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Minimum Aviation System Performance Standards for Aircraft Surveillance Applications

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RTCA/DO-3??

Prepared by: SC-186

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FOREWORD

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RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal Advisory Committee and develops consensus based recommendations on contemporary aviation issues. RTCA's objectives include but are not limited to:

- Coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;
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- Developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
- Assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunications Union and other appropriate international organizations can be based.

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1 PURPOSE AND SCOPE

1.1 Introduction

This document contains Minimum Aviation System Performance Standards (MASPS) for Aircraft Surveillance Applications (ASA). This document is intended to specify requirements for and describe assumptions for all sub-systems supporting the operational application of ASA, e.g., Automatic Dependent Surveillance - Broadcast (ADS-B), Airborne Surveillance and Separation Assurance Processing (ASSAP), and Cockpit Display of Traffic Information (CDTI).

These standards specify characteristics that should be useful to designers, installers, manufacturers, service providers and users for systems intended for operational use within the United States National Airspace System (NAS). Where systems are global in nature, the system may have international applications that are taken into consideration.

Compliance with these standards is recommended as one means of assuring that the system and each subsystem will perform its intended function(s) satisfactorily under conditions normally encountered in routine aeronautical operations for the environments intended. This MASPS may be implemented by one or more regulatory documents or advisory documents (e.g., certifications, authorizations, approvals, commissioning, advisory circulars, notices, etc.) and may be implemented in part or in total. Any regulatory application of this document is the sole responsibility of the appropriate governmental agencies.

Chapter 1 of this document describes the Aircraft Surveillance Applications system and provides information needed to understand the rationale for function characteristics and requirements. This section describes typical applications and operational goals, as envisioned by members of RTCA Special Committee 186, and establishes the basis for the standards stated in Chapters 2 through 4. Definitions and assumptions essential to the proper understanding of this document are also provided in this section. Additional definitions are provided in Appendix A.

Chapter 2 describes minimum system performance requirements for the ASA system under standard operating and environmental conditions. ASA functional requirements and associated performance requirements are provided. ASA Capability Levels (ACLs) are identified and specified.

Chapter 3 contains the minimum performance standards for each subsystem that is a required element of the minimum system performance specified in Chapter 2, as well as the interface requirements between these subsystems. Assumptions about expected standards for systems external to ASA are also documented.

Chapter 4 contains the minimum performance standards for each ASSAP system application requiring the processing of ADS-B messages that have been received and assembled into reports. The applications are grouped into broad categories of situational awareness, spacing applications, and separation applications.

The appendices are as follows:

A: Acronyms and Definitions of Terms
B: Bibliography and References

C: Derivation of Link Quality Requirements for Future Applications
D: Design Trade-Off Considerations
E: Receive Antenna Coverage Constraints
F: Integrity Considerations for ADS-B Applications
G: Latency and Report Time Error Data
H: Derivation of Track Acquisition and Maintenance Requirements
I: Future Air-Referenced Velocity (ARV) Broadcast Conditions
J: (under review to include old DO-242A App J)
K: Compatibility of ASA MASPS with ADS-B standards and fielded systems
L: MASPS / LINK MOPS Compliance Matrices (tentative)
M: Traceability matrix to show disposition of DO-289 and DO-242A into DO-3xx

The word "sub-function" as used in this document includes all components that make up a major independent, necessary and essential functional part of the system (i.e., a subsystem) so that the system can properly perform its intended function(s). If the system, including any sub-functions, includes computer software or electronic hardware, the guidelines contained in [RTCA DO-178B and DO-254] should be considered even for non-aircraft applications.

1.2 System Overview

Today's airspace system provides separation assurance for aircraft operating under Instrument Flight Rules (IFR) via air traffic control and air traffic services (ATC/ATS), which are ground-based. These services utilize ground radar surveillance (primary and secondary surveillance radars), controller radar displays, air route infrastructure, airspace procedures including flight crew see and avoid, and VHF voice communications to assure separation standards are maintained. In the event of failure of this separation assurance system, aircraft equipped with Airborne Collision Avoidance Systems (ACAS), i.e., TCAS, are warned of potential mid-air collisions as a safety back up.

In order to accommodate expected increases in air traffic, a future separation assurance system is evolving using new technologies and automation processing support that is expected to enable the delegation of certain spacing or separation tasks to the flight deck. ASA represents the aircraft-based portion of this future separation assurance system. A wide range of separation assurance applications are expected to be developed over time that will enable enhanced airspace operations. These enhanced operations are intended to provide improved operational efficiencies, such as increased system capacity and throughput, while maintaining or improving air safety. Both aircraft-based and ground-based applications are discussed in this document.

1.2.1 Definition of Aircraft Surveillance Applications

The ASA system comprises a number of flight-deck-based aircraft surveillance and separation assurance capabilities that may directly provide flight crews with surveillance information, as well as surveillance-based guidance and alerts. Surveillance information consists of position and other state data about other aircraft and surface vehicles and obstacles when on or near the airport surface.

ASA applications are intended to both enhance safety and increase the capacity and efficiency of the air transportation system. Safety will be enhanced by providing improved traffic situational awareness to pilots, as well as capabilities to assist in conflict prevention, conflict detection, and 4-D conflict resolution. Capacity and efficiency will be enhanced by enabling aircraft to fly closer to one another and potentially delegating certain spacing or separation tasks to the flight crew, for example:

- Improving runway throughput in instrument meteorological conditions (IMC) through use of new cockpit tools;
- More efficient departure sequencing without increases in ATC workload
- Enabling aircraft in oceanic airspace to fly more optimal cruise profiles and pass other aircraft on parallel routes
- Accommodating more kinds of flight trajectories than ATC currently authorizes.

The individual ASA applications are described in §1.3. It is a goal of these applications to minimize any increase in workload while ensuring safety. Particular attention is paid to preventing workload increases during critical phases of flight, such as final approach and landing.

Some ASA applications are independent of ground systems and air traffic control, while others depend on or interact with services provided by ground systems and air traffic control. This MASPS does specify requirements for ground systems such as Traffic Information Service – Broadcast (TIS-B) and the Automatic Dependent Surveillance – Rebroadcast (ADS-R) service and states assumptions about the functional and performance capabilities of the services they provide to the extent that these are required by ASA applications. ADS-B is used to augment or improve current ATC ground surveillance.

1.2.2 Application Assumptions

To achieve the expected gains, this document makes certain assumptions about the use of new technology. These assumptions include, but are not limited to:

A. Flight crews, in appropriately equipped aircraft, will be able to perform some functions currently done by ATC, some of which may be at reduced separation standards compared to current separation standards.

B. The variability in the spacing between aircraft in the airport arrival and/or departure streams will be reduced with the use of certain ASA applications.

C. Pilots will be willing to accept additional separation responsibility beyond what they have today that is currently provided by ATC.

D. Pilot and ATC workload will not be increased substantially by ASA applications.

E. Most aircraft will eventually be equipped with avionics to perform ASA applications (this is necessary to maximize system benefits).

F. ATC will be willing to act as a “monitor” and retain separation responsibility between designated aircraft.

G. ADS-B avionics and applications will be compatible with future ATC systems and operating procedures.

These assumptions have not yet been fully validated.

1.2.3 ASA Architecture

Figure 1-1 provides an overview of the ASA system architecture and depicts the interfaces between functional elements for an ASA aircraft participant and external systems. The ASA system architecture consists of three major components: subsystems for the transmit participant, subsystems for the receive participant, and the ground systems. The ASA also interfaces with other aircraft systems.

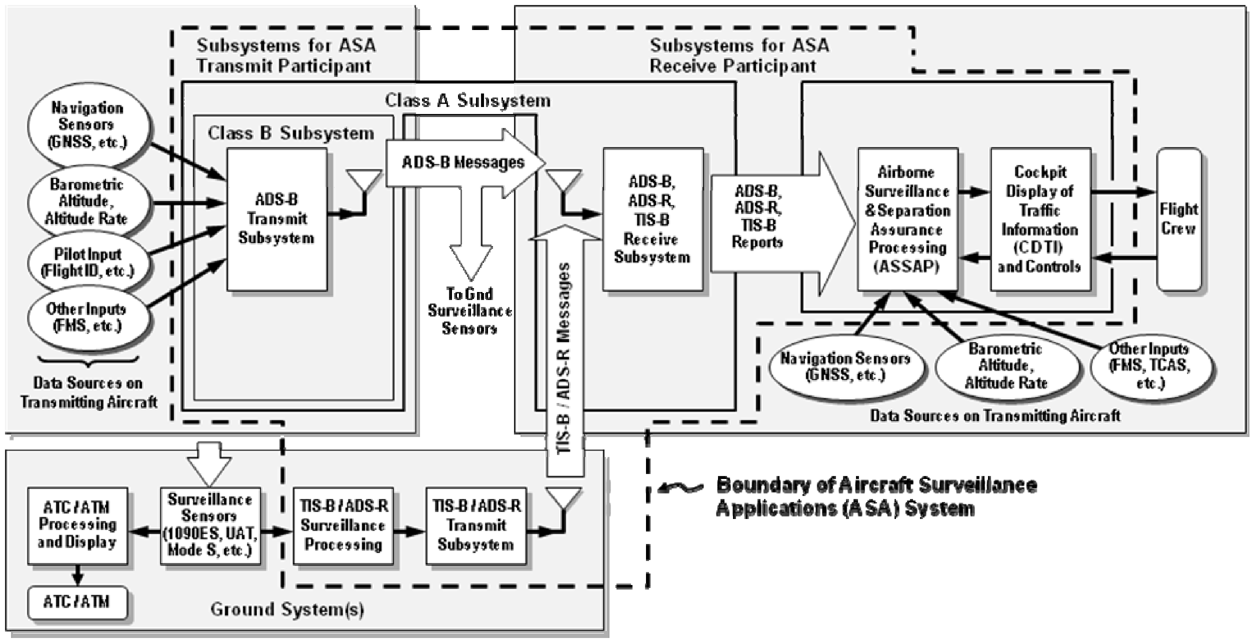

Figure 1-1: Overview of ASA Architecture

Note that there is a clear distinction in the diagram between messages and reports. An ADS-B message is a block of formatted data that conveys the information elements used in the development of ADS-B reports. Message content and formats are unique for each of the ADS-B data links. The MASPS does not address these message definitions and structures. An ADS-B Report contains the information elements assembled by an ADS B receiver using message content received from ADS-B, ADS-R, and TIS-B messages from transmitting airborne and ground participants. These reports are available for use by applications external to the ADS B system.

Aircraft ASA systems which include both link message transmit and receive capability are defined to be Class A systems. Systems which include only the link transmit capability are defined to be Class B systems. Subcategories within the classes define capability thresholds based on parameters such as transmit power and receiver sensitivity to align equipment capabilities with intended applications. Ground systems are defined to be Class C systems.

1.2.3.1 ASA Transmit Participant Subsystem

The subsystem for the ASA transmit participant accepts navigation and other data inputs from the aircraft, processes it to create the link unique ADS-B messages, and then broadcasts those ADS-B messages. The navigation data contains position and velocity information, as well as the accuracy and integrity parameters characterizing that data, either directly from a Global Navigation Satellite System (GNSS) receiver or a GNSS based navigation system. There are increasingly restrictive thresholds for the accuracy and integrity metrics of the navigation data as the system applications progress in criticality from situational awareness to separation assurance.

Other data sources include the barometric altitude and altitude rate and pilot inputs such as the flight identification. A critical performance requirement in the transmit subsystem is minimizing the latency between the time the GNSS sensor makes the position measurement and broadcasting it in the ADS-B messages.

1.2.3.2 ASA Receive Participant Subsystem

The subsystem for the ASA receive participant accepts ADS-B message from aircraft and other vehicles, ADS-R and TIS-B messages from the ground system, and navigation and other data inputs from the aircraft.

1.2.3.2.1 ADS-B, TIS-B, ADS-R Receive Subsystem

The received ADS-B, ADS-R, and TIS-B messages are processed by the ADS-B, ADS-R, TIS-B receive subsystem in the ASA aircraft. The receive subsystem processes these messages and provides reports to the ASSAP subsystem. The reports are then processed by the ASSAP subsystem.

