APPENDIX

AUTOMATIC DEPENDENT SURVEILLANCE — BROADCAST (ADS-B) CONCEPT OF USE

TABLE OF CONTENTS

LIST OF ACRONYMS

ADS	automatic dependent surveillance
ADS-B	automatic dependent surveillance — broadcast
ADS-C	automatic dependent surveillance — contract
ADSP	ADS Panel (of ICAO)
AIS	aeronautical information services
APW	area proximity warning
ASAS	airborne separation assistance system
ASDE	airport surface detection equipment
ASM	airspace management
ATC	air traffic control
ATFM	air traffic flow management
ATM	air traffic management
ATMCP	Air Traffic Management Operational Concept Panel
CAP	controller access parameters
CDTI	cockpit display of traffic information
CNS	communications, navigation and surveillance
CPDLC	controller-pilot data link communications
DLIC	data link initiation capability
ELT	emergency locator transmitter
ETA	estimated time of arrival
FANS	future air navigation systems
F&CM	flow and capacity management
FIS-B	flight information service — broadcast
FMS	flight management system
GNSS	global navigation satellite system
GPW	ground proximity warning

HF	high frequency
HMI	human-machine interface
IAF	initial approach fix
ICAO	International Civil Aviation Organization
IFR	instrument flight rules
MSAW	minimum safe altitude warning
MTCD	medium term conflict detection
OPLINKP	Operational Data Link Panel
PSR	primary surveillance radar
SAR	search and rescue
SARPs	Standards and Recommended Practices
SMC	surface movement control
SSR	secondary surveillance radar
STCA	short term conflict alert
TIS-B	traffic information service — broadcast
VFR	visual flight rules
VMC	visual meteorological conditions

FOREWORD

This document presents the automatic dependent surveillance — broadcast (ADS-B) concept of use and therefore provides a description of the ADS-B system and its detailed role as an application enabling important changes to the future communications, navigation, and surveillance/air traffic management (CNS/ATM) system.

The description of the role of ADS-B will take into account the heterogeneous and evolving situation with respect to the available ground infrastructure, the aircraft capabilities, the airspace regimes, etc. This considerably affects the transition from the current to the future system.

The ADS-B concept of use is illustrated by a number of typical operational scenarios. These scenarios describe the various possible flight phases in a gate-to-gate environment, including airport surveillance. They provide the description of the interactions between the airborne, ground, human and automated elements of the system. Furthermore, the scenarios describe a number of the supported applications and the role of ADS-B as an enabler in a mixed surveillance environment. It should be noted that these chosen scenarios are intended as illustrative examples and do not include all the possible uses of ADS-B.

The ADS-B concept of use describes the role of ADS-B in supporting a future surveillance service. This goes far beyond the current classical ground-based surveillance service and is extended to include air to air use as well as the capability to provide additional data such as state vector and trajectory intent. The levels of surveillance which should be supported by ADS-B are basic surveillance, enhanced surveillance (using state vector) and intent-based surveillance (using trajectory intent) on the ground and in the air, as applicable.

It is noted that the ADS-B role, as detailed in the ADS-B concept of use, is complementary to other enablers such as secondary surveillance radar (SSR), SSR Mode S or automatic dependent surveillance — contract (ADS-C).

An analysis of the impact on various levels (operational, organizational, etc.), stemming from the introduction of the ADS-B system, is also presented in the document.

GLOSSARY OF TERMS

Airborne separation assistance system (ASAS) (under development) — An aircraft system based on airborne surveillance that provides assistance to the flight crew supporting the separation of their aircraft from other aircraft.

ADS contract. A means by which the terms of an ADS agreement will be exchanged between the ground system and the aircraft, specifying under what conditions ADS reports would be initiated, and what data would be contained in the reports.

Note.— The term "ADS contract" is a generic term meaning variously, ADS event contract, ADS demand contract, ADS periodic contract or an emergency mode. Ground forwarding of ADS reports may be implemented between ground systems.

Controller-pilot data link communications (CPDLC) — A data link application that provides a means of communication between controller and pilot, using data link for ATC communications.

Automatic dependent surveillance — broadcast (ADS-B) (under development) — A surveillance technique, which provides the ability for aircraft, airport vehicles and other objects to automatically transmit and/or receive data such as identification, four-dimensional position and additional data as appropriate in a broadcast mode over a data link. For aircraft and airport vehicles the data is derived from on-board navigation and position-fixing systems.

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Chapter 1. Introduction

1.1 Purpose and scope

1.1.1 The purpose of this document is to develop a concept of use for ADS-B. This technology is being developed, tested and is also used operationally in several areas of the world. However, international standards to incorporate ADS-B into the future global CNS/ATM system have not yet been developed. This document is the first step in this ICAO process.

1.1.2 The task assigned by the Air Navigation Commission to the OPLINK Panel was to "develop a concept of use and operational requirements for the application of ADS-broadcast." The scope of this document is restricted to the concept of use portion of that task. It does not contain specific operational requirements, although, its contents will lead naturally to the development of operational requirements for ADS-B.

1.2 Background

1.2.1 In the early 1990's, ICAO approved the concept of Future Air Navigation System (FANS) based on satellite technology, which later evolved into CNS/ATM. The traditional ATC surveillance system has limitations that constrained its capabilities in the current and future ATM environment. These limitations include the following:

a) limited or no conventional surveillance, including non-equipped continental areas, low altitudes, non-continental areas, surface movements, silence cones, blind areas, antenna screening, etc. In some cases (e.g. oceanic areas), this will result in the need for procedural control, using voice position reports;

b) mechanical rotation of the classical radar antennas, leading to inefficient scanning periods and limitations to adaptation of the reporting rate to suit ATC needs. (*Note.— E-SCAN antennas may offer an alternative in this case*);

c) garbling, fruit and splitting;

d) unavailability of aircraft derived data, beyond the Mode A/C identification and altitude data;

e) non-homogeneous operation, caused by the current existence of a diversity of systems with different performance and capabilities;

f) in some regions the shortage of Mode A codes (only 4 096 available) requiring frequent changes of code during the flight which may also create identification ambiguities;

g) lack of capability to support future airborne situation awareness applications, because the corresponding surveillance data are not available to the aircrew; and

h) lack of capabilities to support airport surface surveillance applications.

1.2.2 Due to constraints like these and cost, the necessary levels of capacity, flexibility and efficiency required to meet the future predicted air traffic growth, will not be met by the existing surveillance systems. Various surveillance technologies have been developed to address these limitations. These include Mode S secondary surveillance radar (SSR) with enhanced services, ADS-contract (ADS-C), and ADS-broadcast (ADS-B).

1.3 Concept overview

1.3.1 The first meeting of the ICAO Air Traffic Management Concept Panel (ATMCP/1) defined the air traffic management operational concept as a description of the services that will be required to operate the global air traffic system up to and beyond 2025. The operational concept addresses what is needed to increase user flexibility and maximize operating efficiencies in order to increase system capacity and improve safety levels in the future air traffic management system. The extensive work which has taken place or is currently underway has convinced ICAO that ADS-B functionality has the potential to be one of the key elements necessary in achieving these operational concept goals.

