Cir 326
AN/188

Assessment of ADS-B and Multilateration Surveillance to Support Air Traffic Services and Guidelines for Implementation

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and published under his authority

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FOREWORD

Automatic dependent surveillance — broadcast (ADS-B) and multilateration (MLAT) are additional forms of electronic surveillance that may be used to support air traffic services (ATS) in en-route and terminal area operations. While radar was previously the only form of electronic surveillance used for these operations, ADS-B and MLAT may be introduced in areas that are either not served, or are partially served, by radar. In view of their attractive costs, it is expected that ADS-B and MLAT will increasingly be used in areas where radar may not be economically viable, particularly in less demanding air traffic management (ATM) environments.

This circular provides details of a comparative assessment undertaken by the Separation and Airspace Safety Panel (SASP) that concludes that ADS-B and MLAT can be used to provide ATS surveillance, including separation, subject to certain conditions. The SASP assessment concluded that ADS-B can be used to provide a five nautical mile (5 NM) minimum, subject to certain conditions being satisfied.

For guidance to States, an implementation roadmap and answers to frequently asked questions are included in Chapter 4.

Monitoring of the deployment of State or regional implementations of ADS-B and MLAT by ICAO is anticipated.

Comments from States on this circular, particularly with respect to its application and usefulness, would be appreciated. These comments will be taken into account in the preparation of subsequent material and should be addressed to:

The Secretary General
International Civil Aviation Organization
999 University Street
Montréal, Quebec, Canada H3C 5H7

TABLE OF CONTENTS

Appendices[1]

A General description of the reference radar
B Technical comparison between MSSR, ADS-B and MLAT
C Key ADS-B performance requirements to support the claim that ADS-B surveillance is "as good as the reference SSR"
D Key MLAT performance requirements to support the claim that MLAT surveillance is "as good as the reference SSR"
E1 Summary of data collected and analysis
E2 Data analysis report of the operational trial of ADS-B in the Burnett Basin, Queensland, Australia
E3 Analysis of ADS-B data from an Airbus A330 aircraft
E4 ADS-B and radar detection comparison
E5 ADS-B surveillance requirements to support air traffic control separation standards
E6 ADS-B achieved performance — Capstone Evaluation Report
E7 Initial comparative assessment between enroute radar services and proposed enroute ADS-B services using a 5 NM separation minima
F Miscellaneous multilateration data collection test analysis
F1 Collection of multilateration data vs. GNSS in flight data recordings
F2 New Zealand multilateration technical trial test report
F3 St. Louis Multilateration and Electronic-Scan Precision Runway Monitor Operational Evaluation Test Report, Volume I — Test Report and Volume II — Analysis Reports
F4 Multilateration for PRM approaches
G1 HAZID and mitigation: Extracted from ADS-B implementation safety cases, Australia Burnett Basin Operational Trial
G2 Register report
G3 U.S. Capstone Program ADS-B Radar-Like Services Hazard Analysis Reports, Volumes 1, 2 and 3

1. Appendices A to G3 inclusive are provided on the CD-ROM at the back of this circular.

GLOSSARY

ABBREVIATIONS/ACRONYMS

ADS-B	Automatic dependent surveillance — broadcast
ADSBP	ADSB processor
ADS-C	Automatic dependent surveillance — contract
AIP	Aeronautical information publication
ANSP	Air navigation service provider
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic services
ATSC	Air traffic service communication
CDP	Combined data processor
CLAM	Cleared level adherence monitoring
CNS	Communications, navigation and surveillance
CPDLC	Controller-pilot data link communications
DOP	Dilution of precision
EPU	Estimated position of uncertainty
ES	Extended squitter
FDP	Flight data processor
FHA	Functional hazard analysis
FMS	Flight management system
GBAS	Ground-based augmentation system
GNSS	Global navigation satellite system
GPS	Global positioning system
HFOM	Horizontal figure of merit
HPL	Horizontal protection level
IFR	Instrument flight rules
MLAT	Multilateration
MSAW	Minimum safe altitude warning
MSSR	Monopulse secondary surveillance radar
NACp	Navigation accuracy category for position
NACv	Navigation accuracy category for velocity
NIC	Navigation integrity category
NUC	Navigation uncertainty category
PRM	Precision radar monitor
PSR	Primary surveillance radar
PSSA	Preliminary system safety assessment
RAIM	Receiver autonomous integrity monitoring
RAM	Route adherence monitoring
Rc	Radius of containment
RDP	Radar data processor
REC	Receiver
RGCSP	Review of the General Concept of Separation Panel
RMS	Root mean square
RU	Receiving unit
RVSM	Reduced vertical separation minimum

SASP	Separation and Airspace Safety Panel
SDP	Surveillance data processor
SID	Standard instrument departure
SIL	Surveillance integrity limit
SITA	Service provider
SPI	Special position indicator
SSA	System safety assessment
SSR	Secondary surveillance radar
STAR	Standard instrument arrival
STCA	Short-term conflict alert
TDOA	Time difference of arrival
TMA	Terminal control area
UAT	Universal access transceiver
WAM	Wide area multilateration

EXPLANATION OF TERMS

Accuracy. A measure of the difference between the aircraft position reported in the ADS-B message field, or in the position field of the target report output of the MLAT system, as compared to the true position.

Availability. The ability of a system to perform its required function at the initiation of the intended operation. It is quantified as the proportion of time the system is available to the time the system is planned to be available. Periods of planned maintenance are discounted from the availability figures. Overall availability is composed of:

a) the availability of functions affecting all aircraft (e.g. external positioning function, ground data acquisition function); and

b) the availability of systems affecting only one aircraft (e.g. transponder function), expressed per flight.

For radar and MLAT. The availability of ground components and data transmission equipment will affect the service for all aircraft. The availability of an individual aircraft SSR transponder function will affect the service for that aircraft.

For ADS-B. In addition to the availability of ground receiving and data transmission systems, the availability, in the region, of navigation sources (including satellite constellations) of sufficient quality will affect many aircraft.

Continuity. The probability of a system performing its required function without unscheduled interruption, assuming that the system is available when the procedure is initiated. Overall, continuity is composed of the continuity of:

a) functions affecting all aircraft (e.g. satellite function, ground data acquisition function), expressed in number of disruptions per year; and

b) systems affecting only one aircraft (e.g. transponding functions), expressed per flight hour.

For radar and MLAT. The continuity of ground radar and data transmission equipment will affect the service for all aircraft. The continuity of an individual aircraft SSR transponder function will affect the service for that aircraft.

For ADS-B. In addition to the continuity of ground receiving and data transmission systems, the continuity, in the region, of navigation sources (including satellite constellations) of sufficient quality will affect many aircraft.

Cooperative independent surveillance. Surveillance which uses the SSR transponder replies from an aircraft, but position is determined purely by the ground system.

Dilution of precision (DOP). This is a ratio between the accuracy of the measurement of the received signal and the accuracy of the output due to the geometry between the aircraft and the ground receiving station.

Note.— Given that aircraft move the geometry, the DOP is always changing.

Estimated position uncertainty (EPU). The measure of the accuracy of a position estimate.

Horizontal position accuracy. This is essentially the horizontal position measurement error distribution. For radar, accuracy is usually defined as a bias (offset) and noise. It is assumed that the noise is of Gaussian distribution and the RMS value is quoted. Horizontal position accuracy is normally expressed in terms of range and azimuth dimensions. However, the azimuth error distribution is of prime concern. The overall errors are considered to have the following component errors:

a) core errors (usually expressed as a standard deviation σ);

b) tail errors; and

c) systematic bias.

For ADS-B, accuracy is usually defined as noise. It is assumed that the noise is of Gaussian distribution and the RMS value is quoted. Horizontal position accuracy is usually defined as the radius of a circle centred on the target's reported position such that the probability of the target's actual position being inside the circle is 90 per cent.

For MLAT, accuracy is a function of the geometry between the aircraft and contributing ground stations, independent of on-board systems.

Navigation uncertainty category (NUC). A codified parameter used to report the maximum position error which might not be detected with a predefined probability. NUC originates in a position-determining system and is transmitted by aircraft complying with DO-260/ED-102 or ICAO Annex 10, Amendment 77.

Navigation uncertainty category — position (NUC-P). Uncertainty categories for the position information. Provides a measure of the accuracy of the position information.

Reliability. The probability that the system will deliver a particular message or other data without one or more errors. It is assumed that if the rate of errors is deemed unacceptable by the users, appropriate alternative separation will be provided.

Surveillance integrity limit (SIL). SIL defines the probability of the integrity containment radius used in the NIC parameter being exceeded, without detection. SIL is the probability that the position error is greater than NIC and is undetected. NIC and SIL are transmitted by aircraft complying with DO-260A.

Vertical accuracy. This is essentially the vertical position measurement error distribution. For radar, ADS-B and MLAT, encoders on the aircraft provide the altitude, and the encoded data are transmitted to the radar, ADS-B or MLAT ground station. Therefore, vertical accuracy at ATC processing depends on altimeter accuracy — and the transmission errors resolution. In addition MLAT can provide a measure of the aircraft's geometric altitude, independent of on-board systems.

