October 3, 2007

Mr. Henry P. Krakowski
Chief Operating Officer
Air Traffic Organization
Federal Aviation Administration
800 Independence Avenue SW.
Washington, D.C. 20571

Dear Mr. Krakowski:

On behalf of the Automatic Dependent Surveillance–Broadcast (ADS–B) Aviation Rulemaking Committee (ARC), we are pleased to provide you with a copy of the ARC's report on optimizing the benefits of ADS–B before implementation of a nationwide rule. This report, written without knowledge of the Federal Aviation Administration's (FAA) notice of proposed rulemaking, was written to fulfill the ARC's first tasking.

This report explains the operational benefits of ADS–B and provides the FAA with 12 recommendations on how it could accelerate the delivery of these benefits through early equipage with ADS–B. To significantly accelerate early ADS–B equipage, the ARC believes the FAA will need to offer a combination of financial incentives and operational benefits. In addition, the ARC has confidence in the FAA's ability to deploy the ADS–B ground infrastructure; however, the ARC is concerned with the FAA's ability to approve operational procedures that would provide early operational benefits that can not be achieved with the existing national airspace surveillance infrastructure.

We trust this report will be helpful in your decisionmaking process. We and our fellow ARC members stand ready to assist the FAA in prioritizing implementation of the ARC's recommendations.

Sincerely,

Basil J. Barimo
Air Transport Association of America, Inc.
Co-Chair

Steve Brown
National Business Aviation Association, Inc.
Co-Chair

Enclosure

Optimizing the Benefits of Automatic Dependent Surveillance—Broadcast

REPORT FROM THE ADS–B AVIATION RULEMAKING COMMITTEE

October 3, 2007

TABLE OF CONTENTS

LIST OF FIGURES ..... **iii**

LIST OF TABLES ..... **iv**

ACRONYM LIST ..... **v**

EXECUTIVE SUMMARY ..... **vii**

1.0 BACKGROUND **1**

Expected Rulemaking Action 3
ADS–B System 4
Automatic Dependent Surveillance – Rebroadcast (ADS–R) 8
Traffic Information Service – Broadcast (TIS–B) 8
Flight Information Service—Broadcast (FIS–B) 9
ADS–B and Global Harmonization 10

2.0 OBJECTIVE **13**

3.0 OPERATIONAL BENEFITS **14**

Section 3.1 Obtaining Early Operational Benefits from ADS–B with Existing Aircraft Equipage that Will Not Be Compliant with the Technical Standards of the Proposed ADS–B Rule 14
Section 3.2 Obtaining Operational Benefits from ADS–B Out in Compliance with the Expected Mandate (DO–260A Out and DO–282A Out) 19
Section 3.3 Available and Potential Benefits of ADS–B In 23
Section 3.4 Future Applications 34

4.0 INCENTIVES FOR EQUIPAGE **37**

5.0 RECOMMENDATIONS **40**

Appendix A—ARC Members **A–1**

Appendix B—Benefits Associated with ADS–B in Early Equipage **B–1**

Appendix C—Standards for Avionics for the 1090 MHz Extended Squitter (1090 ES):Status, Surveillance System Impacts, and ATS Provider Implementations August 2007 ..... **C–1**

Appendix D—Standards for Avionics for the Universal Access Transceiver (UAT): Status, Surveillance System Impacts, and ATS Provider Implementation September 2007 ..... **D–1**

LIST OF FIGURES

Figure ES–1—ADS–B Out Program Relationship x
Figure ES–2—ADS–B In and FIS–B Program Relationships xi
Figure 1—Segment 1 and 2 Milestones 2
Figure 2—Overview of ADS–B System 4
Figure 3—ADS–B Out Signal and Enabled Capabilities 6
Figure 4—ADS–B in Signal Sources and Enabled Capabilities 7
Figure 5—Prototype Traffic Display 9
Figure 6—Prototype FIS–B Display 9
Figure 7—Report on Aircraft Equipage (Graphic of Active Mode S and ADS–B Aircraft/Vehicles — All Sites) 14
Figure 8—Current Procedural Separation in the Gulf of Mexico 18
Figure 9—Possible Enabling of Radar-Like Separation Using ADS–B 19
Figure 10—Notional Depiction of Merging and Spacing 22
Figure 11—Prototype display of Runway Occupancy 25
Figure 12—Prototype Display of Enhanced Visual Approach Application 26
Figure 13—Notional Depiction of CAVS 27
Figure 14—Current Oceanic Non-Radar Procedure 28
Figure 15—ADS–B Enabled In-Trail Procedure 29
Figure 16—ADS–B Out Air Transport Equipage Sensitivity Analysis 31
Figure 17—ADS–B In Air Transport Equipage Sensitivity Analysis 32
Figure 18—ADS–B Out Sensitivity Analysis Equipage for General Aviation and Air Taxi Aircraft 33
Figure 19—ADS–B In Sensitivity Analysis Equipage for General Aviation and Air Taxi Aircraft 33

LIST OF TABLES

Table 1—Benefit Accrual for ADS–B Out Benefits 20
Table 2—Aircraft Equipped with DO–282A Standard Compliant Avionics 22
Table 3—ADS–B In Benefits Accrual 24
Table C–1. Comparison of DO–260 and DO–260A Change 2 4

ACRONYM LIST

1090 ES	1090 MHz Extended Squitter
ABESS	Airline Based En Route Sequencing and Spacing
AC	Aircraft
ADS–B	Automatic Dependent Surveillance – Broadcast
ADS–R	Automatic Dependent Surveillance – Rebroadcast
ARC	Aviation Rulemaking Committee
ASDE	Airport Surface Detection Equipment
ASSA	Airport Surface Situational Awareness
ATC	Air Traffic Control
ATM	Air Traffic Management
ATMAC	Air Traffic Management Advisory Committee
ATO	Air Traffic Organization
ATS	Air Traffic Service
ATSP	Air Traffic Service Provider
CAVS	CDTI Assisted Visual Separation
CDA	Continuous Descent Approach
CDTI	Cockpit Display of Traffic Information
CFIT	Controlled Flight Into Terrain
CPR	Compact Position Reporting
EFB	Electronic Flight Bag
ELT	Emergency Locator Transmitter
EMOSIA	European Model for Strategic ATM Investment Analysis
ERAU	Embry-Riddle Aeronautical University
EUROCAE	European Organization for Civil Aviation Equipment
EVA	Enhanced Visual Approach
FAA	Federal Aviation Administration
FAROA	Final Approach Runway Occupancy Awareness
FIS–B	Flight Information Service – Broadcast
GBTs	Ground Based Terminals
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HPL	Horizontal Protection Limit
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IR&D	Independent Research and Development
ISD	In-Service Decision
ITP	In-Trail Procedure
JFK	John F. Kennedy International Airport
JPDO	Joint Planning and Development Office
MASPS	Minimum Aviation System Performance Standards
Mode S	Mode Select
MOPS	Minimum Operational Performance Standards
NACP	Navigation Accuracy Category for Position
NACV	Navigation Accuracy Category for Velocity

NAS	National Airspace System
NextGen	Next Generation Air Transportation System
NIC	Navigation Integrity Category
NM	Nautical Miles
NOTAM	Notices to Airmen
NPRM	Notice of Proposed Rulemaking
NPV	Net Present Value
NUC	Navigation Uncertainty Category
RNAV	Area Navigation
RNP	Required Navigation Performance
RPR	Rulemaking Project Record
RWY	Runway
SAR	Search and Rescue
SARP	ICAO Standard and Recommended Practice
SBS	Surveillance and Broadcast Services
SIL	System Implementation Level
SSR	Secondary Surveillance Radar
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TIS-B	Traffic Information Service - Broadcast
TMA	Traffic Management Advisor
TSO	Technical Service Order
UAT	Universal Access Transceiver (978 MHz data link)
UND	University of North Dakota
VFR	Visual Flight Rules

EXECUTIVE SUMMARY

Automatic Dependent Surveillance–Broadcast (ADS–B) has been identified as a cornerstone technology in the implementation of the Next Generation Air Transportation System. ADS–B is a cooperative surveillance system that uses satellite technology, aircraft avionics, and a flexible ground infrastructure to more accurately and quickly transmit flight information between aircraft and air traffic control. To achieve the key benefits of ADS–B, meet the increasing demands of air travel, and enable the implementation of future applications, all aircraft in a given area will have to be equipped with ADS–B technology. While the Federal Aviation Administration (FAA) expects some level of voluntary equipage with ADS–B avionics, it is unlikely that 100 percent of the necessary population will equip without a mandate.

The FAA chartered the ADS–B Aviation Rulemaking Committee (ARC) to—

> provide a forum for the U.S. aviation community to discuss and review a notice of proposed rulemaking [(NPRM)] for ADS–B, formulate recommendations on presenting and structuring an ADS–B mandate, and consider additional actions that may be necessary to implement those recommendations.

Specifically, while the FAA is finalizing its NPRM, the ARC was tasked by the FAA to develop a report on optimizing the operational benefits of ADS–B before implementation of a nationwide ADS–B airspace rule. This report, written without any knowledge of the contents of the NPRM, is in response to that initial FAA tasking. To achieve a complete level of ADS–B avionics equipage, the ARC expects the NPRM will require ADS–B performance in certain classes of airspace. The ARC believes the benefits of ADS–B will accrue in proportion to the investment made into the system by the FAA, industry, and aviation community in general.

The ADS–B program is multidimensional and has the potential to offer a variety of benefits as the overall system matures. Although further work still lies ahead in global harmonization, one of the key strengths of ADS–B is that it is being adopted as a cost-effective, highly flexible surveillance tool in the global community. A program that offers a first tier of benefits to early adopters will recognize those users as “pioneers.” As the ADS–B system matures and more well-established performance standards find their way into the field, the system will access a broader set of benefits. These benefits will provide incentives to those that choose to update their systems to the recognized standards. And finally, to ensure the system matures to its intended cooperative surveillance environment, a mandate phase will recognize the long-term nature of the solutions.

The ARC expects that the standards for ADS–B avionics equipage will be defined in compliance with two internationally recognized equipment standards—the 1090 MHz extended squitter (1090 ES) frequency and the 978 MHz universal access transceiver (UAT) frequency. These dual links are intended to meet the specific needs of a wide variety of aircraft types and functions. The RTCA standards (DO–260A change 2 for

1090 ES and DO–282A change 1 for UAT) for these links vary somewhat from the standard in aircraft fitted in response to the Elementary and Enhanced Surveillance mandates in Europe. These early-equipped aircraft are expected to have access to limited benefits under the anticipated ADS–B mandate and will support early system-wide data gathering. The full suite of benefits will be made available to those aircraft capable of operating with the baseline performance standards. The ARC further believes the NPRM will specify requirements on the integrity, accuracy, and availability of aircraft position data transmitted in ADS–B messages. If these requirements necessitate augmentation and/or modification of existing navigation sources on aircraft, early implementation of ADS–B and the final rule itself could be affected because of cost-benefit issues.

As the overall ADS–B system matures, additional performance parameters likely will be defined to support ADS–B applications beyond the scope of the FAA's rulemaking. Equipage to these future standards is envisaged as voluntary and benefits-driven. These additional parameters will be captured in evolving standards consisting of, for example, DO–260B/C/D for the 1090 ES ADS–B datalink. While these standards have not been defined to date, they likely will enable higher performance applications and services that will further enhance the capacity, flexibility, and safety of the evolving airspace.

ADS–B consists of two functions: ADS–B Out and ADS–B In. ADS–B Out, defined as the capability necessary to transmit ADS–B messages in compliance with the expected ADS–B rule, is the core of the operational system. ADS–B Out provides the aircraft-derived data to support ground and air applications and services. Figure ES–1 illustrates the relationships between program phases, avionics standards, and benefits provided during operational phases of flight.

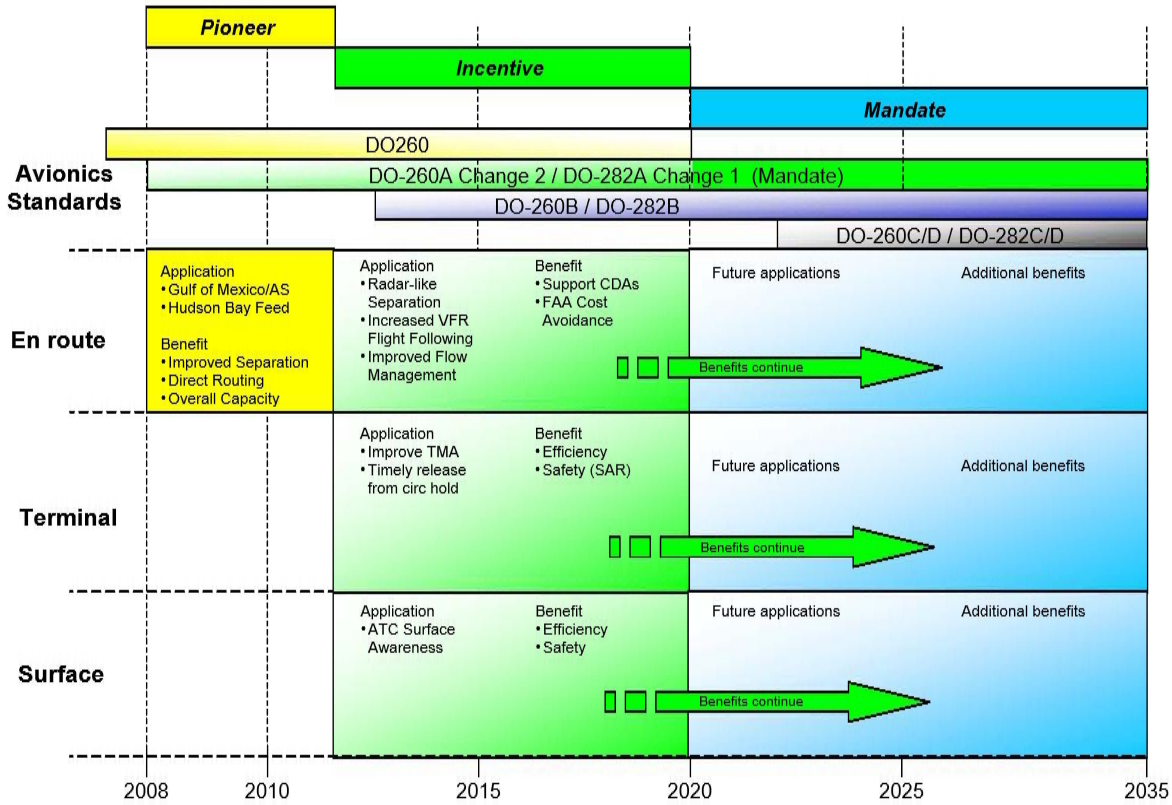


Figure ES–1—ADS–B Out Program Relationship

The ability to receive and display ADS–B messages and broadcast services (both from the ground and directly from other aircraft) is called ADS–B In. Additional airborne applications will be enabled for aircraft capable of receiving the ADS–B Out messages from surrounding aircraft and ground uplinked broadcast services that enable situational awareness, such as the Traffic Information Service–Broadcast and, on the UAT ADS–B datalink, the Flight Information Service–Broadcast (FIS–B). Further, to provide signals from aircraft operating on different datalinks and to transmit broadcast service information, it is necessary to have a rebroadcast function operating from the ground infrastructure called ADS–B Rebroadcast (ADS–R). A timely delivery of ADS–R signals will be necessary to enable advanced applications. Depending on the availability of additional processing and display tools, an expanded set of aircraft-to-aircraft applications and services can be offered. Figure ES–2 illustrates the complementary improvements and benefits possible once an aircraft is able to receive, process, and display the ADS–B and broadcast service information. The additional equipment necessary to support the ADS–B In functionality is outside the expected scope of the NPRM.

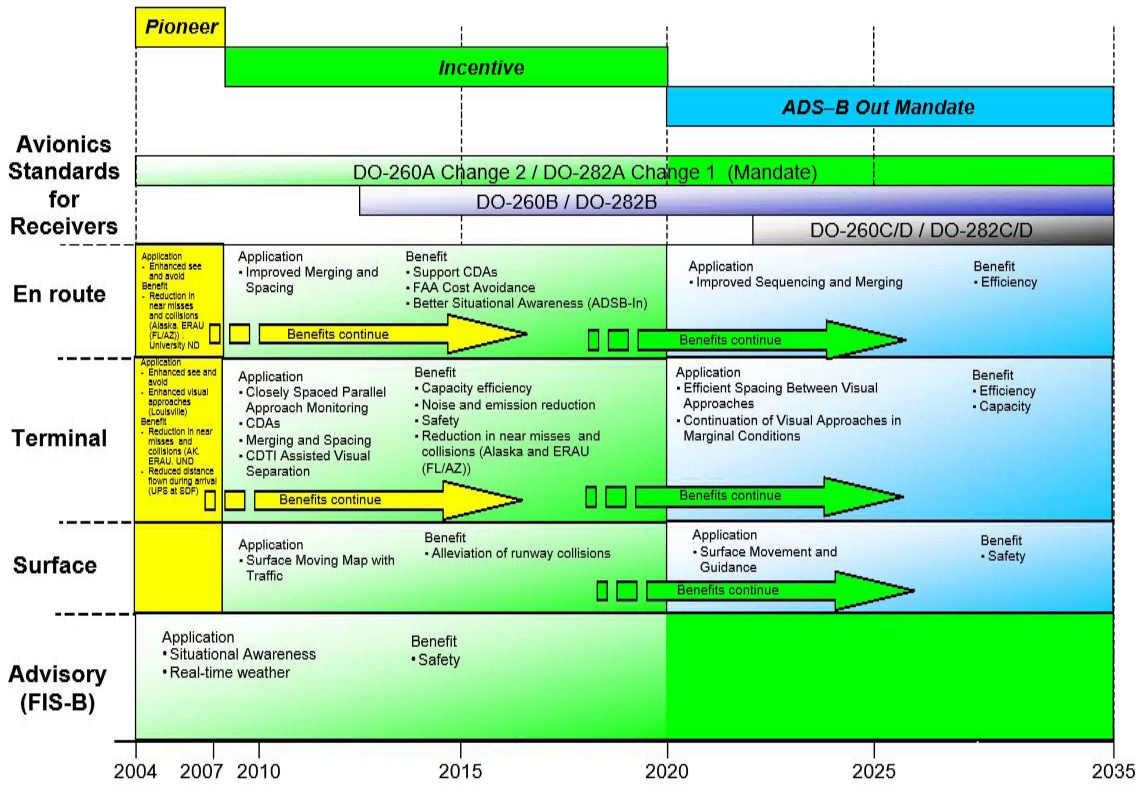


Figure ES–2—ADS–B In and FIS–B Program Relationships

This report discusses the incremental nature of airspace improvements and benefits as the ADS–B system matures, which has been illustrated by the preceding figures. To understand how users might maximize the value of different avionics suites over time, this report explains the benefits of surveillance and broadcast services chronologically and by level of equipage. The report also provides recommendations on how the Government might accelerate the realization of benefits through a mixture of financial incentives and operational benefits for early ADS–B equipage.