1.3.2 The ADS-B concept of use describes the role of ADS-B as one of the enablers of this future global CNS/ATM system. The description of ADS-B in this context is addressed in Chapter 2. It includes functionality, the role of ADS-B in ATM, operational improvements, and typical applications. The applications are illustrated by use of various operational scenarios in Chapter 3. These scenarios include all phases of flight in a gate-to-gate environment, contain certain aspects of the air-air, air-ground, ground-air and ground-ground interactions and the human and automated elements of the system. Finally, Chapter 4 addresses important issues for consideration, while Chapter 5 addresses implementation by States.

1.3.3 During the development of the ADS-B concept of use, considerations were made for other co-existing enablers (ADS-C, TIS-B[1], CPDLC, etc.) in order to identify their complementary roles in the various operational scenarios.

1.3.4 The overall objective is to develop a common understanding of terms, definitions and possible uses of ADS-B in the future environment. A secondary objective is to do this early enough in the various stages of development to influence and facilitate that development.

[1] TIS-B is a service which enables position and other data for non-ADS-B equipped aircraft to be broadcast via ADS-B. It is seen as an important means of supporting ADS-B services during the transition period when it is not feasible or cost-effective to equip all aircraft with ADS-B.

Chapter 2. Concept for Surveillance Using ADS-B

2.1 General

2.1.1 Surveillance is used in civil aviation for a variety of purposes, including ATM, weather reporting, terrain avoidance, and search and rescue. A variety of technologies are used to provide surveillance data for ATM, but only two are fully independent of the targets under surveillance (which may include aircraft, vehicles and a variety of other "traffic"). These independent techniques are visual acquisition and primary surveillance radar (PSR).

2.1.2 All other techniques, including SSR, ADS-C and ADS-B and CPDLC position reports, require varying degrees of cooperation from the target and the carriage of serviceable equipment to facilitate the exchange of surveillance data. For example, both voice and CPDLC position reporting mandate the use of specific communication equipment and are "dependent" on the 4-D navigation data determined by the avionics.

2.1.3 SSR Mode S augments the Mode A/C information (identification and altitude) by including an expanded aircraft address and a two-way data link capability. Mode S also enabled the evolution of the airborne collision avoidance system (ACAS).

2.1.4 As the name implies, ADS can be considered to be a hybrid of "traditional" surveillance techniques, combining a dependence on position reports with the automation that is typical of SSR replies. ADS-C reports are made in accordance with an agreed contract between ATS and the aircraft. Similar to radar, these reports are not received by other aircraft and the reporting intervals are relatively long. Conversely, ADS-B reports are broadcast at more frequent intervals and, in addition to "radar-like" ground surveillance, can provide an airborne surveillance capability. One of the major advantages of ADS-B, ADS-C and Mode S is the ability to convey state vector and intent data.

Note.— Enhanced Mode S can be used to convey intent information to the ground system but not to other aircraft as can be done with ADS-B.

2.2 ADS-B functionality

2.2.1 ADS-B is a surveillance application that allows the periodic transmission of parameters, such as identification, position and position integrity, via a broadcast-mode data link. Any user, either airborne or ground-based, within range of this broadcast may choose to receive, process and display this information. ADS-B information is broadcast without any knowledge of which users may be receiving it and without the expectation of an acknowledgement or reply. In addition to aircraft and vehicles, ADS-B may be used to identify hazards, such as obstacles, skydivers, etc.

2.2.2 ADS-B is automatic in the sense that no flight crew or controller action is required for the information to be transmitted. It is dependent surveillance in the sense that the surveillance-type information so obtained depends on the suitable navigation and broadcast capability in the source emitter.

2.2.3 An ADS-B system consists of the following components (see Figure 1): a transmitting subsystem that includes message generation and transmission functions at the source aircraft/vehicle/obstacle, the data link broadcast medium, and a receiving subsystem that includes message reception and report assembly functions at the receiving aircraft/vehicle or ground system. It should be noted that some ADS-B users may be able to transmit but not receive; some ground-based users may be able to receive but not transmit.

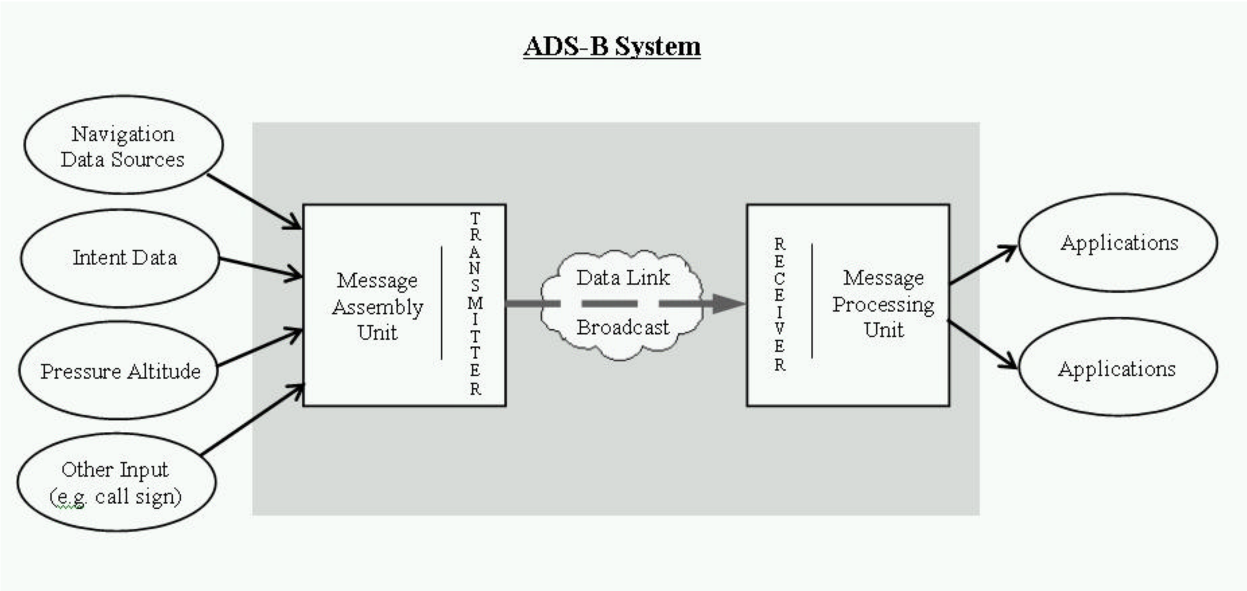

Figure 1. Functional relationship between ADS-B and surveillance applications

2.2.4 The source of the transmitted information as well as the user applications are not considered to be part of the ADS-B system, but their performance needs to be included in defining overall ADS-B system performance.

2.3 The role of ADS-B in air traffic management (ATM)

2.3.1 ATM has been described in the ATM operational concept delivered at ATMCP/1 (Montreal, 18 to 28 March 2002) and presented to the Eleventh Air Navigation Conference (Montreal, 22 September to 3 October 2003) as the dynamic, integrated management of air traffic and airspace — in a safe, economical and efficient manner through the provision of facilities and seamless services in collaboration with all parties. The operational concept also describes a system that provides ATM through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground and/or space-based communications, navigation and surveillance.

