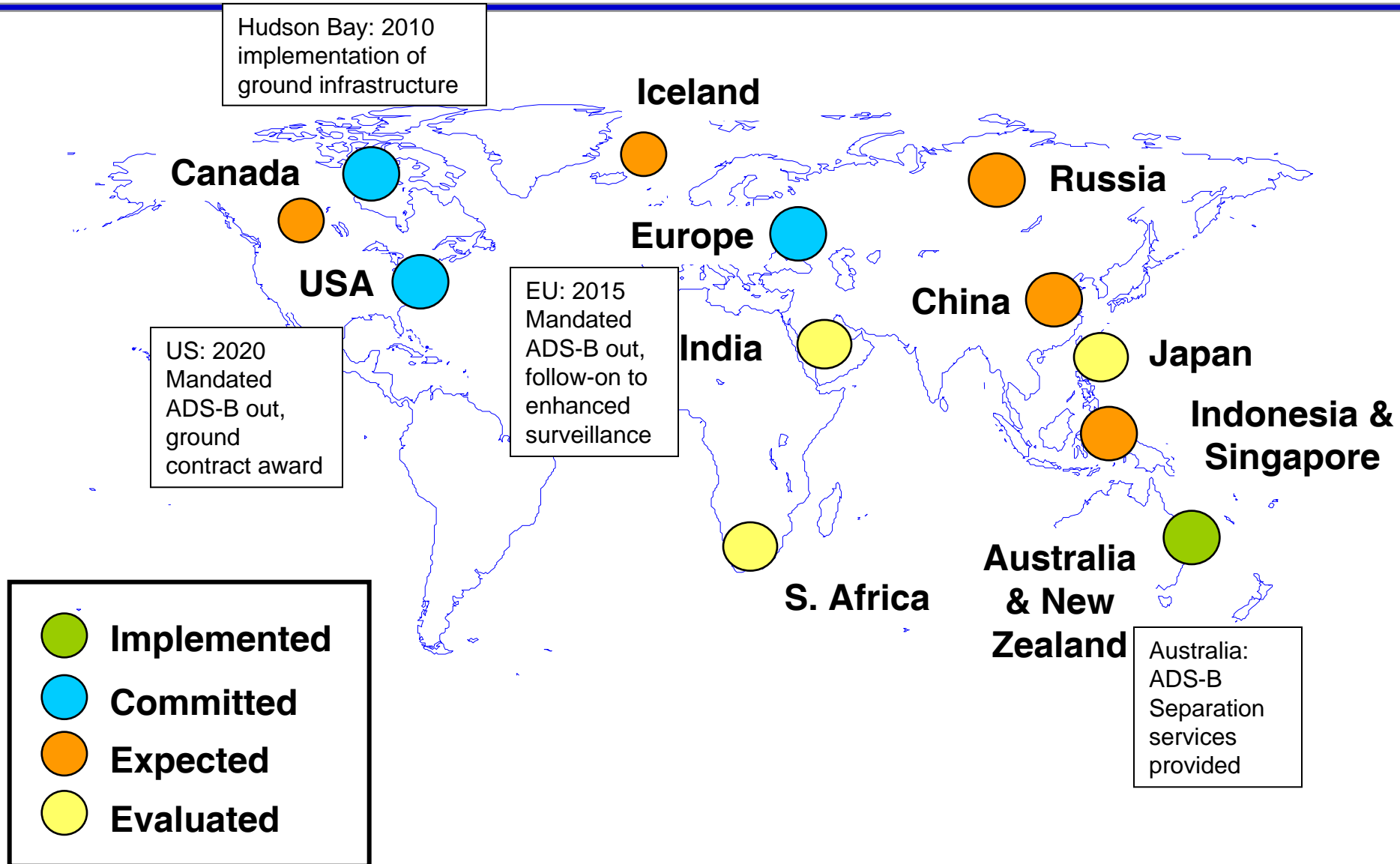**rjhans@mit.edu**

Airline Advisory Board Meeting
November 6, 2008

Automatic Dependent Surveillance- Broadcast (ADS-B)