PUBLICATIONS

(referred to in this circular)

ICAO PUBLICATION

Annexes

Annex 10 — *Aeronautical Telecommunications*, Volume III — *Communication Systems*

Procedures for Air Navigation Services (PANS)

ATM — Air Traffic Management (PANS-ATM, Doc 4444)

Manuals

Global Navigation Satellite System (GNSS) Manual (Doc 9849)

Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689)

Safety Management Manual (SMM) (Doc 9859)

OTHER PUBLICATIONS

EUROCAE

Minimum Operational Performance Specification for Mode S Multilateration Systems for Use in A-SMGCS, ED-117

Safety, Performance and Interoperability Requirements Document for ADS-B-NRA Application, Doc ED-126

Guidelines for Test and Validation Related to Airport CDM Interoperability, Doc ED-146

EUROCONTROL COMPARATIVE ASSESSMENT — SSR TO MLAT

Guidance Material on Comparison of Surveillance Technologies (GMST)

RTCA

Minimum Aviation System Performance Standards for Automatic Dependent Surveillance — Broadcast (ADS-B), RTCA DO-242A

Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using the Global Positioning System, RTCA DO-208

Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance — Broadcast (ADS-B), RTCA DO-260

Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance — Broadcast (ADS-B) and Traffic Information Services — Broadcast (TIS-B), RTCA, DO-260A

Next Generation Air/Ground Communication System (NEXCOM) Implementation Considerations: Factors and Issues to be Considered in Planning for the Transition to Air/Ground, ICAO, VDL Mode 3 Based Integrated Voice and Data Communications in the U.S. National Airspace System (NAS), RTCA, DO-288

Chapter 1

OVERVIEW

INTRODUCTION

1.1 The ICAO Separation and Airspace Safety Panel (SASP) undertook an assessment of the use of automatic dependent surveillance — broadcast (ADS-B) and multilateration (MLAT) to provide surveillance to support air traffic services (ATS). The basis of the assessment was a comparison of ADS-B and MLAT to a reference radar. This assessment resulted in the identification of a number of performance requirements (Appendix C[1]) which must be met for ADS-B or MLAT surveillance to be as good as or better than the reference radar. SASP concluded that ADS-B or MLAT technologies can be used as a means of supporting the provision of ATS surveillance, including separation, in accordance with the requirements in *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444), Chapter 8.

1.2 This circular is a consolidated and single-point reference of the assessment undertaken by SASP and includes:

a) an overview of air traffic control (ATC) surveillance (see Chapter 2);

b) the rationale used by SASP in developing the methodology and arriving at its conclusions (see Chapter 3 and Appendices A and B);

c) the performance requirements attached to the conclusions reached by SASP (see Chapter 3 and Appendices C and D);

d) evidence of the ADS-B and MLAT surveillance performance achieved during several State trials and implementations (see Chapter 3 and Appendices E and F);

e) a compendium of hazards and mitigation measures identified during the development of a safety case to support ADS-B and MLAT trials and implementation (see Chapter 3 and Appendices G and H); and

f) a State implementation roadmap (see Chapter 4).

1.3 The roadmap has been included to define the scope and extent of the SASP assessment and also as guidance to assist regions or States undertaking an ADS-B or MLAT implementation safety assessment (see Chapter 3).

BACKGROUND

1.4 At its tenth Air Navigation Conference (AN Conf/10), ICAO confirmed its commitment to exploring the use of global navigation satellite system (GNSS) and data link communications for the benefit of civil aviation. At AN Conf/11

1. Appendices A to G3 inclusive are provided on the CD-ROM at the back of this circular.

(2003), the ICAO Council endorsed the ADS-B concept of use[2] which describes, *inter alia*, the concept for surveillance using ADS-B[3]. The latter includes a description of the role of ADS-B in air traffic management (ATM), and considers ADS-B to be "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."

1.5 Various ATM improvements[4] and benefits are cited in the concept for surveillance using ADS-B. Within the context of the SASP assessment, it is appropriate to draw attention to two of these benefits:

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

b) 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.

1.6 Additionally SASP considers that ADS-B will improve safety and increase operational efficiency by providing electronic surveillance in airspace where the cost of radar is not justified.

1.7 Although the expression "radar-like services" is used in the ADS-B concept of use, it should be noted that while an ADS-B surveillance system and radar are similar, some aspects such as the failure modes are not identical. ADS-B is characterized by dependence on the aircraft's on-board position determination and ATC surveillance, and therefore a potential for a common mode failure exists. The effect of such a failure is determined by a specific operating environment. For example, in aircraft where GNSS is the sole means of ADS-B position and navigation, GNSS becomes a common point of failure for navigation and ATC surveillance. Such failure modes need to be identified and mitigated during the implementation safety assessment process. The implementation roadmap in Chapter 4 provides guidance on this issue.

1.8 SASP was aware that a number of States were proceeding with trialling and implementation of MLAT systems to provide an additional surveillance medium for air navigation service providers (ANSPs). Of particular interest to those States was the need for separation minima similar to those currently used with radar. As a result, SASP decided to undertake a comparative assessment of MLAT in a similar way that it had done for ADS-B.

1.9 States are implementing MLAT for a number of reasons that include:

a) providing surveillance in airspace in which no surveillance currently exists and implementing new radar systems would not be feasible for commercial, technical or environmental reasons;

b) providing surveillance in areas where terrain makes the deployment of radar difficult;

c) providing a complementary source of surveillance to current radars;

d) facilitating the availability of safety net functions of electronic surveillance (STCA, CLAM, RAM, MSAW) on a cost-effective basis;

e) enhancing the safety of instrument flight rule (IFR) operations in a terrain-critical environment;

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2. AN Conf/11-WP/6, Appendix.
3. Ibid, Chapter 2.
4. Ibid, Chapter 2, 2.3.7.

f) realizing cost savings that could be achieved from the implementation of an MLAT system rather than the life-cycle expenses associated with installing, maintaining and extending existing radar-based surveillance systems; and

g) providing height-keeping monitoring of reduced vertical separation minimum (RVSM) approved aircraft.

Chapter 2

ATC SURVEILLANCE

INTRODUCTION

2.1 This chapter provides a high-level overview of radar and its use by ATC as a tool to provide ATS services including aircraft separation service. The basic operation of the two types of radar used by ATC is discussed and the characteristics relevant to ATC identified. A description of the ADS-B and MLAT systems and their characteristics is provided as an introduction to the assessment of these systems presented in Chapter 3.

RADAR AS AN ATC TOOL

2.2 Knowledge of the position of aircraft is essential to an air traffic controller in the provision of most ATS. Certainly knowledge of aircraft position is required to provide separation services. The knowledge of aircraft position is referred to as surveillance. Position reports from pilots can provide knowledge of the aircraft position to a controller. However, because of the inherent inaccuracy, infrequent updates and margin for error due to misunderstandings, very large spacing between aircraft is required to maintain safety. This technique is known as procedural separation.

2.3 Radar provides the controller with an accurate, trustworthy, on-screen plan view of the aircraft position in real time. The required separation between aircraft for safe operation can be greatly reduced compared to procedural separation.

SURVEILLANCE RADARS

Primary surveillance radar (PSR)

2.4 PSR transmits a high-power signal, some of which is reflected by the aircraft back to the radar. The radar determines the aircraft's position in range from the elapsed time between transmission and reception of the reflection. The direction of the aircraft is the direction the narrow beam radar antenna is facing. PSR does not provide the identity or the altitude of the aircraft. However, PSR does not require any specific equipment on the aircraft.

Secondary surveillance radar (SSR)

2.5 SSR transmits a medium-power signal (interrogation) to the transponder on the aircraft. In response to the interrogation, the transponder transmits a reply to the SSR. SSR determines the aircraft's position in range from the elapsed time between the interrogation and reception of the reply. The direction of the aircraft is determined from the direction the narrow beam radar antenna is facing. The reply contains the aircraft's identity and/or altitude. The identity information is input by the pilot, and the altitude information comes from a barometric encoder or air data computer on the aircraft. SSR will detect only an aircraft fitted with a functioning transponder. SSR with Mode S may also data-link many aircraft parameters, such as heading, track, bank angle and selected altitude, to the radar.

Combined primary and secondary radar

2.6 Combined primary and secondary radar makes use of the advantages of the two types of radar in one installation. Typically, the PSR and SSR antennas are mounted on the same turning gear, and the common processing filters, combines and tracks the radar reports. One track message is output per aircraft each antenna rotation.

Fundamental data

2.7 The fundamental data provided by radar are aircraft position (measured by the radar), aircraft identity and altitude (data-linked from the aircraft to the radar). Further information such as aircraft direction, speed and rate of climb is derived from the above data. These data are collectively called aircraft surveillance data.

Radar display

2.8 Data from a radar sensor may be presented on a stand-alone radar display or combined with data from other remote radar sensors and/or other data in an automation system and then presented on a plan-view situation display.

2.9 The situation display provides air traffic controllers with a plan view of the position of aircraft relative to each other and to geographic features. This supports controllers in providing separation and other services to aircraft.

Separation minima

2.10 Doc 4444, Chapter 8, details radar separation minima of five and three nautical miles. These minima allow for a considerable increase in airspace utilization compared to procedural control, where the cost of radar can be supported.

Safety-net functions

2.11 Automation systems may use surveillance data to implement automated safety-net functions such as route adherence monitoring, cleared level alarm, conflict alert, lowest safe altitude and danger area infringement warning. These facilities increase overall safety.

ADS-B SURVEILLANCE

2.12 ADS-B is a system in which, like radar, the aircraft transmits identity and altitude information to the ground station. However, unlike radar, the position of the aircraft is also determined on the aircraft and transmitted to the ground. The data are broadcast periodically and any receiver (ground or airborne) may receive the data. Additional data such as track vector, speed and alerts of abnormal operation may also be included in ADS-B messages.