To transition to ADS–B as the new primary source of surveillance, all operators within certain airspace will have to equip with ADS–B avionics. Without a requirement for equipage in the nation's busiest airspace, the system cannot provide the benefits necessary to accommodate the current and future needs of the national airspace system (NAS). The aviation community recognizes the substantial benefit that can be gained by NAS users through the equipage of ADS–B avionics. This report explains the operational benefits of ADS–B and provides recommendations on how to accelerate the delivery of these benefits to NAS users through equipage with ADS–B before the expected compliance date. The ARC believes that some combination of financial incentives and operational benefits will be needed to significantly accelerate ADS–B equipage before the compliance date of the proposed rule. The ARC has confidence in the FAA's ability to deploy the ADS–B ground infrastructure. However, the ARC is concerned with the ability of the FAA to approve operational procedures that would provide early operational benefits that cannot be achieved with the exiting

NAS surveillance infrastructure. This report provides 12 recommendations. The key ARC recommendations are that the FAA—

1. **Collaborate with the aviation industry and aggressively develop an appropriate combination of financial incentives and accelerated operational benefits.**

2. **Accelerate and prioritize the identification of operations enabled by ADS–B, with approval of reduced separation standards for initial operations with a high level of user benefits by 2012.**

3. **Establish certification requirements for aircraft displays for ADS–B In applications by 2010.**

1.0 BACKGROUND

The U.S. air transportation system serves as a critical engine of economic growth and facilitates the safe and efficient movement of people and goods across the globe. As the demand for air traffic increases, new solutions must be developed to avoid an increase in costly air travel delays and the associated compromise of our ability as a nation to grow our economy. Congress tasked the Federal Aviation Administration (FAA) with creating the Next Generation Air Transportation System (NextGen) to accommodate the projected increase in demand for air traffic services. NextGen is designed to take advantage of the latest technologies, be flexible enough to accommodate new travel options, and be robust enough to handle a projected increase of up to three times the current level of operations. Recognizing the limits of a radar infrastructure, the FAA proposed a new surveillance system for the national airspace system (NAS). After 4 years of initial operational experience in Alaska, on September 9, 2005, the FAA selected Automatic Dependent Surveillance—Broadcast (ADS–B) as the preferred solution for meeting the future U.S. surveillance needs.

The improved accuracy and update rate of ADS–B in conjunction with other future NAS improvements will allow for an increase of capacity in the NAS. The additional information the system provides to both air traffic control (ATC) and flightcrews through cockpit displays will allow more efficient and safer flight. To achieve these benefits and to develop future applications based on the ADS–B infrastructure, all the aircraft in a given environment must be equipped with avionics that meet the stringent requirements for safe operation in dense U.S. airspace.

To develop, implement, and manage an ADS–B system, the FAA created the national Surveillance and Broadcast Services (SBS) Program Office within its Air Traffic Organization (ATO). The objective of the SBS Program Office is to develop a multi-segment, life cycle- managed, performance-based strategy that aligns with the NextGen vision and generates value for the NAS. Consistent with this goal and in conjunction with other agencies, the SBS Program Office is developing system requirements that meet the need for increased capacity, a comprehensive implementation plan, and a multifunctional backup strategy that can maintain surveillance in the event of a Global Positioning System (GPS) outage. The SBS program builds on the research, development, and safety work conducted by the Capstone Program Office operating ADS–B prototype technologies in Alaska and the Safe Flight 21 Office in the Continental United States.

The FAA intends to provide surveillance and broadcast services in all areas covered by radar today. To provide necessary ground infrastructure for these services, the FAA awarded a contract on August 30, 2007, to a team headed by ITT Corporation with options to extend over the lifecycle of the program. The ADS–B ground infrastructure acquisition has been structured as a multi-year, performance-based service contract under which the vendor will install, own, and maintain the equipment, and the FAA will purchase services in the same way it purchases telecommunications services today. The

FAA will define the services it requires and maintain ultimate control of the data that flows between the vendor's infrastructure, FAA facilities, and aircraft.

The initial scope of the SBS program includes two services (air-to-ground surveillance and traffic/flight information broadcast services) and support of five aircraft applications (enhanced visual acquisition, enhanced visual approaches[1], final approach and runway occupancy awareness, airport surface situational awareness, and conflict detection). The SBS program expects to support additional ADS–B applications in later phases of the program.

The FAA will manage the deployment of the above-listed services by segments. Each program segment has specific goals designed to provide a measured deployment of ADS–B. Figure 1 illustrates some of the key milestones the FAA must achieve to provide a NAS-wide ADS–B infrastructure.

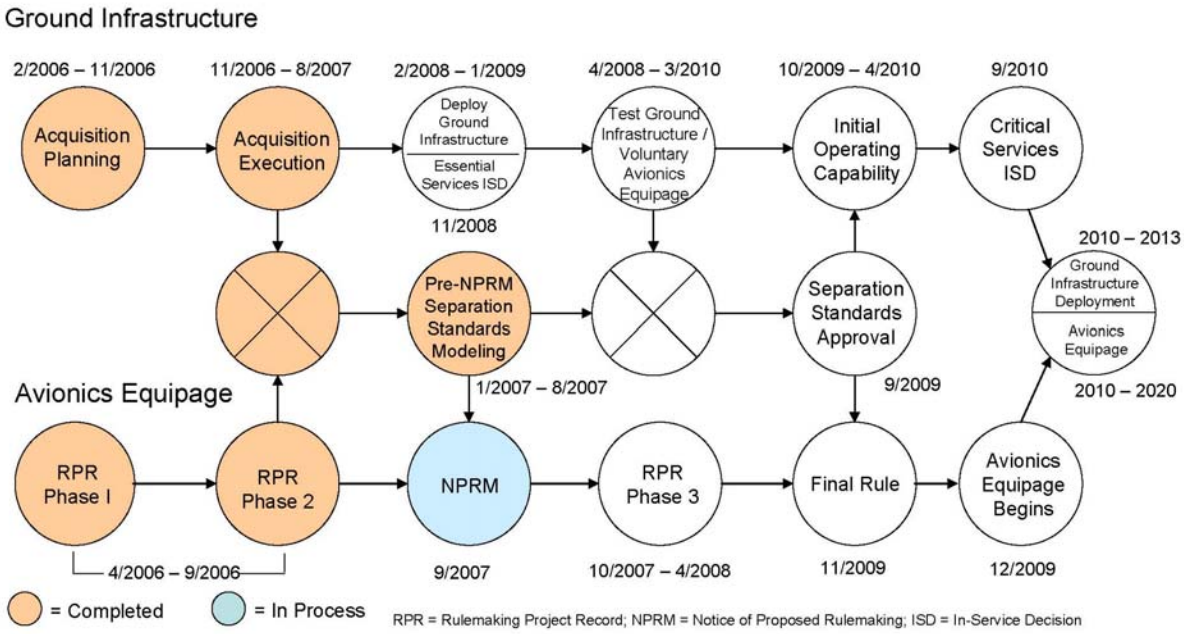


Figure 1—Segment 1 and 2 Milestones

The goal of segment 1 of the program is to prove the concepts of an end-to-end surveillance and broadcast services system. Segment 1 work already has begun and is scheduled to continue until September 2010. This effort includes the development of avionics standards for existing and future ADS–B avionics on both the 1090 ES and UAT datalinks. Development of a ground infrastructure specification, including both the development of ground stations and integration in ATC automation platforms is also part of segment 1. In addition, before a final rule can be issued and segment 2 of the program can commence, there must be approved ADS–B separation standards. Without this

[1] Merging and Spacing and Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS) are a part of the Enhanced Visual Approaches Application.

approval, aircraft cannot be separated from each other using ADS–B and the system would have limited benefit.

During segment 1 of the program, as discussed earlier, the SBS Program Office established a national contract with ITT Corporation to implement a ground infrastructure to support the surveillance and broadcast services applications. Segment 1 of the FAA's program also includes the issuance of a notice of proposed rulemaking (NPRM), which is intended to mandate ADS–B performance in aircraft, and the creation of an ADS–B Aviation Rulemaking Committee (ARC) (see the objective section of this report for further details on the ADS–B ARC). Segment 1 activities also include the completion of the technical analysis required to fully describe the end state broadcast services architecture.

Segment 2 of the program, currently scheduled to run from fiscal year 2009 through fiscal year 2014, includes the NAS-wide deployment of the ADS–B and broadcast services ground infrastructure. This effort includes the integration of the ADS–B system with existing surveillance systems and ATC automation platforms. Previous prototype equipment deployed along the U.S. east coast will be absorbed and expanded on with new equipment. Concurrent with this effort will be a proliferation of avionics equipage at operators who choose to equip in compliance with an expected ADS–B mandate for equipage (see expected rulemaking action section below) or earlier than the mandate requires. The ARC believes there are substantial benefits that could be accrued from early equipage in an optimal deployment of the ADS–B system. Also during segment 2, the FAA will develop future applications of the surveillance and broadcast services infrastructure based on an evaluation of those applications' values to NAS operators.

Expected Rulemaking Action

The ARC has not had any advance information concerning what the FAA will propose in its ADS–B NPRM. However, the ARC assumes that—

- The FAA's NPRM will establish the content and performance of the basic ADS–B Out message that will form the backbone for the evolving cooperative surveillance environment.
- The FAA will establish internationally recognized standards developed by RTCA as the baseline requirement for avionics equipage: DO–260A Change 2 (specifying the requirements for the 1090 MHz extended squitter (1090 ES) frequency) and DO–282A (specifying the requirements for the 978 MHz Universal Access Transceiver (UAT) frequency).
- While the FAA will mandate only ADS–B Out, it also will provide a set of services and applications that build from that core broadcast message to enable ground and limited air-to-air applications (ADS–B In).
- The FAA is establishing functional and performance equipment requirements for identified ADS–B In applications and services. In many cases, the ARC expects

that further applications and services will be defined by users who have specific operational requirements and who will apply for and seek approvals for those operations.

- ADS–B will enable many new and exciting opportunities for improved airspace operational efficiency, flexibility, and safety capabilities.

ADS–B System

ADS–B is an advanced system that uses a datalink to broadcast position and other information from aircraft to ground-based receivers and to other aircraft with receivers. This datalink enables a variety of capabilities on the aircraft and in ATC, as shown in figure 2 below.

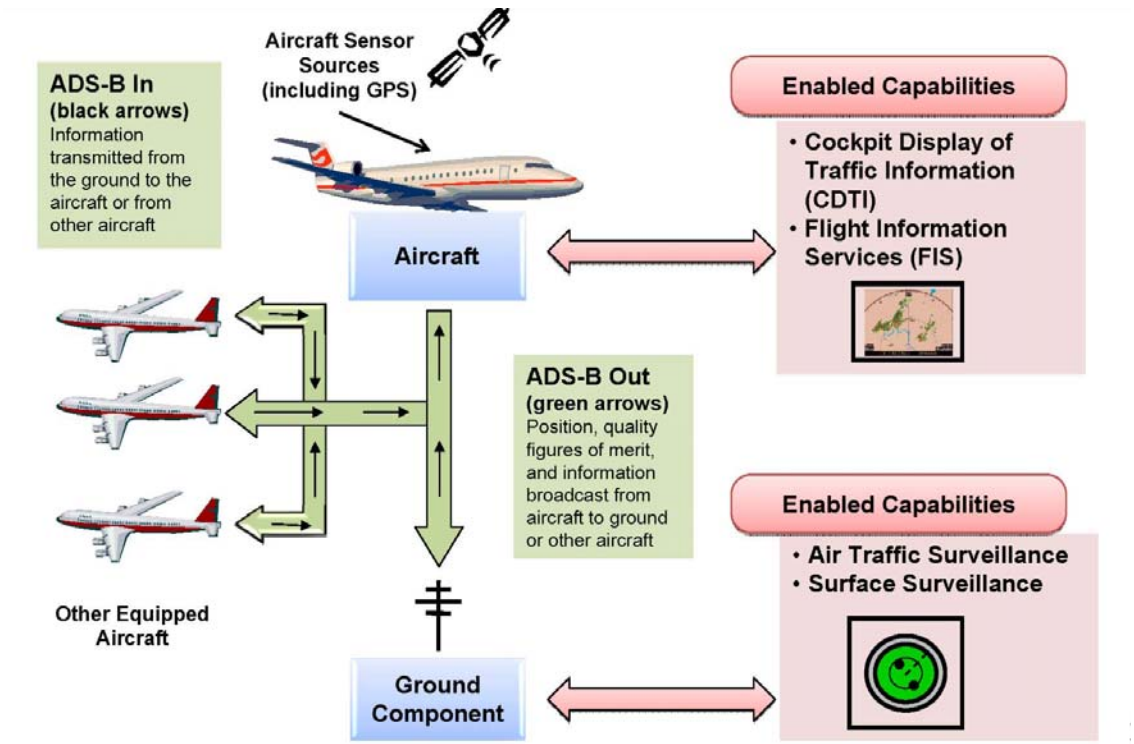


Figure 2—Overview of ADS–B System

The ADS–B system consists of two different functions: ADS– B Out and ADS–B In. The ability to transmit ADS–B messages is referred to as ADS–B Out. ADS–B Out allows for more accurate and timely surveillance as compared to existing primary and secondary radars but does not include the ability to receive, interpret, or display ADS–B signals. To derive the many benefits of the ADS–B system, including the ability for a flightcrew to have situational awareness of proximate traffic or to use other air-to-air applications, aircraft will need to be equipped with an avionics suite and display equipment. These capabilities are referred to as ADS–B In. Applications enabled by

ADS–B vary based on the characteristics of the particular ADS–B system implementation. However, they can generally be divided into capabilities on the aircraft and capabilities enabled on the ground.

Surveillance and broadcast services are expected to be provided by the FAA on two different frequencies, or broadcast links: the 1090 ES frequency and the UAT frequency. The 1090 ES link is more often employed by larger air transport category and air carrier aircraft, and the UAT link is generally used in general aviation aircraft. However, there are notable exceptions to these general guidelines, and providing an ADS–B receiver equipped to receive both links may provide additional value to operators. The ARC acknowledges that Flight Information Service–Broadcast (FIS–B) services cannot be provided on the 1090 ES link. Operators may want to consider examining the advantages of equipping with dual link receivers.

ADS–B Out

As shown in figure 3, using ADS–B Out, an aircraft periodically broadcasts its own sensor information through an onboard transceiver. The ADS–B signal can be received by other aircraft and by ground stations providing information to ATC and other aircraft. Included in this broadcast is the aircraft's flight identification, position (horizontal and vertical), velocity (horizontal and vertical), time, and various performance parameters. Depending on the source of the position information, there will be figures of merit for position precision and integrity. Standards for the information to be included in the ADS–B Out broadcast message are being developed incrementally so there are historical variants as well as projected enhancements. However, the ARC expects that the avionics and information necessary to perform ADS–B Out functions are going to be defined in the NPRM and will apply, subject only to the correction of any errors discovered through additional operational use, to the life cycle of the FAA's SBS program.

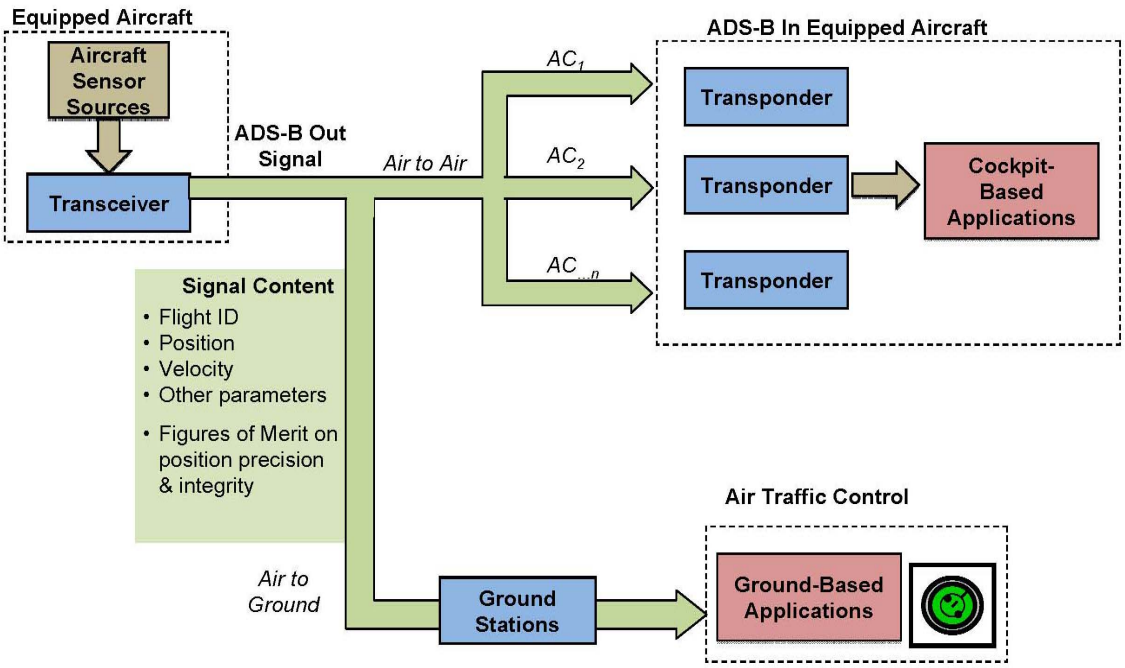


Figure 3—ADS–B Out Signal and Enabled Capabilities

ADS–B Out is automatic in the sense that no pilot or air traffic controller action is required for the information to be transmitted. It is dependent surveillance in the sense that the surveillance information depends on the navigation and broadcast capability of the source. As shown in figure 3, ADS–B Out is used by ATC for surveillance in a manner similar to the use of radar. The broadcast signal can also be received by other aircraft equipped with ADS–B In avionics (as discussed in the next section) to enable cockpit-based applications. Aircraft can be equipped with ADS–B Out without having ADS–B In capability.

ADS–B In

The ability to receive ADS–B signals from the ground and other aircraft, process those signals, and display traffic and information to flightcrews is referred to as ADS–B In, as illustrated in figure 4.