1.2.3.2.2 ASSAP Subsystem

Processing is performed by ASSAP, which takes the incoming surveillance information and processes it according to the appropriate ASA application(s) as selected by the flight crew. For example, the ASSAP may predict a violation of the applicable separation minima, and determine appropriate resolution guidance.

ASSAP is the processing subsystem that accepts surveillance reports, performs any necessary correlation and/or tracking, and performs application-specific separation assurance processing. Surveillance reports, tracks, and any application-specific alerts or guidance are output by ASSAP to the CDTI function. In addition to these interfaces and depending on the actual ASA application, ASSAP may interface to the Flight Management System (FMS) and / or the Flight Control (FC) systems for flight path changes, speed commands, etc.

1.2.3.2.3 CDTI

Display is accomplished through a Cockpit Display of Traffic Information (CDTI). The CDTI provides the flight crew interface to the ASA system. It displays traffic information as processed by the ASSAP. It provides other necessary information, such as alerts and warnings, and guidance information. The CDTI also provides flight crew inputs to the system, such as display preferences, application selection, and designation of specific targets and parameters for certain applications.

The CDTI subsystem includes the actual visual display media, any aural alerting and the necessary controls to interface with the flight crew. Thus, the CDTI consists of a display and a control panel. The control panel may be a dedicated CDTI control panel or it may be incorporated into another control, e.g., a multi-function control display unit (MCDU). Similarly, the CDTI display may also be a stand-alone display (dedicated display) or the CDTI information may be presented on an existing display (e.g., multi-function display).

The TCAS traffic display may be a separate display or TCAS traffic may be integrated with ASA surveillance data and presented in a combined format. If TCAS traffic is integrated with other surveillance data, only one symbol should be displayed to the flight crew for any one aircraft.

Note: *It is highly desirable that the TCAS traffic display be integrated with the CDTI.*

1.2.3.3 Ground Subsystems

1.2.3.3.1 TIS-B

Not all aircraft will be equipped to broadcast their position via ADS-B. It is anticipated that there will be a long transition period over which aircraft owners decide to equip their aircraft, and that some aircraft owners may choose never to equip. In addition, situations will occur where the ADS-B reporting equipment on an aircraft is not operating although it is installed.

To fill this information gap, the concept of Traffic Information Service Broadcast (TIS-B) was developed. Within their coverage areas, ground surveillance systems can determine the positions of transponder-equipped aircraft and broadcast this position data to ASA-equipped aircraft via TIS-B. Recently developed multi-lateration surveillance systems planned for the airport surface can provide position accuracies comparable to those from GPS. Away from the vicinity of the airport, ground radar systems will provide less accuracy, but the position information may still be suitable for providing situational awareness with respect to aircraft not equipped with ADS-B position reporting.

1.2.3.3.2 ADS-R

Automatic Dependent Surveillance – Rebroadcast (ADS-R) messages are crosslink translations from UAT to 1090ES and from 1090ES to UAT provided by the ground surveillance service. The ADS-R service is only provided when an aircraft in range of the broadcast antenna indicates that it has the capability to accept messages that are relayed from the UAT ADS-B link to 1090 ES ADS-B link, and likewise from 1090 ES to UAT equipped aircraft.

1.2.3.3.3 ADS-B Surveillance Sensors

The ADS-B ground system is comprised of a network of radio stations designed to provide surveillance coverage throughout the NAS that is equivalent or better that existing radar coverage. The ADS-B system will provide aircraft position and state data with substantially better accuracy and update rates for ATC automation systems, which provide an opportunity for reduced separation standards and more efficient flight operations.

1.2.4 Relationship to TCAS

The Traffic-Alert and Collision Avoidance System (TCAS), known internationally as the Airborne Collision Avoidance System (ACAS), provides flight crews with a traffic situation display and with safety alerts. Its success, and the attempt to use it for some additional applications for which it was not intended or well suited, helped promote interest in a more general ASA system to address those applications not directly associated with collision avoidance.

TCAS provides a backup safety system for separation assurance. On aircraft that carry both an ASA and a TCAS, the TCAS collision avoidance function must continue to function correctly when ASA fails. This need does not preclude an avionics architecture that integrates TCAS and ASA functionality in the same equipment, provided the frequency of common mode failures is sufficiently small in the context of providing collision avoidance protection when separation provision has failed. The operational uses of TCAS and ASA, and in particular their flight crew interfaces, will have to be carefully coordinated in order to ensure that all the intended safety and operational benefits are provided.

Note: *If future ASA applications are proven to provide increased safety, the interaction between ASA and TCAS may be altered; this will require validation.*

ADS-B surveillance differs from TCAS surveillance in that ADS-B broadcasts position and velocity information while TCAS derives relative position information through an interrogate – reply protocol. ADS-B covers a larger range (potentially 90 to 120 NM), and has greater overall accuracy. Altitude information in both systems is dependent upon on-board equipment. As a last-minute safety system, TCAS only needs to provide surveillance to approximately 15 NM. While TCAS measures range with great accuracy, it is unable to make highly accurate bearing measurements because of the limitations imposed by the available antenna technology that can be installed on aircraft. When GNSS is used as the navigation data source for ADS-B, highly accurate position measurements can generally be provided in all dimensions. This may allow added integrity to vertical height based only on pressure altitude. The relative position between two aircraft is calculated from these position reports, rather than measured, and the accuracy does not depend on the distance between the aircraft. The relative position will also differ from TCAS systems in allowing for relatively compact and inexpensive implementations suitable for categories of aircraft where TCAS is not required and is not economically attractive.

1.2.5 Relationship to Other RTCA / EUROCAE Documents

The diagram in Figure 1 2 shows the relationships between the Aircraft Separation Assurance (ASA) MASPS and other RTCA SC-186 documents, such as the Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Service – Broadcast (TIS-B) MASPS and the various link Minimum Operational Performance Standards (MOPS).

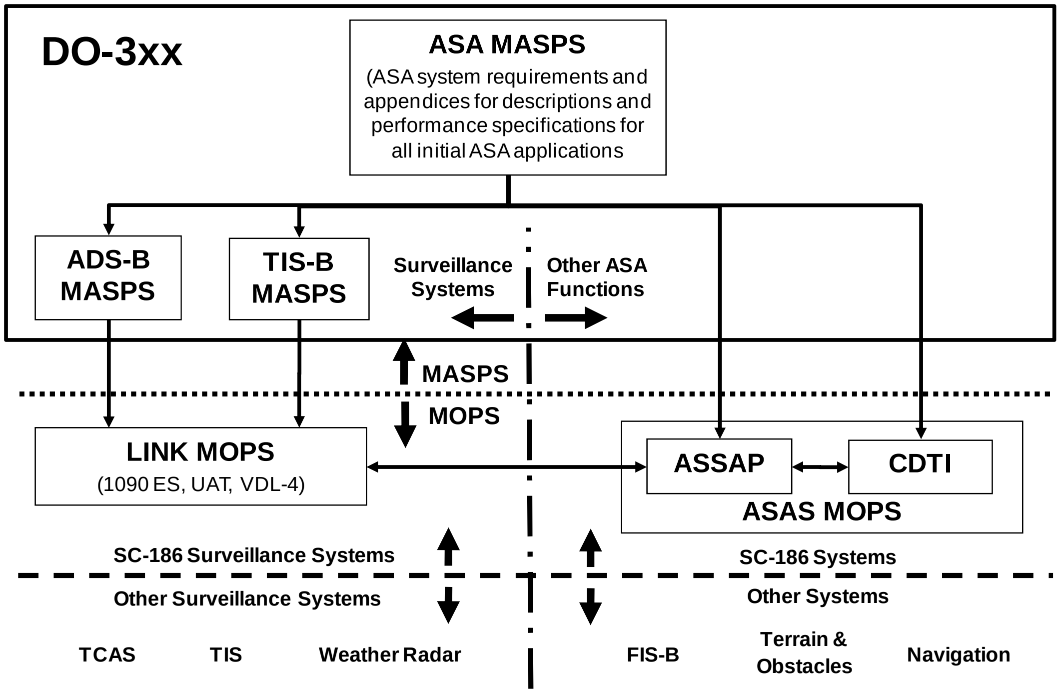

Figure 1-2: Relationship Between ASA MASPS And Other RTCA Documents

Two RTCA link MOPS have been identified: 1090 MHz Extended Squitter ADS-B (1090ES) and Universal Access Transceiver (UAT). The 1090ES MOPS has recently been revised and issued as [RTCA DO-260B], Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services (TIS-B) [RTCA DO-260B]. The UAT MOPS has been published as [RTCA DO-282B], Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast (ADS-B) [RTCA DO-282B]. EUROCAE Working Group 51 has issued [ED-108], a MOPS for VDL Mode 4 and a third ADS-B link. Additionally, EUROCAE Working Group 51 has released [ED-102A] which is identical to [RTCA DO-260B].

Note: *The VDL-4 link MOPS is a EUROCAE document, not an RTCA document.*

The Airborne Surveillance and Separation Assurance Processing (ASSAP) and the Cockpit Display of Traffic Information (CDTI) functions are closely related items and are written as a joint MOPS [RTCA DO-317A], Airborne Surveillance Application System (ASA) MOPS.

Figure 1-2 also shows the functions under the auspices of RTCA SC-186 and those systems outside the scope of RTCA SC-186. This MASPS document makes requirements allocations to the functions under the auspices of RTCA SC-186 and makes assumptions on the systems outside the scope of RTCA SC-186.

Surveillance Systems that are outside of the scope of RTCA SC-186 are the TCAS, Traffic Information Service (TIS), weather radar, and Flight Information Service – Broadcast (FIS-B). Terrain systems, e.g., Terrain Awareness and Warning System (TAWS) and Navigation systems, e.g., GPS, are also outside the scope of RTCA SC-186.

1.3 Operational Application(s)

The situational awareness and separation assurance capabilities of ASA are provided by applications. Numerous applications have been proposed, and it is expected that additional applications will be developed and standardized in future versions of this MASPS. The applications fall into five broad categories: situational awareness, enhanced situational awareness, spacing, delegated spacing, and self-separation.

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 required for these applications Enhanced situational applications add provisions such as cueing to the pilot through indications and alerts, or providing a new separation standard during the procedure.

Spacing applications require flight crews to achieve and maintain a given spacing with designated aircraft, as specified in a new ATC instruction. Although the flight crews are given new tasks, separation provision is still the controller's responsibility and applicable separation minima are unchanged.

In delegated separation applications, the controller delegates separation responsibility and transfers the corresponding separation tasks to the flight crew, who ensures that the applicable airborne separation minima are met. The separation responsibility delegated to the flight crew is limited to designated aircraft, specified by a new clearance, and is limited in time, space, and scope. Except in these specific circumstances, separation provision is still the controller's responsibility. These applications will require the definition of airborne separation standards.

Self separation applications require flight crews to separate their flight from all surrounding traffic, in accordance with the applicable airborne separation minima and rules of flight.

1.3.1 Initial Applications

This document specifies detailed requirements for an initial set of applications.

1.3.1.1 Enhanced Visual Acquisition (EVAcq)

The Enhanced Visual Acquisition (EVAcq), application represents the most basic of ASA applications, and use of the CDTI. The CDTI provides relative range, altitude and bearing data for participating aircraft, which will assist the flight crew in their aircraft visual search task.

1.3.1.2 AIRB

Need to add a paragraph on AIRB.

1.3.1.3 Visual Separation on Approach (VSA)

The Visual Separation on Approach (VSA), application is an extension of the current visual approach procedure. In this application, the CDTI is used by the flight crew to detect and track the preceding aircraft more effectively.

1.3.1.4 Basic Surface Situational Awareness (SURF)

The Basic Surface Situational Awareness (SURF), application is to provide the flight crew with own-ship positional and traffic situational awareness information relative to an airport map. This information may be used to support determination of their position, and subsequently determine the appropriate taxi route while also observing other traffic along that route. The flight crew may use the display as a supplemental aid to their out-the-window visual scan and taxi task. The flight crew must not use the display as the primary means of information for taxiing (i.e., blind taxiing).