2.13 It can be seen that the fundamental data (aircraft identity, position and altitude) provided by ADS-B are the same as radar. The data may be displayed on a stand-alone display or introduced into the automation system, processed and displayed in a similar manner to radar data. Thus, ADS-B shows promise as a source of surveillance data to support ATS currently supported by radar.

2.14 Additional information is derived from the fundamental radar data (aircraft vector, speed and vertical rate). This same information can be provided by ADS-B using on-board equipment; in many cases the data from the aircraft are of higher quality or more timely.

2.15 ADS-B data may also be used to support various safety net functions in the same manner as radar surveillance data.

MLAT SURVEILLANCE

2.16 MLAT is a system that uses currently existing aircraft transponder signals to calculate, usually as a minimum, a three-dimensional position. The system can be considered as being like radar in that it provides target positions the same as SSR, but it measures the aircraft's position using the time difference of arrival (TDOA) of the transponder reply, using a number of receivers consisting of non-rotating antennas positioned within a coverage area to calculate the position of the aircraft using differences in the runtime of transponder responses. Replies from the airborne transponder are received either by SSR or by an interrogation unit that forms part of the MLAT system.

2.17 MLAT systems can be defined as being either passive or active. Passive systems require only ground receivers. An active system requires ground receivers and an interrogator. The latter enables the system to be independent from other sources to trigger transmissions from aircraft.

2.18 MLAT systems will provide a range of data relative to a specific target depending on the airborne derivation of the data. For example, Mode S radar information may contain a 24-bit aircraft address and pressure altitude, while Mode S and 1090ES squitters provide additional data such as state vector information and World Geodetic System — 1984 (WGS-84) position.

2.19 The data may be displayed on a stand-alone display or introduced into an automation system, processed and displayed in a similar manner to radar data. Thus, MLAT can be used as an additional or alternative source of surveillance data to support ATS, including safety net functions currently supported by SSR.

2.20 Wide area multilateration (WAM) is the term typically used to describe the surveillance of en-route airspace while the abbreviation MLAT tends to be employed when discussing the monitoring of terminal airspace and airport surface traffic.

KEY DIFFERENCES BETWEEN RADAR SURVEILLANCE AND ADS-B SURVEILLANCE

2.21 The major difference between radar surveillance and ADS-B surveillance is the means of determining the aircraft position and state vector data.

2.22 Radar measures the aircraft position largely independent of aircraft systems and estimates the aircraft speed, direction, turn rate and other elements of the state vector from successive position reports. ADS-B data-links, to the ground, aircraft position and state vector determined by aircraft avionics. This information may come from the aircraft navigation system or from a stand-alone GNSS receiver/navigator.

2.23 Like radar, in ADS-B the aircraft data also have their source in an air data computer or a barometric encoder. The identity of the flight is supplied by the pilot either directly or via other systems, for example, the flight management system (FMS).

Ground ADS-B installation

2.24 The ground element comprises a simple antenna and receiver. Received messages are forwarded to the automation or display system via communication links.

Situation displays

Simple ADS-B situation display

2.25 ADS-B data may be displayed on a situation display in a similar manner to radar.

Automation system and integrated situation display

2.26 ADS-B data may be provided to an ATM automation system. ADS-B data may be processed and displayed separately from radar and other data, or ADS-B data may be integrated with radar data. See the block diagram of a typical automation system in Figure 2-1.

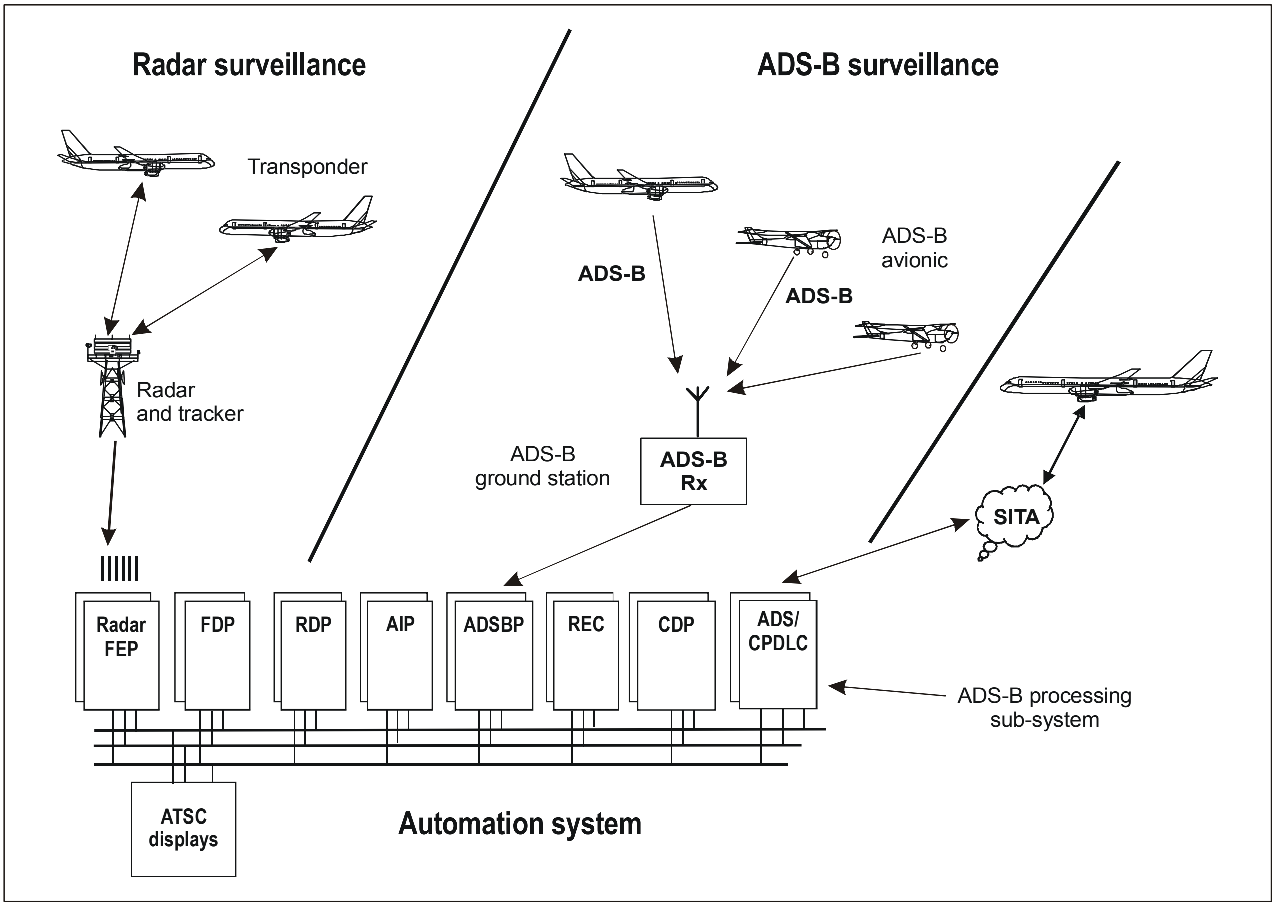

Figure 2-1. Typical ATS surveillance system architecture

Data elements of ADS-B messages

2.27 An ADS-B-equipped aircraft automatically and frequently broadcasts surveillance data via data link messages to the ground station. The key data elements that broadcast messages contain are:

a) aircraft identification and 24-bit address;

b) positioned data (and associated accuracy and integrity information);

c) velocity vector (and vector accuracy);

d) barometric altitude; and

e) status, emergency indicators and SPI:

1) DO-260-compliant aircraft transmit a general emergency alert regardless of the code selected by the pilot. These aircraft are unable to transmit SPI (squawk ident) while the general emergency alert is being transmitted; and

2) DO-260A-compliant aircraft are capable of transmitting the following emergency/urgency modes:

i) emergency;

ii) communication failure;

iii) unlawful interference;

iv) minimum fuel; and/or

v) medical.

Source of data elements in an airborne ADS-B installation

2.28 An ADS-B installation on the aircraft comprises:

a) the ADS-B emitter, the SSR transponder or a stand-alone ADS-B transmitter;

b) data source of the aircraft's position, speed vector (typically the FMS or GNSS receiver/navigator);

c) data source of barometric altitude (typically the air data computer or a stand-alone barometric pressure encoder); and

d) data source of flight identity (entered by the pilot into either the transponder control panel or the FMS which passes the data to the transponder).

2.29 ICAO has standardized three data links which might be used to carry ADS-B data. The comparative assessment detailed in Appendix B relates to the SSR 1090 extended squitter and universal access transceiver data links.

Aircraft source of position data and state vector

2.30 The aircraft positional data, state velocity vector and altitude broadcast by the ADS-B airborne system are used by the ATS to provide an ATC surveillance service. This means that the quality of aircraft positional data, velocity vectors and altitude used by ATC surveillance is determined by the airborne equipment.

2.31 The position and state vector to be data-linked by ADS-B can be provided by either:

a) the position-determining element of the aircraft's navigation system — typically this is the FMS in an aircraft with area navigation capability; and

b) the stand-alone sensor — GNSS receiver.

KEY DIFFERENCES BETWEEN RADAR SURVEILLANCE AND MLAT SURVEILLANCE

2.32 The major difference between radar surveillance and MLAT surveillance is the means of determining the aircraft position. A radar measures the range of the aircraft from the time elapsed from the transmission of interrogation of the aircraft to the reception of the reply. Azimuth is determined from the direction the radar antenna is facing. MLAT calculates the position using the TDOA of one transponder reply at different receiver units positioned strategically in the coverage area (see Figure 2-2). The TDOA is due to the different distances between the aircraft and each of the ground stations.