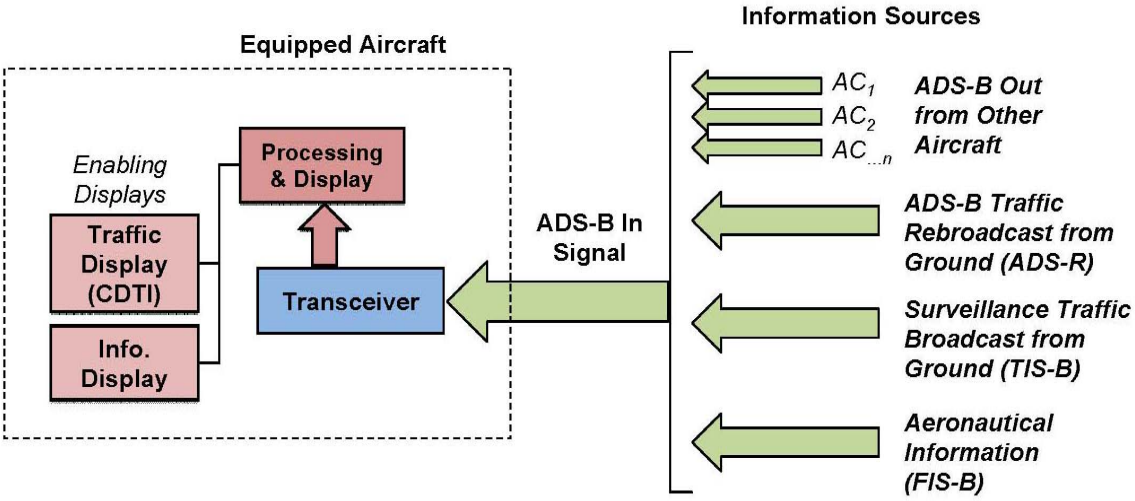


Figure 4—ADS–B in Signal Sources and Enabled Capabilities

As shown in figure 4, an ADS–B In-equipped aircraft can receive information from multiple sources. Achieving benefits from ADS–B In requires onboard processing of the ADS–B signal and integration with aircraft avionics. Processing of the ADS–B signal may be done in terms of a decision logic platform to generate warnings or may be presented on a variety of display platforms. ADS–B In complements ADS–B Out by providing pilots and aircraft navigation systems with advanced positioning information on other aircraft operating nearby. At the most basic level, ADS–B In enhances the flightcrew's situational awareness of other aircraft operating within their proximity with a high degree of precision. The full potential of ADS–B In would allow flightcrews to have situational awareness of the airspace around their aircraft and, independent of ground based systems, plot the most efficient flight path to their destination. All the while, ADS–B In-equipped aircraft would be avoiding other traffic, monitoring for collision potential, and deconflicting flight paths between aircraft.

ADS–B In will require the certification of new cockpit displays and consideration of pilot human factors as well as potential changes to operational procedures both in the cockpit and on the ground. Additionally, the FAA will need to make decisions about electronic flight bags (EFB) for pilots. ADS–B In will be a major element of the future surveillance technology mix in accordance with the International Civil Aviation Organization (ICAO) Global Air Navigation Plan. The FAA has not established performance standards for supplemental, essential, and critical services and applications for ADS–B In and the subsystems needed to support those expanded operations.

Automatic Dependent Surveillance – Rebroadcast (ADS–R)

To take advantage of all ADS–B In applications, flightcrews must have situational awareness that includes both aircraft that are not equipped with ADS–B and aircraft that are equipped with ADS–B but are transmitting on a different frequency. The ARC expects that air carrier and business aviation aircraft will mostly equip with 1090 ES, while general aviation aircraft will equip with UAT. Interoperability between the links would be provided by a service referred to as ADS–R through the ADS–B ground infrastructure.

ADS–R provides an optimized rebroadcast capability for presenting the UAT information to 1090 ES users and the 1090 ES information to UAT users, thereby filling in the total surveillance picture for presentation or processing onboard an aircraft. ADS–R is seen as a potentially critical function as it is intended to support most future ADS–B In functions in the United States. However, ADS–R currently has not been globally adopted. The ADS–R function would not be necessary for any aircraft equipped to receive both 1090 ES and UAT signals.

Traffic Information Service – Broadcast (TIS–B)

ADS–B is a cooperative surveillance environment that requires all users to participate to maximize operational benefits. During the transition period, when only some users have been able to equip with ADS–B, other systems will be necessary to provide the best available information to those seeking the total surveillance picture onboard an aircraft. The TIS–B service uses secondary surveillance radars and multilateration systems coupled with other sources to provide proximate traffic situational awareness, including position reports from aircraft not equipped with ADS–B. However, additional ground processing is necessary to create that information (including a measure of the accuracy and integrity of those messages), and source data may not be equivalent to ADS–B information provided by a participating aircraft. Therefore, the TIS–B signal is planned to be used only as an essential advisory service and not to be employed to separate or maneuver aircraft. The ARC expects that TIS–B will be phased out when all airspace users become cooperative participants in the ADS–B-served airspace via direct air-to-air ADS–B and ADS–R. See figure 5 for a prototype multifunctional aircraft cockpit display that shows both aircraft position reports derived directly from other ADS–B-equipped aircraft and from the TIS–B service (for those aircraft not equipped with ADS–B Out).

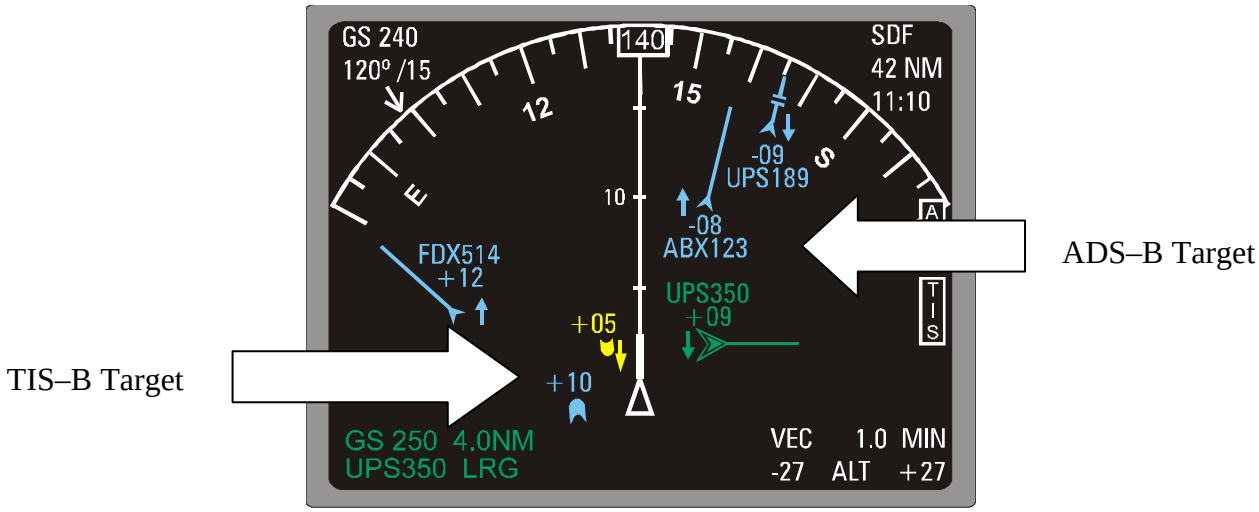


Figure 5—Prototype Traffic Display

Flight Information Service—Broadcast (FIS–B)

The FIS–B service is carried on the UAT channel and provides additional supplementary flight information. The FIS–B services are intended to provide enhanced weather services, textual and graphic weather and terrain information, Notices to Airmen (NOTAM), Temporary Flight Restrictions, and other flight information for processing and display in a single piece of avionics. For the general aviation user, this provides a single platform that will enhance safety through a broader suite of situational awareness services. See figure 6 for a prototype FIS–B aircraft cockpit display.

Figure 6—Prototype FIS–B Display

There has also been some interest expressed by the air transport community in using the FIS–B service to increase the real-time availability of weather data in the cockpit on 1090 ES-equipped aircraft — this would require the aircraft to be equipped with a UAT In capability.

ADS–B and Global Harmonization

ADS–B offers global aviation regulators the opportunity to create an integrated single sky for aircraft flying to international destinations. Through focused global harmonization efforts, aircraft could be enabled to fly the most fuel efficient routes between the world's airports. However, to fully leverage these benefits, U.S. and international regulators will need to agree to compatible equipment standards, interoperability rules, and comparable flight procedures for ADS–B technology. Done properly, this could result in seamless control of air traffic, which would be a technological leap over today's global patchwork of services and control facilities. With many nations on the verge of making critical ADS–B decisions, it is vitally important that all efforts be unified and coordinated.

The FAA, Joint Planning and Development Office (JPDO), ICAO, EUROCONTROL, the European Organization for Civil Aviation Equipment (EUROCAE), Airservices Australia, Japan Civil Aviation Authority, NAV CANADA, and RTCA are fostering the necessary international cooperation required for ADS–B interoperability through their support of the activities of joint standards workgroups. Additionally, several nations have traded key ADS–B subject matter experts to foster greater dialog and exchange concepts and new ideas for ADS–B planning. Such initiatives are defining for international stakeholders the issues related to aircraft equipment standards and air traffic management procedures.

Australia, Canada, and the European Union currently are using ADS–B operationally or demonstrating potential uses of ADS–B. China, Fiji, Hong Kong, India, Indonesia, Japan, Mongolia, New Zealand, Singapore, and Thailand are planning their own trials as well. The United States provided the first operational implementation of ADS–B through its Capstone program in Alaska in 2001 and has conducted ADS–B operational evaluations in the Ohio River Valley.

Australia currently uses ADS–B to provide radar-like separations in non-radar airspace at en route altitudes over much of the Australian continent. Australia will have 22 ADS–B ground stations commissioned by the end of 2007. Combined with the deployment of 6 stations in 2008 and 20 planned additional sites, Australia is on pace to have ADS–B coverage for its entire continental upper airspace. Australia has provided 383 aircraft with ADS–B service approval and has 80 additional aircraft pending approval. Australia has issued a final rule mandating ADS–B equipage in its continental upper airspace with a compliance date of June 2012.

By November 20, 2008, Canada's first ADS–B implementation will provide coverage over 250,000 square nautical miles of Hudson Bay. NAV CANADA projects that ADS–B equipped customers will save $200 million over 15 years. The next phases of the project will deploy ADS–B in the non-radar areas over Northern British Columbia, the Northwest Territories, and Nunavut.

EUROCONTROL's CASCADE is preparing a number of ADS–B Out and In applications for implementation in 2008 and 2011. CASCADE already has organized 11 airlines and 351 aircraft around activities to pioneer standardization, flight trials, and implementation activities, and expects to increase those numbers in Phase Two, which is already underway, to 20 airlines and 450 aircraft. Most likely the first ADS–B applications will be for ADS–B Out in non-radar environments around some secondary airports or between oil rigs and for ADS–B In in–trail procedures over the Atlantic Ocean. Implementation most likely will be voluntary using existing DO–260 certified avionics. An implementing rule is being prepared for ADS–B Out, which is expected to be published in April 2008. This rule is expected to mandate ADS–B Out equipage with DO–260A "change X" around 2015. No rule is expected to mandate ADS–B In.

In the United States, the FAA has been collaborating closely with the user community in developing and maturing ADS–B concepts. Capstone, a joint industry and FAA Alaskan Region effort, was initiated to improve aviation safety and efficiency by putting new technology avionics equipment into aircraft and providing the supporting ground infrastructure. The Capstone program equipped aircraft used by commercial operators in an accident prone area of Alaska with a Government-furnished global positioning system-based avionics package. In addition to the avionics suites, Capstone deployed equipment for improved weather observation, ADS–B ground stations, and flight information services. The FAA conducted a long-term operational evaluations in Alaska to get preliminary assessments of the costs, benefits, operational safety and security, and architectural requirements for ADS–B. The demonstration areas of the program were in a non-radar environment where most of the air carrier operations had been limited to visual flight rules operating conditions. In January 2001, the air traffic controllers in Anchorage, Alaska, were the first in the world to use ADS–B to provide instrument flight rules air traffic control services to Capstone-equipped aircraft in this non-radar demonstration area. Those services continue today. RTCA developed initial avionics standards for the system and refined the avionics standards (to the current level) in 2004 based on feedback from the Capstone operational experiences. As of 2005, Capstone has reduced the accident rate in that part of Alaska by 49 percent.

On December 22, 2006, the FAA announced that it would integrate the Alaska Capstone project into the national ADS–B program. ADS–B systems and services will continue to be deployed throughout Alaska as part of the nationwide rollout of ADS–B.

In the Ohio River Valley of the United States, the FAA has been working very closely with the Cargo Airline Association, and several other industry groups, to demonstrate and refine ADS–B concepts and applications. The initial activities included three operational demonstrations held from 1999 to 2001. Many applications were demonstrated using

aircraft ranging from large transport category aircraft to small general aviation aircraft. Many of the aircraft were equipped with early ADS–B displays. Surface, air-to-air, air-to-ground, and ground-to-air applications were demonstrated. This was the foundational work that ultimately has led to the certification of the initial ADS–B applications and the ground breaking UPS applications of ADS–B being pursued today.

2.0 OBJECTIVE

Through the Air Traffic Management Advisory Committee (ATMAC), industry and user groups have expressed a desire to be more involved in the FAA's ADS–B rulemaking process. The FAA agreed that a wide scope of input would be beneficial to market and manage both the substantial benefits and significant costs of a nationwide ADS–B system. Therefore, on July 15, 2007, the FAA chartered the ADS–B ARC to—

> provide a forum for the U.S. aviation community to discuss and review a notice of proposed rulemaking [(NPRM)] for ADS–B, formulate recommendations on presenting and structuring an ADS–B mandate, and consider additional actions that may be necessary to implement those recommendations.

The ADS–B ARC will submit recommendations to the Administrator through the Chief Operating Officer, Air Traffic Organization.

Specifically, the ARC was given the following two tasks:

> *Task 1*: While the NPRM is being finalized and leading up to its publication, the ARC will serve as a platform for developing a report on optimizing the operational benefits of ADS–B before the implementation of a nationwide ADS–B airspace rule.
>
> *Task 2*: After publication of the NPRM, the ARC will make specific recommendations to the FAA concerning the proposed requirements based on the comments submitted to the NPRM docket.

This report, completed under task 1, will explain the operational benefits of ADS–B and provide recommendations to the FAA on how to optimize these benefits to NAS users through the equipage of ADS–B before the proposed compliance date.

3.0 OPERATIONAL BENEFITS

Section 3.1 Obtaining Early Operational Benefits from ADS–B with Existing Aircraft Equipage that Will Not Be Compliant with the Technical Standards of the Proposed ADS–B Rule

Introduction

As detailed in appendix C, over 5,000 transport category aircraft are equipped with ADS–B avionics for the 1090 ES. The ADS–B avionics of these aircraft, which were implemented but not certified to the requirements of the initial 1090 ES ADS–B standard (RTCA DO–260) most likely will not be compliant with the proposed ADS–B rule, which is expected to be based on a later version of the 1090 ES ADS–B standards, RTCA DO–260A Change 3. See appendix C for more information on the versions of DO–260.

Figure 7 below represents a sample of reports on ADS–B equipage collected by the FAA. It cannot be established whether the aircraft listed as being ADS–B-equipped have ADS–B installations that are compliant with any particular ADS–B data link standard. What figure 7 demonstrates is a level of interest in ADS–B equipage and an early movement by aircraft suppliers to provide an ADS–B capability.

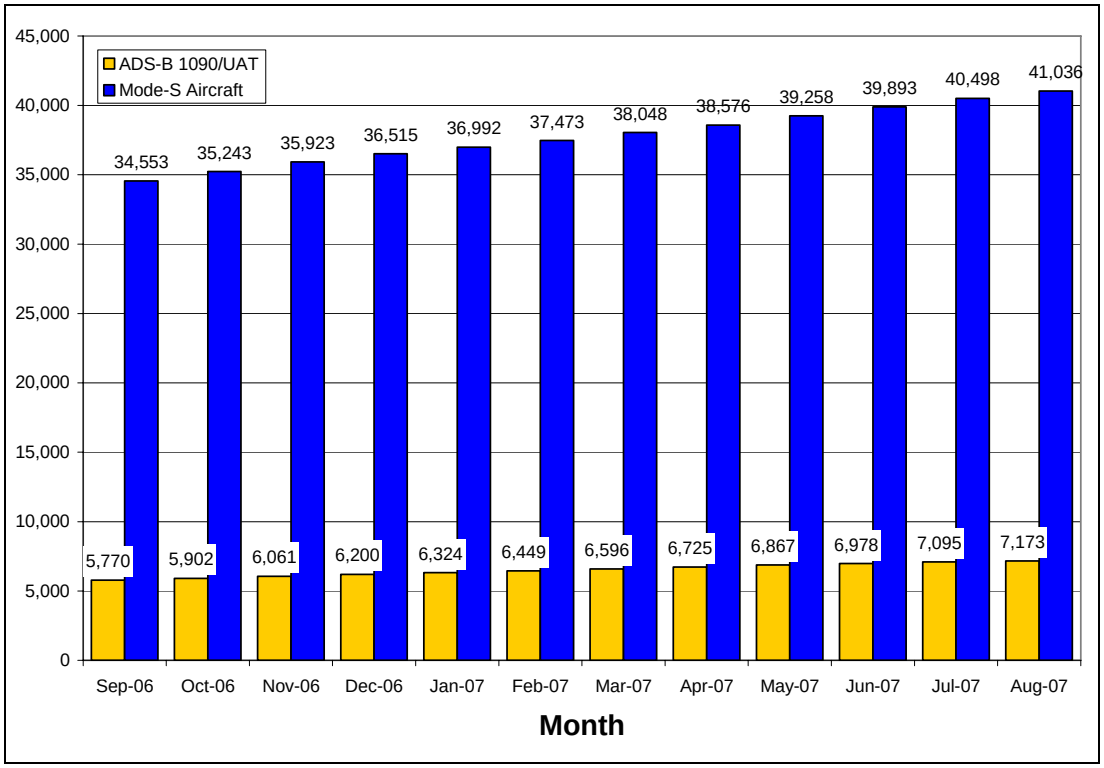


Figure 7—Report on Aircraft Equipage
(Graphic of Active Mode S and ADS–B Aircraft/Vehicles — All Sites)

As of September 2007, Australia offers aircraft that demonstrate sufficient compliance with DO–260 ADS–B-based surveillance services with 5 nautical miles (radar-like) separation in the upper airspace. These aircraft also are candidates to participate in the ADS–B-based EUROCONTROL CASCADE Pioneer Program. Additionally, Canada is planning to offer operational benefits to such aircraft over Hudson Bay.

To provide early ADS–B benefits and, from realization of those benefits, incentivize early equipage with avionics compliant with the NPRM, this report recommends that the FAA and the aviation community pursue opportunities for aircraft with existing DO–260-based avionics to receive operational benefits from ADS–B. These operational benefits would be limited in scope and less than those for aircraft equipped with ADS–B avionics compliant with the proposed rule, and would only be obtained before the compliance date for the proposed rule. Nonetheless, these benefits would provide an initial step toward the benefits of ADS–B with existing avionics, provide additional early credibility to the U.S. ADS–B implementation program, and incentivize equipage with DO–260A Change 3 avionics to obtain much broader benefits than those actually realized with DO–260.

ADS–B Out Benefits

Sharing ADS–B information with third parties could be an early commercially valuable application. If an ADS–B position reports database could be compiled on operations for a particular fleet of aircraft, that monitoring would provide a valuable analysis tool for optimizing fleet management practices. The use of ADS–B analysis at flight schools already has been demonstrated and should continue as flightcrews transition to an ADS–B surveillance environment.

DO–260 1090 ES Avionics

Many transport category aircraft have been delivered with DO–260-capable Mode S transponders or have been upgraded to DO–260-capable transponders for a number of reasons, primarily to satisfy European elementary and enhanced surveillance requirements. Typically, these transponders will broadcast ADS–B if they have a position input. In some installations, the position input only was available to the ADS–B-capable transponder from the flight management system, not from the global positioning system (GPS) source. Consequently, the messages broadcast are not useable for any of the identified ADS–B applications because the accuracy and quality parameters are insufficient. In addition, the various Mode S transponder manufacturers interpreted 1090 ES requirements differently, resulting in inconsistent parameters being broadcast.