1.3.1.5 Oceanic In-Trail Procedures (ITP)

In-Trail Procedures (ITP) in Oceanic Air Space enables flight level change maneuvers that are otherwise not possible within Oceanic procedural separation standards. ITP allows ATC to approve these flight level change requests between properly equipped aircraft using reduced procedural separation minima during the maneuver.

1.3.2 Emerging Applications

This document specifies detailed requirements for an initial set of applications.

1.3.2.1 Airport Surface situational Awareness with Indications and Alerts (SURF IA)

Airport Surface situational Awareness with Indications and Alerts (SURF IA) is a flight-deck based application that adds to the Airport Traffic Situation Awareness application by graphically highlighting traffic or runways on the airport map to inform flight crew of detected conditions which may require their attention. For detected non-normal—alert level—situations, which require immediate flight crew awareness, additional attention getting cues are provided.

1.3.2.2 Traffic Situational Awareness with Alerts (TSAA)

Traffic Situational Awareness with Alerts (TSAA) will provide traffic advisories in the near term by using the CDTI and alerts to assist the pilot or flight crew with visual acquisition and avoidance of traffic in both Visual Meteorological Conditions and Instrument Meteorological Conditions. The application is applicable under both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). It builds on the Basic Traffic Situational Awareness application by providing the pilot or flight crew with alerts for conflicting traffic that may or may not have been pointed out by ATC. This alert is for detected airborne conflicts.

1.3.2.3 Flight-Deck Based Interval Management-Spacing (FIM-S)

Flight-Deck Based Interval Management-Spacing (FIM-S) is a suite of functional capabilities that can be combined to produce operational applications to achieve or maintain an interval or spacing from a target aircraft. ATC will be provided with a new set of (voice or datalink) instructions directing, for example, that the flight crew establish and maintain a given time from a reference aircraft.

1.4 System Scope and Definition of Terms

The ASA system scope is all of the elements depicted in Figure 1-1. It should be noted that the transmit function shown in Figure 1-1 can be implemented in either the airborne segment (ADS-B Out) or in a ground segment, as for the TIS-B or ADS-R functions.

The ADS-B system scope is the middle three elements shown in Figure 1-1, including: the Transmit subsystem, the broadcast link RF medium, and the Receive & report generation function. It should be noted that the transmit function shown in Figure 1-1 can be implemented in the airborne segment (ADS-B Out).

The list of acronyms and all definitions of terms are included in Appendix A.

2 Operational Requirements

2.1 General Requirements

ADS-B is designed to support numerous applications. Many of these applications are described in this Section and in the Appendices.

Since the initial publication of this document, many of the ADS-B Out and ADS-B In applications have undergone a rigorous development of their operational and performance requirements. The high level performance requirements for the ADS-B In applications are summarized in Table 2-7. The high level performance requirements for the ADS-B Out applications are summarized in Table 2-10.

This section describes the operational performance requirements for the existing applications and a candidate set of potential future ADS-B applications. A candidate number of scenarios are defined that identify conditions that are driving factors in deriving full capability ADS-B system-wide functional and performance requirements. This candidate set should not be interpreted as a minimum or maximum for a given implementation. Furthermore, all implementations are not required to support all applications.

The following key terms are used within this section.

- **ADS-B Message.** An ADS-B Message is a block of data that is formatted and transmitted that conveys the information elements used in the development of ADS-B reports. Message contents and formats are specific to each of the ADS-B data links; these MASPS does not address message definitions and structures.

- **ADS-B Report.** An ADS-B report contains the information elements assembled by an ADS-B receiver using messages received from a transmitting participant. These information elements are available for use by applications external to the ADS-B system.

2.1.1 General Performance

2.1.1.1 Consistent Quantization of Data

When the full resolution of available aircraft data cannot be accommodated within an ADS-B Message, a common quantization algorithm **shall** (242AR2.1) be used to ensure consistent performance across different implementations. To minimize uncertainty, a standard algorithm for rounding/truncation is required for all parameters. For example, if one system rounds altitude to the nearest 100 feet and another truncates, then the same measured altitude could be reported as different values.

➔ACTION DEAN: Review the Link MOPS and specify the quantization algorithm. ←

Note: *Users of the ADS-B Message formats should perform a comparison between the quality metrics applied and the resolution of each message element that those metrics are applied against. There are some combinations of message data* *elements and quality metrics that are not compatible. For example, in the 1090 MHz Extended Squitter system, the Airborne Velocity Message (Register 09_{16}) Subtypes 1 or 3 (subsonic) with a minimum resolution of 1 knot (~0.5 m/s) and NAC_V = 4 (Velocity accuracy < 0.3 m/s). Another example would be the Airborne Velocity Messsage Subtypes 2 or 4 (Supersonic) with a minimum resolution of 4 knots (~2 m/s) and NAC_V = 3 (Velocity accuracy < 1 m/s) or NAC_V = 4.*

2.1.1.2 ADS-B Reports Characteristics

The output of ADS-B **shall** (242AR2.2) be standardized so that it can be translated without compromising accuracy. The ADS-B Reports should support surface and airborne applications anywhere around the globe and should support chock-to-chock operations without the need for pilot adjustments or calibrations.

2.1.1.3 Expandability

Applications envisioned for using the information provided by ADS-B are not fully developed. In addition, the potential for future applications to need information from an ADS-B system is considered fairly high. Therefore the ADS-B system defined to meet the requirements in these MASPS needs to be flexible and expandable. Any broadcast technique should have excess capacity to accommodate increases and changes in message structure, message length, message type and update rates.

Note: *The update rate is the effective received update rate as measured at the receiving end system application (e.g., the automation system interface by ADS ground processing), not the transmission rate of the ADS-B system.*

These MASPS identifies different report parameters with different update rates. In some cases the resolution of the parameters may be different depending on the intended use. Ideally, the system should be designed so that message type, message structures, and report update rates can be changed and adapted by system upgrades.

2.2 System Performance – Standard Operational Conditions

2.2.1 ADS-B System-Level Performance

The standard operating conditions for ADS-B are determined by the operational needs of the target applications listed in Table YY. System performance requirements and needs for ADS-B are provided in terms of the operational environments and the information needs of applications making use of ADS-B information in those environments.

The following subsections describe representative scenarios used to derive ADS-B system-wide functional and performance requirements.

Application scenarios are grouped according to whether the user is operating an aircraft/ vehicle (ADS-B In) or is an Air Traffic Services provider (ADS-B Out). These scenarios outline the operational needs in terms of the information required, such as its timeliness, integrity, or accuracy. The intent for these is to meet the requirements in a manner which is independent of the technology which provides the underlying needs. Information timeliness, for example, may be provided either through a higher transmission rate or through a transmission environment that has a higher message delivery success rate.

A high level assessment of operational considerations for each airborne ADS-B In application category is summarized in Table 2-5. The top level traffic ("targets") performance requirements for the existing ADS-B In applications versus the minimum performance levels for each category of ADS-B transmit sources (i.e., ADS-B [direct air to air], ADS-R and TIS-B) are presented in Table 2-7. The airborne source's performance levels are from the FAA Final ADS-B Out Rule and Advisory Circular AC20-165 (Refs TBD). The TIS-B and ADS-R performance levels are from the latest version of the SBS ICD (Ref TBD).

A summary of the broadcast information provided by ADS-B and its applicability to the target applications is provided in Table 2-6. Assumptions for A/V-to-A/V scenarios are summarized in Table 2-8. A summary of ATS provider surveillance and conflict management current capabilities for sample scenarios is provided in Table 2-9(a). Additional and refined capabilities appropriate for ADS-B are provided in Table 2-9(b). Note that earlier versions of this document used the term "Station-Keeping" to describe a category of ADS-B In applications. Those applications are categorized as "Spacing Applications" in this version. Also previous versions used the term "Cooperative Separation" to describe an advanced category of ADS-B In applications. That category is now designated as "Delegated Separation" applications in this document.

Table entries not containing references supporting the value specified are based on operational judgment and may need further validation.

Table 2-5: High Level Considerations for ADS-B In Applications by Category

	1 SA Applications			2 "Enhanced SA" Applications			3 Spacing Apps		4 Delegated Separation Applications				5 Self Separation	
	Airborne	Approach	Surface	Oceanic	Approach	Surface	EnRoute / Terminal		EnRoute / Terminal				EnRoute / Terminal	
Requirement	AIRB	VSA	SURF	ITP	CAVS/ CEDS	SURF IA	FIM-S	Advanced	FIM-DS	DS-C/P	ICSPA	DSWRM	FC	Self Sep
Separation Responsibility	ATC (1)	ATC (1, 2)	ATC (1)	ATC	ATC	ATC	ATC	ATC	Shared	Shared	Shared	Shared	Aircraft	Aircraft
100% Out Equipage?	No	No	No	No	No	No	No	No	?	?	?	?	?	?
(Direct or via TIS-B)														
100% In Equipage?	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Operational Conditions	TBD	VMC Only	No Reqmt	VMC / IMC	VMC / IMC	No Reqmt	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC
3D / 4D Intent Data?	No	No	No	No	No	No	?	?	?	?	?	?	Yes	Yes
Wake Vortex Data?	No	No	No	No	No	No	No	No	No	?	?	Yes	?	?
Increased Perf Levels? (3)	No	No	?	No	Yes	Yes	?	?	Yes		Yes	Yes	Yes	Yes
(> FAA 2020 Mandate)														

Notes:

1. *Only when aircraft is on IFR Flight Plan.*
2. *ATC for all aircraft except ATC designated traffic to follow.*
3. *Performance level used for comparison is that of FAA Final ADS-B OUT Rule and AC 20-165 (Ref TBD).*

Table 2-6: Required Information Elements to Support Selected ADS-B Applications

Information Element ↓	Aid to Visual Acquisition (AIRB)	Spacing	Delegated Separation Assurance & Sequencing	Simultaneous Approaches	Airport Surface (A/V to A/V & A/V to ATS)	Flight Path Deconfliction Planning (Self Sep)	ATS Surveillance ADS-B OUT	TSAA Traffic Situation Awareness W/Alerts	Notes
Identification									
Flight ID (Call Sign)		•	•	•	•	•	•		1
Address	•	•	•	•	•	•	•	•	
Category			•	•	•	•	•		
Mode A Code							•		
State Vector									
Horizontal Position	•	•	•	•	•	•	•	•	
Vertical Position	•	•	•	•		•	•	•	
Horizontal Velocity	•	•	•	•		•	•	•	
Vertical Velocity	•	•	•	•		•	•	•	
Surface Heading					•				
Ground Speed					•				
NIC		•	•	•	•	•	•	•	
Mode Status									
Emergency/ Priority Status	•	•					•		
Capability Codes		•	•	•	•	•	•	•	
Operational Modes		•	•	•	•	•	•	•	
NACp	•	•	•	•	•	•	•	•	
NACv		•	•	•	•	•	•	•	
SIL		•	•	•	•	•	•	•	
SDA	•	•	•	•	•	•	•	•	
ARV			**TBD**						
Intent Data			**TBD**			**TBD**		**TBD**	

Notes for Table 2-6:

- *= Expected Application Requirement*

1. *A/Vs not receiving ATS services are not required to transmit call sign.*
2. *Application requirements are referenced in Section 4.*
3. *ADS-B is one potential means to provide intent information to support ATS. Other alternatives, not involving ADS-B, may become available.*

<u>Table 2-7:</u> ADS-B Transmit Sources – Minimum Required Performance vs ADS-B In Application Requirements