2.33 Like SSR, in MLAT the identity of the flight (Mode A and/or Mode S flight ID) is supplied by the pilot either directly or via other systems. Both radar and MLAT can receive aircraft altitude data (Mode C/S) from the aircraft's air data computer or a barometric encoder; in addition MLAT systems can measure the aircraft's altitude using TDOA.

Ground MLAT installation

2.34 The ground element comprises a network of receiving units (RUs) each comprising an antenna and receiver interconnected by a telecommunications network to a central processor. A source of interrogation to elicit replies from the transponders is required; this usually is an interrogator specific to an MLAT installation. Replies received at each RU are processed and forwarded to the central processor via communication links. The central processor, by comparing the TDOA of one reply at each RU, calculates the three-dimensional position of each aircraft. Position reports are passed from the central processor to the display or automation system.

Situation displays

Simple MLAT situation display

2.35 MLAT data may be displayed on a situation display in a similar manner to radar.

Automation system and integrated situation display

2.36 MLAT data may be provided to an ATM automation system. MLAT data may be processed and displayed separately from radar and other data such as ADS-B, or MLAT data may be integrated with other data such as radar and ADS-B (see Figure 2-1).

Data elements of MLAT messages

2.37 Data elements used in MLAT systems will be those transmitted from Mode A/C and S transponders.

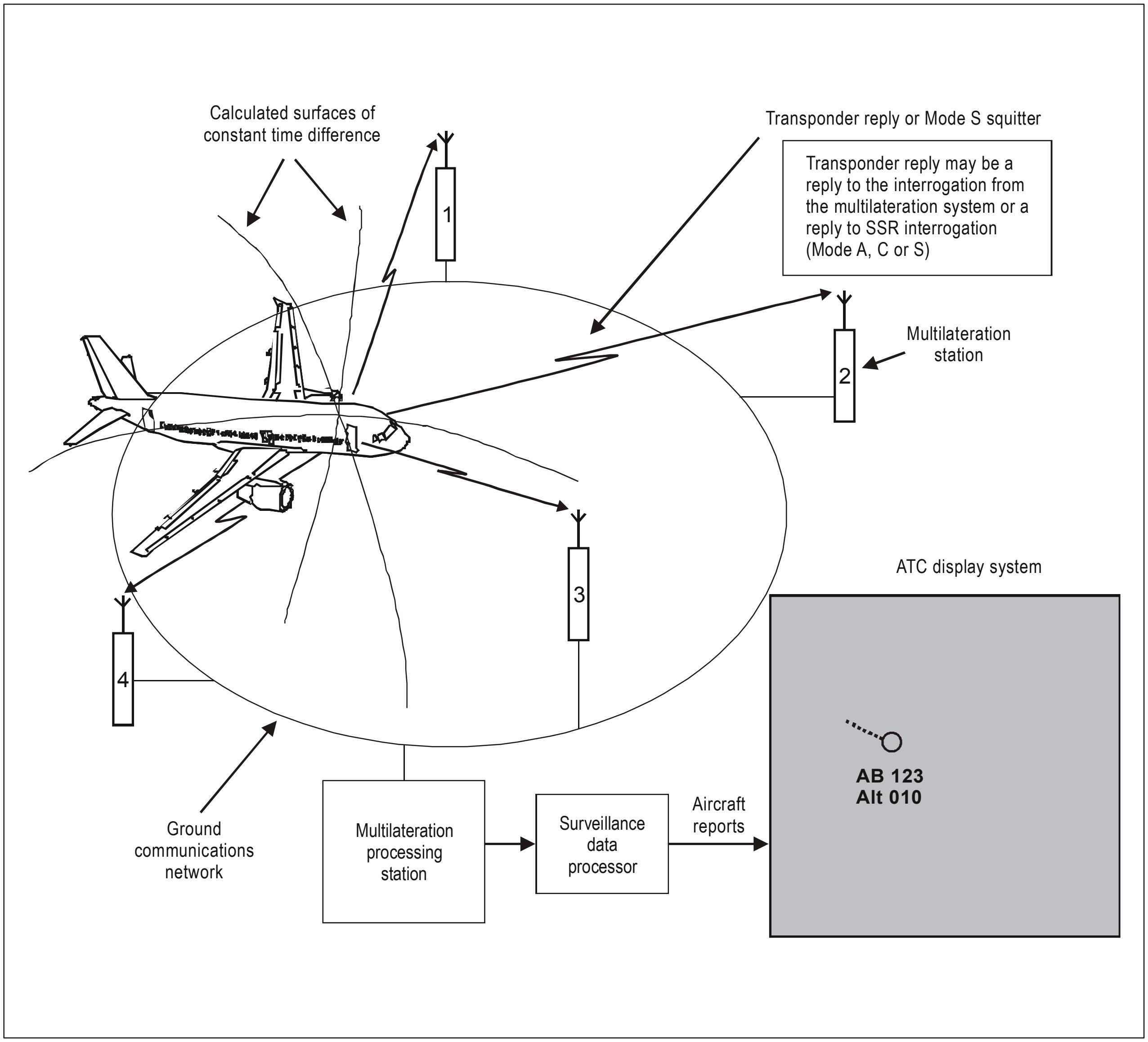

Figure 2-2. Typical MLAT ATC surveillance system architecture

ATC SURVEILLANCE PERFORMANCE CHARACTERISTICS

2.38 Table 2-1 details surveillance data elements and their associated essential performance characteristics for radar, ADS-B and MLAT. For example, the position of the aircraft needs to be known by the controller; the accuracy of the position and integrity of the position data are also important.

Note 1.— In Table 2-1, the light grey shading shows where a data element is elaborated in the technical comparison attached to this document; the dark grey shading is used for the specific case of velocity vector. This data element, with ADS-B, can either be originated at the airborne level or derived from two consecutive positions on the ground. X means that the surveillance characteristics of the related data element could be affected at that level, and • means that the performance parameter value is expected not to be degraded between origination and end use.

Note 2.— For radar, position integrity and accuracy are known performance characteristics and therefore are indicated as "fixed" in the table. However, for ADS-B and MLAT, those characteristics are dynamic and have also been derived into data elements that therefore have their own performance characteristics (latency, reliability).

Table 2-1. Surveillance data elements and performance characteristics

Data element	*Performance characteristics*	*SSR*		*ADS-B*		*MLAT*	
		Ground	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*
Position	Accuracy	X (fixed)		•	X NIC/NUC	X (dynamic)	
	Integrity	X (fixed)		•	X SIL/NUC	X (fixed)	
	Update rate	X		X	X	X	
	Latency	X		X	X	X	
	Reliability	X		X	X	X	
Position NIC or NUC	Latency			X	X		
	Update rate			X	X		
	Reliability			X	X		
Position SIL	Latency			X	X		
	Reliability			X	X		
Velocity vector	Accuracy	X		• (or X)	X	X (dynamic)	
	Integrity	X		• (or X)	X	X	
	Update rate	X		X	X	X	
	Latency	X		X	X	X	
	Reliability	X		X	X	X	
Altitude	Accuracy	•	X	•	X	•	X
	Integrity	•	X	•	X	•	X
	Update rate	X	X	X	X	X	X
	Latency	X	X	X	X	X	X
	Reliability	X	X	X	X	X	X
Identification/identity	Integrity	•	X	•	X	•	X
	Reliability	X	X	X	X	X	X
	Latency	X	X	X	X	X	X
	Update rate	X	X	X	X	X	X
Emergency/SPI	Reliability	X	X	X	X	X	X
	Update rate	X	X	X	X	X	X
	Latency	X	X	X	X	X	X

ATC SURVEILLANCE PERFORMANCE AND SYSTEM SAFETY

2.39 Paragraphs 2.21 to 2.37 introduced the generic performance elements as identified by SASP. SASP aims to introduce safety-related aspects and clarify their relationship with the performance elements.

2.40 While the major objective of the performance elements is to ensure that the system will perform its intended function, a safety assessment shall also demonstrate that the system will not induce dangerous situations. In particular, before approval of the use of ADS-B or MLAT, the communications, navigation and surveillance/air traffic management (CNS/ATM) system elements will need to be qualified to ensure that the system performs as intended (performance) and is acceptably safe (safety). Post implementation, the system shall also be monitored to ensure that the adequate level of safety is maintained or improved. Performance therefore covers rather nominal modes of operations whereas safety focuses on non-nominal modes.

2.41 Of particular interest for safety is the identification of hazards, their effect and consequences on operation and the related mitigation means (references to annexes).

2.42 Performance requirements such as accuracy, integrity and availability may be viewed as safety pillars of the ATC surveillance system and integral to safety assurance. These performance requirements which speak directly to the maintenance of the safety of the ATC surveillance system are not enough. Therefore, in order to ensure that ADS-B or MLAT implementation is safe, airspace planners must undertake a safety assessment in parallel to the performance assessment, whereby hazards are identified and mitigation means put in place to reduce the risk that may be engendered by these hazards.

Chapter 3

ASSESSMENT OF ADS-B AND MLAT SURVEILLANCE

INTRODUCTION

3.1 This chapter presents the comparative assessments of ADS-B and MLAT surveillance undertaken by SASP to establish that these systems can be used to provide ATS surveillance, including separation, subject to certain conditions.

3.2 The assessments were accomplished by using a methodology developed by the Review of the General Concept of Separation Panel (RGCSP), now SASP. This methodology is explained below, as is the rationale behind its use and the conclusions drawn from it.

Note 1.— SASP initially used this methodology to establish a 5 NM separation minimum for ADS-B.