2.3.2 This operational concept identifies seven interdependent components of the future ATM system. They comprise:

a) airspace organization and management;

b) aerodrome operations;

c) demand and capacity balancing;

d) traffic synchronization;

e) conflict management;

f) airspace user operations; and

g) ATM service delivery management.

2.3.3 Inherent to this concept are the characteristics of scalability and adaptability, according to the specific needs and operational environment of each State and region. ADS-B shares these characteristics in that specific applications of the technology may be implemented according to need.

2.3.4 ADS-B is an enabling technology that will enhance the provision of ATM in a variety of applications, from "radar-like" air traffic control purposes to enhanced situational awareness on the flight deck. ADS-B also enables the exchange of information related to meteorology, navigation, surveillance and other operational information in an integrated manner.

2.3.5 ADS-B applications will have a direct effect upon aerodrome operations, traffic synchronization, airspace user operations, and conflict management. These effects will then influence the nature of airspace organization and management, demand and capacity balancing, and ATM service delivery management.

2.3.6 In summary, it should be emphasized that ADS-B could provide surveillance coverage from "gate-to-gate", i.e. from the aircraft's first movement on the ground through all phases of flight and back onto the ground until engine shutdown at the destination.

2.3.7 **ATM improvements and benefits**

2.3.7.1 ADS-B and its applications are expected to provide important operational improvements by addressing some of the limitations of the current surveillance system, optimize the controller/flight crew workload and provide benefits in the areas of safety, capacity, efficiency and environmental impact, thus contributing to the overall CNS/ATM objectives. These benefits include the following:

a) extension of the surveillance coverage for low altitudes (below existing radar coverage) and areas where no radar coverage currently exists, leading to more efficient use of airspace;

b) enabling a seamless "gate-to-gate" surveillance service, not only to international civil aviation but should include general aviation and military operations;

c) use of aircraft-derived data in a variety of systems e.g. ground-based conflict alert, minimum safe altitude warning, danger area proximity warning, automated support tools, surveillance data processing and distribution, as well as enabling access by the controller to state vector parameters, (sometimes referred to as *controller access parameters (CAP)*);

d) airborne surveillance capability that can improve flight crew situational awareness and enable the introduction of airborne separation assistance systems;

e) increasing airport safety and capacity, especially under low visibility conditions, by providing airport surface surveillance and, at the same time, protecting against runway incursions. ADS-B will enable the identification and monitoring of relevant airport vehicles as well as aircraft;

f) changes to airspace sectorization and route structure resulting from improved surveillance should provide more efficient routing;

g) reduced infrastructure costs. Especially, in airspace in which all aircraft are ADS-B equipped, it may be possible to decommission some radar equipment. Where multiple surveillance coverage is presently required, optimization of the surveillance infrastructure should be achieved by the implementation of the most efficient mix of radar sensors and ADS-B. Consequently, ADS-B coverage could reduce the required number of radar sensors; and

h) cost savings achieved from the implementation of an ADS-B based surveillance system rather than the life cycle expenses associated with installing, maintaining, and extending existing radar-based surveillance systems.

2.3.7.2 It is recognized that other technologies e.g. Mode S enhanced surveillance, ADS-C and ground-based multilateration systems can also deliver some of the above benefits.

2.4 ADS-B applications

2.4.1 Overview

2.4.1.1 In an effort to provide the operational improvements identified above, a number of applications are being investigated and in some cases are already being implemented. These applications are not intended to be all inclusive; however they do cover a major portion of the applications that are being considered in the short to medium term. Recognizing that each service is at a different stage in its development only some of the applications described in Table 1 below are contained in the scenarios (paragraph 3.2 refers).

Category	Applications
Ground-based surveillance applications	a) ATC surveillance in airspace with radar coverage; b) ATC surveillance in airspace without radar coverage;

Category	Applications
	c) airport surface surveillance; and d) aircraft derived data for ground-based ATM tools.
Aircraft-based surveillance applications	a) situational awareness 1) enhanced traffic situational awareness on the airport surface 2) enhanced traffic situational awareness during flight operations 3) enhanced visual acquisition 4) enhanced successive visual approaches b) Airborne spacing and separation 1) Enhanced sequencing and merging operations 2) In-trail procedure 3) enhanced crossing and passing operations
Other applications	Ramp control/gate management Noise monitoring Flight following (for AOC, flying schools) Remote airport charges issuing Enhanced situational awareness of obstacles SAR, ELT, emergency response

Table 1. Potential ADS-B applications being considered as candidates for future implementation.

2.4.2 **Ground-based surveillance applications**

2.4.2.1 ATC surveillance for airspace with radar coverage

2.4.2.1.1 The improved accuracy and higher update rates of the ADS-B reports, in combination with other capabilities, may enhance surveillance services and allow the application of reduced separation standards.

2.4.2.1.2 This application will enhance ATC surveillance currently provided by radar, in en-route airspace. An example is the case of surveillance in areas where single radar coverage is provided. Where SSR is used, ADS-B can provide a backup system and supplement radar position updates through additional position reports. Where PSR is used ADS-B can provide additional data, such as aircraft identification and barometric altitude.

2.4.2.1.3 In these environments ADS-B can also provide additional aircraft-derived data, which can enhance the surveillance data processing (e.g. intent data, state vector).

2.4.2.2 ATC surveillance in airspace without radar coverage

2.4.2.2.1 This application will provide ATC surveillance in non-radar areas, (e.g. remote continental areas, offshore operation areas or certain oceanic areas). The purpose is to enhance traffic information and separation services.

2.4.2.2.2 Even where ADS-C is used ADS-B can provide more frequent position updates facilitating a possible reduction in separation minima.

2.4.2.3 Airport surface surveillance

2.4.2.3.1 This application will provide a new source of airport surveillance information for safer and more efficient ground movement management at airports. Relevant airport ground vehicles can also be equipped with ADS-B and displayed, together with aircraft, on a situation display.

2.4.2.3.2 ADS-B will support ground conflict detection by providing frequent updates to aircraft and vehicle positions, enabling the monitoring of aircraft and vehicles to protect against runway incursions.

2.4.2.4 Aircraft derived data for ground-based ATM tools

2.4.2.4.1 This application will provide additional aircraft-derived data such as state vector and intent data via ADS-B to be used by the ATC ground system for developing or enhancing automated support tools such as:

a) conformance monitoring;

b) conflict prediction;

c) conflict detection;

d) minimum safe altitude warning;

e) danger area proximity warning; and

f) traffic sequencing.

2.4.3 **Aircraft-based surveillance applications**

2.4.3.1 Situational awareness

2.4.3.1.1 Situational awareness applications are aimed at enhancing the flight crews' knowledge of the surrounding traffic situation, both in the air and on the airport surface, and thus improving the flight crew's decision process for the safe and efficient management of their flight. No changes in separation tasks or responsibility are envisaged through the implementation of these applications.

2.4.3.1.2 Appropriate training will be necessary to prevent inappropriate use of enhanced traffic situational awareness such as inadequate questioning, or unexpected manoeuvres, which could be disruptive to ATC.