		1 SA Applications			2 "Enhanced SA" Applications			3 Spacing Applications		4 Delegated Separation Applications				5 Self Separation	
		Airborne	Approach	Surface	Oceanic	Approach	Surface	EnRoute / Terminal		EnRoute / Terminal				EnRoute / Terminal	
		AIRB	VSA	SURF	ITP	CAVS	SURF IA	FIM-S		FIM-DS	ICSPA	DS-C/P	DSWRM	FC	Self Sep
TRANSMIT SOURCES		DO-319	DO-314	DO-322	DO-312	"VSA+"	DO-323	SPR FRAC Version			DO-289 Appx J				
A. Airborne Platforms															
Accuracy (NACp)	8	5	6	7 / 9 4)	5		9 / 10 / 11	6 / 7			9				
Integrity (NIC)	7	N / A	6	N / A	5		N / A	5 / 7			9				
Vel Acc (NACv)	1	1	1	2	1		1	1 / 2			3				
Src Integ Lvl (SIL)	3	N / A	1	N / A	2		2	2			2				
(SDA)	2	1	1	1 / 2 2)	2		2	< 1x10^{-6} / flt hr 6)			TBD				
Flight ID	Yes	N / A	Required	N / A	Required		N / A	Required			Required				
B. Ground Segment: ADS-R															
Accuracy (NACp)	9 max	5	6	7 / 9 4)	N / A		9 / 10 / 11	6 / 7			9				
Integrity (NIC)	8 max	N / A	6	N / A	N / A		N / A	5 / 7			9				
Vel Acc (NACv)	1	1	1	2	N / A		1	1 / 2			3				
Src Integ Lvl (SIL)	3	N / A	1	N / A	N / A		2	2			2				
(SDA)	2	1	1	1 / 2 2)	N / A		2	< 1x10^{-6} / flt hr 6)			TBD				
Flight ID	Yes	N / A	Required	N / A	N / A		N / A	Required			Required				
C. Ground Segment: TIS-B															
Accuracy (NACp)	6 / 9 1)	5	6	7 / 9 4)	N / A		9 / 10 / 11	6 / 7			9				
Integrity (NIC)	0	N / A	6	N / A	N / A		N / A	5 / 7			9				
Vel Acc (NACv)	0	1	1	2	N / A		1	1 / 2			3				
Src Integ Lvl (SIL)	0	N / A	1	N / A	N / A		2	2			2				
(SDA)	2 3)	1	1	1 / 2 2)	N / A		2	< 1x10^{-6} / flt hr 6)			TBD				
Flight ID	No	N / A	Required	N / A	N / A		N / A	Required			Required				

<u>Notes for Table 2-7:</u>

1. *TIS-B NACp values are for airborne / surface targets in the Surface Environment. TIS-B NACp values for the En Route & Terminal Environments are TBD.*

2. *FAA TSO-C195 states applications' Hazard Level for ownship when airborne or on surface > 80 knots = Major (SDA=2), Hazard Level for ownship < 80 knots = Minor (SDA=1).*
3. *TIS-B Service does not broadcast an SDA value but SBS ICD defines TIS-B service SDA equivalent to 2.*
4. *SURF surface targets require NACp >=9, SURF airborne targets require NACp = 7 or 9 depending on parallel runway spacing.*
5. *The airborne source's performance levels are from the FAA Final ADS-B Out Rule and Advisory Circular (Refs TBD). The TIS-B and ADS-R performance levels are from the latest version of the SBS ICD (Ref TBD).*
6. *This is an assumption in the FIM-S SPR. Will be revisited when FIM-S MOPS is developed.*

Table 2-8: Summary of A/V-to-A/V Performance Assumptions for Support of Indicated Applications

	Operational Capability						
Information ↓	**Aid To Visual Acquisition**	**Conflict Avoidance and Collision Avoidance**		**Separation Assurance and Sequencing**	**Flight Path Deconfliction Planning**	**Simultaneous Approach**	**Airport Surface (Blind Taxi and Runway Incursion) (Note 8)**
		Future Collision Avoidance	**Terminal Spacing**	**Free Flight/ Delegated Separation in Overflight**	**Delegated Separation in Oceanic/ Low Density En route**		
Initial Acquisition of Required Information Elements (NM)	10	20	20	40 (50 desired) (Note 7 & 9)	90 (120 desired) (Note 7)	10	5
Operational Traffic Densities # A/V (within range) (Note 4)	21 (< 10 NM)	24 (< 5 NM); 80 (< 10 NM); 250 (< 20 NM)	6 (< 20 NM)	120 (< 40 NM)	30 (< 90 NM)	32 landing; 3 outside extended runway; 5 beyond runway	25 within 500 ft 150 within 5 NM
Alert Time (Note 3)	n/a	1 min	2 min	2 min	4.5 min (6 min)	15 sec	10 s (Blind Taxi) 5 s (Runway Incursion)
Expected NAC_P	n/a	10	10	10	6	10	10
Expected NAC_V	n/a	3	3	3	3	3	4
Service Availability % (Note 5)	95	99.9	99.9	99.9	99.9	99.9	99.9

Notes for Table 2-8:

1. *n/a (not applicable) = the requirement is not stressful and would not be higher than any other requirement, i.e., does not drive the design.*
2. *References are provided where applicable. Alert time data is provided in Appendix TBD for simulated scenarios. Else, best engineering judgment was used to obtain performance data.*
3. *Best engineering judgment applied. Not intended to prescribe alert time for airspace.*
4. *System must support all traffic in line of sight that have operational significance for the associated applications (i.e., within operationally relevant ranges and altitudes for these applications). The numbers in the table indicate the number of aircraft expected to participate in or affect a given operation. (Refer to Table TBD for requirements which are based on operational traffic densities derived from the Los Angeles basin model).*
5. *Service availability includes any other systems providing additional sources of surveillance information.*
6. *See Appendix TBD for alert times in simulated scenarios.*
7. *Initial acquisition of intent information is also required at this range.*
8. *This includes inappropriate runway occupancy at non-towered airports.*
9. *The operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.*

2.2.1.1 ADS-B System-Level Performance—Aircraft Needs

The following scenarios focus on aircraft systems and applications that use surveillance information pertaining to other aircraft within operationally relevant geometries and ranges. These scenarios assume that participating aircraft are CDTI equipped, with appropriate features, to assist in these operations. However, this does not imply that CDTI is required for these applications. Detailed traffic display requirements are provided in the appropriate application MOPS [12]. Air-to-air capabilities enabled by ADS-B equipage classes are depicted in Figure 2-3. The applications are identified [Abbreviation] by the terminology used in the AIWP Version 2 document (Ref TBD).

Note: *For aircraft (targets) that will support higher integrity categories of ADS-B In applications such as spacing or delegated separation, a capability to independently validate the ADS-B surveillance information is likely to be required [6]. Alternative validation means are under study. An example of this independent validation would be the possible use of TCAS ranging data to validate the received Version 0 and 1 ADS-B Position Messages. This has been required by the FAA for the In Trail Procedure (ITP) in the FAA ITP Policy Memo, Ref TBD. Application developers should note the useful range of TCAS for this function is well below the effective range of the higher ADS-B classes such as A3.*

2.2.1.1.1 Aircraft Needs While Performing Aid to Visual Acquisition [AIRB]

Transmission, air-to-air reception, and cockpit display of ADS-B information enables an aid to visual acquisition, also known as the Airborne Situational Awareness CDTI application (AIRB). This scenario is applicable in all airspace domains when ownship is airborne. See Table 2-6 for the information exchange needs and Table 2-8 for operational performance requirements to support the aid to visual acquisition.

2.2.1.1.2 Aircraft Needs for Approach Applications – Enhanced Visual Approach [VSA, CAVS]

The enhanced visual approach (VSA) application is an extension of the current visual approach procedure. In this application, the CDTI is used by the flight crew to detect and track the preceding aircraft. The CDTI may also be used to monitor traffic on a parallel approach. This application is expected to improve the safety as well as the routine performance of visual approaches, and in an advanced version (CAVS) to reduce the weather conditions during which "visual" approaches can be conducted.

2.2.1.1.3 Aircraft Needs for Future Collision Avoidance [ADS-B Integrated Collision Avoidance]

A future collision avoidance system based on ADS-B could contain enhancements beyond the present TCAS capability; for example:

- A surveillance element that processes ADS-B data,
- A collision avoidance logic that makes use of the improved surveillance information in detecting and resolving collision threats,
- A cockpit display of traffic information (CDTI) that may include predictive traffic position, enhanced collision alerts, and related information,
- A means of presenting Resolution Advisory (RA) maneuver guidance to the flight crew, possibly in the horizontal dimension as well as vertical.

TCAS II systems requirements have been updated to incorporate a hybrid surveillance scheme (combining active TCAS interrogation and passive reception of ADS-B broadcast data) to further reduce interference with ground ATS in the Hybrid Surveillance application, RTCA DO-300 (Ref TBD). Future enhancements may use ADS-B data in horizontal miss-distance filtering to further reduce the number of unnecessary RAs. Other modifications may include the use of ADS-B information in aircraft trajectory modeling and prediction.

These early applications of ADS-B in enhanced TCAS systems, beyond improving the performance of those systems, will also serve to validate the use of ADS-B through years of flight experience. The use of ADS-B to either supplement TCAS/ACAS or drive an independent CAS needs to be studied and simulated, addressing such issues as:

- Interoperability with existing collision avoidance systems,
- Mechanisms for aircraft-aircraft maneuver coordination,

- Optimization of threat detection thresholds,
- Surveillance reliability, availability and integrity,
- Need for intruder aircraft capability and status information,
- Handling special collision avoidance circumstances such as RA sense reversals,
- Data correlation and display merge issues, etc.

Further studies and test validation will need to be conducted to ensure compatibility of ADS-B with existing systems. Investigations will also be conducted to assess the need for a separate crosslink channel to handle information requests (such as for tracked altitude and rate, maneuver coordination, intruder capability, etc.).

Ultimately, assuming full ADS-B equipage and successful validation, collision avoidance based on active interrogation of transponders could be phased out in favor of ADS-B. The broadcast positions and velocities from the surrounding aircraft and the predicted intersection of their paths with own aircraft will be used to identify potential conflicts. Horizontal trajectory prediction based on the ADS-B data could reduce the number of unnecessary alerts, and will result in more accurate conflict prediction and resolution.

See Table 2-6 for the information exchange needs and Table 2-8 for operational performance requirements to support collision avoidance.

Because a threat of collision could arise from a failure in ADS-B, future collision avoidance applications may need a method to validate, independently, any ADS-B data they use. It might become possible to eliminate the need for independent validation if it is demonstrated that ADS-B can provide sufficient reliability, availability, and integrity to reduce, to an acceptable level, the risk that collision avoidance based on ADS-B would fail when the risk of collision arises from a failure of ADS-B.

Environment

The transitional environment will consist of mixed aircraft populations in any combination of the following equipage types:

- Users of ADS-B that are transponder equipped.
- Enhanced TCAS, that can broadcast and process ADS-B messages to improve TCAS/ACAS surveillance functions.
- Legacy TCAS II, including Mode S transponders.
- Sources and users of ADS-B that are not equipped with transponders.
- Aircraft equipped with transponders, but not with ADS-B.

Operational Scenario

The scenario used for analysis of the collision avoidance capability of ADS-B consists of two co-altitude aircraft initially in a parallel configuration with approximately 1.5 NM horizontal separation and velocities of 150 knots each. One of the aircraft performs a 180 degree turn at a turn rate of 3 degrees per second which results in a head on collision if no evasive action is taken. The false alarm scenario used for analysis consists of two aircraft in a head-on configuration both with speeds of 150 knots.

2.2.1.1.4 Aircraft Needs While Performing Spacing Applications [FIM-S, TBD]

A combination of FMS and ADS-B technology will enable pilots to assist in maintenance of aircraft spacing appropriate for a segment of an arrival and approach. At busy airports today aircraft are often sequenced at altitude to intervals of 10 to 12 miles. If looked at in terms of time over a point, the aircraft are roughly 80 seconds apart. Other than the cleared arrival flight path, pilots do not know the overall strategy or which aircraft are involved. Controllers begin speed adjustments and off arrival vectoring to assist in maintaining this interval and in achieving mergers of traffic. As the aircraft arrive at the runway, the spacing has in some cases been reduced to 2.5 miles or 55 seconds at approach speed. The speed adjustments and vectoring are an inefficiency that is accepted in the name of safety.

With ADS-B, the pilot can assist the controller's efforts to keep the spacing appropriate for the phase of flight. This is not to say that the pilot assumes separation responsibility, but rather assists the controller in managing spacing, while flying a prescribed arrival procedure. The arrival procedures could be built so that with the normally prevalent winds, aircraft could be fed into the arrival slot with a time interval that would hold fairly constant through a series of speed adjustments. The speeds, allowable speed tolerance and desired spacing would all be defined by the procedure or specified by the controller based on ground automation systems.