MIT ICAT

Global Navigation Satellite System

Other Aircraft

Coverage Volume

Air Vehicle Component

Air to Air

ADS-B Out
Position & intent broadcast from aircraft to ground or other aircraft

Air to Ground

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

Ground Component

Avionics Integration

ATC Integration

Aircraft Cockpit

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

↑ *Cockpit*

↓ *ATC*

Operating Procedures

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

Air Traffic Control

ADS-B As Global ATM Modernization Enabler

Hudson Bay: 2010 implementation of ground infrastructure

Iceland

Canada

Russia

Europe

USA

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

China

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

India

Japan

Indonesia & Singapore

S. Africa

Australia & New Zealand

Australia: ADS-B Separation services provided

Legend:
- 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
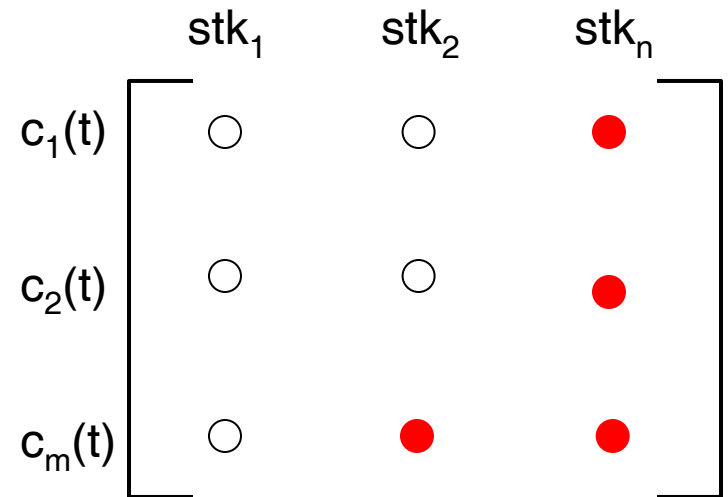 - Ground infrastructure deployed early, desire to achieve benefit

- **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

$$
\text{Benefits} \quad
\begin{array}{c}
 \\
b_1(t) \\
 \\
b_2(t) \\
 \\
b_m(t)
\end{array}
\begin{bmatrix}
stk_1 & stk_2 & stk_n \\
\bullet & \bullet & \circ \\
\bullet & \circ & \circ \\
\bullet & \circ & \circ
\end{bmatrix}
$$

Benefits

$$
\begin{array}{c}
 \\
c_1(t) \\
 \\
c_2(t) \\
 \\
c_m(t)
\end{array}
\begin{bmatrix}
stk_1 & stk_2 & stk_n \\
\circ & \circ & \bullet \\
\circ & \circ & \bullet \\
\circ & \bullet & \bullet
\end{bmatrix}
$$
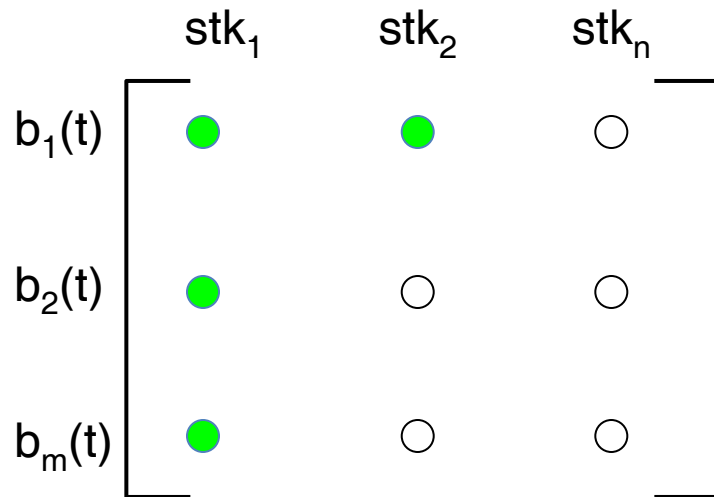
Costs

Operating Capabilities

Applications

Operating Procedures

Aircraft Operational Capability

ATC Operational Capability

Ground Infrastructure

Application 1

Application 2

….