2.4.3.1.3 Enhanced traffic situational awareness on the airport surface

2.4.3.1.3.1 This application provides the flight crews with an enhanced traffic situational awareness on the airport surface for both taxi and runway operations, at all times and particularly in low visibility conditions. The objectives are to improve safety on pushback, at taxiway crossings and before entering the runway.

2.4.3.1.4 Enhanced traffic situational awareness during flight operations

2.4.3.1.4.1 This application provides the flight crews with an enhanced traffic situational awareness during flight operations, irrespective of visual conditions. Additional data are provided to flight crews to supplement traffic information provided either by controllers or other flight crews. This could ease the aircrew comprehension of the ATC instructions, potentially decrease voice communications and, where CPDLC and/or high frequency (HF) is implemented, compensate for the loss of party line. Consequently, the objectives should result in improvements to safety and the efficiency of air traffic services.

2.4.3.1.5 Enhanced visual acquisition

2.4.3.1.5.1 This application is an aid for the flight crews to enhance their visual acquisition capability, particularly with respect to "see and avoid" procedures as they apply to VFR/VFR and IFR/VFR operations in airspace classes D, E and G. Indeed, we have reached the limits of the conventional "see and avoid" principle because of the increasing speed of aircraft, the poor external visibility in modern cockpits and pilots' workload in some phases of flight.

2.4.3.1.6 Enhanced successive visual approaches

2.4.3.1.6.1 This application is an aid for the flight crews to perform successive visual approaches when they are responsible for maintaining visual separation from the aircraft they are following. The objectives are to perform successive visual approach procedures on a more regular basis to enhance the runway throughput, and to conduct safer operations.

2.4.3.2 Airborne spacing and separation applications

2.4.3.2.1 Enhanced sequencing and merging operations

2.4.3.2.1.1 The objective is to redistribute tasks between the controllers and the flight crews related to sequencing (e.g. in-trail following) and merging of traffic. The controllers will be provided with new procedures that would enable a flight crew to establish and maintain a given time or distance from a designated aircraft. The flight crews will perform these new tasks using an advanced human-machine interface. The expected benefits are enhanced controller task management, and a more consistent adherence to required spacing values.

2.4.3.2.2 In-trail procedure in oceanic airspace

2.4.3.2.2.1 The in-trail procedure in non-radar oceanic airspace would allow in-trail ADS-B equipped aircraft, which may not be longitudinally separated from each other by the existing distance-based separation minimum, to climb or descend through each other's flight levels. The objective is to improve the utilization of oceanic airspace by facilitating a higher rate of flight level changes than is currently provided, yielding better flight efficiency (e.g. fuel savings, avoiding turbulent flight levels).

2.4.3.2.3 Enhanced crossing and passing operations

2.4.3.2.3.1 The objective is to redistribute tasks between the controllers and the flight crews related to crossing and passing designated traffic. The controllers will be provided with new procedures that would enable a flight crew to manoeuver, based on controller instructions, so as to achieve a given separation value from a designated aircraft. The flight crews will perform these new tasks using an advanced human-machine interface. The main expected benefit is increased controller availability through the redistribution of tasks.

2.4.4 **Other applications**

2.4.4.1 Other ADS-B applications being considered in aviation forums, panels and industry groups to varying degrees include:

a) monitoring of aircraft to ensure that flight paths are complied with in noise sensitive environments (e.g. curfew);

b) facilitating the collection of data for the issuing of aviation charges in remote areas where this may be applicable;

c) allowing flying schools to monitor the progress of inexperienced pilots — e.g. solo navigation flights;

d) enabling the display of temporary obstacles — e.g. a construction crane equipped with an ADS-B emitter; and

e) Search and rescue (SAR), emergency locator transmitter (ELT), emergency response. Avionics could be specifically designed to broadcast appropriate ADS-B messages upon activation after a crash. Digitally-coded ADS-B messages could be broadcast on the media that supports normal ADS-B message traffic.

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Chapter 3. Operational Scenarios

3.1 Description of ADS-B and its environment

3.1.1 The operational environments in which ADS-B will be used may include any of the following characteristics:

a) varying infrastructure capabilities, ranging from the lack of any surveillance means up to the co-existence of ADS-B with different types of conventional data sources such as primary and secondary surveillance radars. It is expected that a variety of other technologies such as ADS-C and CPDLC will play a complementary role in the provision of ATC service;

b) mixed aircraft equipage levels, at least in the transition period;

c) varying airspace types (e.g. different traffic density levels);

d) varying flight phases, e.g. airport surface, TMA, en-route, non-continental, continental; and

e) varying types of application/services in different environments.

3.1.2 The broadcast mode in ADS-B provides surveillance data to all who can receive the transmission. This includes airborne surveillance functions as well as ground surveillance functions. Depending on the type of airspace, phase of flight and operational conditions, various ADS-B report rates can be applied in order to fulfil the update rates required by the different applications.

3.2 Scenario descriptions

3.2.1 The following scenarios describe the flight of XYZ123, a 50-seat commuter aircraft operating a scheduled service from a capital city to a small regional centre. Whilst the names, call signs and flight numbers are fictitious, the scenarios are intended to describe the near-term utility of ADS-B technology in a variety of applications.

Note.— The intent of these scenarios is to demonstrate possible functions of ADS-B, rather than to limit what ADS-B could possibly be used for.

3.2.2 Surface operations scenario

3.2.2.1 XYZ123 is parked at the terminal gate, awaiting the arrival of connecting passengers from ABC022. The airport is covered by low cloud and ABC022 is established on the instrument approach in heavy rain. On his cockpit display of traffic information (CDTI), the Captain of XYZ123 observes ABC022 conduct a missed approach and contacts the company dispatcher, who has also been following the progress of ABC022 on a workstation display. They agree that the passengers will not make the connection and the doors are closed.

3.2.2.2 The crew of XYZ123 check the cockpit display, wait for an aircraft to move clear and request a push-back clearance. With heavy rain obscuring the view of the manoeuvring area, the surface movement controller checks the display for vehicles or aircraft in the vicinity and approves the push-back. Once the tug disconnects, the crew of XYZ123 again check their CDTI for proximate traffic and complete their pre-taxi checks.

3.2.2.3 The rain is still falling heavily when the crew of XYZ123 request taxi clearance on schedule. The tower is quite busy with a number of arrivals conducting missed approaches and the surface movement controller workload is high with limited visibility, crowded gates and the morning peak just beginning. The controller notes the data tag of XYZ123 identifies it as being CDTI-equipped, and issues a clearance to follow HIPPO35 via taxiway B to holding position E for Runway 27.

3.2.2.4 The crew of XYZ123 note the position of HIPPO35 on their CDTI and follow at a closer distance than would normally (safely) be permitted due to the low visibility. At taxiway E the commuter slows and turns towards the Runway before stopping at the holding point, while HIPPO35 continues slowly east to hold for a full-length departure. The crew call ready on the tower frequency.

3.2.2.5 Both the crew of XYZ123 and the aerodrome controller observe that the upwind threshold of Runway 27 is still occupied by CAR004, an airport safety officer making a runway inspection. XYZ123 is instructed to line up and hold, and prior to entering the runway the crew checks the approach path with their CDTI, noticing that DEF987 is established on final at 10 miles and ABC022 established at 14 miles.