Procedures need to be developed to accommodate merges; this could be done on the aircraft by the use of Required Time of Arrival, or on the ground using the ATC automation ground systems. The benefits would not only be in fuel savings but in reduced ATS communications requirements and increased capacity as standard operating procedures would govern more of the arrival operations.

See Table 2-6 for the information exchange needs and Table 2-8 for operational performance requirements to support a terminal spacing application.

Environment

Spacing may occur in all operational domains. The subsequent scenario will focus on a terminal spacing application.

Operational Scenario

Terminal spacing will start at approach control and end at landing. Two aircraft are in a high volume terminal environment with mixed equipage. Both aircraft are under positive control by the terminal area controller, who issues an instruction to the in-trail aircraft to maintain a fixed separation (distance or time) behind the lead aircraft. The in-trail aircraft has a cockpit traffic display that can show the lead aircraft.

ADS-B terminal airspace spacing can assist flight crews in the final approach. An opportunity for spacing occurs with aircraft cleared to fly an FMS 4D profile to the final approach fix. Another aircraft can perform ADS-B spacing to follow the lead aircraft using a CDTI that provides needed cues and situational data on the lead and other proximate aircraft. In this scenario, spacing allows a lesser equipped aircraft to fly the same approach as the FMS-equipped aircraft. The in-trail aircraft will maintain minimum separation standards, including wake vortex limits, with respect to the lead aircraft.

2.2.1.1.5 Aircraft Needs for Delegated Separation Assurance and Sequencing [FIM-DS, DS-C, DS-P, FIM-DSWRM, Integrated ACAS]

Delegated separation applications are an operational concept in which the participating aircraft have the freedom to select their path and speed in real time. Research is in progress to fully develop operational concepts and requirements for delegated-separation. Delegated separation applications use the concept of "alert" and "protected" airspace surrounding each aircraft. In this concept, both general aviation and air carriers would benefit. Aircraft operations can thus proceed with due regard to other aircraft, while the air traffic management system would monitor the flight's progress to ensure safe separation.

Delegated separation applications include a transfer of responsibility for separation assurance from ground based ATC to aircraft pairs involved in close proximity encounters. The delegation of responsibility may not be for all dimensions i.e., ATC may only delegate a responsibility for cross track separation from a particular aircraft to the flight crew. In this scenario ATC would retain the responsibility for longitudinal (along-track) separation and altitude separation from all other aircraft. Per Table 2-5, participating aircraft will be specially equipped with high accuracy and high integrity navigation capabilities and high reliability ADS-B capability for these increased criticality flight operations. The airborne separation assurance function includes separation monitoring, conflict prediction, and providing guidance for resolution of predicted conflicts.

See Table 2-6 for the information exchange needs and Table 2-8 for operational performance requirements to support aircraft needs while performing delegated separation applications.

Note that to support delegated-separation, aircraft must be able to acquire both state vector and intent information for an approaching aircraft at the required operational range.

Environment

Each delegated separation applications aircraft supports electronically enhanced visual separation using a cockpit display of traffic information. All delegated separation applications aircraft perform conflict management and separation assurance. The pilot has available aircraft position, velocity vector information, and may have tactical intent information concerning proximate aircraft. Instead of negotiating maneuvers, the pilot uses "rules of the air" standards for maneuvers to resolve potential conflicts, or automatic functions that provide proposed resolutions to potential conflicts. There is a minimal level of interaction between potentially conflicting aircraft. Each aircraft in delegated separation applications airspace broadcasts the ADS-B state vector; higher capability aircraft equipped with flight management systems may also provide intent information such as current flight path intended and next path intended.

Only relevant aircraft will be displayed on the CDTI although hundreds of aircraft may be within the selected CDTI range, but well outside altitudes of interest for conflict management. Once both aircraft have been cleared for delegated-separation, the ATS provider will monitor the encounter but is not required to intervene.

Operational Scenario

Delegated separation applications are applicable in all operational domains, including, for example, en route aircraft overflying high density terminal airspace containing both airborne and airport surface traffic. The worst case conflict is two high speed commercial aircraft converging from opposite directions. Each aircraft has a maximum speed of 600 knots, resulting in a closure speed of 1200 knots (note that at coastal boundaries and in oceanic airspace, the potential exist for supersonic closure speeds of 2000 knots). A minimum advance conflict notice of two minutes is required to allow sufficient time to resolve the conflict

Messages to indicate intended trajectory are used to reduce alerts and improve resolution advisories. These intent messages include information such as: a) target altitude for aircraft involved in vertical transitions; and b) planned changes in the horizontal path.

The specific scenario used for evaluation of the delegated separation applications conflict detection requirements consists of two aircraft traveling with a speed of 300 knots each. The aircraft are initially at right angles to each other. One of the aircraft executes a 90 degree turn with a 30 degree bank angle. The geometry is such that a collision would occur if no evasive action were taken. A conflict alert should be issued with a 2 minute warning time.

The false alarm delegated separation applications scenario assumes a separation standard of 2 NM. Two aircraft approach each other in a head-on configuration. Each aircraft travels at a speed of 550 knots. The final horizontal miss distance of the two aircraft is 13,500 feet, slightly greater than the assumed separation standard. It is desired to keep false alarm rates low.

2.2.1.1.6 Aircraft Needs for Flight Path Deconfliction Planning (Delegated Separation in Oceanic / Low Density En Route Airspace)

➔ ACTION DEAN: Need to fix this whole section

[ITP, ICSR, TBD]

This scenario addresses ADS-B requirements for aircraft performing delegated-separation while operating in oceanic or low density en route airspace. In such an operational environment there is a need to support cockpit display of traffic information and conflict detection at relatively longer ranges than for operations in higher density airspace.

See Table 2-6 for the information exchange needs and Table 2-8 for operational performance requirements to support aircraft needs while performing delegated separation in low density en route airspace (requirements are also listed as flight path deconfliction planning).

Environment

Participating aircraft are in oceanic or low density en route airspace performing delegated separation. Each participating aircraft supports an extended range cockpit display of traffic information. The pilots have available state vector, identification, and intent information concerning proximate aircraft. (Some near-term operational environments may allow delegated-separation without provision of full intent information, but require at least a 90 mile range in the forward direction).

Operational Scenarios

For these scenarios, all aircraft within the 90 mile range are ADS-B equipped and have CDTI. The pilot can elect to display all aircraft or relevant aircraft. Once participating aircraft are cleared for delegated-separation, the ATS provider will monitor the encounter but is not required to intervene. Scenarios include in-trail climb and descent, spacing, passing, and separation assurance.

2.2.1.1.7 Aircraft Needs While Performing Delegated Separation Simultaneous Approaches

[PCSPA, ICSPA]

Operational improvements through the use of ADS-B for closely spaced runway operations are categorized as delegated separation applications. ADS-B supported applications will enable increased capacity at airports currently without PRM support. ADS-B permits faster detection times for the blunder, resulting in the ability to operate with lower separations between runways for simultaneous approaches. By providing information in the cockpit, the pilot can detect and react to a blunder without incurring delays associated with the controller-to-pilot communication link. Currently, allowances are made for such communication problems as blocked transmissions and non-receipt of controller maneuver instructions. These allowances are needed to achieve desired levels of safety but they result in greater separation between runways than would be required if pilots received the critical information more quickly. Note that the example ICSPA application described in Appendix J of RTCA DO-289 (Ref TBD) has ATC delegating responsibility for cross track separation to the airborne segment while retaining separation responsibility for along track and altitude separation. The high level requirements for this example ICSPA application are provided in Table 2-7.

See Table 2-6 for the information exchange needs and Table 2-8 for operational performance requirements to support aircraft needs while performing simultaneous independent approaches.

Environment

The environment includes aircraft on final approach to parallel runways as well as aircraft in the runway threshold area. ADS-B will be used to assure safe separation of adjacent aircraft.

Operational Scenarios

The scenario used for evaluation of closely spaced parallel runway approaches was a 30 degree blunder.

- Case 1: Runway centerline separation is 1000 feet.
- Case 2: Runway centerline separation is 2500 feet.
- Evader aircraft speed is 140 knots; intruder aircraft speed is 170 knots.

- The intruder aircraft turns 30 degrees, at 3 degrees per second, with a resulting near mid-air collision.

- A false alarm scenario consists of the two runway spacings with normal approaches and landings.

- Plant noise (normal aircraft dynamics in flight) is added to the aircraft trajectories to simulate total system error in the approach.

2.2.1.1.8 Aircraft Needs While Operating on the Airport Surface [SURF, SURF IA]

On the airport surface, ADS-B may be used in conjunction with a CDTI to improve safety and efficiency. The pilot could use CDTI and a moving map display for basic surface situational awareness. Advanced surface applications could support traffic alerting, low visibility taxi guidance and surface spacing. ADS-B used in conjunction with a moving map display may be used to show cleared taxi travel paths. Other proximate vehicles within the surface movement area and aircraft may also be identified using ADS-B information. At night, or at times of poor visibility, the airport surface digital map may be used for separation and navigation purposes. To support spacing on the airport surface, the in-trail aircraft needs to monitor the position and speed of the lead aircraft and to detect changes of speed to ensure that safe separation is maintained (see §TBD).

An additional operational need is for detection of unauthorized aircraft intrusion into the runway and taxiway protected area. Runway incursion detection while operating on the airport surface is different from airborne conflict detection. Because of the geometry and dynamics involved, extended projection of aircraft position based on current state vector is not feasible for runway incursion detection; however, projections on the order of 5 seconds may be feasible.

See Table 2-6 for the information exchange needs and Table 2-8 for operational performance requirements to support aircraft needs while operating on the airport surface.

Environment

The environment includes aircraft and vehicles moving on the airport surface (i.e., runways and taxiways), as well as approaching and departing aircraft. ADS-B will be used to monitor this operational environment.

Operational Scenarios

<u>Blind Taxi:</u>

The aircraft are taxiing in conditions of impaired visibility (down to 100 meters RVR). One aircraft is following another, with both maintaining 30 knots. The desired spacing between the aircraft while moving is 150 meters (nose to tail). The lead aircraft decelerates at 1.0 m/sec^2 until it stops. The pilot in the following aircraft is alerted to the lead aircraft's deceleration. Pilot reaction time is 0.75 seconds. The in-trail aircraft deceleration is 1.0 m/sec^2 to a stop. The required minimum separation is 50 meters under such conditions (nose to tail).

<u>Runway Incursion:</u>

An aircraft is on final approach while another aircraft is stopped at the hold short line, approximately 50 m from the runway edge. The stopped aircraft begins to accelerate at 1.0 m/ sec^2 and intrudes onto the runway. An alert should be generated approximately 5 seconds before the aircraft intrudes onto the runway.

2.2.1.1.9 Aircraft Needs for Self Separation – [Flow Corridors and Self Separation Applications]

The long term roadmap for ADS-B In surveillance applications is the concept of self separation where the flight crew assumes the primary responsibility for separation assurance for a defined segment of the flight and ATC assumes a secondary monitoring function. As part of their responsibility, the flight crew is granted authority to modify their trajectory within defined degrees of freedom without renegotiating with ATC. The self-separation portion of the flight generally terminates with an agreed time of arrival at the point where separation responsibility is transferred back to the ATC. The application can be implemented in either a homogeneous environment, in which all aircraft are self-separating, or in a mixed-operations environment, in which some aircraft are receiving a separation service from the ATC. In mixed operations, ATC is not responsible for separating any aircraft where any of the relevant aircraft includes a self-separating aircraft.

Per Table 2-5, this concept could require increased performance requirements that would support this category of higher integrity airborne functions. It could also potentially require the broadcast of new classes of data such as intent data and/or wake vortex parameters that are not currently required for existing categories of ADS-B In applications.

2.2.1.2 ADS-B System-Level Performance—ATS Provider Needs for Separation and Conflict Management

The following discussion focuses on ground ATS surveillance and automation systems that use ADS-B surveillance information pertaining to aircraft within the area of operational control (ADS-B Out). A summary of the current ATS surveillance system capabilities is provided in Table 2-9(a). While the individual parameter values in the table may not be directly applicable to the ADS-B system, the ADS-B System is expected to support equivalent or better overall system level performance for the cited applications. ADS-B Out requirements, developed for the regional mandates, are expected to satisfy the required surveillance performance for the ADS-B In air-to-air applications.