Application x
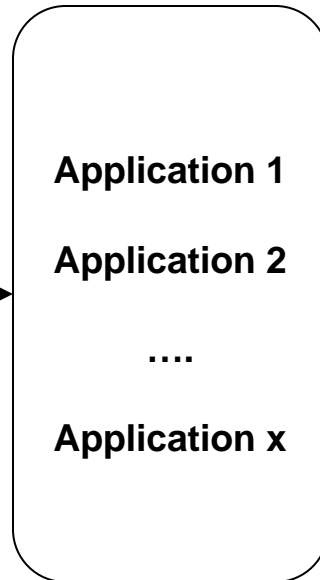
	stk_1	stk_2	stk_3
$b_1(t)$	●	●	●
$b_2(t)$	●	◐	○
$b_3(t)$	●	○	○

benefits

	stk_1	stk_2	stk_3
$c_1(t)$	○	○	●
$c_2(t)$	○	◐	●
$c_3(t)$	●	●	●

costs

Legend

Level of Benefit/Cost

Significant	Some/Indirect	None/ Insignificant
●	◐	○
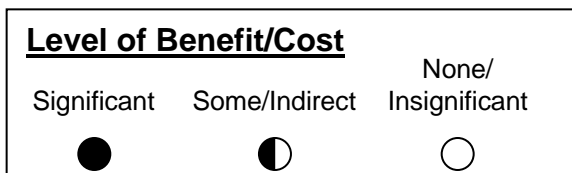
Fundamental Challenges in Safety Approval of ADS-B Capabilities

- **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
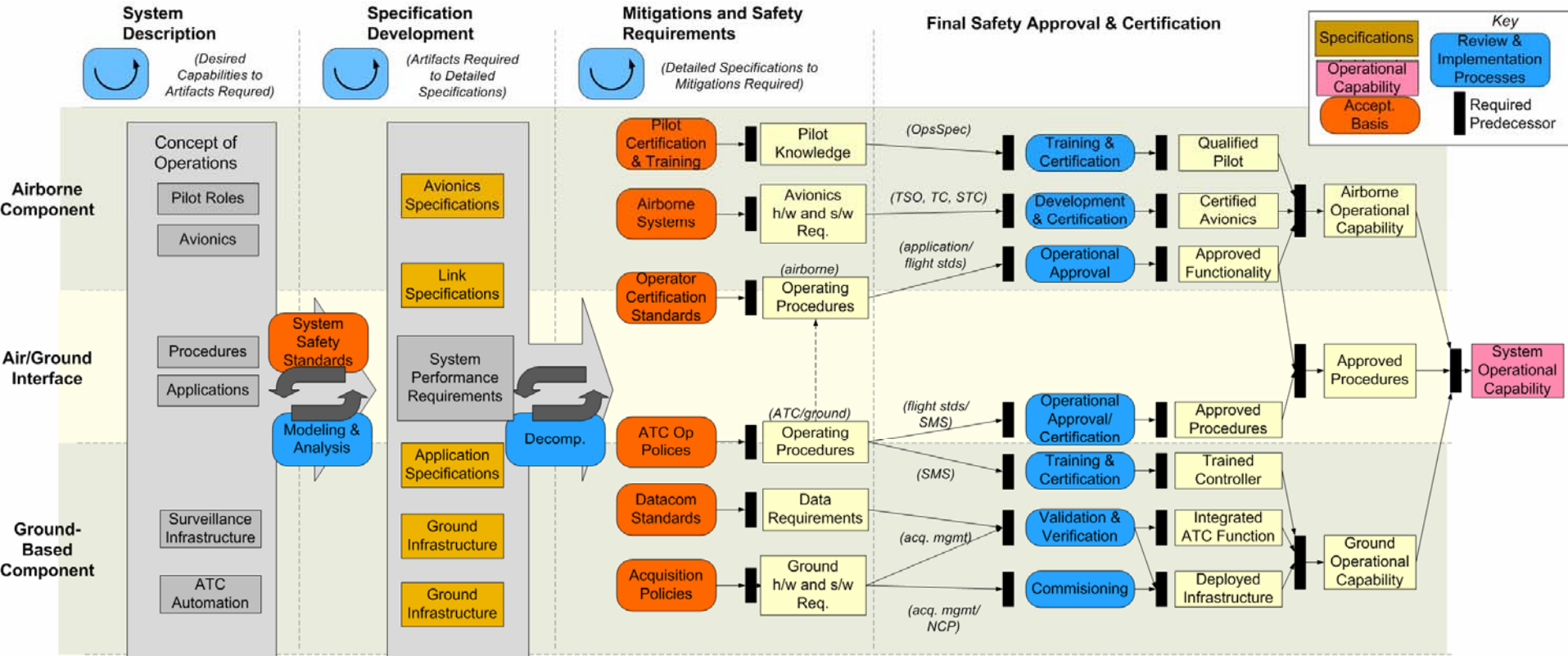
Application Categories