After Australia levied firm requirements for DO–260-based 1090 ES avionics, all problem Mode S transponders with DO–260-based 1090 ES now have service bulletins that correct the inconsistencies. However, there is no process, except for those aircraft transiting Australian airspace and for the emerging CASCADE Pioneer Program in Europe, that requires the service bulletins to be installed or for operators to correct any wiring problems between aircraft sources of ADS–B data and the ADS–B avionics of

those aircraft. In addition to ground automation requirements discussed later, there will have to be a process to ensure all DO–260-based Mode S transponders with ADS–B capability are broadcasting properly calculated performance measures, because there is no way for ground systems to know.

For all the applications in appendix B that are noted to be realizable with DO–260-based avionics, the fusion of surveillance sources in the ATC automation system is assumed. A primary reason that fusion is needed is the lack of the 4096 code as a message parameter in the DO–260 ADS–B message set (resolved with DO–260A). The current terminal and en route surveillance/automation systems in the United States have no way of associating an aircraft with a flight plan except by use of a 4096 code. To use DO–260 ADS–B avionics, a method would have to be established to associate a DO–260 ADS–B message with a flight plan. This could be done in the fusion process. Such a fusion approach alone, however, could limit the identified ADS–B benefits to a radar environment. Almost all of the interim potential ADS–B benefits for DO–260 1090 ES ADS–B equipage that have been identified are in the radar environment, with the exception of the Gulf of Mexico (see the discussion below). It may be possible to associate an aircraft with its flight plan in the radar environment and carry that association when the aircraft enters the non-radar airspace of the Gulf of Mexico.

To realize the benefits noted as achievable in appendix B by DO–260-based ADS–B-equipped aircraft, the following two key conditions must be met:

- The FAA must develop a process to ensure (1) all DO–260-based equipment properly calculate performance parameters and (2) the equipment is properly integrated (for example, correctly wired to appropriate aircraft data sources) into the aircraft to ensure sufficient compliance with DO–260.

- The FAA must develop a method to associate a flight plan with ADS–B messages from a DO–260-equipped aircraft.

The FAA needs to examine the timing and expense of meeting these conditions to assess the viability of providing operational benefits to DO–260-equipped aircraft.

The ARC notes that a further consideration for operators is the cost of any DO–260-compliance service bulletin (such cost being highly specific to the particular DO–260-based Mode S transponder manufacturer and the aircraft integration of that transponder) versus the cost of a DO–260A Change 3 service bulletin and the associated time and processes involved before DO–260 is chosen as an interim solution to achieve limited ADS–B benefits until the mandate date (as opposed to a direct upgrade to DO–260A Change 3 to obtain larger benefits).

An Opportunity for Initial ADS–B Benefits with DO–260-based Avionics: ADS–B in the Gulf of Mexico

The oceanic operations in the Gulf of Mexico region have increased from 61,000 operations in 1996 to 100,000 operations in 2005. It is estimated that traffic will reach 119,000 operations in 2007. Traffic management initiatives are routinely used to manage the high traffic volume in this constrained airspace. Because of limited availability of radar coverage, the north-south traffic has to be cleared via non-radar routings (15 minutes in-trail unless compatible speeds, then 10 minutes in-trail). The communication between flightcrews and air traffic controllers is limited and at times is unreliable.

The ARC finds that the initial benefits of ADS–B implementation in the Gulf of Mexico would be more north-south routings and, with DO–260 equipment, the separation between aircraft might be reduced to 10 nautical miles or less. As aircraft become equipped with DO–260A Change 3 equipment, it will be possible to reduce the separation to 5 nautical miles or maybe even 3 nautical miles between aircraft, thus providing additional capacity. The ability to provide radar-type separation also will enable aircraft to use area navigation (RNAV) routes that increase fuel efficiency and allow more direct routings. The ARC notes that these routes should be available when initial ADS–B procedures are be implemented in 2010.

If ATC facilities south of the Gulf of Mexico equip with ADS–B, there will be an increased handoff capability at all altitudes. This also will enable enhanced automated flight plan information exchange between the United States and Mexico.

ADS–B will provide the ability to improve service to the helicopters flying to the oil platforms in the Gulf of Mexico by providing ATC surveillance at low altitudes well beyond the current radar coverage. This will allow the helicopter operators to receive instrument flight rules (IFR) ATC services, thus providing them with improved operations during IFR conditions and improving overall safety. The helicopter operators may also benefit from improved fleet tracking as well as weather in the cockpit (FIS–B) services.

There are several issues that will affect the implementation of ADS–B in the Gulf of Mexico. ADS–B-aircraft equipage will play a very important role as some users may not see enough benefit to equip their fleet before any mandate. Separation between mixed equipped aircraft may result in the need for exclusionary altitudes for non-equipped aircraft. (The mixed equipage issue between DO–260 and DO–260A will end in 2020 when DO–260 is phased out.)

There also may be a need to track the installation of DO–260-based ADS–B equipment to specific aircraft registration, as discussed in the section on DO–260 section above. Additionally, a solution will need to be implemented to associate a DO–260-equipped aircraft in non-radar airspace with a flight plan, as also discussed in the section above.

ADS–B implementation in the Gulf of Mexico will result in more aircraft that may require more air traffic sectors and additional controllers.

There are known benefits of ADS–B installation in the Gulf of Mexico, and this report recommends that the potential provision of partial ADS–B benefits to DO–260-equipped aircraft be aggressively studied and, if feasible, implemented.

One potential use of the DO–260 standard avionics is a reduction in separation in non-radar areas such as the Gulf of Mexico. While the DO–260 standard is not likely to be certified for aircraft separation at the same level as the DO–260A standard, some incremental benefits could be accrued by certifying DO–260 avionics for a separation standard that would still improve capacity in the non-radar area of the Gulf of Mexico.

Currently, air traffic controllers use forms of procedural separation at both high and low altitudes in the Gulf of Mexico. These procedures dictate that aircraft must be kept far apart to maintain a high level of safety; at high altitudes the standard separation is 15 minutes, which is equivalent to approximately 120 nautical miles (see figure 8 below).

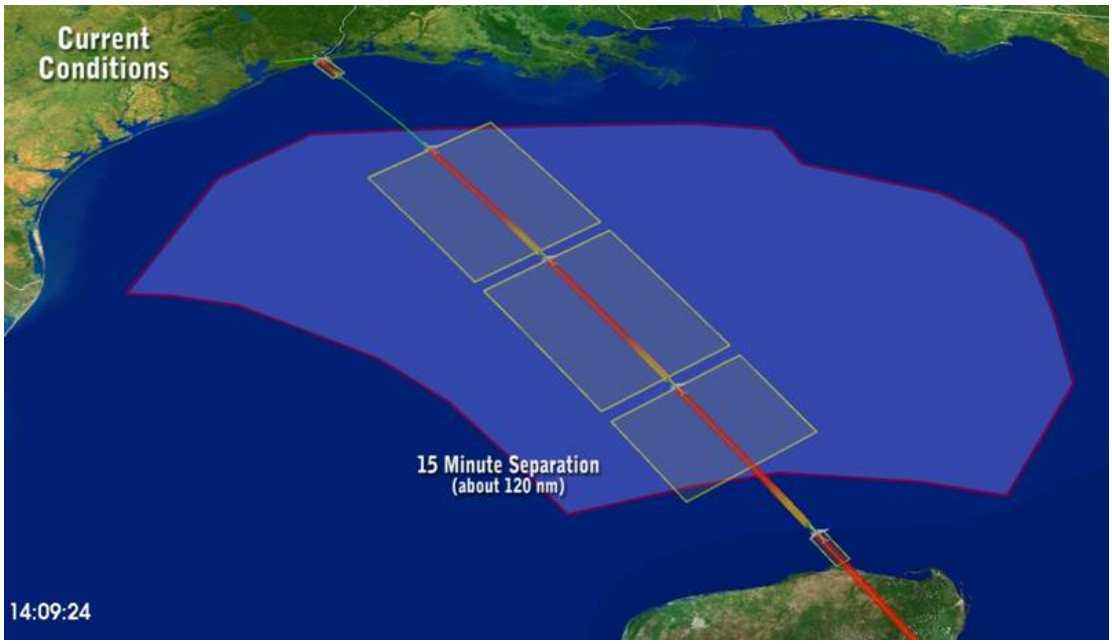


Figure 8—Current Procedural Separation in the Gulf of Mexico

If ATC were supplied with some form of surveillance, aircraft could fly closer together without compromising safety. ADS–B In capability would not necessarily be required to achieve a reduction in separation standards, as the responsibility of separating aircraft would still lie with the air traffic controllers. Figure 9 gives a national depiction of how a transition to surveillance-based ATC procedures could increase the efficiency and capacity of non-radar airspace like that in the Gulf of Mexico.

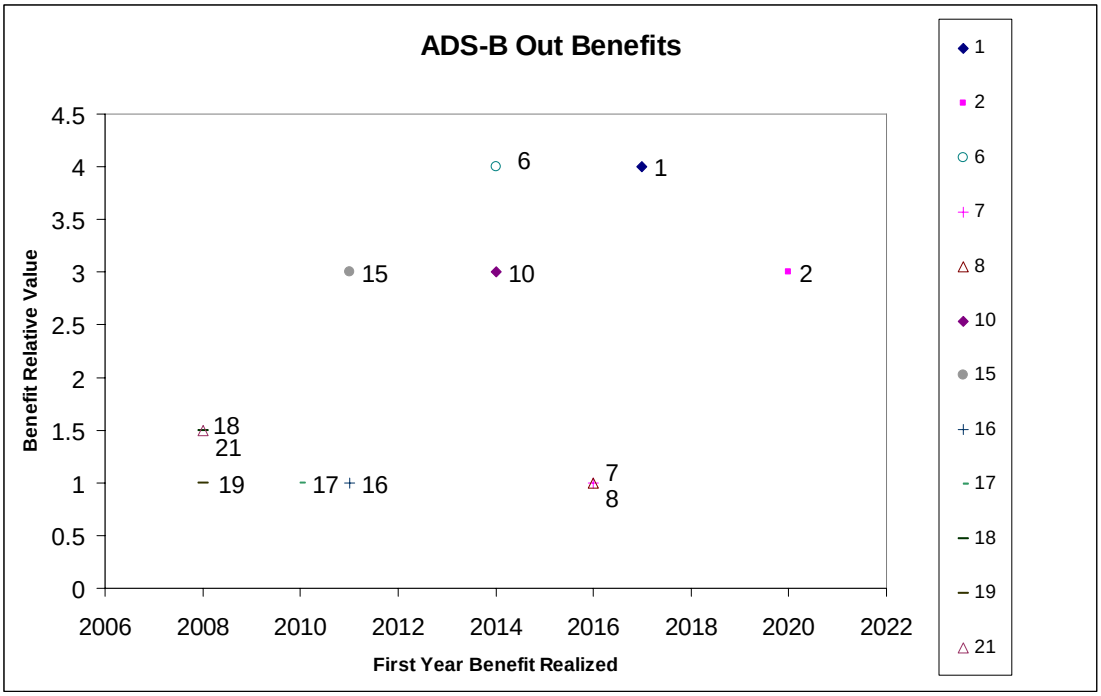
Figure 9—Possible Enabling of Radar-Like Separation Using ADS–B

International coordination still would be necessary to ensure optimal use of north-south routes, but U.S. ATC could take advantage of east-west routes to provide a more direct routing between major transport hubs. This benefit could probably not be achieved in an environment with aircraft not equipped with DO–260A avionics. If the FAA were to establish a preferential routing system based on level of equipage, it would incentivize early equipage with ADS–B-compliant avionics and allow a protected environment for those who equip to derive maximum benefits from their avionics suite.

Section 3.2 Obtaining Operational Benefits from ADS–B Out in Compliance with the Expected Mandate (DO–260A Out and DO–282A Out)

ADS–B Out Benefits

ADS–B test bed areas such as Alaska and Louisville International Airport already have made use of procedures and routes that have been made available by ADS–B. Some of these benefits might be transferred to the NAS as the nationwide level of equipage increases. Table 1 describes the relative value and anticipated benefit accrual dates for ADS–B Out benefits.



Legend	Benefit
1	Improve en route conflict probe.
2	Improve traffic management advisor.
6	More efficient merging and spacing because of increased surveillance (quantified in SBS Program business model. Benefit first realized in 2014 for NAS (includes 2008 for UPS)).
7	ATC surface management.
8	ATC surface safety.
10	Surveillance cost avoidance.
15	Radar-like IFR separation (en route/oceanic).
16	Optimal routing (Gulf).
17	Access to lower routes (Alaska only).
18	Increased VFR flight following (Alaska only).
19	Improved search and rescue (Alaska only).
21	Gate-to-gate company flight tracking (Alaska only).

Table 1—Benefit Accrual for ADS–B Out Benefits[2]

The ADS–B Out performance requirement expected to be mandated by the FAA provides substantial performance improvements compared to most existing surveillance systems. The benefits that accrue from the improved accuracy and update rate of the ADS–B system can result in a wider array of service availability for individual operators in addition to providing the national airspace capacity necessary to meet increasing demand for air travel.

[2] Benefit relative value key in present value measured in millions of dollars: 1 = <$100M; 2 = $100M to $300M; 3 = $300M to $500M, 4 = >$500M.

Because ADS–B ground units are smaller and easier to deploy than a conventional radar system, it likely will become cost effective to expand the existing air traffic surveillance coverage in the NAS. Radar-like services, such as aircraft separation, already have been provided in the State of Alaska, where placement of primary radar systems was impractical. The FAA should investigate a similar expansion of services into non-radar airspace in the NAS as a whole.

Because ADS–B transmits a signal directly from the aircraft, ADS–B Out also provides some safety benefits in terms of an additional tool for search and rescue. The FAA should evaluate whether ADS–B can be used as a replacement for existing safety requirements, such as the emergency locator transmitter (ELT).

Many high value flight procedures that are unavailable or rarely used today because of he technological constraints of radar could be enabled with ADS–B Out. For example, ADS–B Out coupled with a tool imbedded in ATC automation systems could allow for existing separation standards to be employed without the need for air traffic controllers to include extra separation to compensate for radar inaccuracies. Successful integration of ADS–B into existing automation systems could also enable improved ATC-based merging and spacing procedures and surface situational awareness for controllers that does not exist at many airports today.

ATC-Based Merging and Spacing Benefit Example

ATC-based merging and spacing is enabled by the ADS–B Out improved update rate and accuracy at range from a receiver over primary radar. Air traffic controllers will be able to issue speed and heading directions farther out from the airport runway, decreasing the need for large adjustments in heading and speed, which increase noise and decrease potential efficiency of operations and fuel savings.

This benefit can be accrued through modification of air traffic control automation systems to employ Airline Based En Route Sequencing and Spacing tool, enabling ATC-based merging and spacing operations in medium density airspace. High-density merging and spacing operations could be enabled using ADS–B In technology and additional NextGen systems (see section 3.4).

Some of the benefits that may be derived from the ATC-based merging and spacing applications include a reduction in high speed/high altitude vectoring, communication, workload, fuel burn, noise, time and distance flown. Figure 10 below provides a notional example of merging and spacing approximate distances at Louisville International Airport.

Figure 10—Notional Depiction of Merging and Spacing

Current DO–282A Equipage

Table 2 shows figures for aircraft currently equipped with DO–282A standard compliant avionics in specific areas. A broader sense of the level of equipage could be inferred from figure 7 in section 3.1 of this report.

Table 2—Aircraft Equipped with DO–282A Standard Compliant Avionics

Region	No. of Airplanes Equipped
Alaska	375
North Carolina	25
Washington DC Region	20
Embry Riddle (Arizona and Florida)	78
University of North Dakota	62

Further Separation Reduction with DO–260A-compliant Avionics

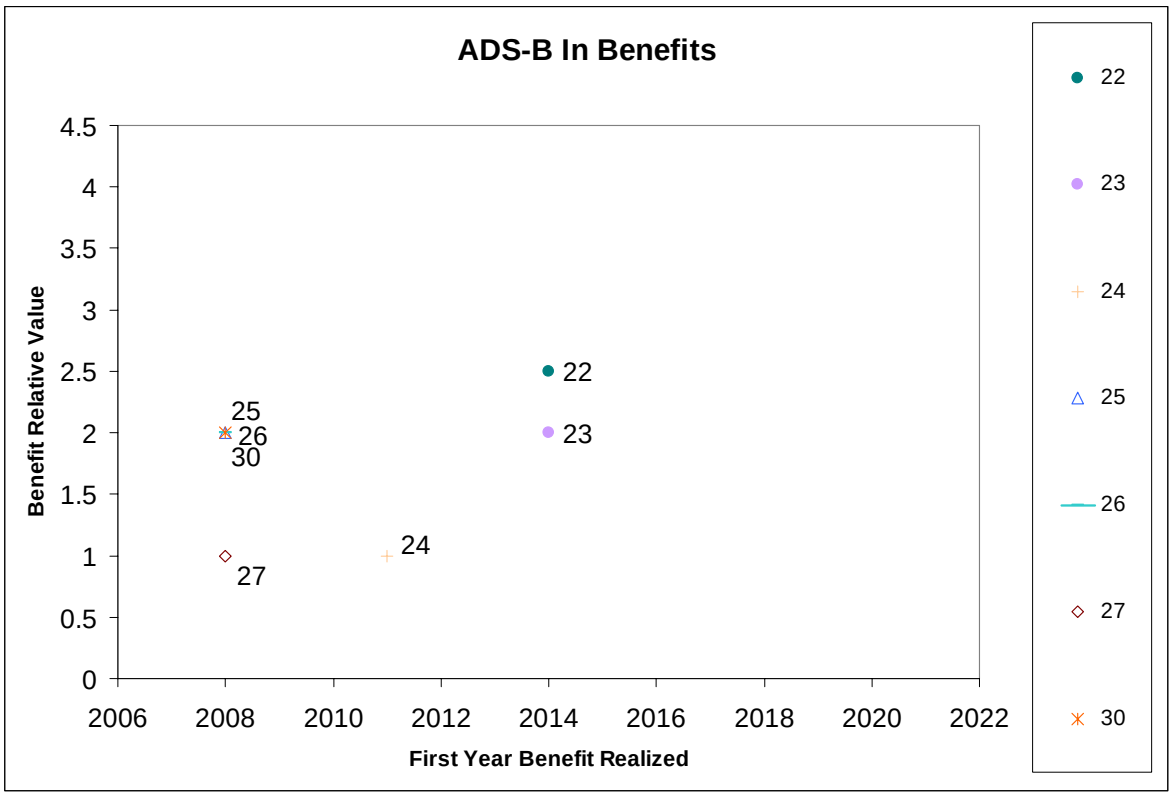
As discussed in section 3.1 of this report, aircraft separation could be reduced in the Gulf of Mexico because of the new surveillance capability supplied by ADS–B. The additional avionics and system level integrity parameters provided by DO–260A compliant avionics should allow for a smaller margin of error around the position reports from an aircraft and therefore more closely spaced aircraft at the target level of safety. Figures 8 and 9 in section 3.1 of this report illustrate the notional effects of improving upon existing procedural separation methods.