Note 2.— Appendices A to F[1] *are relevant to this chapter.*

SCOPE

3.3 In the context of the scope of this comparative assessment, it is useful and necessary to distinguish between assessments undertaken by States for the purposes of implementation at the local or regional level and that undertaken by SASP from a global perspective. An assessment undertaken for global purposes does not always contain the information required to address specific local implementation requirements.

3.4 This difference in the scope of the assessment is depicted in Figure 3-1, which suggests, for example, that because the local operational environment into which a SASP-developed standard is to be integrated largely determines safety considerations, the full safety assessment can be completed only for each local implementation. As such, airspace planners need to complement the SASP assessment with a local or regional implementation-focused assessment. It should be noted that a local implementation assessment may not necessarily require a regional assessment but may be initiated by an ANSP on a case-by-case basis.

Note 1.— In undertaking a "global" assessment, the SASP is not able to assess all of the factors that might affect safety during implementation. States should note that SASP's assessment is usually based on a number of assumed characteristics related to either the airspace environment or aircraft performance. These characteristics may not necessarily be the same as those relevant to any particular local, regional or State implementation.

Note 2.— A local implementation assessment would normally be a supporting activity for a State assessment and focus specifically on implementation issues such as hazard identification. However, there may be circumstances where the service provider may need to review the SASP global assessment and/or the regional assessment taking particular note of the assumed characteristics used in that assessment.

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1. The Appendices are provided on the CD-ROM at the back of this circular.

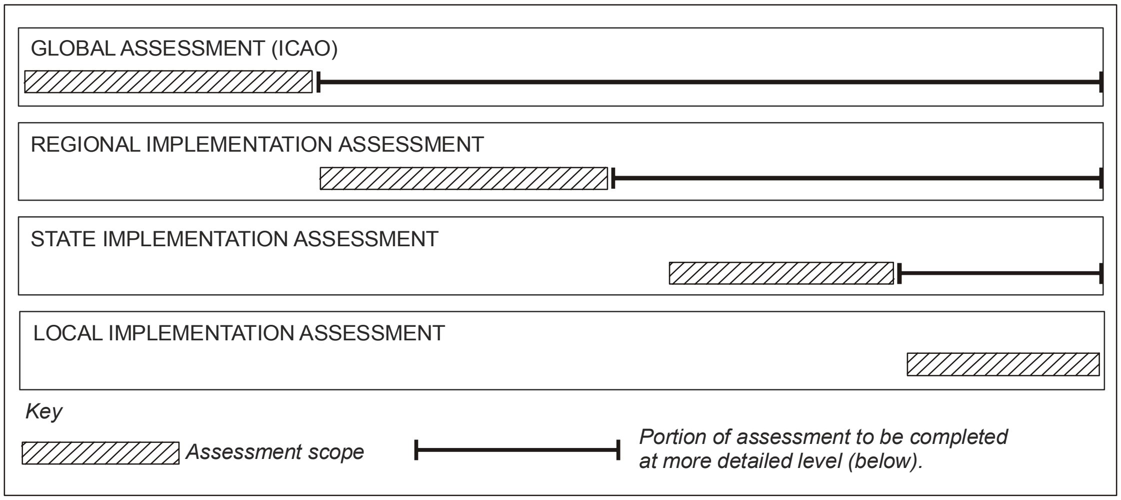

Figure 3-1. Difference in the scope of the assessment

Note 3.— In undertaking a regional implementation a supporting safety assessment should begin with a review of the SASP global assessment, taking particular note of the assumed characteristics used in that assessment. Where these characteristics are the same as or more stringent than those within the region, then the region needs to focus only on undertaking an assessment of issues related specifically to implementation.

Note 4.— A State assessment need not necessarily follow a regional assessment but could be initiated by a State on its own initiative. In this case, as with the regional assessment, a supporting safety assessment should begin with a view of the SASP global assessment taking particular note of the assumed characteristics used in that assessment. Where these characteristics are the same as or more stringent than those within the State, then the State needs to focus only on undertaking an assessment of issues related specifically to implementation.

OBJECTIVES OF THE SASP ASSESSMENT

3.5 The general objective of the SASP assessment detailed in this document is to demonstrate that ADS-B or MLAT surveillance can be used to provide surveillance services in accordance with PANS-ATM, Chapter 8, in an ADS-B or MLAT only environment, or an environment where a combination of surveillance systems are utilized. In providing separation services as detailed in PANS-ATM, Chapter 8, it should be noted that States or regions may chose to use a broader standard (see Annex 11, Chapter 3, 3.4).

ASSUMPTIONS

3.6 Several assumptions were made during the assessment of ADS-B or MLAT surveillance by SASP with regards to the application of separation minima similar to that used for the reference radar (see Appendix A).

3.7 The main assumption made was that in applying the separation minima using ADS-B or MLAT in a manner similar to applying the same minima using radar, only the means of surveillance would change when ADS-B or MLAT is used. Therefore:

a) the requirement for direct voice communications remains unchanged; and

b) the required navigation capabilities of the aircraft remain unchanged.

Note.— The surveillance performance data detailed in Appendix D are from medium-density terminal and en-route operations.

3.8 A further assumption was that aircraft position and associated accuracy and integrity information is available from the aircraft for ADS-B surveillance.

CONSTRAINTS AND ENABLERS

3.9 Although the SASP assessment was limited to a subset of global common denominators that are independent of a specific operating environment, this has been mitigated by several enabling factors:

a) three States have, in conjunction with relevant stakeholders, independently undertaken operational trials in low complexity airspace using 1090ES or universal access transceiver (UAT) data link. The relevant data are available in Appendix E;

b) one State has implemented MLAT and five States have undertaken operational trials using MLAT. The relevant data are available in Appendix F;

c) while initial implementation of ADS-B and MLAT has been in less demanding ATM environments in order to obtain operational experience, it is anticipated that ADS-B and MLAT will be employed in more demanding environments in due course;

d) a compendium of implementation hazards and controls identified by States is provided in Appendices G and H; and

e) a State implementation roadmap is provided in Chapter 4.

DEVELOPMENT OF THE ASSESSMENT METHODOLOGY

3.10 In order to assess the suitability of ADS-B or MLAT for use by the ATS, SASP sought to follow the guidance from the *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689). However, cognizant of the objectives of the assessment (see 3.5) SASP was mindful of the purpose of both the manual and the safety assessment methodologies it contains. While the manual is intended to guide airspace planners seeking to implement airspace changes, the methodologies are geared towards the determination of new separation minima for en-route operations, particularly in the context of the required navigation performance (RNP) concept and area navigation techniques.

3.11 For the reasons described in 3.3 and 3.4, it became obvious that it would not be possible to follow the guidance in Doc 9689 in its totality when seeking to assess safety from a global perspective due to all the possible variations in airspace systems and the application of separation minima. As a consequence, SASP reasoned that it was not seeking to determine a new separation minima, but rather to demonstrate that a technology different to radar could be used to provide ATS, including separation, in accordance with the requirements in the PANS-ATM. To achieve this, SASP determined that it would be reasonable to compare the different ADS-B and MLAT technologies with the existing radar technology.

3.12 The fact that the ADS-B concept of use (see Chapter 1) envisages using ADS-B surveillance to provide "radar-like air traffic control" would suggest that some level of similarity exists. Doc 9689 identifies the minimum requirements for a reference system to be considered sufficiently similar to a proposed system:

a) the separation minima must not be less in the proposed system than in the reference system;

b) the proposed means of communication and surveillance must be no worse in terms of accuracy, reliability, integrity and availability than those of the reference system;

c) the frequency and duration of the application of minimum separation between aircraft must not be greater in the proposed system than in the reference system; and

d) the navigation performance (typical and non-typical) of the population of aircraft in the proposed system should be no worse in terms of its effect on collision risk, in any dimension, than that of the aircraft in the reference system.

3.13 For this reason, SASP agreed to undertake a technical comparison using a reference radar system already used to provide a 3 NM separation minimum judged to be safe.

3.14 The view of SASP was that, in 3.12 above, a) is a requirement and b) was assessed and met in the comparative assessment completed by the group. However, items c) and d) necessarily need to be assessed as part of any State or regional implementation, given the differing airspace systems globally, which would take into account variances in traffic density and fleet navigation performance.

Comparison of surveillance systems — better or at least no worse than the reference radar

3.15 Given the extensive use of radar by most States, SASP considered it reasonable to compare the achieved performance of a (reference) radar system with that of a (proposed) ADS-B and MLAT surveillance system with a view to demonstrating that ADS-B and MLAT surveillance is better or at least no worse than the reference radar.

3.16 Within the context of the assessment objectives above, the technical comparison of these two ATC surveillance systems would require:

a) the selection of a reference radar used to provide a 3 NM separation minima in either the en-route or terminal area operations; and

b) undertaking a technical and operational comparison between ADS-B and MLAT surveillance and the reference radar.

3.17 The working hypothesis of this approach was that if the achieved performance of ADS-Bs and MLATs proved to be "better or at least no worse than" the reference radar then the objectives of the assessment would be satisfied — given its scope.

3.18 This comparative assessment was then applied with a view to validating the working hypothesis. It will be seen that the application of this methodology was focused on a technical comparison of the performance of radar with ADS-B and MLAT based on the assumptions identified above. It was considered that States would assess airspace characteristics, aircraft capability and traffic demand to ensure that the required safety level of any implementation would meet the required standard.

APPLICATION OF THE ASSESSMENT METHODOLOGY

3.19 Using the above rationale, SASP undertook a sequence of steps, some of which were completed under the auspices of SASP and others as part of site-specific ADS-B and MLAT surveillance trials and implementations. This is reflected in Table 3-1.