- **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**
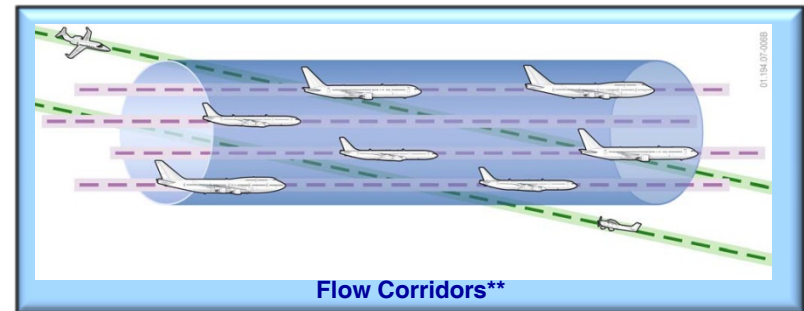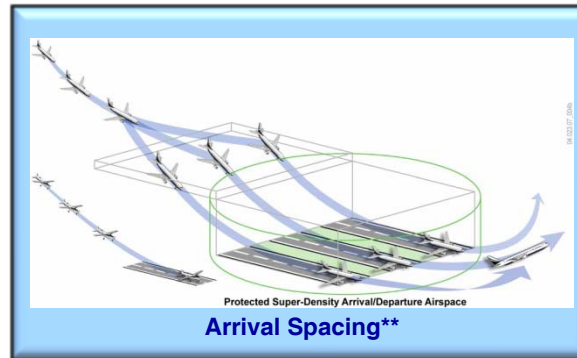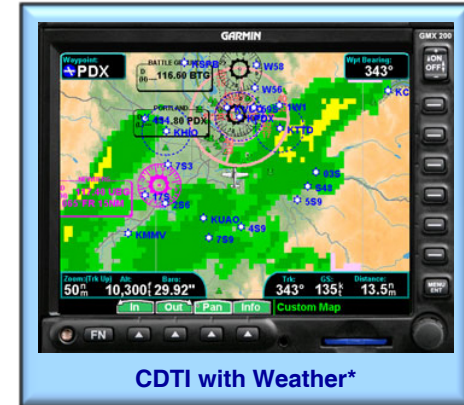 - *Flow Corridors*
  - *Closely Spaced Routes*

- **Conflict Resolution**

- **Trajectory Planning**
  - *Route or Flight Level Optimization*

- **Separation Responsibility**
 - *Delegated Separation*
  - *Self-Separation*

CDTI with Weather*

Arrival Spacing**

Flow Corridors**

Garmin GMX 200 Multi-Function Display
•*NextGen CONOPS June 2007

MIT Pilot Survey (Ted Lester 2007)