For aircraft required to support ATS surveillance in en route and terminal airspace, a capability to independently validate the ADS-B surveillance information is likely to be required [6]. Alternative validation means are under study. An example of this independent validation would be in areas of radar coverage the use of radar ranging and azimuth data to validate the received ADS-B position messages.

The current en route and terminal surveillance environments consist of primary radars and SSRs providing high altitude and terminal airspace coverage. While air carrier operations generally stay within en route and terminal radar coverage, commuter, corporate, and general aviation operators frequently conduct operations that extend outside radar coverage. Existing radar technology provides surveillance performance and capabilities that fully support the current ATS operational concepts, but the benefits in some low traffic areas do not justify the cost of a full radar system. Improved surveillance capabilities, based on ADS-B, will provide in a cost effective manner, the extended coverage necessary to support advanced ATS capabilities. ADS-B broadcasts will be received, processed, fused with other traffic management information, and provided to the system having ATS jurisdiction for that airspace.

Table 2-9(a): Summary of Expected ATS Provider Surveillance and Conflict Management Current Capabilities for Sample Scenarios

	Operational Capability			
Information ↓	**En Route**	**Terminal**	**Airport Surface**	**Parallel Runway Conform Mon.**
Initial Acquisition of A/V Call Sign and A/V Category	within 24 sec.	within 10 sec.	within 10 sec.	n/a
Altitude Resolution (ft) (Note 5)	25	25	25	25
Horizontal Position Error	388 m @ 200 NM 116 m @ 60 NM 35 m @ 18 NM	116 m @ 60 NM 35 m @ 18 NM	3 m. rms, 9 m. bias [15],[6], [11]	9 m.
Received Update Period (Note 2)	12 sec. [10]	5 sec. [6]	1 sec.	1 sec.
Update Success Rate	98%	98%	98% [6]	98%
Operational Domain Radius (NM)	200	60	5	The lesser of 30 NM, or the point where the aircraft intercepts the final approach course
Operational Traffic Densities (# A/V) (Note 3)	1250 [6]	750 [6]	100 in motion; 150 fixed	50 dual; 75 triple; w/o filter: 150
Service Availability (%) (Note 4)	99.999 [10] 99.9 (low alt)	99.999 [10] 99.9 (low alt)	99.999 [10]	99.9

Table 2-9(b): Additional Expected Capabilities Appropriate for ADS-B Supported Sample Scenarios

	Operational Capability			
Information ↓	**En Route**	**Terminal**	**Airport Surface**	**Parallel Runway Conform Mon.**
Altitude Rate Error (1σ)	1 fps	1 fps	1 fps	1 fps
Horizontal Velocity Error (1σ)	5 m/s	0.6 m/s	0.3 m/s	0.3 m/s
Geometric Altitude	Yes	Yes	Yes	Yes

Notes for Table 2-9(a) and Table 2-9(b):

n/a (not applicable) = the requirement is not stressful and would not be higher than any other requirement, i.e., does not drive the design.

1) *References are provided where applicable. Else, best judgment was used to obtain performance data.*
2) *Received update period is the period between received state vector updates. A/V Call Sign and A/V Category can be received at a lower rate.*

3) *One or multiple ground receivers may be used in the operational domain to ensure acceptable performance for the intended traffic load. The numbers in the table indicate the number of aircraft expected to participate in or affect a given operation. (Refer to Table 2-8 for requirements which are based on operational traffic densities derived from the Los Angeles basin model).*
4) *Service availability includes any other systems providing additional sources of surveillance information.*
5) *Altitude accuracy: Some aircraft currently have only 100 foot resolution capability.*

As ADS-B is introduced, it is important for ATS to retain the flexibility to continue to use the existing surveillance systems based on SSR transponders. Therefore, it can be expected that in radar controlled environments, equipping with ADS-B will not initially eliminate the current requirement to carry SSR transponders. It may be possible in some cases for an aircraft to equip with ADS-B without adding a transponder. Many automation systems rely on SSR Mode A codes to identify aircraft. Use of ADS-B reports by the ground surveillance systems may require correlation with an ATS assigned SSR Mode A code for some applications.

Currently ground-based surveillance systems are mostly independent of aircraft navigation systems and surveillance data is largely verified through ground surveillance monitoring systems. Initially, some level of navigation independence and verification will continue to be required for ATS surveillance applications in certain airspace. The surveillance capabilities in Table 2-9(a) are acceptable because they are part of the current airspace management system, which has this level of independence. A detailed failure modes and effects analysis should be performed before a surveillance system that is less independent of aircraft navigation systems is approved for operational use.

Note: *Surveillance of air traffic plays a significant role in aviation security. For security reasons, ATS surveillance requirements in certain airspace may include a need for independent sources of surveillance information.*

2.2.1.2.1 ATS Provider Needs for Separation and Conflict Management in En Route and Terminal Airspace

Current requirements in the En Route and Terminal airspace are deemed to be much less stressful than the other applications in Section TBD. This airspace may be further divided into the use of ADS-B Out in Non Radar Airspace (NRA) and ADS-B Out in Radar Airspace (RAD). Characteristics of surveillance systems currently in use in the NAS for En Route and Terminal are listed in Table 2-9(a). These characteristics are provided for information and comparison only. ADS-B will support equal or better surveillance application performance (e.g., see Table 2-9(b)). Traffic densities and operational domain radius can be used for expected loading on the ADS-B data link broadcast medium.

The high level performance requirements for the existing ADS-B Out NRA, RAD and APT applications are contained in Table 2-10.

The existing degree of independence between navigation and surveillance will be needed in the future until combined system performance standards are developed [6].

Table 2-10: ADS-B Out Applications - Minimum Performance Requirements

	NRA – 3 NM EnRoute	NRA – 5 NM EnRoute	RAD – 5 NM Enroute	RAD – 3 NM Terminal	RAD–2.5 NM Approach	RAD-2.0 NM Approach	RAD-Independent Parrallel Approach
	DO-303	**DO-303**	**DO-318**	**DO-318**	**DO-318**	**DO-318**	**D0-318**
NACp	6	5	7	8	8	8	8
NACv	N / A	N / A	N / A	N / A	N / A	N / A	N / A
Vertical Accuracy, 95%	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft
SIL	2	2	3	3	3	3	3
NIC	5	4	5	6	7	7	7
SDA	2	2	2	2	2	2	2

Note: *Refer to the FAA Final ADS-B OUT Rule.*

2.2.1.2.2 ATS Provider Needs for Separation and Conflict Management on the Airport Surface [Do we include the APT Application in this section?]

On the airport surface, ADS-B will provide improved surveillance within the surface movement area. The system will display both surface vehicles and aircraft within the surface movement area to provide a comprehensive view of the airport traffic. Surveillance information will be provided to all control authorities within the airport, coverage will be provided for moving and static aircraft and vehicles, and positive identification will be provided for all authorized movements.

ATS will utilize ADS-B information to provide services consistent with a move toward Delegated separation applications. In this environment, a majority of aircraft will need to be equipped with ADS-B in order to provide significant benefit to the user or ATS service providers.

In the early stages of implementation, functions supported by ADS-B can be integrated with the controller's automation tools to provide several benefits including:

1) Reduction in taxi delays, based on improved controller situational awareness,

2) Operation in zero-visibility conditions for equipped aircraft and airport surface vehicles, and

3) Improved controller ability to predict and intervene in potential incursions, along with a reduction in false alarms.

In the long term, ADS-B would become the principal surveillance system to support surveillance of the airport surface movement area. For air traffic management, controllers, and air carriers, the greatest additional benefits would result in reducing taxi delays and coordinating with arriving and departing traffic. These long-term benefits are based on the use of cockpit automation and exchange of data between the cockpit and airport automation systems. This includes moving map displays, data linking of taxi routes, etc.

The airport traffic management system continuously monitors each aircraft's current and projected positions with respect to all possible conflicts. Detectable conflicts should include:

- Potential collision with a moving/active aircraft or vehicle,
- Potential collision with a known, static obstacle, aircraft, or vehicle,
- Potential incursion into a restricted area (weight/wingspan limited areas, closed areas, construction areas, etc.).
- Potential incursion into a controlled area (runways, taxiways, ILS critical areas, etc.).

It may be necessary for the ATS system to make use of known routes and conformance monitoring to effectively detect these conflicts.

Aircraft type classification, status and clearance information will play an important role in conflict management processing. Individual areas may be restricted to certain vehicles or aircraft and not others. For example, a taxiway may be off limits to vehicles over a specified weight. In this case, a conflict or taxiway incursion alert will be generated if a heavy vehicle approaches or enters the taxiway while a lighter vehicle would have unrestricted access. In addition, an aircraft may be cleared to enter selected areas at specific times. For example, if an aircraft is cleared for a runway, it may enter it without restriction. If an uncleared aircraft enters the runway, a runway incursion alert will be generated.

Environment

Operational environment includes airport movement area up to 1500 ft above airport level so as to cover missed approaches and low level helicopter operations. The surface movement area is that part of an airport used for the takeoff, landing, and taxiing of aircraft.

Operational Scenario

Participants are high-end aircraft performing taxi and departures during low visibility arrival operations (visibility less than 200 meters).

Aircraft are approaching an active runway with aircraft on final approach. ADS-B is used to provide the pilot and controller with alert information of potential conflicts. This alert information consists of an indication to the pilot and controller of the time remaining until a conflict will occur.

Requirements

See Table 2-6 for information exchange needs and see Table 2-9(a) and Table 2-9(b) for operational performance needs to support ATS surveillance on the airport surface.

Surface surveillance should interface seamlessly with terminal airspace to provide information on aircraft 5 NM from the touchdown point for each runway.

2.2.2 ATS Conformance Monitoring Needs

With ADS-B, ATS would monitor the ADS-B messages ensuring that an aircraft maintains conformance to its intended trajectory. Conformance monitoring occurs for all controlled aircraft or airspace, and applies to all operational airspace domains. In the case of protected airspace or SUA, conformance monitoring is performed to ensure that an aircraft does not enter or leave a specific airspace.

In the terminal environment, the ATS provider will monitor the aircraft's reported position and velocity vector to ensure that the aircraft's current and projected trajectory is within acceptable bounds. The increased accuracy and additional information directly provided by the aircraft (via ADS-B), in comparison to radar-based monitoring, will result in quicker blunder detection and reduce false alarms.

2.2.2.1 Operational Scenario (Parallel Runway Monitoring)

A specific example of conformance monitoring is PRM and simultaneous approach, a surveillance and automation capability that enables a reduction in minimum runway spacing for independent approaches to parallel runways in IMC. All aircraft participating in a given parallel approach should be ADS-B equipped.

Initial use of ADS-B for PRM could be achieved before full equipage by limiting access to parallel approaches at specified airports only to ADS-B equipped aircraft. This may not be practical until a significant number of aircraft are equipped with ADS-B. When sufficient aircraft are equipped for ADS-B, an evolution to the full use of ADS-B to support PRM can occur. At that time, radar-based PRM system would no longer be needed.

2.2.2.2 Requirements

See Table 2-6 for information exchange needs and see Table 2-9(a) and Table 2-9(b) for operational performance needs to support ATS parallel runway conformance monitoring.

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3 ADS-B and Airborne Systems Definition and Performance Requirements

This section defines, within the context of ASA operational applications, the ADS-B System and its functional and performance requirements. The system description and user equipage classifications are summarized in Section 3.1. The broadcast information element requirements are given in Section 3.2. System application requirements are given in Section 3.3. Subsystem requirements are stated in Section 3.4, and ADS-B output report characteristics supporting application needs are described in Section 3.5.

3.1 System Descriptions

3.1.1 ADS-B Subsystem Description (Transmit and Receive)

This section describes the ADS-B system, provides examples of ADS-B system architectures, and defines ADS-B equipage classes.