The FAA is pursuing separation standards for ADS–B mandate compliant avionics that are equivalent to the en route and terminal standards that exist with radar today. Once those standards are complete, a reduction in separation standards might be possible and should be pursued in the Gulf of Mexico and elsewhere in the NAS. Once the separation standards work has been completed, aircraft could be separated at 5 nautical miles in much the same way as they are handled in most en route airspace today.

Section 3.3 Available and Potential Benefits of ADS–B In

ADS–B In Benefits

The relative value of some of the ADS–B applications, including an estimate of when benefits should begin accrual under the current FAA program plan, is displayed in table 3 below.



Legend	Benefit[3]
22	More efficient spacing during visual approaches (quantified in SBS Program business model. Benefit first realized in 2014 for NAS (includes 2009 for UPS)).
23	Continuation of visual approach in marginal conditions (quantified in SBS Program business model. Benefit first realized in 2014 for NAS (includes 2009 for UPS)).
24	Increased surface safety.
25	Fewer aircraft-to-aircraft conflicts.
26	Fewer weather-related accidents.

[3] All values derived from potential ADS–B In and Out benefits, SBS scope, and existing technical standard orders.

Legend	Benefit[3]
27	More efficient route in adverse weather.
30	Fewer CFIT accidents (increased equipage).

Table 3—ADS–B In Benefits Accrual[4]

See appendix B for benefits and applications associated with DO–260A ADS–B In early equipage. These FAA-funded applications are not the only ones identified as being of value to users.

ADS–B In Applications

ADS–B In capability would enable a display of the TIS–B and FIS–B services and a platform for other situational awareness applications. These applications provide benefits to operators who choose to equip with DO–282A- or DO–260A-compliant ADS–B In capability in addition to the expected mandate of ADS–B Out. NAS users should be able to begin accruing these benefits as soon as they equip with ADS–B In, regardless of the equipage level of other aircraft. Brief descriptions of the applications are included below.

Airport Surface Situational Awareness

The objective of this application is to reduce the potential for deviations, errors, and collisions through an increase in flightcrew situational awareness while operating an aircraft on the airport movement area. Flightcrews will use a cockpit display to increase awareness of other traffic positions on the airport movement area. Additionally, the display could be used to determine the position of ground vehicles, for example, snow plows, emergency vehicles, tugs, follow-me vehicles, and airport maintenance vehicles.

Final Approach and Runway Occupancy Awareness

The objective of this application is to reduce the likelihood of flightcrew errors associated with runway occupancy and to improve the capability of the flightcrew to detect ATC errors. The application involves the use of a cockpit display that depicts the runway environment and displays traffic from the surface up to approximately 1,000 feet above ground level on final approach and will be used by the flightcrew to help determine runway occupancy. Figure 11 below depicts a prototype display of this function.

[4] Benefit relative value key in present value measured in millions of dollars: 1 = <$100M; 2 = $100M to $300M; 3 = $300M to $500M, 4 = >$500M

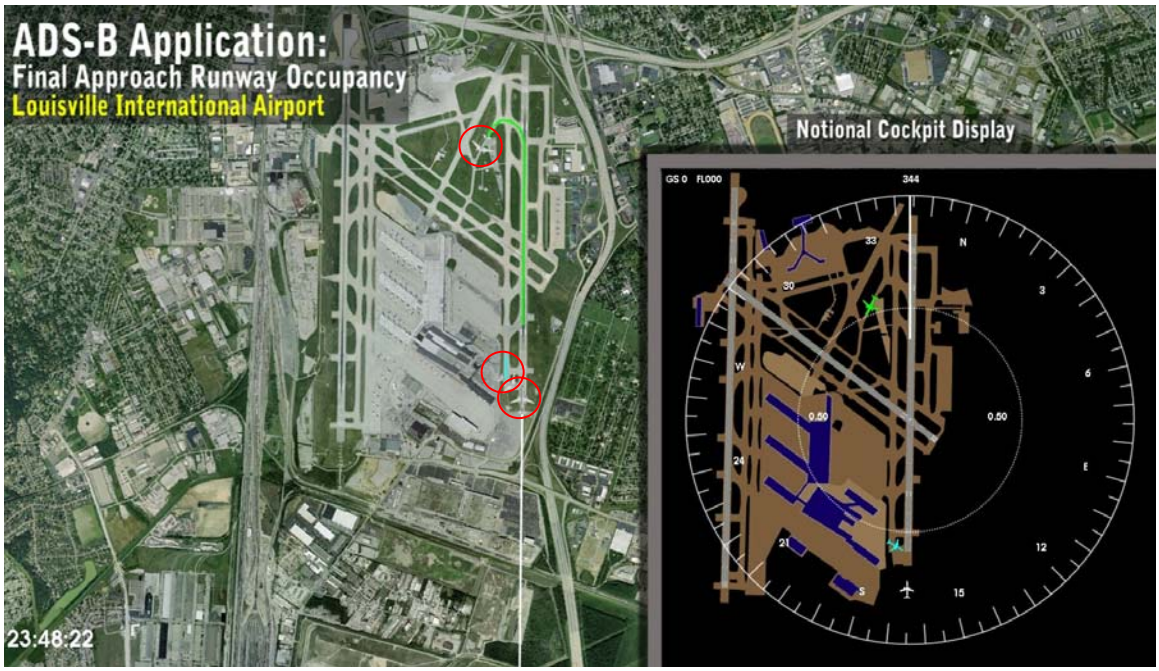


Figure 11—Prototype display of Runway Occupancy

Enhanced Visual Acquisition

The objective of this application is to provide the flightcrew with enhanced traffic situational awareness in controlled and uncontrolled airspace and airports. The application uses a cockpit display to enhance out-of-the-window visual acquisition of air traffic. Flightcrews will refer to the display during the instrument scan to supplement visual observations. The display can be used t either o initially detect an aircraft or to receive further information on an aircraft that has been reported by ATC. The application provides the flightcrew with the relative range, altitude, and bearing of other aircraft.

Enhanced Visual Approach

This application is intended to enhance successive approaches for aircraft cleared to maintain visual separation from another aircraft on the approach. The goal is to maintain visual approach procedure operation arrival rates even during periods of reduced visibility or obstructions to vision (for example, haze, fog, and sunlight). To achieve this objective, flightcrews will be supported by a cockpit display of nearby traffic. This will provide continually updated identity and position information to assist the flightcrew with achieving and maintaining visual contact with relevant traffic. Additional information such as range and speed will be provided to assist flightcrews in monitoring their distance from the preceding aircraft. The display may also be used to monitor aircraft on approach to parallel runways. A prototype of this display function is shown in figure 12.

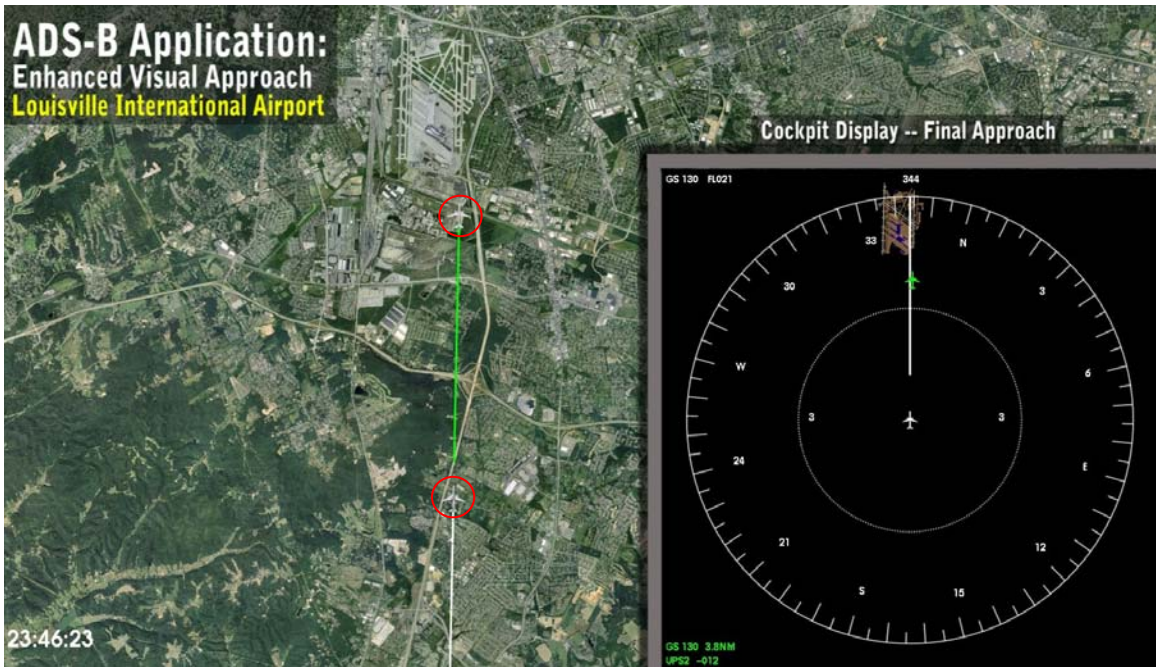


Figure 12—Prototype Display of Enhanced Visual Approach Application

Conflict Detection

The objective of the application is to provide alerting and relevant traffic information to help the flightcrew identify conflicts with other aircraft based on current flight status and intentions. Aircraft equipped with a cockpit display have the capability to display aircraft location. More than simply displaying traffic, the application will alert flightcrews to developing conflicts. Also, the long surveillance range afforded by ADS–B will enable alerts to be issued in time to solve the conflict with minimum disruption to the flight path.

> **NOTE: The conflict detection application is intended by the FAA to be an advisory ADS–B-enabled capability for properly equipped aircraft and is not intended as a traffic collision avoidance system replacement.**

In addition to the above-described applications (enhanced visual acquisition and conflict detection), the FAA will provide the data necessary to enhance see-and-avoid capability for aircraft that are not broadcasting an ADS–B message via TIS–B service available above 6,000 feet NAS-wide and even lower in the vicinity of the service broadcast points.

CDTI Assisted Visual Separation (CAVS)

ADS–B In technology could also enable the continuation of visual approaches in circumstances that would dictate their termination today. Termination of a visual approach because of an aircraft losing visual contact of another aircraft because of factors other than IFR conditions is a relatively frequent occurrence that entails additional delays, fuel burn, and arrival inefficiency. The FAA is researching and

developing CAVS to enable the continuation of visual approaches through the use of a cockpit display.

During a CAVS procedure (see figure 13), an air traffic controller would provide a traffic advisory at the time a flightcrew could get an initial out-the-window acquisition of an aircraft arriving ahead of them and correlate the position of the aircraft with a cockpit display of traffic information (CDTI). If the flightcrew were granted a clearance for visual separation and the air traffic controller were aware of their ADS–B In level of equipage, the flightcrew could be given clearance to maintain a visual separation even if the aircraft they are following is lost in glare, city lights, or other types of view obstructions. Once the lead aircraft is lost out-the-window, the CDTI would be used to maintain separation until landing. The types of environments where a CAVS can be made available would need to be fully defined to make use of this application.

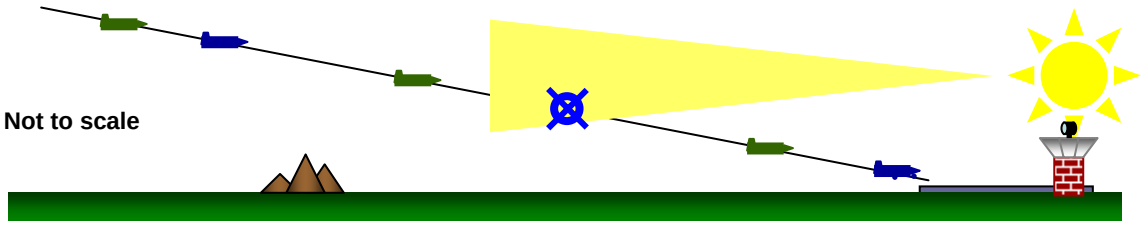


Figure 13—Notional Depiction of CAVS

Aircraft-Based Merging and Spacing

Aircraft-based merging and spacing in high-density airspace is enabled by the ADS–B In functionality and builds on the earlier-described ATC-based merging and spacing. In this application, the air traffic service provider supplies an aircraft with direction on which aircraft to follow, and time interval space behind that aircraft. This information is loaded into aircraft systems, with flightcrew awareness and approval, and the flightcrew would use onboard speed advisories from en route through CDA to landing.

In-trail Procedures

Another application that may provide increased value to operators traveling in en route airspace is the development of in-trail procedures during flight that would enable aircraft to adjust their altitude to pass each other even when there is no radar surveillance available. In today's environment, an air traffic controller separates aircraft based on information derived from equipment onboard an aircraft and relayed to them by a flightcrew. See figure 14 below.

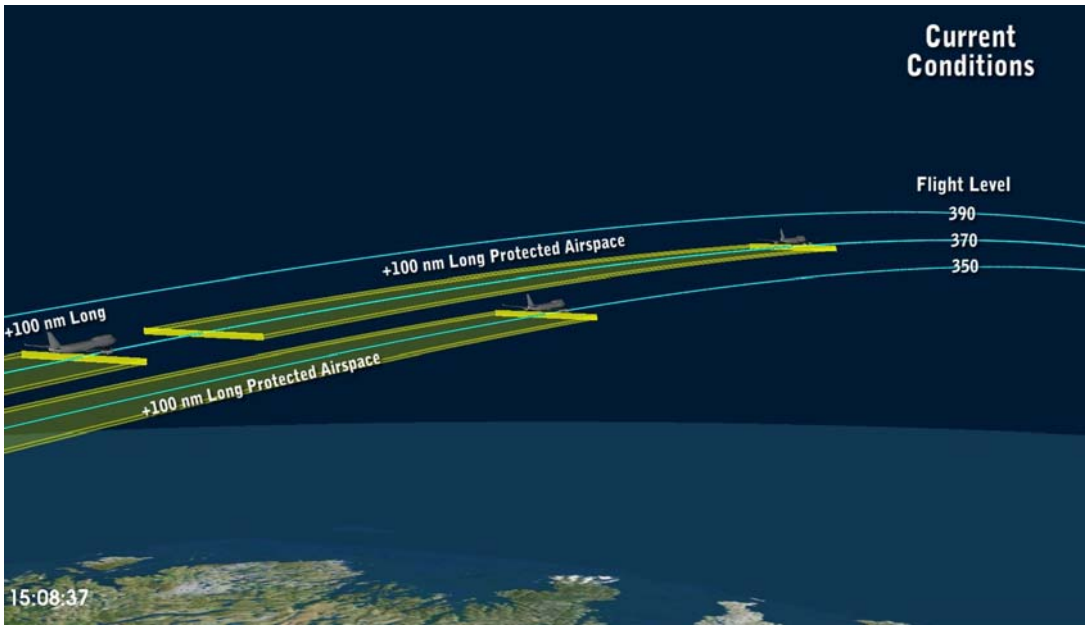


Figure 14—Current Oceanic Non-Radar Procedure

Aircraft equipped with ADS–B In functionality will receive ADS–B data from surrounding aircraft, and use a cockpit display and software that provide data that qualify the aircraft to arrange an in-trail passing procedure with ATC. See figure 15 below. The flightcrew would request, and the air traffic controller may approve, a flight level change based on information derived in the cockpit and the air traffic controller's awareness of the traffic picture. No direct airborne monitoring from ATC during the adjustment would be required. The air traffic controller would retain responsibility for separation, but safety would be maintained based on the information provided by ADS–B. The procedural separation provided today in non-radar en route airspace does not provide ATC with sufficient information on aircraft position to allow this type of procedure to occur. Increased availability of in-trail procedures would provide increased efficiency and safety (for example, fuel savings and avoiding turbulent flight levels).

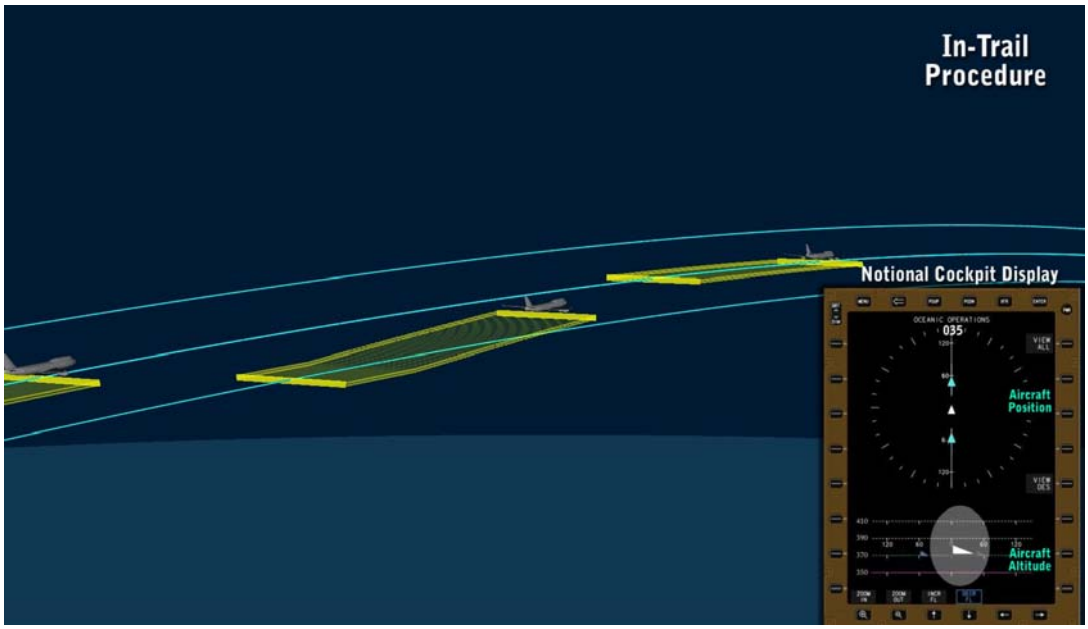


Figure 15—ADS–B Enabled In-Trail Procedure

Other ADS–B In Applications

ADS–B In capability on an aircraft coupled with a display function sets a platform for the development of a wide array of services that could be developed by the Government or by industry to provide flight services directly to the cockpit.

FIS–B Applications

The FIS–B is enabled by UAT data link and is not related to DO–260 or DO–260A standards. The primary objective of FIS–B is to provide flightcrews with improved access to weather information and aeronautical data. The data will be provided in-flight directly to the cockpit to enhance flightcrew situational awareness. The focus in the FIS–B application is improved access to standard text weather products (for example, Metrological Aviation Report, Terminal Aerodrome Forecasts, Significant Meteorological Advisory, and Pilot (weather) Reports), as well as standard graphical products (for example, next generation weather radar depictions).