- *A web based survey of pilot perception of ADS-B benefits.*
- *1136 Valid responses were obtained between 06/06/2007 and 07/31/2007.*
- *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%*
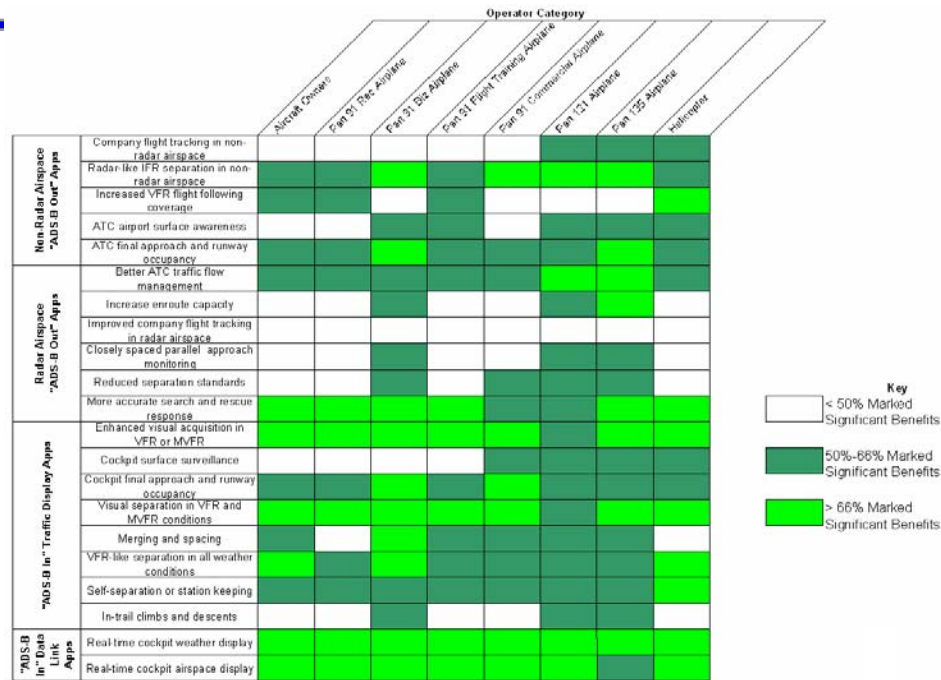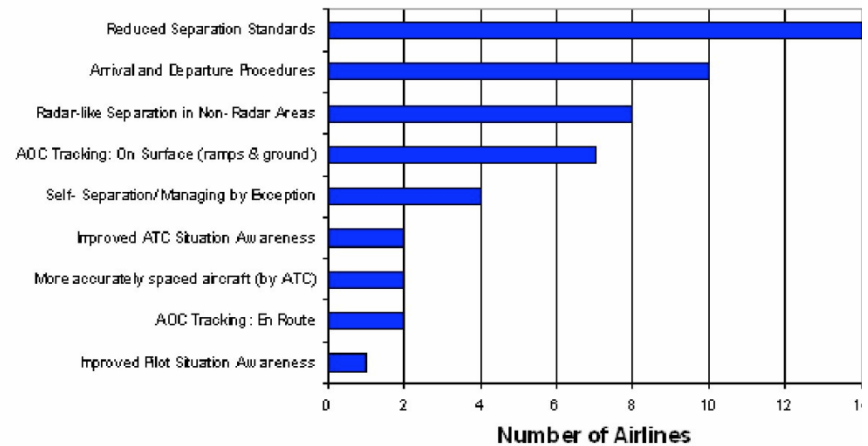
MIT Airline Survey (Jenny Hu 2008)