3.2.2.6 ABC022 is executing an airborne spacing procedure, approximately 4 NM behind DEF987 after having been vectored into that position by the approach controller. Through CDTI display of intent and actual data from DEF987, ABC022 is able to maintain a steady 85-second spacing behind the preceding aircraft all the way down to the runway threshold.

Surface operations scenario			
Event	**Users**	**Applications**	**ATM functions**
Pre-pushback	Aircraft Dispatcher	Ramp control	Aerodrome operations Airspace user operations Conflict management Traffic synchronization
	XYZ123	Enhanced situational awareness	
Pushback and start	SMC	Principal ATC surveillance	
	XYZ123	Enhanced situational awareness	
Taxi	SMC	Principal ATC surveillance	Aerodrome operations

Surface operations scenario			
Event	**Users**	**Applications**	**ATM functions**
	XYZ123	Enhanced situational awareness Enhanced visual acquisition Surface navigation	Airspace user ops
Runway entry	Tower	Supplemental ATC surveillance	Conflict management
	XYZ123	Enhanced situational awareness	Traffic synchronization
	CAR004	Enhanced situational awareness	
Final approach	ABC022 DEF987	Airborne spacing Enhanced situational awareness Separation assistance	Conflict management Traffic synchronization

3.2.3 Busy terminal and busy en-route airspace scenario

3.2.3.1 XYZ123 is lined up, ready for an intersection departure on Runway 27, while the aerodrome safety officer is completing a runway inspection at the western end. Behind XYZ123, DEF and 987 and ABC022 are established on final for Runway 27 and HIPPO35 is holding at the holding position at the departure end. The use of ADS-B displays has enabled shared situational awareness of traffic between ATC, the safety officer and two of the flight crews. HIPPO35 is not CDTI equipped and, in the heavy rain, its crew is barely able to see the commuter on the runway. Within a minute the safety officer is clear of the runway and once the controller instructs the airport safety officer to remain clear, he then clears XYZ123 for take-off. The crew of XYZ123 conducts a visual scan of the runway, crosschecks their CDTI and advances the power levers. Once established in the climb, the crew of XYZ123 calls the departure controller and is cleared to climb to FL150, an intermediate level, due to an opposite direction medical aircraft receiving priority and maintaining FL160. The CDTI shows the crew a steady stream of inbound aircraft tracking via the standard arrival routes to the north and south-east, and they are able to quickly locate the medical aircraft tracking from the north-east, 65 miles ahead. The crew of XYZ123 determines that there is no advantage to maintaining the present high rate of climb and requests an increase in speed to minimize the time to passing.

3.2.3.2 The departure controller has the two aircraft identified on radar, but is using the ADS-B intent data being broadcast by both aircraft to supplement the radar surveillance. With this enhanced information the departure controller reclears XYZ123 direct to its destination, watches the intent data change as the crew updates their flight management system, and then transfers the commuter to the en-route controller responsible for the next sector.

3.2.3.3 Through the medium-term conflict detection tool the en-route controller observes that the new clearance will result in the two aircraft passing with a lateral separation of 3.5 miles, approximately 42 miles from the radar head. As the tool is augmented by the availability of intent and actual data through ADS-B it is able to predict the passing distance with higher accuracy. At this range a 5 mile radar separation standard is normally required, but because both aircraft are ADS-B equipped, the surveillance performance, including a faster update rate means that a reduced separation minimum can be applied. When the crew of XYZ123 contacts the air traffic control centre, the controller is able to remove the restriction and re-clears the commuter to the planned FL250.

3.2.3.4 During the climb, the crew have also been monitoring an unidentified target uplinked by TIS-B that appears intermittently on the CDTI, slightly to the left of track and tracking slowly westwards. The symbol indicates that it is based on a primary radar return, suggesting to the crew that it is probably a recreational aircraft operating well below the control area. Nevertheless, the crew performs a visual scan in the direction indicated on the CDTI.

Busy terminal & busy en-route airspace scenario			
Event	**Users**	**Applications**	**ATM functions**
Take-off	Tower	Supplemental ATC surveillance	Airspace user ops Conflict management Traffic synchronization
	XYZ123	Enhanced situational awareness	
Departure	ACC	Supplemental ATC surveillance ATM tools	
	XYZ123	Enhanced situational awareness	
Climb	ACC	Supplemental ATC surveillance ATM tools	
	XYZ123	Enhanced situational awareness	

3.2.4 En-route low density airspace scenario

3.2.4.1 XYZ123 is cruising at FL250 and the crew has been tracking direct to their destination since shortly after departure. The aircraft is now in relatively low density airspace and passed out of radar coverage shortly after top of climb. Nevertheless, the aircraft is still identified on the en-route controller's situation display by virtue of its ADS-B data link capability. The destination is just over forty minutes ahead.

3.2.4.2 The crew has been monitoring the VHF emergency frequency and suddenly detects an emergency locator beacon transmission. The crew reports the beacon to ATC and continues to monitor the signal, which grows progressively weaker. At the request of ATC, the crew scans their CDTI for any stationary ADS-B targets and reports the location and call sign of an aircraft apparently on the ground, 96 miles to their west. The ELT signal fades after a few minutes as XYZ123 continues north-east.

3.2.4.3 The crew checks the destination weather and prepares for descent. The CDTI shows a company aircraft, XYZ205, inbound to the same destination from the south-east with a similar distance to run. Company Operations has also been monitoring both aircraft and has arranged for reserve staff to handle

XYZ205 at a stand-off parking position. Operations has also noted that XYZ123 is currently 2 minutes ahead of schedule.

3.2.4.4 Eighty-five miles from the destination the crew receives clearance for descent to 4 000 feet and information on crossing VFR traffic in Class E airspace 30 miles ahead at 8 500 feet. Using the CDTI the crew locates the traffic and confirm that the selected descent profile should ensure adequate separation.

3.2.4.5 The en-route controller also notes that the two aircraft will pass safely and clears the commuter direct to the initial approach fix for Runway 36. The en-route controller then advises the crew of XYZ123 that they will be sequenced to follow XYZ205, the company traffic.

3.2.4.6 A short time after updating the flight plan data with the direct track to the initial approach fix (IAF), the en-route controller receives an alert that the ADS-B intent data received from the aircraft's flight management system (FMS) does not match flight plan data. The graphical display of the erroneous intent data reveals that the aircraft is still broadcasting its intent to track directly to the aerodrome.

3.2.4.7 Before the controller can initiate a transmission querying the route data, the crew amend the route in the FMS to reflect the new clearance and the controller's alert is cancelled.

3.2.4.8 Some minutes later the controller notes that XYZ123 has reduced speed and will be adequately separated from the preceding traffic at the fix. Just before the airspace boundary, the en-route controller transfers XYZ123 to the tower/approach controller.