While the FAA is focused on providing elementary weather products in the near future, it is envisioned that the program will evolve to provide flightcrew with enhanced weather and aeronautical data. As a result, the flightcrew will have better information on such hazards as icing, turbulence, and volcanic ash. Based on this information, flightcrew will have the ability to make better in-flight decisions, including better strategies for avoidance of areas of hazardous weather and, thereby, reduce the frequency of weather-related accidents.

In addition to safety considerations, the efficiency of flight operations also can be increased with improved access to weather information. Next generation weather radar graphics will offer the opportunity to make earlier decisions for deviations around some

convective weather hazards, and provide a better characterization of all convective weather hazards.

Better and timely access to weather information via FIS–B also reduces the risk of operator deviations and landing at an alternate airport because of unknown or uncertain weather conditions at the intended destination airport. This leads to the benefit of reduction in unnecessary cancellations and diversions during marginal weather conditions.

Controlled-flight-into-terrain (CFIT) accidents are defined as those in which the flightcrew inadvertently allows the aircraft to strike terrain, a water surface, or an obstacle, even though the aircraft is under his or her full control. In almost all cases, these accidents are attributable, to some extent, to the flightcrew's lack of awareness of the aircraft's altitude relative to proximate terrain and obstacles. CFIT accidents usually occur during flight conditions in which the flightcrew cannot visually ascertain terrain or obstacle clearance (for example, visual obscuration from fog, clouds, or precipitation; nighttime with unlighted terrain features; and poor contrast in the landscape because of snow and glassy water surfaces).

A basic objective of the FAA is to provide flightcrew who are operating aircraft not included under the Terrain Awareness and Warning System (TAWS) mandate (aircraft with fewer than six passenger seats, which account for over 90 percent of aircraft in the continental United States) with a safe and cost-effective means to be aware of the aircraft's altitude with respect to the surrounding terrain. The focus is on the display of the navigation situation and terrain information. The equipment also provides an alerting function that monitors terrain clearance and issues an appropriate warning to the flightcrew if inadequate terrain clearance is anticipated. The latter is an enhancement over TAWS that provides incremental benefits for aircraft already equipped with TAWS.

Another FIS–B service that offers a user benefit is the uplink and appropriate display of NOTAM information. Critical information such as temporary flight restrictions and runway closures are provided to users via NOTAMs. Timely NOTAM information that is easily accessible to users is expected to reduce aviation accidents and incidents.

DO–282 Equipage

The improved surveillance capability of the ADS–B system may provide an increase in the type and availability of high-efficiency operations in the NAS. However, those aggregate benefits are not expected to accrue at levels that would be of substantial value to an individual user until a high level of equipage has been achieved. However, there will be a variety of services available immediately to users to who choose to equip with ADS–B In technology. In areas where multiple aircraft have been equipped with ADS–B In, there may also exist a potential to employ advanced air-to-air applications (see section 3.4). Those air-to-air applications will be available to ADS–B In users regardless of what link they are transmitting on. The broadcast services of TIS–B and FIS–B are only available on the UAT datalink. Since 2003, aircraft equipped with UAT have benefited from receiving traffic, weather, terrain, and flight information data.

Equipage Sensitivity Analysis

The value of the above applications to different user groups has been estimated by the FAA. The sensitivity analysis the FAA conducted in support of this report revealed that the rate of equipage contributed to the net present value (NPV) of ADS–B equipage differently for different user groups. Figures 16 and 17 illustrate the NPV effect of early equipage of both ADS–B Out and In (respectively) on air transportation aircraft. The FAA concluded that accelerating ADS–B Out equipage improves business case results by increasing benefits associated with ATC efficiencies, merging and spacing, and the Gulf of Mexico. However, accelerating and increasing ADS–B In equipage for this same population did not improve the business case because equipage requires additional high-priced retrofit installations that do not outweigh the benefits of the initial advisory applications being deployed by the FAA.

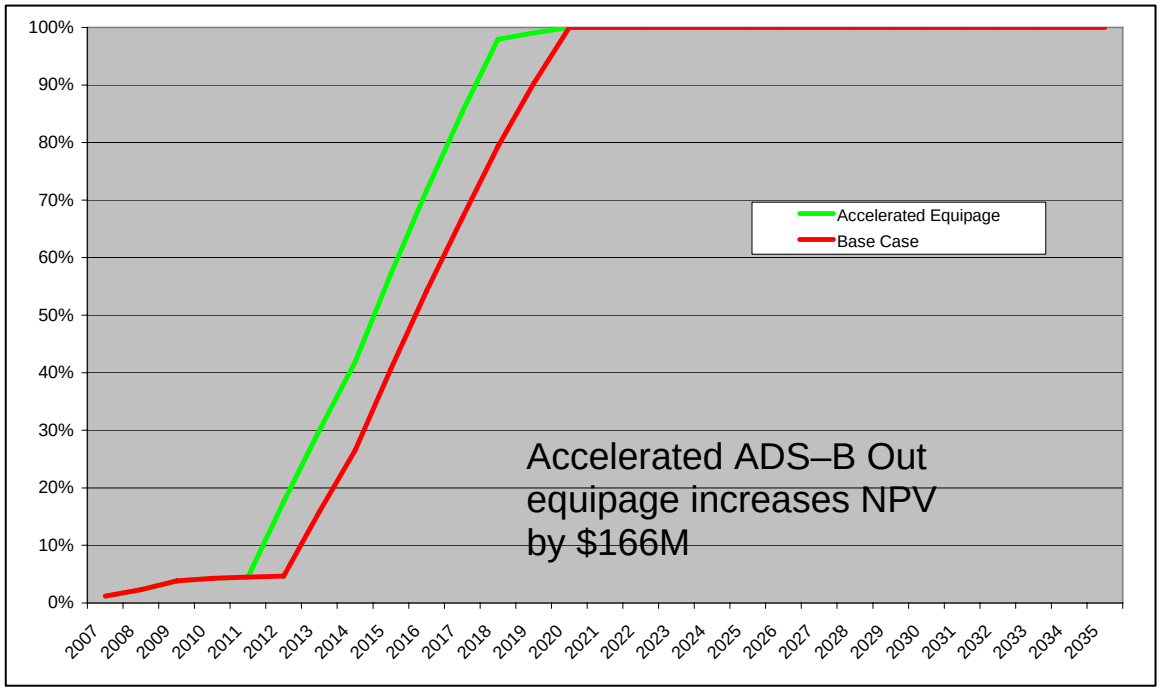


Figure 16—ADS–B Out Air Transport Equipage Sensitivity Analysis

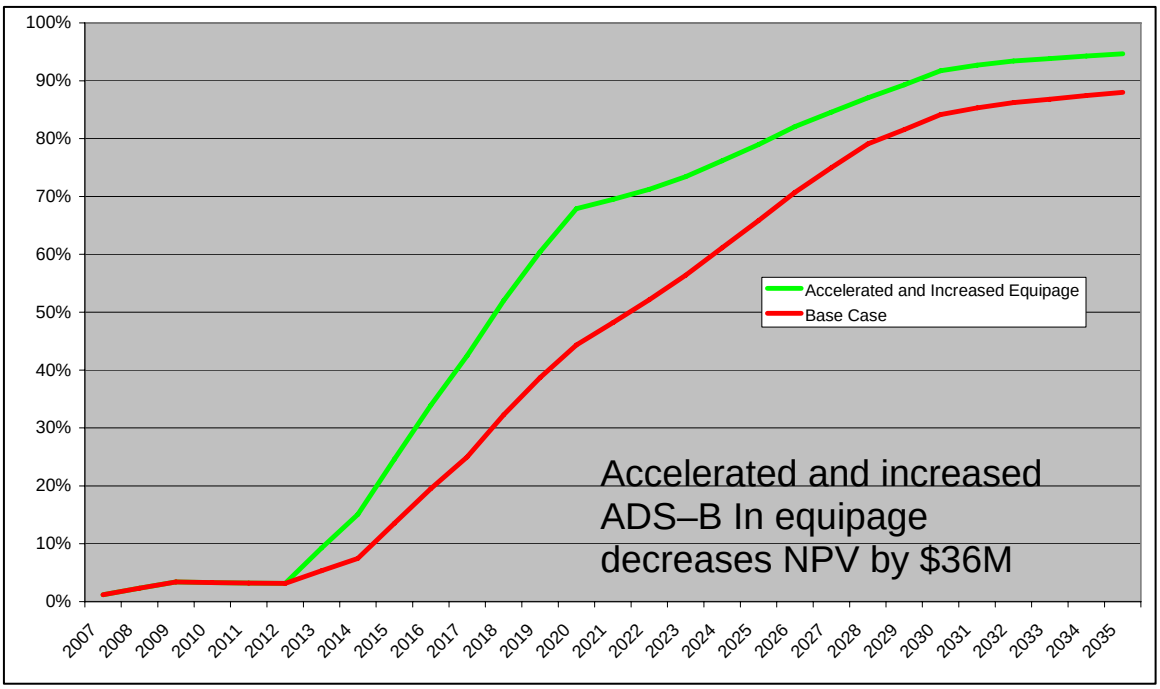


Figure 17—ADS–B In Air Transport Equipage Sensitivity Analysis

General aviation and air taxi aircraft tended to derive more benefit from early equipage of ADS–B In the FAA analysis. The earlier general aviation users equipped, the higher the total value of the ADS–B In equipage. Figures 18 and 19 illustrate that for this aircraft population, accelerating and increasing ADS–B Out and In equipage improves the business case by increasing benefits associated with FIS–B and TIS–B services and initial advisory applications.

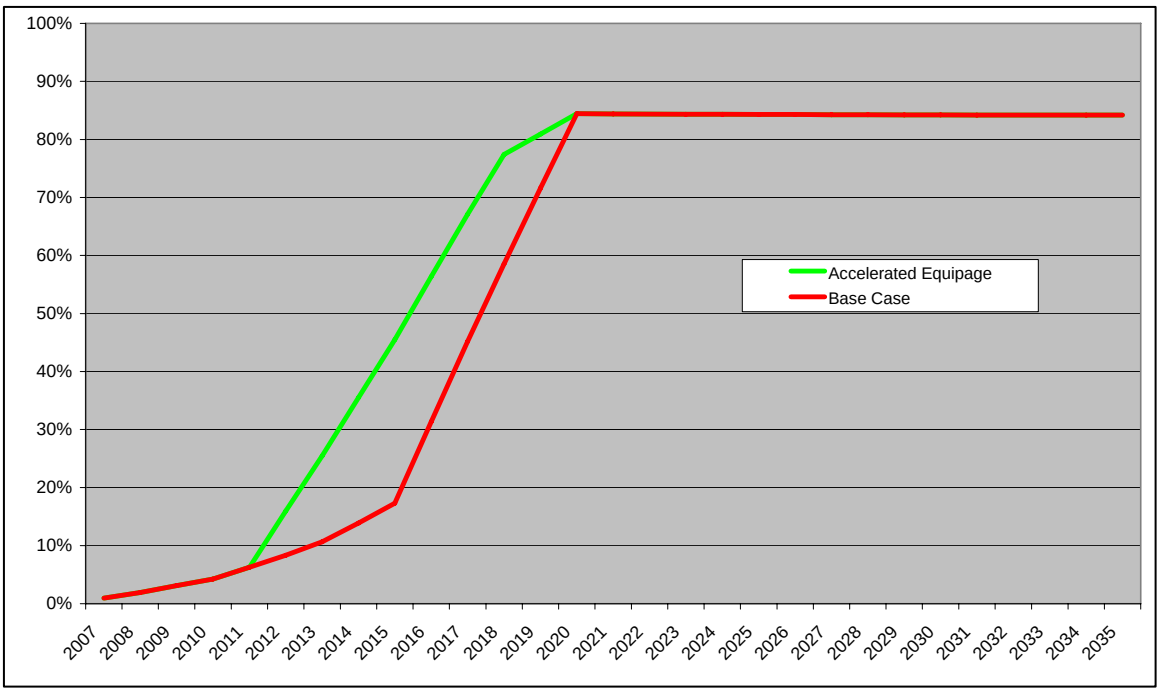


Figure 18—ADS–B Out Sensitivity Analysis Equipage for General Aviation and Air Taxi Aircraft

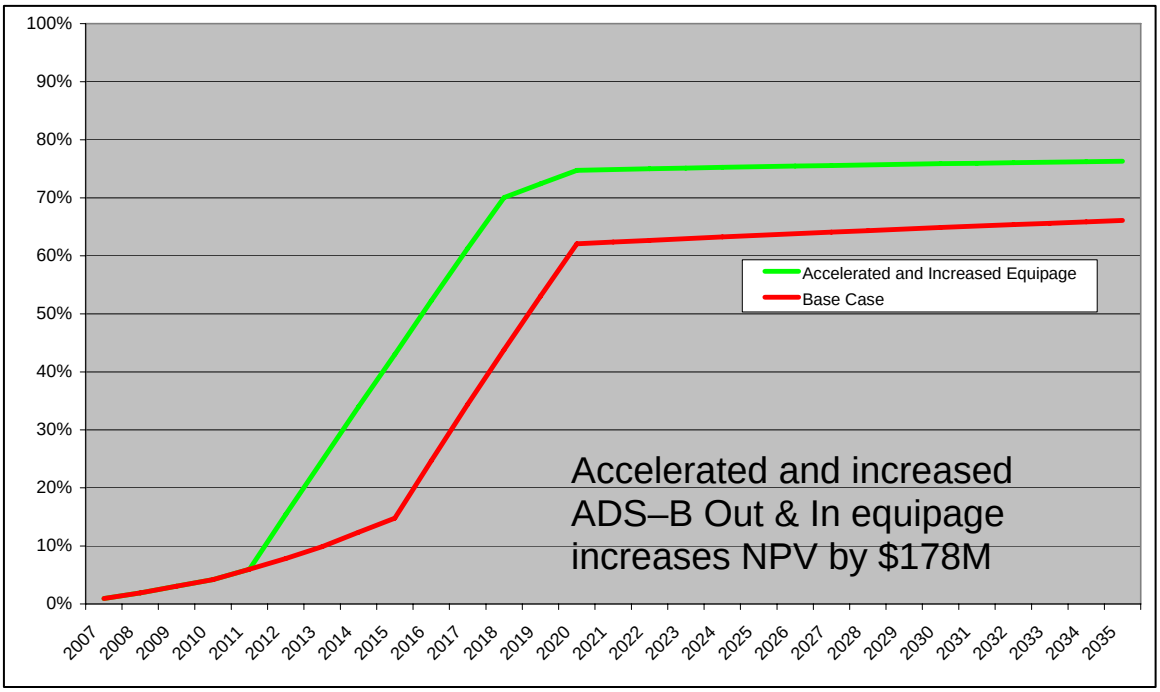


Figure 19—ADS–B In Sensitivity Analysis Equipage for General Aviation and Air Taxi Aircraft

ADS–B In Early Equipage Issues

There are a number of issues that must be addressed by the FAA and NAS users and suppliers before the benefits of ADS–B In equipage can achieve a high level of certainty. Regarding the display function, the FAA has yet to certify many specific display packages for various functions and applications. Without a clear understanding of what equipage will be suitable for performing specific operations, it will be difficult for users to commit to equipage.

Another significant cost associated with ADS–B equipage is the cost of retrofitting aircraft that do not currently have ADS–B mandate compliant avionics. The additional costs involved in retrofit may not be practical for some aircraft, especially those that would be taken out of service before the compliance date of the proposed rule. The ARC recommends that the FAA commission a project to address the complex certification requirements of ADS–B In avionics and develop ways to decrease the costs and uncertainty around ADS–B In reception and display equipment.

Certification of one or several electronic flight bags (EFBs) may mitigate the uncertainty around avionics. However, it is incumbent upon industry to apply for certification of this equipment for certain functions. Certification of new types of equipment for even existing operations—not including future capabilities such as possible reduction of separation standards—traditionally has been a lengthy process, often entailing years of effort. Training flightcrews to use new equipment, applications, and procedures also may delay the accrual of benefits until the proposed rule compliance date if not managed effectively. If these processes cannot be accelerated, it could hinder a decision to equip early with ADS–B avionics despite existing benefits.

The air transportation industry will have to weigh the progress of ADS–B certification and application acceleration projects, in addition to a normal assessment of costs and benefits. Significant and quantifiable benefits likely will be required to justify the early equipage of aircraft fleets, especially those fleets that may be retired before the proposed compliance date.

Section 3.4 Future Applications

This section describes future applications of ADS–B that have been conceptualized but are still either speculative or being researched. These applications are expected to require ADS–B capabilities or information beyond that described in RTCA DO–260A Change 3 or RTCA DO–282A Change 1.

Each application is described briefly, along with the general benefit mechanism and recipients.

ADS–B Out

An advanced application area for ADS–B Out is for improved flight path conformance monitoring. The two expected application domains for improved flight path conformance monitoring in the NAS are—

- National and Homeland security applications, and
- Air traffic management (ATM) applications.

The above application domains would use aircraft flight path intent information (for example, next waypoint) and possibly autopilot state, via the aircraft ADS–B message, to significantly improve flight path monitoring. Benefits of the security applications could include fewer false alerts and perhaps aircraft operations closer to sensitive areas. Benefits for the ATM applications could include improved conflict detection or blunder protection algorithm performance, and would probably allow reduced separations standards for a given target level of safety.

ADS–B In

There are a variety of advanced applications for ADS–B In and these applications are expected to provide the largest user benefits. Therefore, absent any future regulatory actions by aviation regulators, these applications likely will motivate equipage, and future revisions of ADS–B standards, to the extent this may be needed.

Advanced Surface Operations

The advanced surface operations applications, including high-speed runway turnoff guidance and low visibility taxi capability, would increase airport throughput in low visibility conditions that are equivalent to visual conditions. High-speed runway turnoff guidance uses a primary field-of-view display in low visibility to provide surface traffic awareness from ADS–B In to ensure the high-speed turnoff is cleared of traffic. This capability would improve runway occupancy times in visual conditions and allow interarrival aircraft spacing reductions. The low visibility taxi application would require an airport surface map and surface traffic awareness via ADS–B In, probably with taxi clearance displayed. This application may be able to rely on aircraft “avoidance” of surface traffic (or “coordination” with same) to reduce air traffic service provider workload and improve safety. These capabilities would build on applications/capabilities described in previous sections.

Advanced Terminal Applications

Advanced extended terminal operations applications, including airborne merging and spacing and use of aircraft intent information, are aimed at providing airport throughput in low visibility conditions equivalent to visual conditions, as well as improved operations in visual conditions via reduced spacings at the target level of safety. Airborne merging and spacing uses intent information from aircraft being followed or merged-behind (both route and along-path planned airspeeds schedule). Improved surveillance along with aircraft/ATC automation allows aircraft to perform continuous descent arrivals from top-of-descent to near the final approach fix while maintaining precise interarrival times at the runway threshold. This is an extension of earlier-described airborne merging and spacing applications. The use of aircraft intent information allows even more closely spaced terminal area routes than described in earlier sections. This includes departures and arrivals using RNP capabilities, and

parallel approaches down to 700 feet centerline separation. This is an extension of earlier-described applications.

Advanced En Route and Cruise

The advanced en route/cruise applications including in-trail passing, aircraft RNP capabilities, delegated separation, and aircraft-based separation management, are aimed at providing increased airspace throughput at the target level of safety.