- 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%

Perceived Benefit

Number of Airlines
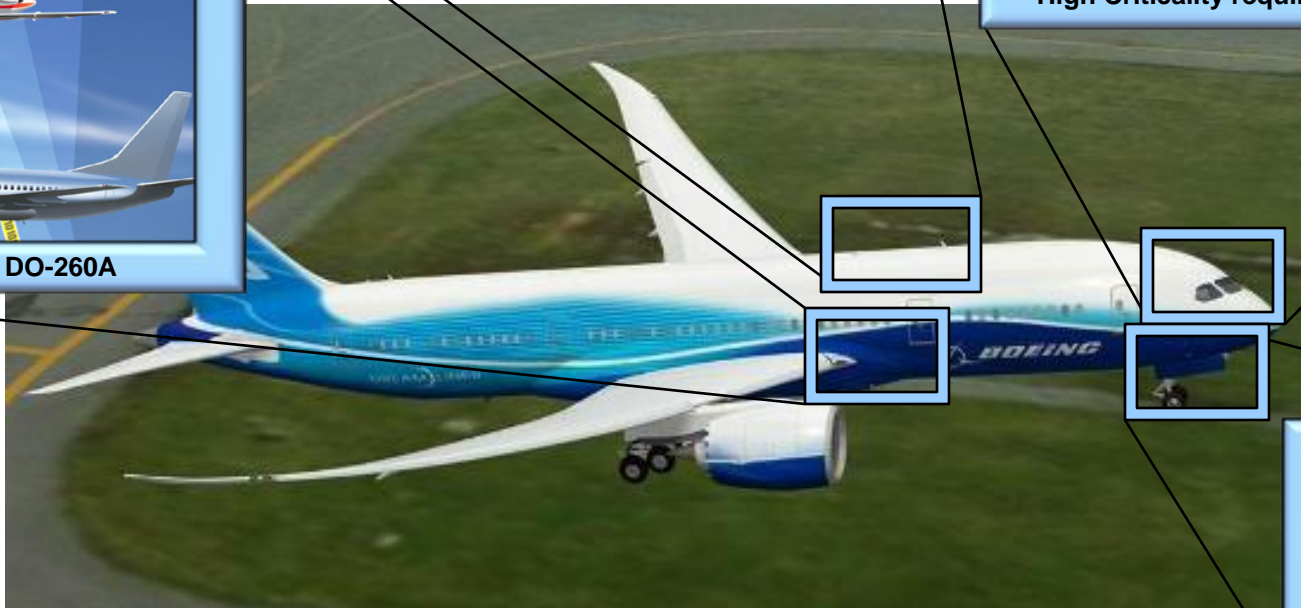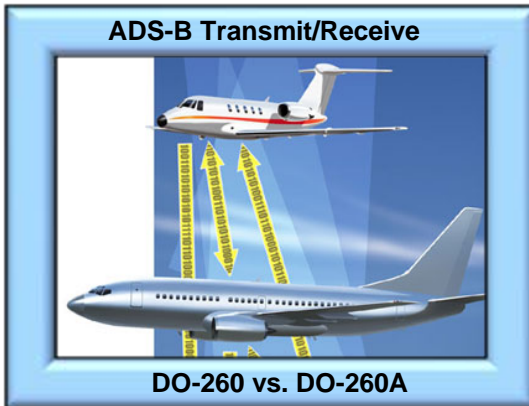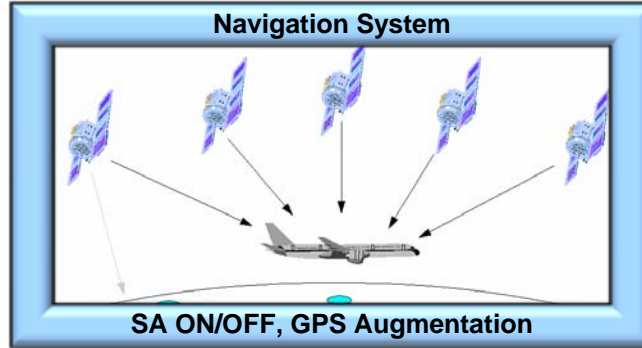
Comparison of Survey Conclusions