En-route low density airspace scenario			
Event	Users	Applications	ATM functions
Cruise	ACC	Principal ATC surveillance	Airspace user ops Conflict management Traffic synchronization
	XYZ123	Enhanced situational awareness	
	AOC	Gate management	
ELT report	ACC	SAR alerting and reporting	
Descent	ACC	Principal ATC surveillance ATM tools	
	XYZ123	Enhanced situational awareness Separation assistance	

3.2.5 **Non-radar terminal airspace scenario**

3.2.5.1 At 30 NM from destination XYZ123 contacts the tower/approach controller. As expected, no further descent is assigned at this stage due to obstacle and terrain clearance considerations. The CDTI is displaying a number of temporary obstacles associated with building construction that have been equipped with ADS-B emitters. The pilots are also aware that there is a current NOTAM advising that the ADS-B emitter on one of the temporary obstacles is out of service.

3.2.5.2 Weather conditions are improving with each minute, and at 20 NM, XYZ123 is established in visual meteorological conditions (VMC) and requests a visual approach. They are informed that they will be number 2 in sequence behind XYZ205 and are instructed to report sighting the company traffic. With the aid of the CDTI, the crew is quickly able to make visual contact with XYZ205 and replies that they have the company traffic in sight at their 2 o'clock at 6 miles. They are instructed to follow XYZ205 "number 2" for a visual approach and because they had previously been advised to expect this and had already slowed down appropriately, no further speed adjustment is necessary.

3.2.5.3 At the same time the XYZ company ground service controller notes the earlier estimated time of arrival (ETA) and dispatches the required refuelling, catering and baggage handling section earlier than planned. This eliminates service delays at the parking area, reduces excessive fuel burn and reduces environmental impact.

3.2.5.4 Established on final, the crew notes that the speed of the preceding traffic has reduced significantly. To maintain spacing they also reduce speed, just as XYZ205 advises the tower/approach controller that they have encountered turbulence on final.

3.2.5.5 The aerodrome controller notes the reduced speed of both aircraft on the screen and contacts XYZ123 to ensure that they were aware of the turbulence report. This report is also input into the ATC host computer where it is transmitted via FIS-B to affected traffic.

3.2.5.6 The runway threshold is currently displaced due to works in progress. A number of targets can be seen on the CDTI, although on the current range the display is a little cluttered. A larger scale display is selected, and three service vehicles as well as an emergency vehicle can be seen operating in the work area.

3.2.5.7 XYZ205 lands and vacates the runway. The controller checks that the runway is clear visually, and also by reference to the tower air situation display. XYZ123 is reminded of the displaced threshold, and is cleared to land. The crew also carry out a similar check for runway occupancy, before acknowledging the clearance.

3.2.5.8 After landing and vacating the runway, XYZ123 is instructed to taxi to gate 3 via taxiway Alpha, traffic is XYZ205 heading for the stand-off parking area.

Non-radar terminal airspace scenario			
Event	**Users**	**Applications**	**ATM functions**

Arrival	Tower	Principal ATC surveillance	Airspace user ops Conflict management Traffic synchronization
	XYZ123	Enhanced situational awareness Obstacle clearance Enhanced visual acquisition	
Approach	Tower	Principal ATC surveillance	
	XYZ123	Enhanced situational awareness Separation assistance	
Landing	Tower	Principal ATC surveillance	Aerodrome operations Airspace user ops Conflict management Traffic synchronization
	XYZ123	Enhanced situational awareness	
Taxi	SMC	Principal ATC surveillance	
	CGSC	Ground handling	
	XYZ123	Enhanced situational awareness Surface navigation	

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Chapter 4. Issues

4.1 There are many issues associated with the transition to the air traffic management operational concept envisioned by the ICAO ATMCP. These issues have been discussed and documented in various ICAO meetings and publications, and are as relevant to ADS-B as they are to other systems and technologies. The following are technical and operational issues to consider during development and implementation of ADS-B. This list is not exhaustive, but serves as a guide for States considering ADS-B technology.

4.2 Technical issues

4.2.1 Technical standards

4.2.1.1 As ADS-B technology matures, the technical standards for the airborne as well as the ground systems are being refined. This leads to the need to potentially upgrade these systems to meet new national and international requirements. Efforts are underway within ICAO to ensure global interoperability for ADS-B technology.

4.2.2 Dependent type of surveillance based on navigation data

4.2.2.1 If both the ADS-B and navigation systems are using the same source data (e.g. global navigation satellite system (GNSS)) then a common point of failure exists and appropriate mitigation measures should be implemented to meet operational requirements. This has to be taken into account in the development of the system, in terms of meeting the overall system performance requirements.

4.2.2.2 This issue can be addressed as follows:

a) top-down approach, based on the definition of requirements for the future surveillance system, including ADS-B. These requirements have to be fulfilled, during the validation process, in order to allow the operational use of ADS-B;

b) the use of ADS-B as a principal means will be investigated, based on the confidence which will be built on its quality of service; and

c) requirements for the input data quality (e.g. navigation data), in order to ensure the required level of performance of the data providers.

4.2.3 Validity of intent data

4.2.3.1 Additional work is required to ensure the validity of intent data, before using it in the envisaged ADS-B applications.

4.2.4 Aircraft installation

4.2.4.1 Various types of aircraft will have different installation certification and integration requirements with corresponding differences in costs. Antenna placement in relation to other systems' antennae, navigation system integration, compatibility with various ADS-B link technologies, and cockpit controls and displays issues will all have to be resolved. Certification will also vary with intended function (e.g. ATC surveillance services, air-to-air situational awareness) as well as aircraft type (e.g. single engine aircraft versus heavy jet aircraft).

4.2.5 Remote ground stations

4.2.5.1 Installation, certification, and maintenance monitoring of remote ADS-B ground stations to meet intended level of service raise their own issues. These include leasing agreements, power requirements, communications to a central facility (e.g. air traffic control centre), installation accessibility and security.

4.2.6 Automation system adaptation

4.2.6.1 Ground-based air traffic control system adaptation to facilitate the acquisition, processing and distribution of ADS-B data is a major issue. The automation's capacity for handling the data (e.g. processing power available, local area network, data storage capacity), maintenance monitoring, correlation between various surveillance sources (e.g. radar, ADS-C, ADS-B), and integration into existing safety functions (e.g. conflict alert, minimum safe altitude warning) are a few areas to consider.

4.2.7 Security

4.2.7.1 The flexibility and versatility of the proposed ADS-B system will allow for many safety and capacity enhancing applications in the short and long term. As applications approach maturity and their requirements become more complex, they also become more sensitive to outside interference. With the discussed widespread deployment of this system this issue must be addressed pro-actively.

4.2.7.2 The interference sources can be malicious or accidental and can occur intermittently or for an extended period. The interference can be a localized source causing for example a "co-channel interference" problem up to a military denial of airspace operation involving active jamming. The sources, causes, and effects of an interference event can be broadly categorized into several groups. There are practical limits that must be recognized due to technological, political, and fiscal reasons. Not all solutions will be technical, that is, come from a box. Some of the solutions may be procedural, legal, technical or a combination of all. In short, States will need to consider the likelihood and severity of interference by conducting appropriate hazard and safety assessments as a means of developing mitigation strategies.

4.2.7.3 Operational security/communications security issues

4.2.7.3.1 Intentional meaconing, interference, jamming, or intrusion to do harm to aircraft, it's occupants or the aviation system.

4.2.7.3.2 Jamming is an effective way to disrupt CNS/ATM operations. An opponent could jam the system with a transmitter tuned to the applicable frequency with enough power to override owner's signals at the receivers.