3.1.1.1 Context Level Description

Context diagrams, which are data flow diagrams at successive levels of system detail, are used to define information exchanges across system elements and indicate how required functions are partitioned. The following subsections present context diagrams for ADS-B at three successive levels of detail: the ADS-B system level, subsystem level, and functional level.

3.1.1.1.1 System Level

ADS-B system level information exchange capabilities are illustrated in the top-level context diagram of Figure 3.1.1.1.2a. As depicted in this and subsequent figures, four symbols are used to define data flows in context diagrams:

Entities external to the ADS-B System are identified by rectangles

Data flows are labeled lines with directional arrowheads

Processes are defined by circles

Data storage or delays are indicated by parallel lines.

Information flows into or out of any context layer must be consistent with those identified at the next layer.

The ADS-B system level includes ADS-B subsystems supporting each participant and the means necessary for them to exchange messages over the broadcast medium. The ADS-B system accepts own-ship source data from each of N aircraft/vehicle interactive participants, B aircraft/vehicle broadcast-only participants, and G fixed ground broadcast-only participants, and makes it available through the RF medium to each of the other N interactive participants as well as R receive-only ground sites. Interactive ground facilities may also exist in some ADS-B systems.

In Figure 3.1.1.1.2a, own-ship source data for each broadcasting participant are denoted by the subscript “o” and include:

Own-ship geometric and air mass referenced state vector reports (SV_o) which include aircraft position, velocity, navigation integrity category (NIC_o) indicating integrity containment radius R_C of position data, and address, Ad_o.

Mode-status reports (MS_o) which include address, Ad_o, aircraft/vehicle identification ID_o (flight or tail number if enabled by user, and aircraft category), emergency/priority status, information on supported applications, and navigation accuracy categories indicating the accuracy of position (NAC_P) and velocity (NAC_V) data.

On-condition or event-driven reports (OC_o) include aircraft/vehicle address Ad_o. Types of OC reports include Target State reports containing selected altitude and selected heading information, and Air Referenced Velocity reports, which include air speed and heading.

Data for on-condition or event-driven reports are accompanied as needed by appropriate control inputs (e.g., “transmit an ADS-B message under these conditions” as opposed to following a strictly periodic pattern of transmission). Messages transmitted by other ADS-B system participants are received by the onboard ADS-B subsystem and used to generate ADS-B reports (indicated by subscript “i”) which are made available for onboard applications. The address, common to all message types, is used for correlating received information. System level requirements are given in §3.3 and format characteristics associated with the required information exchanges are summarized in §3.5.

3.1.1.1.2 Subsystem Level

Further details of the many-to-many information exchange supported by the ADS-B system are given in the subsystem level context diagram of Figure 3.1.1.1.2b. Subsystems supporting each type of participant are shown in the figure with their respective user interfaces and associated message exchanges over the RF medium. As described above, the aggregate of all ADS-B subsystems interconnected over the broadcast medium comprises the ADS-B system.

Interactive Aircraft/vehicle participant system interfaces to the supporting ADS-B subsystem are illustrated in the upper left part of the figure. State vector source data (SV_o) are provided by the platform dynamic navigation systems and sensors. Mode-status and on-condition source data (MS_o, OC_o) are available from onboard flight status source data or by flight crew entry. This own-ship information is transmitted over the RF medium as appropriately encoded ADS-B messages (M_o). Similarly defined messages are received from other participants (Mi), processed by the subsystem, and made available as ADS-B reports (SV_i, MS_i, OC_i) to surveillance-related on-board applications. The operational mode is determined by the subsystem control logic, e.g., a different broadcast mode may be used while on the airport surface.

Functional capabilities and information flows for other classes of subsystems are also indicated in Figure 3.1.1.1.2a. Other subsystem classes are aircraft/vehicle broadcast-only (requiring inputs from an onboard navigation system and database, but providing no output information to on-board applications); fixed ground broadcast-only (requiring previously surveyed data inputs); and ground receive-only (providing ADS-B reports to support ATS and other applications). Subsystem control inputs are shown as dashed lines for each subsystem. Subsystem requirements are given in §3.4.

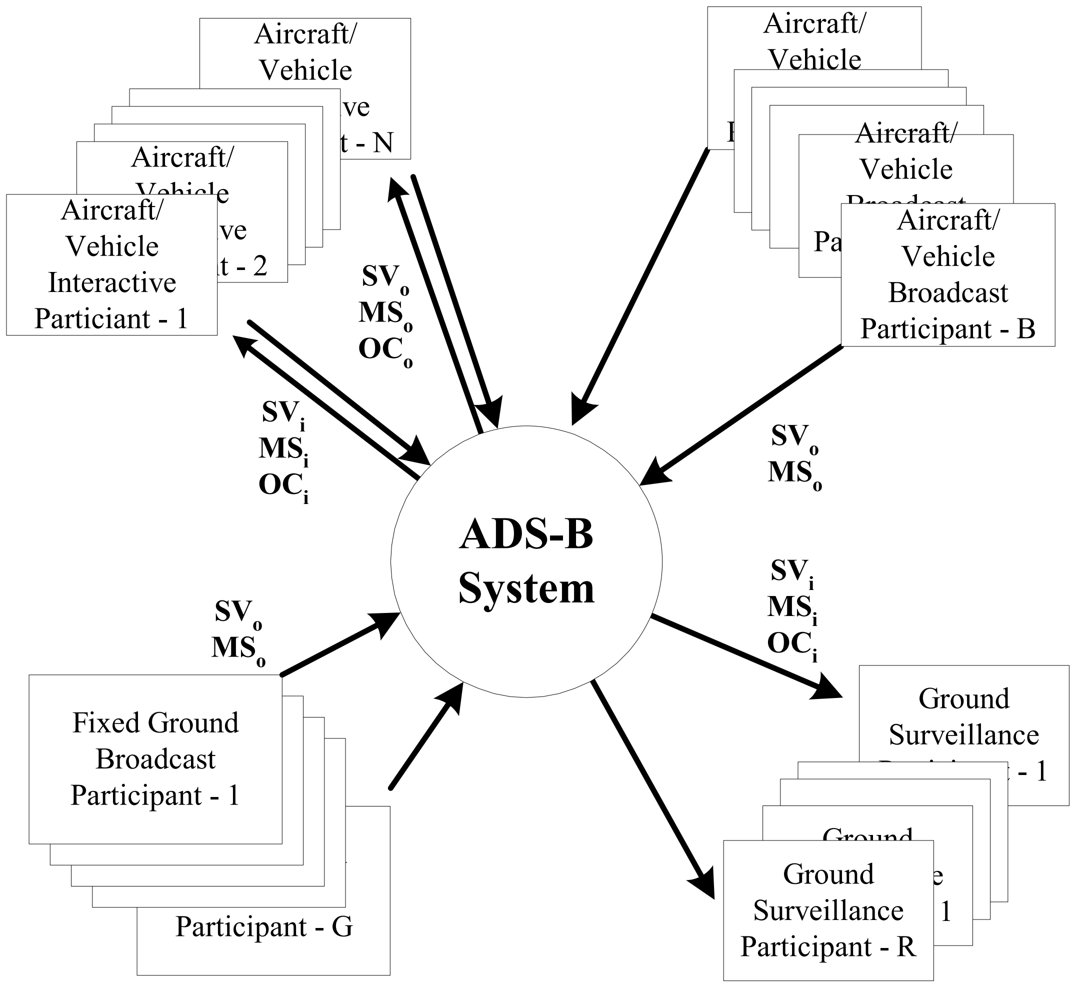
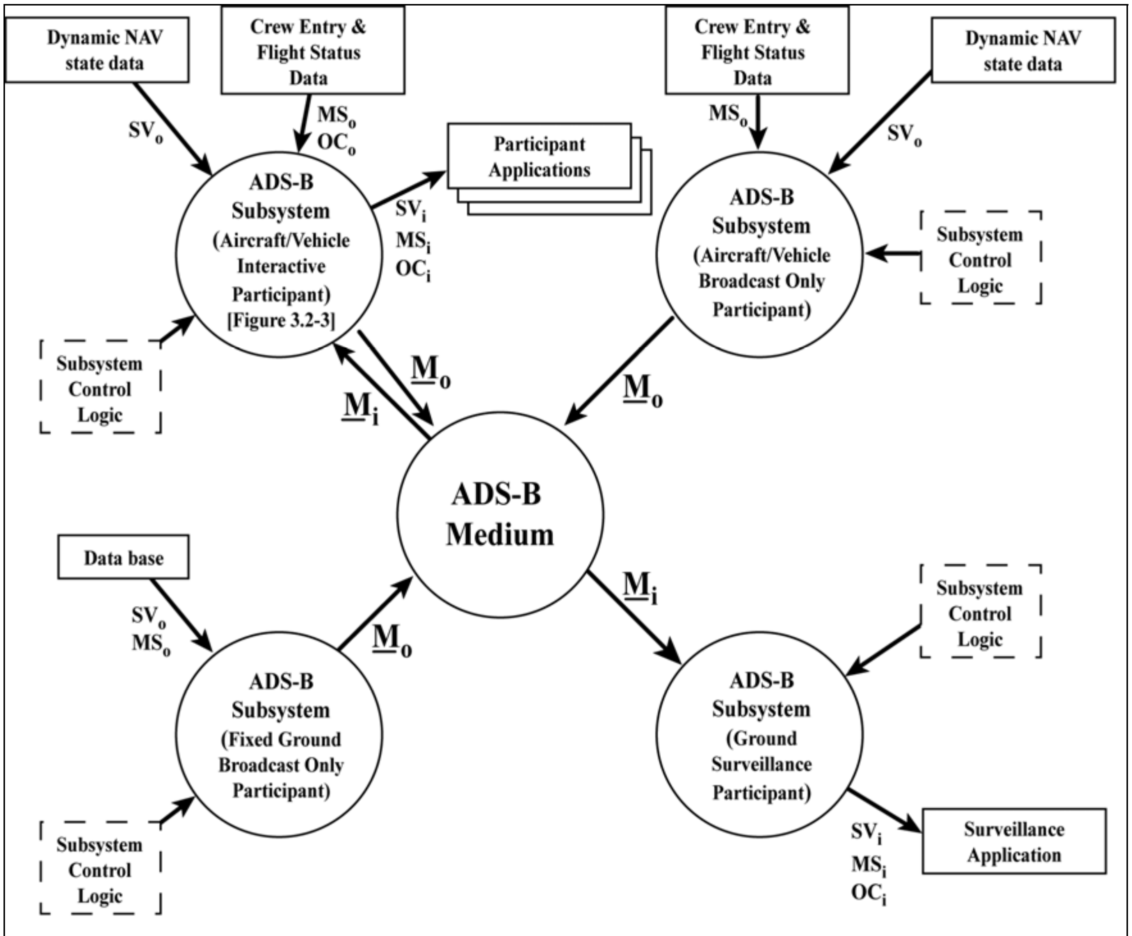


Figure 3.1.1.1.2a: Illustrative ADS-B System Level Context Diagram

Abbreviations:

SV_o = own state vector source data
MS_o = own mode-status source data
OC_o = own event driven or on condition source data
SV_i = other participants' state vector reports
MS_i = other participants' mode-status reports
OC_i = other participants' on condition reports



Note: $\underline{M}_o$ represents own ship transmitted messages. $\underline{M}_i$ denotes messages received from other participants. The vector notation, $\underline{M}$ denotes one or more messages, depending on implementation. Different participants may supply and/or use different types of information.