In-trail passing and/or merging into or leaving in-trail flows is an extension of the earlier-described in-trail climb procedure. This is envisioned to be most useful in an air traffic service provider-established route or aircraft flow, where aircraft are responsible for maintaining assigned spacing from other aircraft during passing or merging maneuvers within the route or flow. The expected benefits are improved air traffic service provider /airspace capacity, improved fuel efficiency for operators, reductions in air traffic service provider workload, and potential reductions in separation standards at the target level of safety.

Aircraft RNP capabilities, combined with ADS–B In surveillance and on-board spacing or "conflict detection" algorithms, should allow reduced longitudinal and lateral separations in oceanic airspace. The expected benefits are improved airspace capacity and improved fuel efficiency for operators.

Delegated separation (to aircraft) is a broad category of operations referring to any separation tasks delegated by the air traffic service provider to suitably equipped aircraft (delegation can range from one to several aircraft). Such aircraft would need onboard conflict detection automation and some conflict resolution capability. The expected benefits are improved air traffic service provider /airspace capacity and/or reductions in air traffic service provider workload.

Using aircraft-based separation management (self-separation), aircraft are fully responsible for maintaining separation from other aircraft in accordance with rules and approved separation standards, probably in segregated airspace, but under the assumption that traffic flow management functions are performed by the air traffic service provider, a flight operations center, or both via some collaborative process. The expected benefits are routings closer to operator preference, reductions in air traffic service provider workload, and less reliance by operators on air traffic service provider services.

FIS–B Applications

The advanced application of FIS–B is to transmit dynamic airspace changes to aircraft operating in the NAS. This application is an envisioned expansion of "Reduction in Accidents and Incidents Due to Improvements in Aeronautical Data (NOTAMs)" in appendix B. Dynamic airspace notifications can be applied to special use airspace or temporary flight restrictions (or similar restricted airspace), benefiting all users because restricted airspace is only applied when needed. Such notifications can also be applied to flexible class B openings/closings based on airport operating configurations, benefiting lesser-equipped aircraft that wish to transit this airspace.

4.0 INCENTIVES FOR EQUIPAGE

Introduction

The aviation community makes its equipage decisions based on a thorough financial evaluation. Therefore, any incentives for ADS–B equipage must involve a financial cost-benefit evaluation. The ARC conducted a brainstorming session and identified a number of incentives, some with direct financial impact and others without, that could be used to encourage voluntary equipage. The ARC did not conduct any extensive analysis on any of the options, including the legality. In addition, not all ARC members agree that all incentives listed are viable options.

The ARC believes that operational benefits are not enough to encourage voluntary equipage, and some financial incentives would be necessary to encourage early equipage. The Government, and to some extent state and local authorities, can affect that cost-benefit evaluation through direct financial incentives or the creation of operational benefits that reduce costs and positively affect an operator's bottom line. However, the decisions to equip are different in the general aviation and air carrier communities, and general aviation operators may elect to invest in new equipment regardless of the cost-benefit analysis.

Financial Incentives

The following are some mechanisms by which the ARC believes the Federal Government can fund or partially fund ADS–B avionics equipment, some of which are described further. The Government can—

- Pay for the certification, purchase, and installation of the equipment.
- Provide a grant for the equipment.
- Provide an investment tax credit.
- Provide adjustments to the existing aviation excise tax rate.
- Encourage market competition through research and development tax credits specifically targeted at ADS–B avionics development.
- Reduce landing/overflight fees for ADS–B-equipped aircraft.
- Reduce or waive registration fees.
- Provide a fuel tax break for equipped aircraft.
- Provide interest-free loans for equipage that are paid back when benefits are accrued.

Government-purchased equipment

The Alaska Capstone program relied on Government-purchased avionics equipment as the starting point for operators to equip with ADS–B avionics. This provided a base of airplanes with installed equipment where quantifiable benefits were identified by the FAA. The benefits of equipage, including safety, provided an encouragement for additional operators to invest in ADS–B avionics.

Investment tax credits

Investment tax credits have been introduced by Congress to encourage investment in certain property or equipment. This option would require Congress to authorize an investment tax provision specifically for ADS–B avionics. This investment tax provision would involve a basic cost to the Government and would provide an opportunity for a company to offset taxes on profits through the investment tax credit.

Aviation taxes

Aviation taxes make up the bulk of the money the aviation community pays for the FAA's aviation infrastructure. Congress would have the option of creating an incentive for equipping with ADS–B by lowering the effective excise tax rate (either fuel or other mechanisms) for operators who elect to equip.

Research and development tax credits

All avionics development involves significant investments by the equipment manufacturer and installer in research, development, engineering, and certification costs. The Government has the option of creating research and development tax credits targeted at the development of ADS–B avionics. Currently, there is a research and development tax credit in place, and several research and development tax credits have existed since introduced in 1981. A targeted research and development tax credit for ADS–B avionics could provide further incentive for companies to develop avionics.

Other Incentives

The following are some operational incentives by which the ARC believes the Federal Government can encourage equipage. The Government can—

- Identify the benefits and savings with existing equipment (DO–260) and use this information to promote further investment.
- Accelerate development of procedures and an intended set of functions.
- Provide preferred access to additional capacity and efficiencies enabled by ADS–B equipage.
- Accelerate identification of high-value operations enabled by ADS–B that would support reduced separation standards.
- Remove equipment (for example, transponders, ELTs (couple with search and rescue)) and reduce/eliminate recurring inspections.

- Increase program confidence using memorandums of understandings for joint investments and schedule stability.
- Provide local incentives/engagement (for example, deicing stations, sell data to airports, broaden existing pilot program and commitment to leverage State and local investment to supplement what's being done at the Federal level).
- Use equipment to see vehicles on the runway to reduce runway incursion events and consider extending coverage areas beyond the baseline.
- Facilitate more practical and low-cost displays.

5.0 RECOMMENDATIONS

Consistent with the objective of this report, the ARC has attempted to identify incentives to accelerate ADS–B equipage before the compliance date of the proposed nationwide ADS–B airspace rule. These incentives generally fall into two categories: financial incentives and operational benefits. The financial incentives identified take a number of forms, varying from tax breaks to equipment grants and subsidies. The operational benefits may be characterized as the enablement, through ADS–B equipage, of operations that cannot be performed with the existing NAS surveillance infrastructure and procedures.

The ARC believes some combination of financial incentives and operational benefits will be needed to significantly accelerate ADS–B equipage before the compliance date of the proposed rule. The ARC notes that such a combination has been employed since 2001 to achieve the present level of ADS–B equipage in the NAS.

The ARC has confidence in the FAA's ability to deploy the ADS–B ground infrastructure. However, the ARC is concerned with the ability of the FAA to approve operational procedures that would provide early operational benefits that cannot be achieved with the exiting NAS surveillance infrastructure.

The ARC presents its recommendations to the FAA below. The ARC's first three recommendations have been identified as being particularly critical to achieving early ADS–B equipage. The ARC will work with the FAA to prioritize implementation of its recommendations.

The ARC recommends that the FAA—

1. **Collaborate with the aviation industry and aggressively develop an appropriate combination of financial incentives and accelerated operational benefits.**

   The FAA should complete a legal and financial review of the financial incentives listed in this report and evaluate whether financial incentives for ADS–B equipage could be provided. The Government should carefully evaluate the timing of any financially based incentive to determine when it would have the most positive impact. The ARC expects that the next FAA reauthorization will be in 2012, which would provide an opportunity to include specific financial incentives. Each of the financial incentives listed in this report would involve a direct cost to the Government that would have to be offset in the existing pay-and-go situation.

2. **Accelerate and prioritize the identification of operations enabled by ADS–B, with approval of reduced separation standards for initial operations with a high level of user benefits by 2012.**

   To determine which applications should be given the most resources and attention, the FAA and the aviation community will have to identify the level of demand for given operations. Specifically, the aviation community should, in an operationally driven manner, investigate which operations to focus on when prioritizing the certification of operations employing reduced separation standards. The FAA must, as it has indicated it will, approve ADS–B-based separation standards equivalent to those used today with radar before the ADS–B final rule is issued. Given that certification of reduced separation standards is expected to be a lengthy process, one way to accelerate ADS–B equipage is to start certifying immediately those operations where reduced separation standards are of the most value to NAS users. Such operations are not currently within the funded scope of the SBS program. Approval of initial high-value operations by 2012 is needed to coincide with the deployment of high-value zones in the national ADS–B ground infrastructure.

3. **Establish certification requirements for aircraft displays for ADS–B In applications by 2010.**

   No mandate is planned for the equipage of ADS–B In equipment; however, the services provided by ADS–B In capability are very useful to flightcrews and necessary to enable future air-to-air applications. Those services will be acquired by users based solely on a cost-benefit analysis. The FAA should create a dedicated group to resolve the display requirements, including human factors considerations. If the FAA can better define its requirements for ADS–B In to perform a wide variety of high-value operations and lower the cost of those systems, a higher level of ADS–B In equipage becomes likely.

4. **Extend the coverage of the ADS–B ground infrastructure to include high-value non-radar areas beyond those currently identified.**

   The benefits of ADS–B in terminal surface and en route environments where radar exists today provides substantial value. The FAA should establish a forum to determine which areas outside that baseline would provide the greatest benefits to NAS operators. Surveillance and broadcast services in areas where no coverage exists today provide the most relative value and safety increases to the existing surveillance infrastructure. The FAA should have a mechanism to evaluate how the SBS program's scope might be expanded to accrue benefits in non-radar areas.

5. **In the Gulf of Mexico area—**

   - **Deploy an ADS–B infrastructure south of the Gulf of Mexico to facilitate ADS–B traffic feeds.**

   - **Apply radar-like separation standards in the Gulf of Mexico for DO–260-equipped aircraft.**

6. **Establish a mechanism to verify that existing DO–260 installations are capable of being used to achieve early operational benefits.**

   As of September 2007, over 5,000 aircraft are capable of transmitting 1090 ES ADS–B messages. Almost all of these aircraft transmit ADS–B messages that generally follow the requirements of RTCA DO–260. However, none of these DO–260 implementations have been TSO-certified to the requirements of DO–260. Initial RTCA DO–260A TSO certifications are in process or are complete for at least two avionics manufacturers.

   Several years of actual use of ADS–B in Alaska by ATC led to a number of changes to ADS–B avionics being requested by the U.S. operational community. Most of these changes were implemented in DO–242A, and all of them were implemented in DO–260A. Two of the most important of these ATC-requested changes were the transmission in ADS–B messages of the Mode 3/A code ("4096 code") assigned to the aircraft by ATC and the ability for a controller to use ADS–B to "IDENT" an aircraft that had declared an emergency. The inclusion of the Mode 3/A code in ADS–B messages was seen as being particularly important operationally with regard to aircraft identification/handoff and flight plan registration.

7. **Collaborate with the aviation industry to determine by 2010 which non-ADS–B avionics can be replaced by ADS–B equipage.**

   Operators would have an increased incentive to equip if ADS–B avionics could provide relief from other requirements. ADS–B message elements and requirements share a significant overlap with existing equipage on the aircraft, including several types of transponders and the ELT system.

8. **Provide preferred access to additional capacity and efficiencies enabled by ADS–B equipage.**

   The Gulf of Mexico has been identified as one area where the establishment of preferential routes could provide substantial benefits. The FAA should investigate what other routes, including routes in existing surveillance areas, could be employed to maximum benefits.

9. **Leverage the benefits of ADS–B information to incentivize equipage by establishing agreements with specific operators.**

The FAA should be able to provide ADS–B flight monitoring information or accelerated deployment of ADS–B and broadcast services at air transport hubs in exchange for an agreement to equip. By tailoring equipage to the needs of the earliest operators through formal agreements, the confidence in the ADS–B schedule accrual of benefits could increase.

10. **Continue to establish agreements with local and State governments to leverage the benefits of ADS–B.**

    By operating on a local level with specific airports, as well as local and State governments, the FAA could continue to provide targeted benefits without the constraints of national deployment.

11. **Evaluate the extension of coverage of ADS–B in airport non-movement areas.**

12. **Develop an economic decision tool for aircraft owners and operators to evaluate the direct benefits and costs involved in equipping with ADS–B.**

    The ARC believes the FAA should develop a tool for operators to assess the benefits of both early equipage and when full equipage is required by the mandate. This tool would allow an operator to evaluate early equipage in the context of existing equipage. Assuming operators have a long lead time to equip their aircraft, they would be able to examine various equipage strategies. This approach could be tailored to an operator's specific environment and needs, taking local constraints into account. Typically, in a mandate situation, the only additional cost for early equipage is the cost of money.

    The decision tool would be similar in form and function to the European Model for Strategic ATM Investment Analysis (EMOSIA). The EMOSIA is generic to cover any change in the air traffic management (ATM) environment. The ADS–B tool would be specific to ADS–B equipage, but should still provide targeted input to an array of stakeholders and use a full scope of possible cost and benefits to arrive at a net present value of different levels of ADS–B equipage.

APPENDIX A—ARC MEMBERS

Mr. Doug Arbuckle, Joint Planning and Development Office

Mr. Basil Barimo, *Co-Chair*, Air Transport Association of America, Inc.

Mr. Steve Brown, *Co-Chair*, National Business Aviation Association, Inc.

Mr. Jim Byrum, Cessna Aircraft Company

Mr. Vincent Capezzuto, *Designated Federal Official*, FAA, En Route and Oceanic Services

Ms. Sarah Dalton, Alaska Airlines

Mr. Jerry Davis, Airbus

Mr. Bruce DeCleene, FAA, Aircraft Certification Service

Mr. Jim Duke, Air Line Pilots Association

Mr. Ken Dunlap, International Air Transport Association

Mr. Scott Foose, Regional Airline Association

Mr. R. John Hansman, Massachusetts Institute of Technology

Mr. Rick Heinrich, Rockwell Collins

Mr. Jens Hennig, General Aviation Manufacturers Association

Mr. Bob Hilb, United Parcel Service

Mr. Randy Kenagy, Aircraft Owners and Pilots Association

Mr. George Ligler, Project Management Enterprises, Inc.

Mr. John McGraw, FAA, Flight Standards Service

Mr. Jeff Mittelman, MITRE/CAASD

Mr. William Richards, Boeing

Mr. Sam Seery, Garmin

Mr. Allan Storm, Department of Defense

Mr. Dale Wright, National Air Traffic Controllers Association

APPENDIX B—BENEFITS ASSOCIATED WITH ADS–B IN EARLY EQUIPAGE

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
ADS–B Out Surveillance Benefits in Radar Airspace							
ATC Efficiencies	Improve En Route Conflict Probe (1)	URET becomes an R-side tool per OEP; improved surveillance allows reduction in alert parameters from 8nm to 7nm, reducing alerts and providing more efficient maneuvers	Efficiency (User Benefit)	Y 2017 based on URET migration to R-side	4	N/A	Sec. 3.2 (Sec 3.1 w/ fusion)
	Improve Traffic Management Advisor (2)	Improved surveillance increases the accuracy of meter fix projections enhancing the benefits of TMA	Efficiency (User Benefit)	Y 2020 based on conservative assumption; possible for earlier mixed equipage benefits	3	N/A	Sec. 3.2 (Sec 3.1 w/ fusion)
	More efficient release from circular holding (3)	Improved surveillance aids in reducing unnecessary gaps between aircraft as they are released from holding patterns	Efficiency (User Benefit)	N	Not fully quantified but expected to be in group 1 or 2	N/A	Sec. 3.2 (Sec 3.1 w/ fusion)

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
	Enable RNAV procedures where current surveillance doesn't support (4)	Approaches to adjacent airports can be separated using RNAV procedures if the paths are separated by at least 4,300 ft. It is feasible to do with today's radar but it is not being done. Examples include JFK RWY 13L and LGA RWY 4.	Efficiency (User Benefit)	N	Not fully quantified but expected to be in group 2 or 3 at a minimum	N/A	Sec. 3.2 (Sec 3.1 w/ fusion)
	Enhanced surveillance fusion (5)	Contributes to benefits above; need further definition for additional benefits			Contributes to benefits above	N/A	Sec 3.1
	More efficient ATC-based merging and spacing due to improved surveillance (6)	Improved surveillance along with ATC automation allows CDAs in higher density environments than can be accomplished today	Efficiency (User Benefit)	Y 2009 UPS only; NAS-wide 2014 based on SBS implementation schedule	4	N/A	Sec 3.2
	ATC Surface Management (7)	Upgrading remaining ASDE–3 sites to include target IDs enhances ATC situational awareness	Efficiency (User Benefit)	Y (ASDE-3 Sites Only) 2016 based on SBS implementation schedule	1	N/A	Sec 3.1

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
ATC Safety	ATC Surface Safety (8)	Upgrading remaining ASDE–3 sites to include target IDs enhances ATC situational awareness	Safety (User Benefit)	Y (ASDE-3 Sites Only) 2016 based on SBS implementation schedule	1	N/A	Sec 3.1
ATC Safety	Improved Search and Rescue (9)	Updating flight plans to indicate ADS–B equipage would enhance SAR	Safety (User Benefit)	N	Not fully quantified but expected to be in group 1 or 2	N/A	Sec 3.2
Surveillance Replacement	Surveillance Cost Avoidance (10)	Implementation of ADS–B allows for the reduction of SSRs by approx 50% as well as surface movement radar	Cost Avoidance (FAA Benefit)	Y 2014 based on when investments in radar would be made if ADS–B was not pursued	3	N/A	Sec. 3.2 (Sec 3.1 w/ fusion)
	Mode-S Transponder Certification Cost Savings (11)	Download of ADS–B message sets and registers may reduce requirements and costs of biennial transponder certification	Cost Savings (User Benefit)	N	Not fully quantified but expected to be in group 1 or 2	N/A	Sec 3.1

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
Operator Tools	Gate to Gate Company Flight Tracking (12)	Distribution of surveillance data via service provider would enable application (surface coverage at ASDE airports)	Efficiency/Safety (User Benefit)	N	???	N/A	Sec 3.1
Operator Tools	Surface Management Systems (13)	Distribution of surveillance data via service provider would enable decision support tools at AOCs (surface coverage at ASDE airports)	Efficiency (User Benefit)	N	??? (potential to be in group 3 or above)	N/A	Sec 3.1
Enable ADS–B In	Better utilization of ADS–B In (14)	Increased situational awareness for users who equip with ADS–B In thus increasing their benefits	Efficiency/Safety (User Benefit)	Y (embedded in estimates)	??? (embedded in ADS–B In estimates)	Supports other users with ADS–B In	Sec 3.1
ADS–B Out Surveillance Benefits in Non-Radar Airspace (but within ADS–B service area)							
ATC Services	Radar-Like IFR Separation (en route/oceanic) (15)	Surveillance in non-radar airspace allows for reduced separation	Capacity (User Benefit)	Y (Gulf Only) 2011 based on SBS implementation schedule	3	N/A	Sec. 3.2 (Sec 3.1 w/ fusion)