Note.— Jammers operate against receivers; not transmitters.

4.2.7.3.3 Spoofing

4.2.7.3.3.1 Spoofing is false position information that can arise from a deliberate act or a failure mode. "Principal means" ADS-B usage for surveillance or navigation is especially vulnerable. If successful it's effects could span from an irritation to the controllers and pilots and possibly degraded operation to enabling the perpetrator(s) to display an entirely false track from an aircraft.

4.2.7.3.4 Confidentiality of flight information

4.2.7.3.4.1 ADS-B provides accurate position and identification information (e.g. flight identification and aircraft address) broadcast to any airborne or ground receiver within range. Some aircraft may not want to be identified such as military, VFR aircraft not being provided air traffic services, executive transportation, etc. so consideration needs to be given for a privacy mode (equivalent to a 1200 or VFR transponder code.) This issue is based on expressed interest by business jet community for anonymity of passengers due to possible high profile. Political leaders may need anonymity during travels.

4.2.7.3.5 Intentional monitoring by non-users for intelligence gathering or direct action

4.2.7.3.5.1 This publicly broadcast data can also be used for intelligence gathering against individual aircraft and controlling agencies. Most recipients are legal groups such as news organizations, travel-related businesses, aviation aficionados, non-participating governments, etc. that are outside affected flight operations and civil aviation organizations. These groups fulfil a legitimate need in society and depend on the publicly available data.

4.2.7.3.5.2 Illegal groups such as terrorist organizations and criminal groups can likewise use this for illegal and potentially harmful purposes.

4.2.7.3.5.3 Applicability of equipage requirements may preclude State aircraft from participating or limiting their transmissions. This would impact the effects of non-participatory aircraft in the air traffic system.

4.2.8 Performance of the data link

4.2.8.1 Bandwidth and performance of the ADS-B data link is dependant upon the complexity of the scenarios that are envisaged and could be major issues.

4.2.8.2 For example, the level of equipage (i.e. which airport vehicles and/or obstacles are fitted with ADS-B emitters), the number of aircraft involved and possible use of TIS-B will need to be considered. These are all factors which may influence the available bandwidth of the ADS-B data link.

4.3 Operational issues

4.3.1 Human factors issues

4.3.1.1 The human factors considerations associated with ADS-B, are dependent not on the technology, but on the specific applications. That is, the issues are dependent upon the answers to questions, such as:

a) what is the information to be displayed (e.g. aircraft position data or derived aircraft intent)? Different information will need to be presented in different ways;

b) who (e.g. flight crew, air traffic controller) is the user of this information? Displays will need to be developed and evaluated for cockpit and ATM applications;

c) how will the information be displayed to the user? Depending on the application, it may be necessary to differentiate information that is based on ADS-B from information based on other sources of surveillance, such as radar data;

d) how will the information be used (e.g. for traffic situation awareness, station-keeping, aircraft manoeuvring)? The information and the way in which it is displayed must be capable of supporting the decisions that the users will make based on the ADS-B information.

4.3.1.2 While the specific issues will depend on the specific applications, there are general issues that should be anticipated. These include:

a) *effective integration of ADS-B information into the ATM's situation display*. The broadcast position of aircraft equipped with ADS-B could be different than the position reported by radar. These positions will need to be reconciled so that only one position (preferably the most accurate position possible) is displayed for a single aircraft. Since not all aircraft will be ADS-B equipped, controllers may need to know which aircraft are ADS-B equipped and whether the aircraft position is being reported by ADS-B or radar returns. Depending on the application, controllers may also need to know which displayed aircraft are equipped with a CDTI using ADS-B data. All of this adds information to be integrated into the present displays;

b) *interoperability and effective integration of ADS-B information into the flight deck*. Interoperability with all systems to be integrated with ADS-B, such as CPDLC, will need to be closely examined. Conflict detection and resolution tools used by flight crews and controllers (such as ACAS, conflict probes) will need to provide information that is consistent with (or at least compatible with) the ADS-B information;

c) *limitations of the technology*. Users will need to fully understand the limitations of the information presented and be informed of any known degradations or failures. Back-up procedures, to be used in the event of a failure, will need to be developed for flight crews and controllers;

d) *degree to which the displayed information supports the application*. ADS-B is an enabling technology for a progression to the future CNS/ATM system. The degree to which the ADS-B information supports spacing and separation tasks and the degree to which flight crews and controllers can be expected to successfully accomplish and integrate these tasks will need to be assessed. How the information is displayed will be as important as the integrity of the information in supporting the user's confidence in the system; and

e) *effects on workload*. The effects of the additional information, and the procedures associated with specific applications, on the workload of the user will need to be assessed. The information needs to be integrated so that it is unambiguous, immediately useful, and does not interfere with other critical information.

4.3.1.3 Substantial progress is underway in the investigation of several of the issues identified above. Successful exploitation of ADS-B technology will require a continuation of these efforts with a continued emphasis on human factors issues. A comprehensive and proactive approach to human factors considerations will help ensure full realization of the proposed benefits of ADS-B applications.

4.3.2 Procedures development, separation standards, airspace design, and training issues

4.3.2.1 In support of new operations, appropriate procedures, separation standards, airspace design, and training will have to be developed to effectively utilize ADS-B and its applications. Controllers, pilots, and maintenance technicians, as well as others who may use ADS-B or be impacted by the procedures need proper training on normal and failure mode operations. In addition, airspace design (e.g. size of ATC non-radar sectors vs. radar/ADS-B sectors) will need to be considered for the services provided.

4.3.3 Fleet equipage

4.3.3.1 With the availability of various ADS-B technologies and the cost of equipping or re-equipping aircraft, it is unlikely that aircraft will have homogeneous equipment. This will be true during the transition period as well as at the end of it. The ground systems will have to be capable of processing data from aircraft of varying sophistication. In the cockpit, the traffic information service — broadcast (TIS-B), may be of particular importance, ensuring consistency on the air and the ground traffic situation displays.

4.3.4 Transition issues

4.3.4.1 The main issue with regard to the impact from the transition towards the ADS-B system is related to the mixed equipage environment. In the foreseeable future, the systems have to be capable of coping with a heterogeneous set of aircraft capabilities, types of surveillance sensors, local system sophistication etc. and should be capable of providing the required quality of service both on the ground and on board the aircraft. This quality of service should be at least equal to that of the current system in place.

4.3.5 **Institutional**

4.3.5.1 There are common types of institutional issues regardless of the State implementing ADS-B. These include such things as legal issues (e.g. ASAS-applications separation responsibility), radio spectrum allocation/management, flight standards, and certification issues. Each State will have to resolve these, but global harmonization needs to be considered for consistency.

4.3.6 **Environmental issues**

4.3.6.1 With any new system, environmental issues need to be considered to include noise abatement, airspace constraints, and remote ground system installations.

4.3.6.2 Early studies have shown significant fuel savings and resultant emission reductions from the implementation of CNS/ATM systems and procedures. A recent study by ICAO's Committee on Aviation Environmental Protection (CAEP) identified savings of about 5 per cent to be expected by 2015 in the continental United States and Europe as a result of specific, planned implementation of CNS/ATM systems.