Level of Benefit	Airlines	Pilots
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
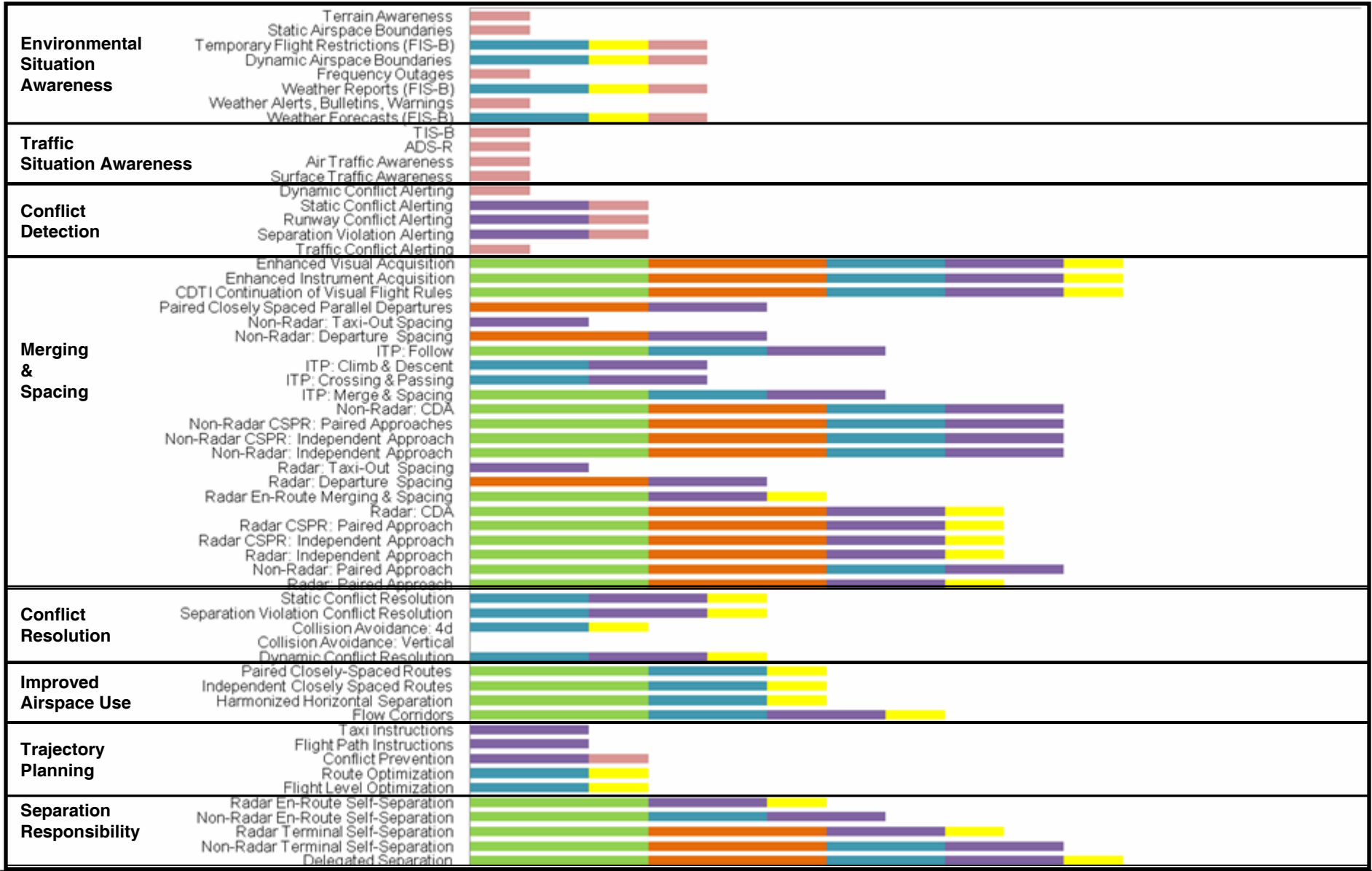
Aircraft Equipage

Trade Space	Old		New	
DO	260		260A	
SA ON/OFF	ON		OFF	
Display	Side		Forward	
GPS Augmentation	None		Yes	
Software Cert. Level	D	C	B	A

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

Package A

Trade Space	Old	New		
DO	260	260A		
SA ON/OFF	ON	OFF		
Display	Side	Forward		
GPS Augmentation	None	Yes		
Software Cert. Level	D	C	B	A

- Current Equipage

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

Package B

Trade Space	Old	New		
DO	260	260A		
SA ON/OFF	ON	OFF		
Display	Side	Forward		
GPS Augmentation	None	Yes		
Software Cert. Level	D	C	B	A

- 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

Trade Space	Old	New		
DO	260	260A		
SA ON/OFF	ON	OFF		
Display	Side	Forward		
GPS Augmentation	None	Yes		
Software Cert. Level	D	C	B	A

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

- **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.**