Table 3-1. ADS-B and MLAT surveillance trials and implementations

Step 1: A reference radar was selected and its general performance described. This reference system is used to provide a 3 NM separation minima for both en-route and terminal area operations.	***Output 1:*** Preliminary benchmark set against which ADS-B and MLAT surveillance could be compared — see Appendix A.
Step 2: Identification of radar display data that influence controller working practices, e.g. HMI, conflict resolution.	***Output 2:*** Key characteristics specific to ADS-B and MLAT surveillance were identified and selected to allow comparison to the reference radar — see Appendix B.
Step 3: A technical comparison of the key characteristics was undertaken between the reference radar and ADS-B and MLAT surveillance — see Appendix B.	***Output 3:*** Minimum performance requirements ADS-B and MLAT surveillance identified — see Appendix C.
Step 4: Completion of several safety cases for site-specific ADS-B and MLAT implementation and/or trials.	***Output 4:*** A compendium of hazards and mitigation measures were extracted from safety cases, including characteristics specific to ADS-B and MLAT systems — see Appendices G and H.
Step 5: ADS-B and MLAT surveillance implemented operationally or on a trial basis at several specific locations.	***Output 5a:*** The compendium of hazards and mitigation measures were updated in the light of experience gained during the trial — see Appendices G and H. ***Output 5b:*** ADS-B and MLAT surveillance trials demonstrated that achieved performance is "better or at least no worse than" that of the reference radar — see Appendices E and F. ***Output 5c:*** Amendment to PANS-ATM definitions and Chapter 8 to enable ADS-B and MLAT 3 NM and 5 NM separation minima.

Note 1.— The safety cases were undertaken by a number of States listed in Appendices E and F. These listings of hazards and mitigation measures are not complete given their site-specific nature, and risk classifications have been removed to avoid incorrect inferences being drawn. Nevertheless, the hazards are considered in their totality and their relationship to each other examined during the safety assessments for implementation.

Note 2.— Appendices E and F and the various sub-appendices provide evidence of achieved ADS-B and MLAT surveillance performance during ADS-B and MLAT surveillance implementation trials.

CONCLUSIONS

3.20 The application of the above process demonstrated that ADS-B and MLAT surveillance is better or at least no worse than the reference SSR and therefore no less safe than radar.

3.21 As such, ADS-B or MLAT surveillance can be used to provide a 2.5 NM, 3 NM or 5 NM separation minima as prescribed in PANS-ATM whether ADS-B or MLAT is the sole means of ATC surveillance or used together with radar. There is a requirement for a region or State to undertake a safety assessment that demonstrates that the intended safety level will be met using ADS-B or MLAT.

3.22 To this end, a State implementation roadmap is provided in Chapter 4; it will be seen that this roadmap relies upon the various outputs from the application of the SASP safety assessment.

Chapter 4

STATE IMPLEMENTATION ROADMAP

INTRODUCTION

4.1 The successful implementation of ADS-B or MLAT surveillance depends upon careful planning and a methodical approach. This chapter covers both these elements by providing a sequence of flow diagrams which together constitute a State implementation roadmap for the guidance of States seeking to implement ADS-B or MLAT. It is complemented by the Appendices[1] to this document.

ASSUMPTIONS

4.2 The State implementation roadmap contained in this chapter is based upon the assumptions that a need for ADS-B or MLAT surveillance has been identified and that the necessary consultation has taken place with airspace users.

IMPLEMENTATION CONSIDERATIONS

4.3 The implementation of ADS-B or MLAT surveillance is a lengthy process that may take a State several years to achieve. There are several reasons for this, some of which are interrelated:

a) dependence of ADS-B on appropriate airborne equipage means that aircraft will need to be certified to the appropriate level to enable ADS-B. This may require States to consult on a regional basis to achieve commonality in aircraft certification where possible;

b) a monitoring programme should be considered to ensure specified avionic performance requirements are maintained;

c) ADS-B surveillance depends on GNSS to perform the airborne navigation function (position determination and tracking) and ATC surveillance; therefore, safety requirements may be extensive and take considerable time to realize;

d) the licensing of air traffic controllers who currently hold procedural ratings requires training and considerable time if these controllers are to be “converted” to providing ATC service using ADS-B or MLAT surveillance. Human Factors considerations would also need to be addressed;

e) the installation of ADS-B or MLAT ground stations and ATC systems is demanding in terms of time and resources; and

1. The Appendices are provided on the CD-ROM at the back of this circular.

f) the creation of a “surveillance-based” airspace concept can be time-consuming and complex.

4.4 For the purposes of providing implementation guidance, it is necessary to attempt to balance the complexity of ADS-B or MLAT implementation against the regional and national diversities of project planning. In pursuit of this balance, the State implementation roadmap has been limited in detail and neither it nor the explanatory notes should be viewed as comprehensive checklists. These roadmaps are provided for the guidance of regions and States, and they do not purport to cover all aspects of implementation.

4.5 The State implementation roadmap is comprised of four processes, A to D:

a) Process A: Definition of an airspace concept;

b) Process B: Identification of ADS-B or MLAT performance requirements;

c) Process C: Safety assessment (initial, implementation and operational); and

d) Process D: Preparation for implementation.

4.6 Although only Process D is identified as preparation for implementation, it is evident that all four processes are concerned with preparing for the implementation of ADS-B or MLAT surveillance. Although the processes are shown in sequence, there are overlaps between them and several iterations between them are possible. As will be seen, the safety assessment cited in Process C is part of all the other processes.

PROCESS A: DEFINTION OF AIRSPACE CONCEPT

4.7 Deciding how ADS-B or MLAT surveillance is to be used in a given airspace includes determining, for example, the separation minima to be used in that airspace and ensuring that the ADS-B or MLAT surveillance equipment can support the minima (Process B). This has a direct effect on the airspace concept that can be elaborated; an airspace concept which is to be supported by procedural control, i.e. without ATC surveillance, is usually not similar to one used where ATC surveillance is to be used.

4.8 The effect of introducing ADS-B or MLAT surveillance into a terminal control area (TMA) formerly controlled by procedural means can be used by way of an example. In such a case, it is likely that the ANSP will wish to make changes to the standard instrument departure (SID) and standard instrument arrival (STAR) structure (or introduce SID and STAR) and to realign the entry and exit points from the TMA and perhaps relocate the holding areas. Of necessity, this adjustment to the terminal airspace structure will affect the en-route airspace structure (or vice versa, if the change is generated in the upper airspace), and the airspace concept needs to be defined, tested and validated prior to implementation and use of ADS-B and MLAT surveillance.

4.9 This process is reflected in Figure 4-1, which also shows that the definition of the airspace concept needs to be followed up by the remaining two processes.

PROCESS B: IDENTIFICATION OF ADS-B OR MLAT PERFORMANCE REQUIREMENTS

4.10 One of the biggest advantages provided by the deployment of ADS-B or MLAT surveillance is the potential use to be made of the ATC surveillance separation minima provided in the PANS-ATM.