4.3.6.3 To put these savings in perspective, this study projected the total fuel use by civil aviation in 2015 as 325 million tons. A one per cent reduction would save 3.25 million tons of fuel equivalent to 10.25 million tons of CO_2.

4.3.6.4 ADS-B would enable new or improved applications which are expected to contribute significantly to these savings by providing more direct or efficient routings, and easier access to the optimum altitudes and airspeeds.

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Chapter 5. Implementation

5.1 Planning

5.1.1 There is a range of activity that needs to take place to bring an ADS-B application from initial concept to operational use. This section documents these activity areas under the topics of collaborative decision making, system compatibility and integration, while the second section of this chapter provides a checklist to assist States with the management of ADS-B implementation activities.

5.1.2 Implementation team to ensure international coordination

5.1.2.1 Any decision to implement ADS-B by a State should be based on consultation with the wider ATM community. Moreover, the implementation should also be coordinated between States and Regions, in order to achieve maximum benefits for airspace users and service providers.

5.1.2.2 An effective means of coordinating the various demands of the affected organizations is to establish an implementation team. Team composition may vary by State or Region, but the core group responsible for ADS-B implementation planning should include members with operational expertise in aviation disciplines, with access to other specialists as may be required.

5.1.2.3 Ideally, such a team should comprise representatives from the ATS providers, regulators and airspace users, as well as other stakeholders likely to be influenced by the introduction of ADS-B, such as manufacturers and military authorities. All identified stakeholders should participate as early as possible in this process so that demands are identified prior to the making of schedules or contracts.

5.1.2.4 The role of the implementation team is to consult widely with stakeholders, identify operational needs, resolve conflicting demands and make recommendations to the various stakeholders managing the implementation. To this end, the implementation team should have high-level access to the decision-makers.

5.1.3 System compatibility

5.1.3.1 As indicated by the descriptive scenarios in Chapter 3, ADS-B has potential use in almost all environments and operations and is likely to become a mainstay of the future ATM system. Engineering and operational trials have been initiated to validate uses in various locations, and it now appears that its first applications will be in niche areas where radar surveillance is not available or possible. The isolated use of ADS-B has the potential to foster a variety of standards and practices that, once expanded to a wider environment, may prove to be incompatible with neighbouring areas.

5.1.3.2 Given the international nature of aviation, special efforts should be taken to ensure harmonization though compliance with ICAO Standards and Recommended Practices (SARPs). The choice of actual technologies to implement ADS-B should consider not only the required performance of individual components, but also their compatibility with other CNS systems.

5.1.3.3 The future concept of ATM encompasses the advantages of interoperable and seamless transition across flight information region (FIR) boundaries and ADS-B implementation teams should conduct simulations, trials and cost/benefit analysis to support these objectives.

5.1.4 Integration

5.1.4.1 ADS-B implementation plans should include the development of both business and safety cases. The adoption of any new CNS system has major implications for service providers, regulators and airspace users and special planning should be considered for the integration of ADS-B into the existing and foreseen CNS/ATM system. The following briefly discusses each element.

5.1.4.2 Communication system

5.1.4.2.1 The communication system is an essential element within CNS. An air traffic controller can now monitor an aircraft using ADS-B where previously only voice position reports were available. However, a communication system that will support the new services that result from the improved surveillance will be necessary. Consequently, there is an impact of the ongoing ADS-B related work on the communication infrastructure developments.

5.1.4.3 Navigation system infrastructure

5.1.4.3.1 ADS-B is dependent upon the data obtained from a navigation system (typically GNSS), in order to enable its functions and performance. Therefore, the navigation infrastructure should fulfil the corresponding requirements of the ADS-B application, in terms of:

a) data items; and

b) performance (e.g. accuracy, integrity, availability etc.).

5.1.4.3.2 This has obviously an impact on the navigation system development, which evolves in parallel with the development of the surveillance system.

5.1.4.4 Other surveillance infrastructure

5.1.4.4.1 ADS-B may be used to supplement existing surveillance systems or as the principal source of surveillance data. Ideally, surveillance systems will incorporate data from ADS-B and other sources to provide a coherent picture that improves both the amount and utility of surveillance data to the user. The choice of the optimal mix of data sources will be defined on the basis of operational demands, available technology, safety and cost-benefit considerations.

5.2 Implementation checklist

5.2.1 The purpose of this implementation checklist is to document the range of activities that need to take place to bring an ADS-B application from an initial concept to operational use. This checklist may form the basis of the terms of reference for an ADS-B implementation team, although some activities may be specific to individual stakeholders.

5.2.2 The activities are listed in an approximate sequential order. However, each activity does not have to be completed prior to starting the next activity. In many cases, a parallel and iterative process should be used to feed data and experience from one activity to another. It should be noted that not all activities will be required for all applications.

5.2.3 **Concept phase**

a) construct operational concept:

1) purpose;

2) operational environment;

3) ATM functions; and

4) infrastructure;

b) identify benefits:

1) safety enhancements;

2) efficiency;

3) capacity;

4) environmental;

5) cost reductions;

6) access; and

7) other metrics (e.g. predictability, flexibility, usefulness);

c) identify constraints:

1) pair-wise equipage;

2) compatibility with non-equipped aircraft;

3) need for exclusive airspace;

4) required ground infrastructure;

5) RF spectrum;

6) integration with existing technology; and

7) technology availability;

d) prepare business case:

1) cost benefit analysis; and

2) demand and justification.

5.2.4 **Design phase**

a) identify operational requirements:

1) security; and

2) systems interoperability;

b) identify human factors issues:

1) human-machine interfaces;

2) training development and validation;

3) workload demands;

4) role of automation vs. role of human;

5) crew coordination/pilot decision-making interactions; and

6) ATM collaborative decision-making;

c) identify technical requirements:

1) standards development;

2) data required;

3) functional processing;

4) functional performance; and

5) required certification levels;

d) equipment development, test, and evaluation:

1) prototype systems built to existing or draft standards/specifications;

2) developmental bench and flight tests; and

3) select technology;

e) develop procedures:

1) pilot and controller actions and responsibilities;

2) phraseology;

3) separation/spacing criteria and requirements;

4) controller's responsibility to maintain a monitoring function, if appropriate;

5) contingency procedures; and

6) emergency procedures;

f) prepare design phase safety case[2]:

1) safety rationale;

2) safety budget and allocation; and

3) functional hazard assessment.

5.2.5 **Implementation phase**

a) prepare implementation phase safety case[2];

b) conduct operational test and evaluation:

1) flight deck and ATC validation simulations; and

2) flight tests and operational trials;

c) obtain systems certification:

1) aircraft equipment; and

2) ground systems;

d) obtain regulatory approvals:

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[2] Or methodology as required by the safety management system implemented by the individual ATS provider

1) flight operations; and

2) air traffic;

e) implementation transition:

1) continue data collection and analysis;

2) resolve any unforeseen issues; and

3) continue feedback into standards development processes; and

f) performance monitoring to ensure that the agreed performance is maintained.

5.2.5.1 Once the implementation project is complete, the ongoing maintenance and upgrading of both ADS-B operations and infrastructure should continue to be monitored internally and externally, through the appropriate forums.

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