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
	Optimal Routing (16)	Surveillance in non-radar airspace allows for an increase in direct routes	Efficiency (User Benefit)	Y (Gulf Only) 2011 based on SBS implementation schedule	1	N/A	Sec. 3.2 (Sec 3.1 w/ fusion)
	Access to Lower Routes (17)	Surveillance in non-radar airspace supports utilization of additional lower routes	Capacity (User Benefit)	Y (AK Only) 2010 based on SBS implementation schedule	1	N/A	Sec. 3.2
	Increased VFR Flight Following (18)	Surveillance in non-radar airspace increases ATC situational awareness	Safety (User Benefit)	Y (AK Only) 2008 based on existing activities in AK and SBS implementation schedule	Not quantified separately 1 to 2	N/A	Sec. 3.1
	Improved Search and Rescue (19)	Surveillance in non-radar airspace increases ATC situational awareness	Safety (User Benefit)	Y (AK Only) 2008 based on existing activities in AK and SBS implementation schedule	1	N/A	Sec. 3.2

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
	Reduce unnecessary intercepts of friendly aircraft (20)	Surveillance in non-radar airspace increases ATC situational awareness	Security (Government Benefit)	N	1	N/A	Sec. 3.1
Operator Tools	Gate to Gate Company Flight Tracking (21)	Distribution of surveillance data via service provider would enable application	Safety/Efficiency (User Benefit)	Y (AK Only) 2008 based on existing activities in AK and SBS implementation schedule	Not quantified separately 1 to 2	N/A	Sec. 3.1
ADS–B In Applications							
Visual Approaches	More Efficient Spacing During Visual Approaches (22)	Enhanced Visual Approach (EVA) application	Efficiency (User Benefit)	Y 2014 based on SBS implementation schedule and assumed equipage curves	2/3	CDTI/EVA	Sec. 3.3

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
	Continuation of Visual Approaches in Marginal Conditions (23)	CDTI Assisted Visual Separation (CAVS) application	Capacity (User Benefit)	Y UPS only 2009; NAS-wide 2014 based on SBS implementation schedule and assumed equipage curves	2	CDTI/CAVS	Sec. 3.3
Pilot Situational Awareness	Increased Surface Safety (24)	Airport Surface Situational Awareness (ASSA) and Final Approach Runway Occupancy Awareness (FAROA) applications	Safety (User Benefit)	Y 2011 based on assumed equipage curves	1	CDTI/ASSA/FAROA	Sec. 3.3
	Fewer Aircraft-to-Aircraft Conflicts	Cockpit display of traffic information enhances pilot situational awareness	Safety (User Benefit)	Y 2008 based on SBS implementation schedule and assumed equipage curves	2	TIS–B	Sec. 3.3

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
	More efficient merging and spacing due to improved surveillance	Improved surveillance along with ATC automation allows CDAs in higher density environments than can be accomplished today	Efficiency and Capacity (User Benefit)	Y 2009 UPS only; NAS-wide 2014 based on SBS implementation schedule	4	N/A	Sec 3.3 and 3.4
Broadcast Services (TIS–B and FIS–B)							
TIS–B	Fewer Aircraft-to-Aircraft Conflicts (25)	Cockpit display of traffic information enhances pilot situational awareness	Safety (User Benefit)	Y 2008 based on SBS implementation schedule and assumed equipage curves	2	TIS–B	Sec. 3.3
FIS–B	Fewer Weather Related Accidents (26)	Display of weather information enhances pilot situational awareness, reducing encounters with hazardous weather	Safety (User Benefit)	Y 2008 based on SBS implementation schedule and assumed equipage curves	2	FIS–B	Sec. 3.3

	Benefit Elements (Number corresponding to graphics)	Key Assumptions	Benefit Category	Quantified in FAA SBS Program Business Model	Relative Value Benefits thru FY35 1: Less than $100M PV; 2: $100M to $300M PV; 3: $300M to $500M PV; 4: $500M+ PV	ADS–B In	Cross Ref. to Report Section
	More Efficient Routes in Adverse Weather (27)	Display of weather information enhances pilot situational awareness, resulting in more efficient deviations around hazardous weather	Efficiency (User Benefit)	Y 2008 based on SBS implementation schedule and assumed equipage curves	1	FIS–B	Sec. 3.3
	Reduction in Unnecessary Cancellations and Diversions During Marginal Weather Conditions (28)	Display of weather information enhances pilot situational awareness, resulting in improved go/no-go decisions	Efficiency (User Benefit)	N	Not fully quantified but expected to be in group 1	FIS–B	Sec. 3.3
	Reduction in Accidents and Incidents Due to Improvements in Aeronautical Data (NOTAMs) (29)	Display of NOTAMs enhances pilot situational awareness	Safety (User Benefit)	N	Not fully quantified but expected to be in group 1	FIS–B	Sec. 3.3
Enabling Benefits	Fewer CFIT Accidents (increased equipage) (30)	ADS–B In equipage for Broadcast Services will increase number of users with moving map displays and terrain awareness capabilities	Safety (User Benefit)	Y 2008 based on assumed equipage curves	2	Moving map display	Sec. 3.3

APPENDIX C—STANDARDS FOR AVIONICS FOR THE 1090 MHZ EXTENDED SQUITTER (1090 ES):STATUS, SURVEILLANCE SYSTEM IMPACTS, AND ATS PROVIDER IMPLEMENTATIONS AUGUST 2007

Introduction

RTCA and EUROCAE published in September 2000 RTCA DO–260/ED-102, Minimum Operational Performance Standards (MOPS) for ADS–B avionics supporting the transmission/reception of ADS–B messages using 1090 ES. The 1090 ES has been generally agreed to be the basis for international interoperability of ADS–B implementations for at least the next several decades.

After (1) several years of initial use of ADS–B OUT in Alaska with an ADS–B message set equivalent to that in DO–260; and (2) further development of ADS–B IN application requirements, RTCA published RTCA DO–260A in 2003 and has since published two changes to that document.

This paper summarizes and motivates key differences between DO–260 and DO–260A Change 2, reviews current implementations of 1090 ES on aircraft and their certification status, and discusses how 1090 ES standards are being invoked in ADS–B implementations around the world.

RTCA DO–260 and RTCA DO–260A Change 2

RTCA DO–260 was developed, jointly with EUROCAE, in 1998 to 2000 as the 1090 ES implementation of the ADS–B Minimum Aviation System Performance Standards (MASPS), RTCA DO–242 (February 1998). When DO–260 was published in 2000, RTCA, EUROCAE, and ICAO standards for 1090 ES were harmonized.

Two major developments shaped the introduction of an updated ADS–B MASPS (DO–242A) and, subsequently, an updated 1090 ES MOPS (DO–260A).

First, the U.S. began using ADS–B OUT in Alaska in 2001 and gained operational experience with ADS–B. That the UAT ADS–B datalink (as opposed to 1090 ES) was used in Alaska is unimportant to this discussion, since the messages to be transmitted to ATC by both 1090 ES and UAT in this time frame were similarly compliant with the ADS–B MASPS. Several years of actual use of ADS–B by ATC led to a number of changes to ADS–B avionics being requested by the U.S. operational community. Most of these changes were implemented in DO–242A and all of them were implemented in DO–260A. Two of the most important of these ATC-requested changes were the transmission in ADS–B messages of the Mode 3/A Code (“4096 code”) assigned to the aircraft by ATC and the ability for a controller to use ADS–B to “IDENT” an aircraft that had declared an emergency. The inclusion of the Mode 3/A code in ADS–B messages

was seen as being particularly important operationally with regard to aircraft identification/handoff and flight plan registration.

Second, further developments in ADS–B In application requirements led to several important changes to DO–260. First, enhanced reception techniques were developed to improve the air-to-air range of the 1090 ES subsystem. Further, additional ADS–B message parameters providing information on the quality of the transmitted position and velocity data were codified. Finally, a number of additional flags were added to 1090 ES ADS–B messages, further information was included in ADS–B messages to support applications on the airport surface, support was provided for the receipt of Traffic Information Service-Broadcast (TIS–B) messages, and corrections were made to several DO–260 algorithms.

The ADS–B data quality parameters added in DO–260A resulted in the single Navigation Uncertainty Category (NUC) parameter of DO–260 being superseded in DO–260A by five ADS–B information quality parameters, including Navigation Integrity Category for Position (NIC), Navigation Accuracy Category for Position (NACP), and Navigation Accuracy Category for Velocity (NACV). The differentiation of position integrity (e.g., GNSS Horizontal Protection Limit or Containment Radius from an RNP-certified Flight Management System) and 95 percent accuracy indicators has been found particularly important for airport surface applications of ADS–B as well as for operational approval of a number of ADS–B OUT applications. RTCA DO–260 initially permitted its NUC parameter to be calculated using as a source either an integrity parameter or a 95 percent accuracy indicator: Change 1 to DO–260 requires that an integrity parameter be used as the source for NUC.

The development of DO–260A was done by RTCA without a joint-document agreement with EUROCAE. After the publication of DO–260A in 2003, ICAO standards for 1090 ES were updated to permit either DO–260 or DO–260A implementations for transmission of ADS–B messages. ICAO standards for 1090 ES receivers require the improvements developed in DO–260A. Changes 1 and 2 to RTCA DO–260A were subsequently developed in light of further experience with 1090 ES (particularly in Australia), the need to support ADS–B Rebroadcast, and to clarify and harmonize terminology with other ADS–B standards. These changes have been harmonized as appropriate with ICAO. Table C–1 provides a more detailed comparison between DO–260 and DO–260A Change 2.

A Change 3 to DO–260A is currently in development by RTCA, with the primary purpose of ensuring, at the request of the European operational community, that the Mode 3/A code is transmitted in ADS–B messages on a worldwide basis. (Change 2 localizes transmission of the Mode 3/A code to the United States.)

Current 1090 ES Avionics and their Certification

As of September 2007, over 5000 aircraft are capable of transmitting 1090 ES ADS–B messages. Almost all of these aircraft transmit ADS–B messages that generally follow the requirements of RTCA DO–260. None of these DO–260 implementations have been TSO-certified to the requirements of DO–260. Initial RTCA DO–260A TSO certifications are in process or are complete for at least two avionics manufacturers.

Current DO–260-based implementations were generally done in the context of implementing 1090 ES in a Mode S transponder that was in the process of being upgraded to comply with European requirements for Elementary/Enhanced Surveillance. Certification of these implementations was completed in accordance with the TSO for Mode S transponders, which does not levy the requirements of DO–260 for 1090 ES functionality. Moreover, these implementations were generally complete before the FAA issued TSO C–166 to form a certification basis for 1090 ES avionics compliant with DO–260.

The FAA received no applicants for certification of DO–260 compliant avionics under TSO C–166 before the issuance of TSO C–166A in December 2006 for the certification of 1090 ES avionics to the requirements of DO–260A Change 2. The ability to certify DO–260 implementations has been withdrawn by the FAA in light of the anticipated use of DO–260A Change 2 in U.S. ADS–B rulemaking.

ATS Provider Implementations of 1090 ES-based ADS–B

From discussions within the ATMAC ADS–B Work Group and with the EUROCONTROL CASCADE Program Office, the United States and Europe plan to use DO–260A as the baseline for ADS–B rulemaking. The European operational community has documented several concerns with DO–260 implementations. These concerns have been addressed in DO–260A Change 2, with the exception of broadcasting the Mode 3/A code outside of the United States, which is the primary motivation for the upcoming Change 3 to DO–260A, as discussed above. Additionally, Europe is also implementing a Pioneer Program to obtain near-term benefit and operational experience using existing 1090 ES ADS–B avionics—this program will accept participants transmitting 1090 ES in general conformance with DO–260.

Australia's ADS–B implementation supports either DO–260 or DO–260A (with the provision that the NUC for DO–260 equipped aircraft be computed based upon an integrity parameter such as a GNSS Horizontal Protection Limit). Australia's ATC automation system does not require the transmission of the Mode 3/A code in ADS–B messages but rather relies upon alternative mechanisms for flight plan registration and aircraft identification/handoff. These alternative mechanisms will be recognized in an Appendix to upcoming RTCA/EUROCAE standards for the use of ADS–B for ATC surveillance in areas of radar coverage. These standards will specify the transmission of the Mode 3/A code in ADS–B messages as a means of mitigating a number of potential operational hazards. Canada is implementing ADS–B over the Hudson Bay and plans to support DO–260 and DO–260A implementations of 1090 ES.

The Australia ADS–B and EUROCONTROL Pioneer Programs have instituted checking of the ADS–B installations of DO–260-based participating aircraft to ensure sufficient compliance with the requirements of DO–260. Australia's checking is expected to cease once recent rulemaking which mandates the use of GNSS Horizontal Protection Limit in calculating the DO–260 NUC ADS–B message parameter has been in effect for a suitable period of time.

Table C–1. Comparison of DO–260 and DO–260A Change 2

Output Capabilities	**Receiving**	
	DO–260	**DO–260A Change 2**
ADS–B MASPS Version	DO-242	DO-242A
Technical Standard Order (TSO)	TSO-C166	TSO-C166a
Position, Velocity, Identification Messages	YES	YES
Emergency/Priority Status Messages	YES	YES
MOPS Version Number	Not identified	YES
NUC ADS–B Quality Parameter	Installation ambiguity: Corrected in Change 1 to require use of HPL	
NIC, NIC_{BARO},NAC_P, NAC_V, and System Implementation Level (SIL) SIL ADS–B Message Quality Parameters	NO	YES
Enhanced Reception Techniques	NO	YES: Only applies to Receivers
Air/Ground Determination/Validation	Errors, unless updates in TSO-C166 or DO–260 Change 1 are followed	YES
Transmission of Mode 3/A ("4096") Code in ADS–B Message Set	Optional in DO–260 Change 1	YES-Required
ADS–B Rebroadcast	NO	YES: Only applies to receivers
Reasonableness Tests on Compact Position Reporting (CPR) of Latitude and Longitude	NO	YES: Only applies to receivers
TCAS Availability Flag	NO	YES
TCAS RA Active Flag	NO	YES
CDTI Availability Indicator	NO	YES
ARV Report Capability Flag	NO	YES
Target State Capability Flag	NO	YES
Trajectory Change Capability Flag	NO	YES
IDENT Active Flag	NO	YES
Receiving ATC Services Flag	NO	YES
A/V Length/Width Code	NO	YES

APPENDIX D—STANDARDS FOR AVIONICS FOR THE UNIVERSAL ACCESS TRANSCEIVER (UAT): STATUS, SURVEILLANCE SYSTEM IMPACTS, AND ATS PROVIDER IMPLEMENTATION SEPTEMBER 2007

Introduction

The UAT concept was developed in the mid-1990's at the MITRE Corporation under Independent Research and Development (IR&D) funding. The technology was designed to support ADS–B and broadcast uplink services such as Flight Information Service-Broadcast and Traffic Information Service-Broadcast. Initially used operationally in a "pre-MOPS" form in Alaska in 2001, UAT avionics have been standardized by both RTCA and ICAO. UAT is expected, in accordance with the July 2002 FAA ADS–B Link Decision, to be one of two ADS–B datalinks implemented in the United States, particularly for general aviation aircraft.

This paper summarizes UAT standards, reviews current implementations of UAT on aircraft and their certification status, and discusses current and planned UAT implementation.

UAT Standards

UAT prototype development at the MITRE Corporation was followed by the development of "pre-MOPS" UAT avionics and ground stations for initial operational use in the FAA Capstone Program in Alaska, beginning in 2001. The "pre-MOPS" units provided an ADS–B message set in general compliance with that specified in the initial ADS–B Minimum Aviation System Performance Standards (MASPS), RTCA DO–242, February 1998. Additionally, "pre-MOPS" UAT avionics provided for uplink of situational awareness information from UAT Ground Broadcast Terminals (GBTs) procured and installed by the FAA.

Initial deployment of the "pre-MOPS" UAT units was planned to be followed by a retrofit of UAT avionics and GBTs to be in compliance with/consistent with an eventual UAT Minimum Operational Performance Standard (MOPS), to be finalized after several years of operational experience with ADS–B had been achieved.

Three major developments shaped the development of UAT standards in 2001 through 2004.

First, as discussed above, the United States began using ADS–B OUT in Alaska in 2001 and gained operational experience with ADS–B. Several years of actual use of ADS–B by ATC led to a number of changes to ADS–B avionics being requested by the U.S. operational community. The changes recommended by ATC before mid-2002 were implemented in an updated ADS–B MASPS, RTCA DO–242A (June 2002) and the initial DO–242A-compliant UAT MOPS, RTCA DO–282 (August 2002). All of the

remaining ATC-recommended changes were implemented in DO–282A (July 2004). Two of the most important of these ATC-requested changes were the transmission in ADS–B messages of the Mode 3/A Code ("4096 code") assigned to the aircraft by ATC and the ability for a controller to use ADS–B to "IDENT" an aircraft that had declared an emergency. The inclusion of the Mode 3/A code in ADS–B messages was seen as being particularly important operationally with regard to aircraft identification/handoff and flight plan registration.

Second, further developments in ADS–B IN application requirements led to several important changes to DO–242 and were reflected in DO–242A and DO–282. Additional ADS–B message parameters providing information on the quality of the transmitted position and velocity data were codified. Further information was included in ADS–B messages to support applications on the airport surface, and several new status flags were added to the ADS–B message set.

Third, the UAT system went through ICAO standardization. Several changes resulting from UAT SARPs and ICAO Manual development were reflected in DO–282A. UAT SARPs have been approved for incorporation into Annex 10 with an effective date of November 2007. The UAT frequency of 978 MHz has achieved worldwide spectrum approvals for ADS–B transmissions from aircraft, and radio regulation changes to confirm spectrum approval for UAT uplinks on a worldwide basis are in process and are supported by ICAO.

Change 1 to DO–282A was issued in December 2006 to clarify the definitions of several ADS–B message quality parameters, harmonizing those definitions across all pertinent RTCA ADS–B standards.

Current UAT Avionics and their Certification

As of September 2007, over 700 aircraft are capable of transmitting UAT ADS–B messages. Approximately 550 of these aircraft operate in the United States. All of these aircraft have TSO-certified UAT avionics to a certification baseline of TSO C–154 (November 2002) plus "Capstone extensions" which effectively provide compliance with TSO C-154A (June 2005). TSO C–154B has been subsequently issued by the FAA in December 2006 to reflect the approval of Change 1 to DO—282A and to provide a certification baseline for an optional diplexer which permits UAT avionics to share Mode A/C/S transponder antennas.

Presently there is one manufacturer of certified UAT avionics. All fielded UAT avionics can readily be updated to compliance with TSO C–154B via a field service bulletin with no hardware changes.

ATS Provider Implementation of UAT

The FAA continues to provide UAT-based ADS–B separation services in major portions of Alaska. A number of additional UAT GBTs are operating as of September 2007 elsewhere in the United States, providing uplink services. The FAA intends to implement nationwide UAT coverage in the 2013 time frame.

Two hundred sets of UAT avionics have been contracted for by the Civil Aviation Flight University of China. Five UAT GBTs have been installed, with two additional GBTs planned. The Civil Aviation Authority of China is reported to be evaluating UAT for broader deployment as part of a new low altitude surveillance architecture.