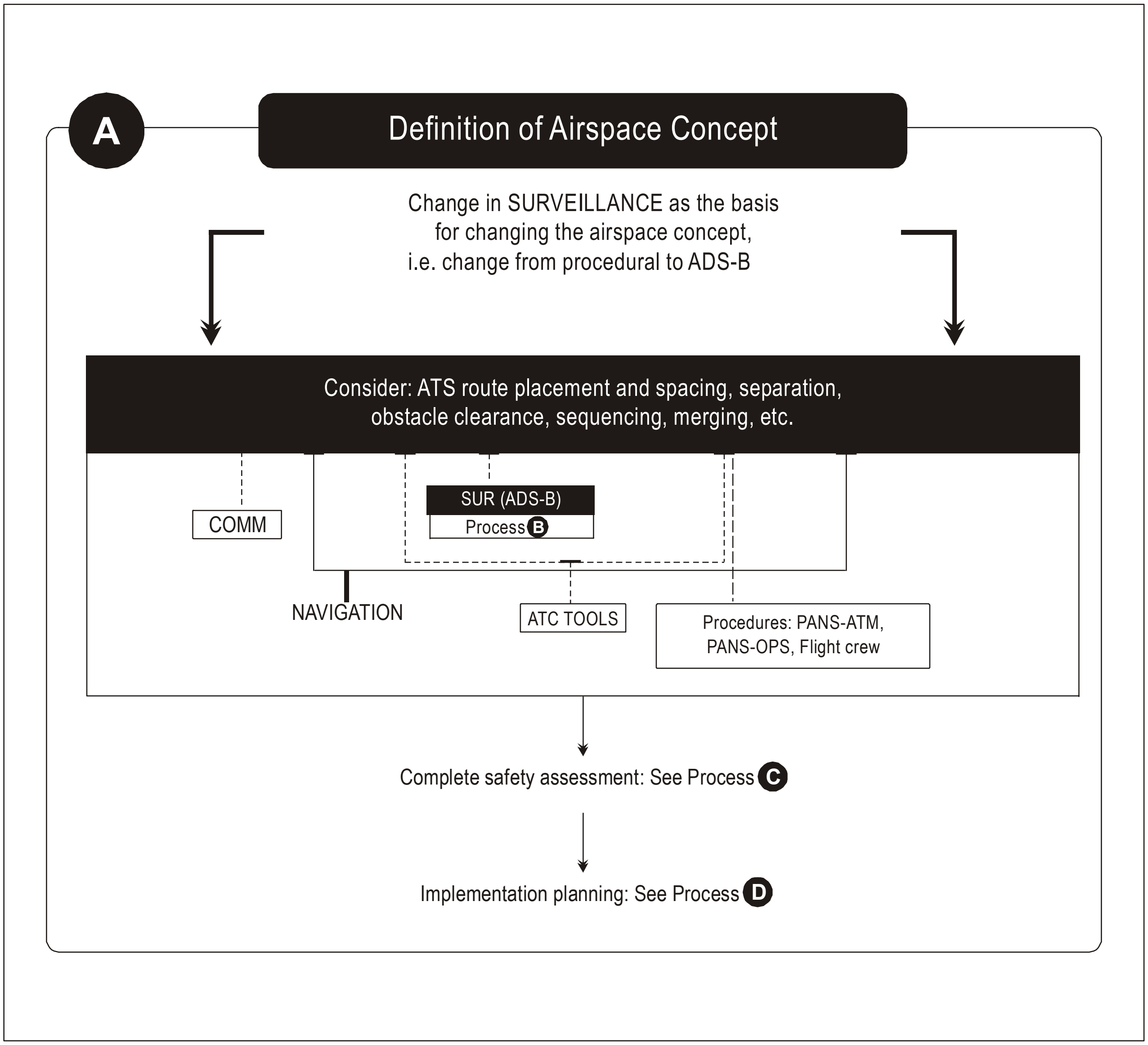

Figure 4-1. Concept to accommodate ADS-B

4.11 Inasmuch as any separation minima in the PANS-ATM cannot be used "off the shelf", the same is true of the separation minima for ADS-B or MLAT surveillance. States and regions need to undertake a safety assessment as prescribed in the *Safety Management Manual (SMM)* (Doc 9859) and the PANS-ATM when seeking to use the separation minima described in the PANS-ATM. Notably, to be ICAO-compliant the separation minima used by a State or region cannot be less than the minima cited in the PANS-ATM, but they may be greater.

4.12 One of the critical aspects of determining whether ADS-B or MLAT surveillance can support the separation minima of the PANS-ATM concerns the technical performance of the equipment. This is not the only consideration, however, as can be seen from the sequence of processes in this chapter.

4.13 The SASP methodology considered only the reference system when used in low-complexity airspace as described in Chapter 3. States planning to implement ADS-B or MLAT in airspace environments similar to those assumed in the SASP assessment need not repeat the technical comparative assessment if their safety assessment does not require it.

4.14 States planning to implement ADS-B or MLAT in more complex airspace environments may need to undertake a comparative assessment if so required by their safety assessment. The methodology used could be as shown in Figure 4-2. It starts with a State selecting a reference MSSR to use as the basis of comparison.

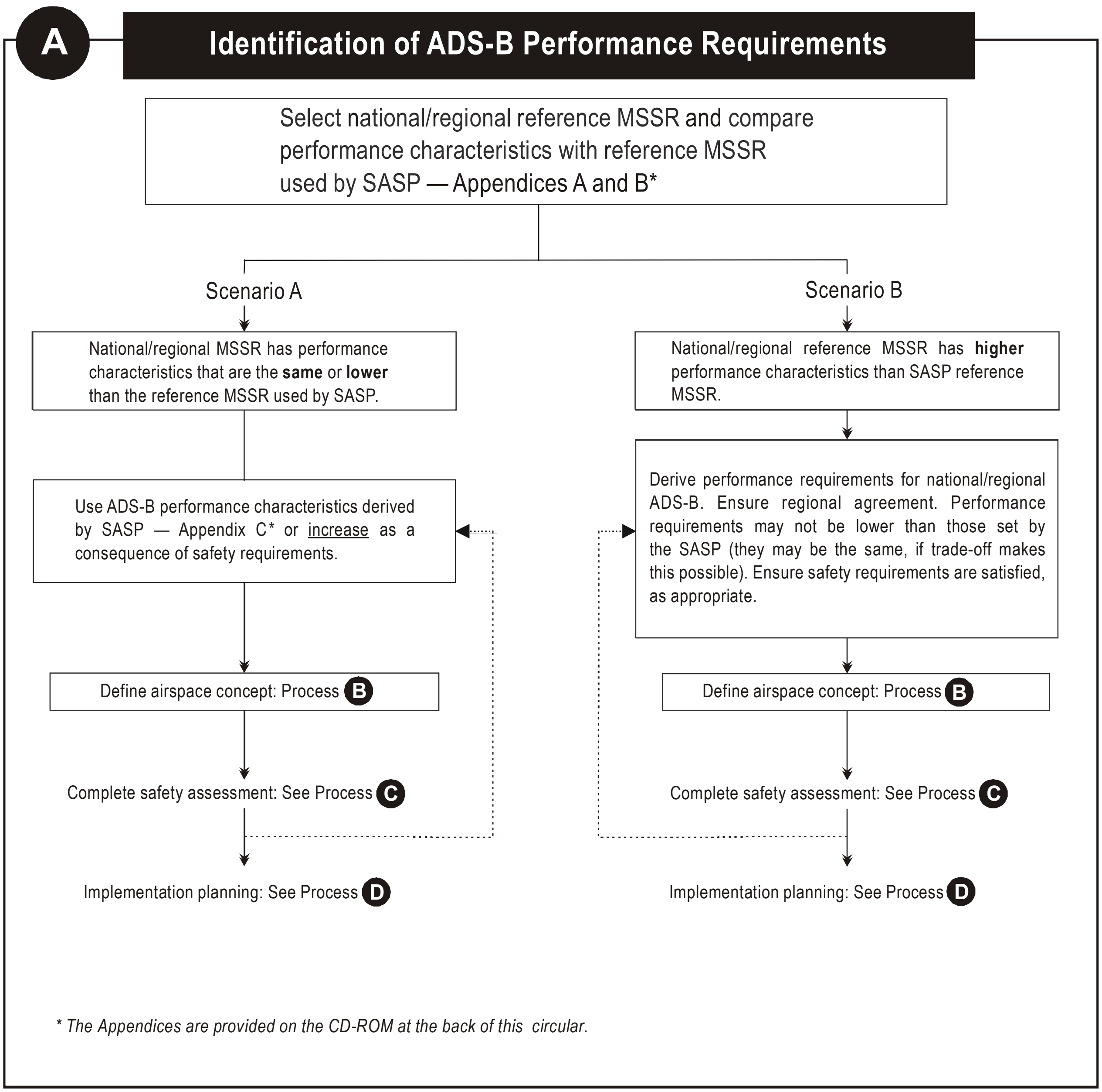

Figure 4-2. Identifying ADS-B performance requirements

Low-complexity airspace

4.15 If the State's safety assessment determines that the assumptions of the SASP comparative assessment can be met, then there is no requirement to undertake a technical comparative assessment. The SASP ADS-B or MLAT performance characteristics therefore immediately apply.

Complex airspace

4.16 In this section it is assumed that the safety assessment has required the State to undertake a full technical comparative assessment. This requires the State to select a reference MSSR to use as the basis of comparison.

4.17 The reference MSSR chosen by the State must be capable of supporting the target separation minima. Alternatively if a State or region uses an MSSR with particular performance characteristics in another location to support the target separation minima, this MSSR can be used as the "benchmark" or "reference" MSSR by the State/region.

4.18 Having selected this benchmark, the first task of the State or region is to compare the performance characteristics of its reference MSSR with the reference MSSR used by SASP. If the performance of the State or regional reference MSSR is equal to or less than that of the reference MSSR used by SASP, States and regions are strongly advised to use the SASP reference MSSR as the reference MSSR for their purposes. Without considering safety requirements, this would suggest that the SASP ADS-B or MLAT performance characteristics immediately apply.

4.19 If, on the other hand, the performance of the State or regional reference MSSR is more demanding than that of the reference MSSR used by SASP, States and regions should use their own reference MSSR as the benchmark against which the ADS-B or MLAT performance requirements are determined for their region or State (see Figure 4-3).

4.20 The key performance characteristics of the SASP reference MSSR are listed in Appendix A to this manual. The comparison between this reference and the ADS-B or MLAT surveillance performance requirements is shown in Appendix B. Specific ADS-B and MLAT performance requirements determined by SASP are provided in Appendix C.

4.21 It should be noted that the performance characteristics of the ADS-B or MLAT surveillance equipment are only part of the processes that need to be completed to determine whether or not the PANS-ATM separation minima and procedures can be applied. The safety assessment which follows after the airspace concept has been defined can also identify particular safety requirements which may impact upon the performance requirements of the ADS-B or MLAT equipment. At worst, it may require performance requirements to be increased.

PROCESSES C AND D: SAFETY ASSESSMENT AND PREPARATION FOR IMPLEMENTATION

4.22 Doc 9859 describes the safety assessment process. This process effectively spans across all other processes involved in the preparation for ADS-B or MLAT implementation and thus applies to Process A: Definition of the airspace concept; Process B: Determination of performance requirements; and Process D: Preparation for implementation. It assumes the existence of a national safety policy and that a State plan will be formulated for the implementation of ADS-B or MLAT surveillance.

4.23 Figure 4-4 shows Processes C and D side by side; it depicts, primarily, how the airspace concept defined under Process A is subjected to a functional hazard analysis (FHA). Notably, the airspace concept includes more than the routes, holds and airspace management. The entire concept rests on CNS/ATM enablers, and it is this total concept that is subjected to an FHA. To this end, hazards and identified mitigations contained in Appendix E to this document may be referenced by States and regions, mindful that these hazard listings are incomplete. Once the FHA has been completed and safety objectives identified, the airspace system (i.e. the total system comprising all elements of

CNS/ATM) can be designed to meet the safety objectives. Once designed, the system can be subjected to a preliminary system safety assessment (PSSA) and, to this end, the airspace concept and all elements therein subjected to this level of assessment. From an airspace concept perspective, this involves validation of the airspace concept, usually by real-time simulation. From an equipment perspective, this may involve ADS-B or MLAT equipment trials such as those carried out at Burnett Basin and Brisbane in Australia, and Alaska in the United States (see Appendices E and F). Site acceptance tests are also undertaken with regard to equipment and at this point the equipment is signed off. The safety requirements emanating from the PSSA effectively determine whether it is necessary to undertake an iteration and revisit the performance requirements for ADS-B or MLAT determined under Process B.

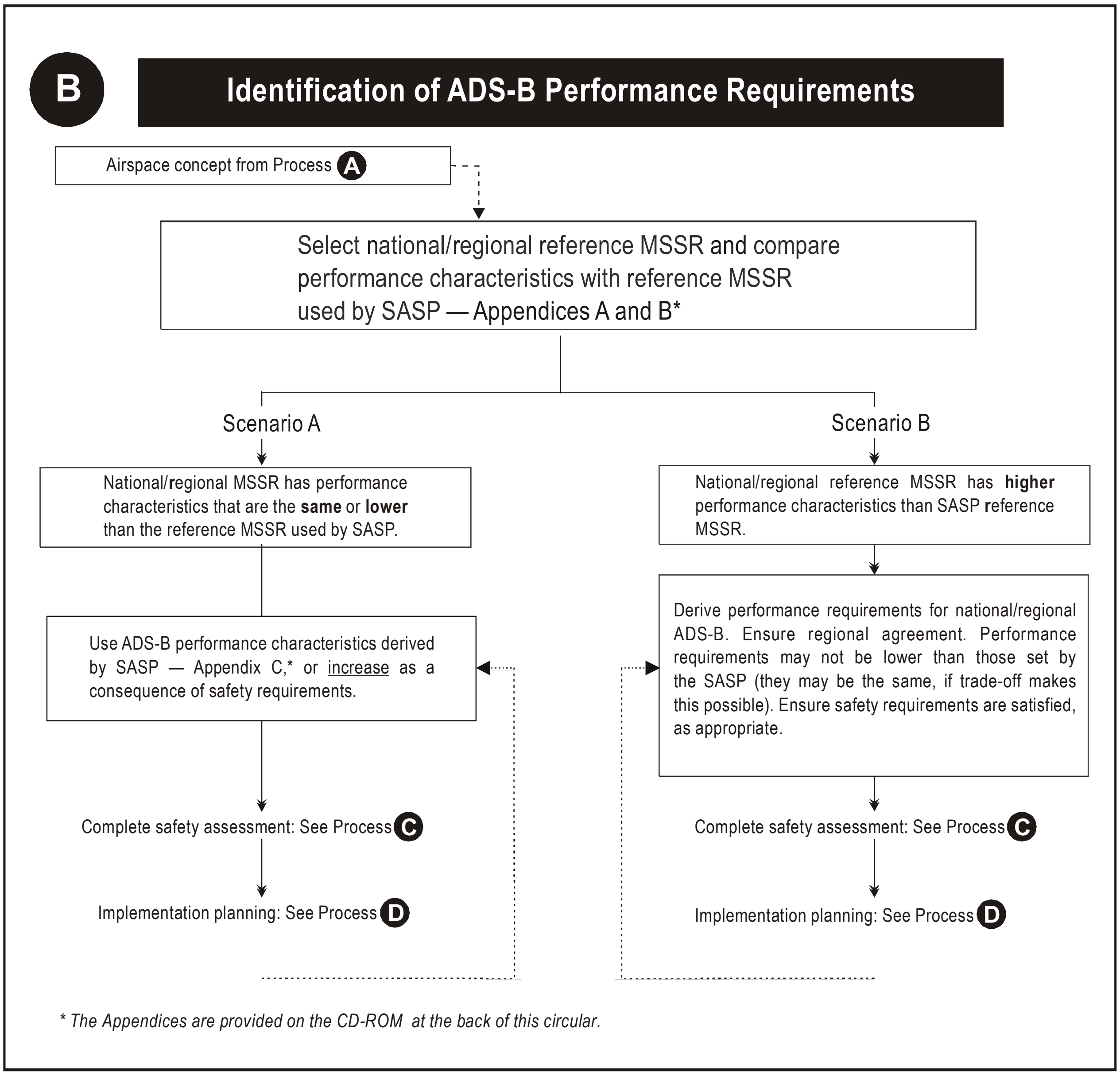

Figure 4-3. Identifying ADS-B performance requirements

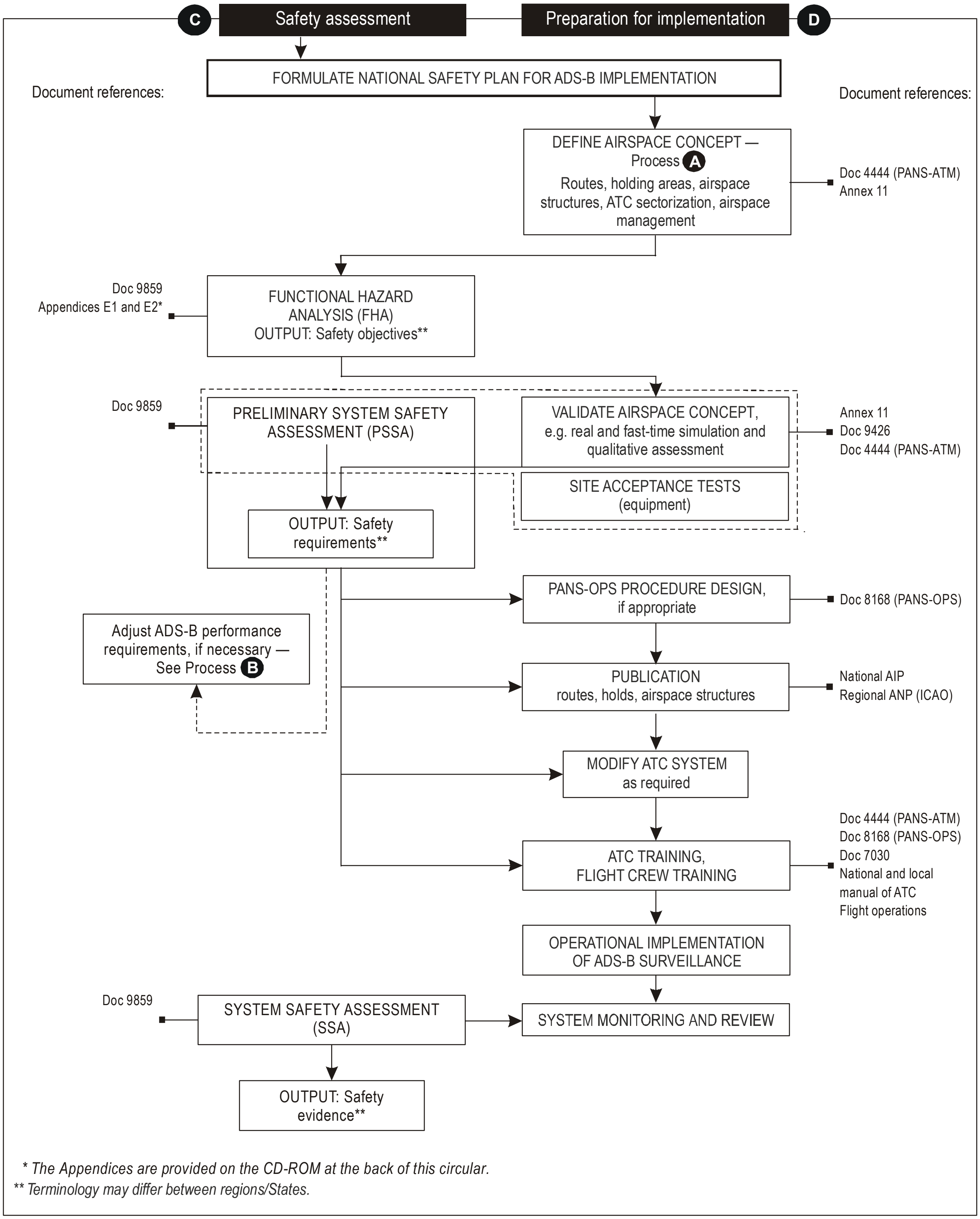

Figure 4-4. Safety assessment and preparation for implementation

When would iteration be necessary between safety and performance requirements?

4.24 If, for example, ADS-B is to be deployed in an area where sole reliance is placed on GNSS for both the navigation (position determination) and surveillance functions, this suggests that the entire airspace concept or total system could be subjected to vulnerability in that a common point of failure exists, viz. GNSS. As such, the PSSA may identify a safety requirement exists to ensure adequate continuity of navigation and surveillance. Alternatively procedural mitigators may be implemented. States should identify the best risk controls depending on local circumstances. It is not a given that a common point of failure exists in all environments simply because both navigation (position determination) and surveillance use GNSS.

Countdown to implementation

4.25 Once the validation processes are complete, ANSPs and operators effectively start the countdown to implementation. This is usually an extremely busy period when regulations need to be modified, ATC and crew training takes place, and State aeronautical publications and the regional air navigation plan need to be developed.

4.26 Operational implementation does not mark the end of safety assessment. As long as the airspace system (formerly a concept) continues to exist, so does the safety assessment process. The SSA relies on safety evidence being provided by post-implementation monitoring so that the total system continues to be safe.

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