<u>Figure 3.1.1.1.2b:</u> ADS-B Subsystem Level Context Diagram for ADS-B System

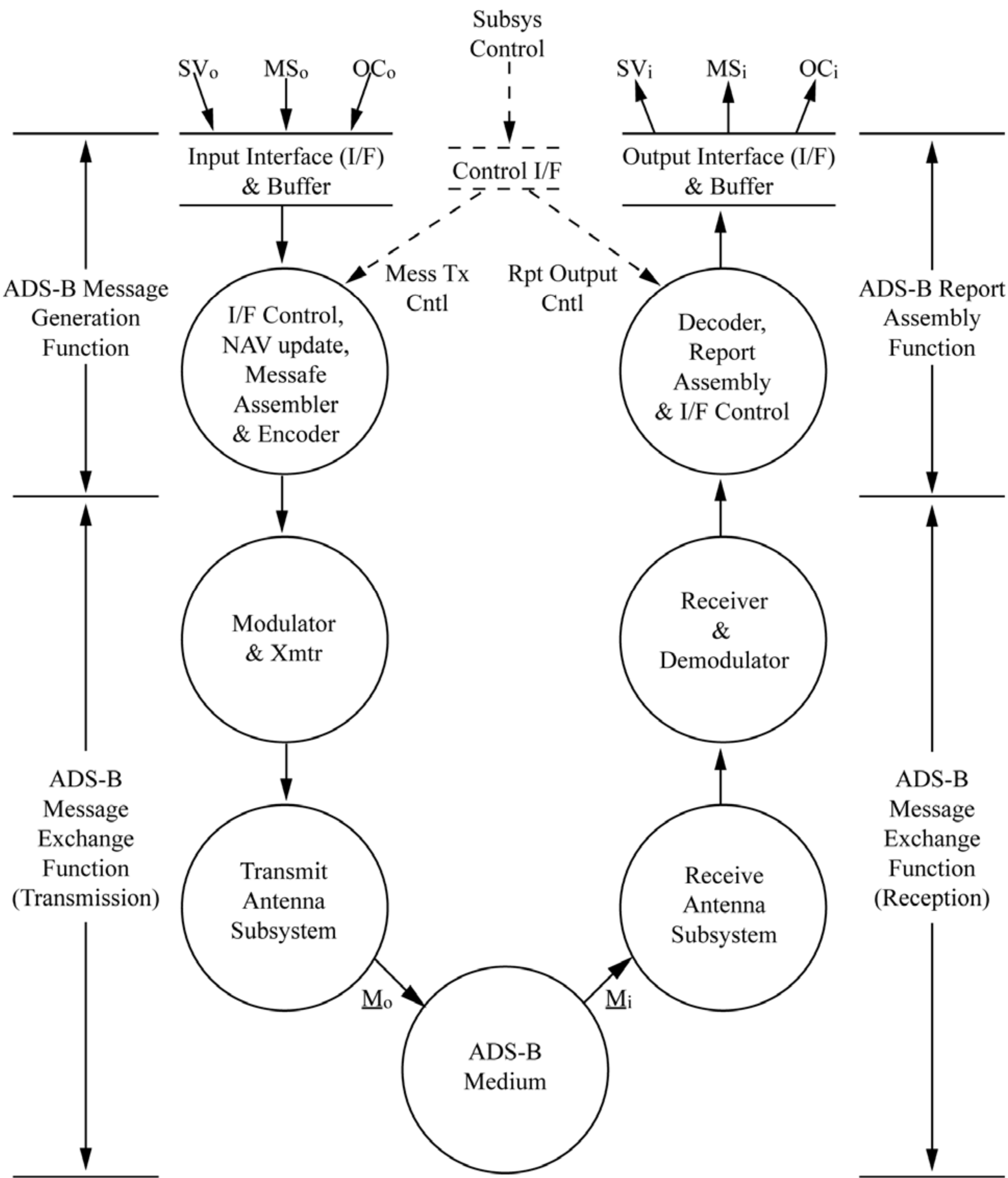


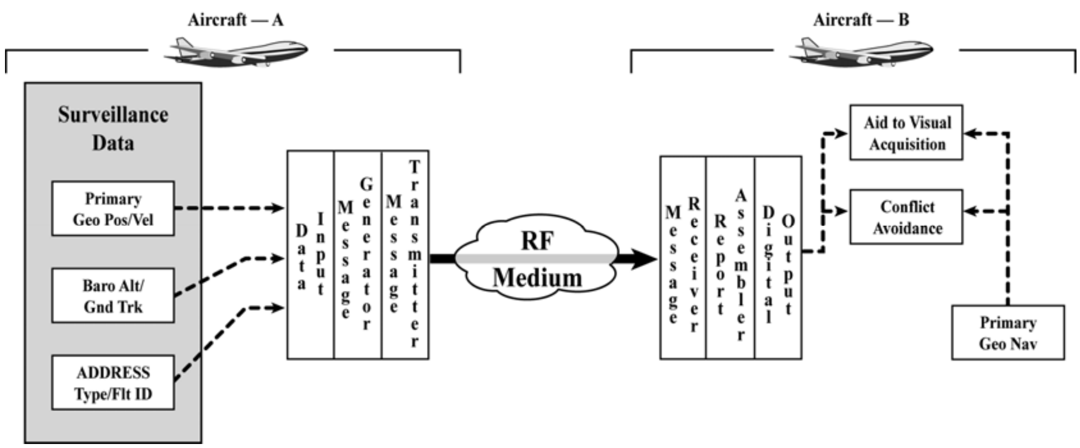
Figure 3.1.1.1.2c: ADS-B Functional Level Context Diagram for Aircraft Interactive Subsystem

3.1.1.1.3 Functional Level

Subsystem functional partitioning and interfaces are illustrated for an interactive aircraft participant in the functional level context diagram of Figure 3.1.1.1.2c. Functional capabilities required to 1) accept source data inputs and control information to the subsystem from onboard systems, and generate the required ADS-B messages; 2) exchange messages with other ADS-B participants; and 3) assemble ADS-B reports containing required information from other participants for use by onboard applications, are outlined here. Subsystem functional partitioning and interfaces for broadcast-only and receive-only participants are described by an appropriate subset of this functionality.

3.1.1.2 Participant Architecture Examples

Examples of ADS-B subsystem architectures and their interactions are given in Figure 3.1.1.2a, Figure 3.1.1.3a and Figure 3.1.1.3b. Figure 3.1.1.2a illustrates the minimum capabilities on-board aircraft A to support aid to visual acquisition and ADS-B conflict avoidance on-board aircraft B.



<u>Figure 3.1.1.2a:</u> Example of A/C Pair Supporting Aid to Visual Acquisition and Conflict Avoidance Applications

Figure 3.1.1.3a illustrates expanded capabilities enabled by the more sophisticated onboard avionics. With more capable ADS-B transmit and receive avionics, and the ability to support appropriate user applications, each aircraft may be approved for more advanced ADS-B applications.

Figure 3.1.1.3b illustrates ADS-B applied to air-ground surveillance. The precise velocity, geometric and air mass data along with selected altitude and heading information provided by ADS-B enables advanced surveillance and conflict management implementations. Ground system track processing and correlation of ADS-B data with other ground derived surveillance data can provide an integrated view to ground automation and controller interfaces.

Approval for the above operational uses of ADS-B requires certification of ADS-B equipage integrated with other aircraft/vehicle and ground systems and demonstration of acceptable end-to-end performance. The approved system design must include the originating sources and the user applications necessary to support appropriate operational levels defined above. Interdependencies between the ADS-B subsystems, interfacing sources and user applications will probably need to be addressed as part of the subsystem certification process. The distributed elements of the total system comprising the operational capability typically will be individually certified.

3.1.1.3 Equipage Classifications

As illustrated above, ADS-B equipment must be integrated into platform architectures according to platform characteristics, capabilities desired and operational objectives for the overall implementation. The technical requirements for ADS-B have been derived from consolidation of the scenarios presented in Section 2 within the context of the use of the ADS-B System as primary-use capable. The operational capabilities are divided into hierarchical levels (with each level including all capabilities of the preceding level):

Aid to Visual Acquisition: basic state vector information

Conflict Avoidance and Collision Avoidance: state vector information augmented with identification

Separation Assurance and Sequencing: pair-wise assessment with strategic intent information (TS)

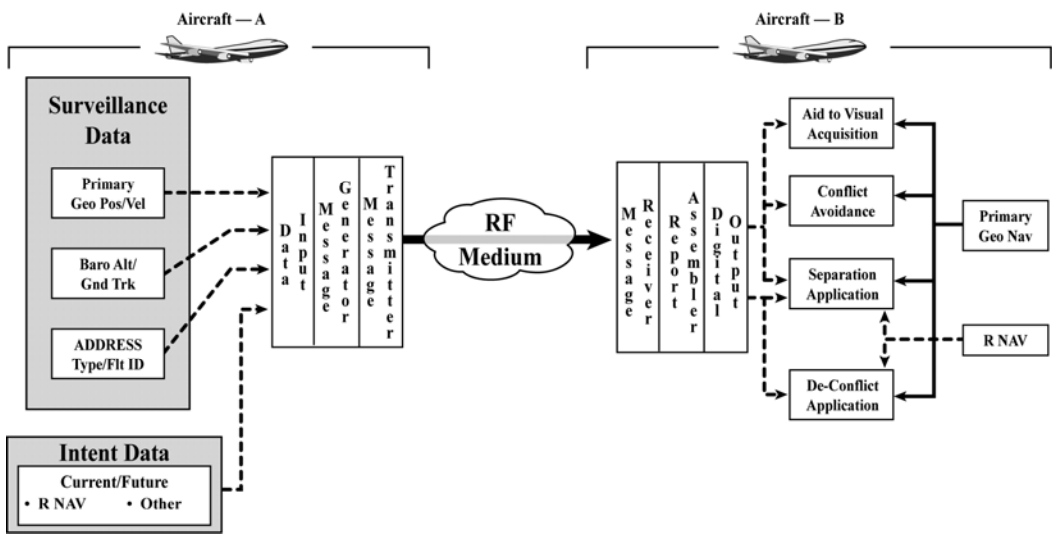


Figure 3.1.1.3a: Example of A/C Pair Capable of Supporting Advanced ADS-B Applications

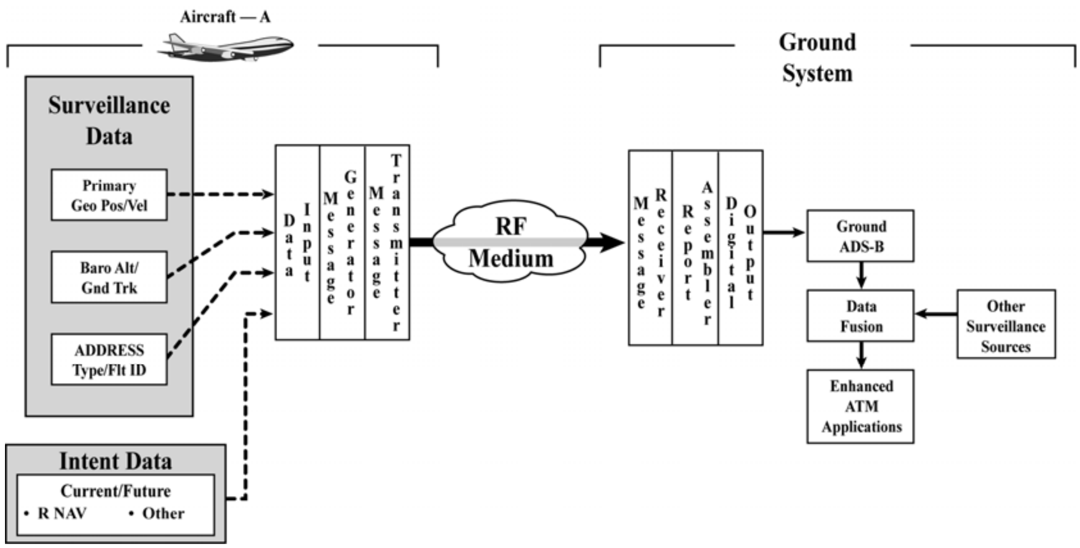


Figure 3.1.1.3b: Example of ADS-B Support of Ground ATS Applications

ADS-B equipage is categorized according to the classes listed in Table 3.1.1.3.2a. ADS-B equipage classes are defined in terms of the levels of operational capabilities discussed above. The classifications include airborne and ground participants, and include those that are fully interactive and those that only receive or transmit. In addition to defining equipage classifications the table summarizes salient features associated with these capabilities.

ADS-B systems used on surface vehicles are expected to require certification similar to that applicable to airborne ADS-B systems in order to ensure conformance to required transmission characteristics. If required due to spectrum considerations, surface vehicles must have an automatic means to disable transmission of ADS-B messages when outside the surface movement area.

3.1.1.3.1 Interactive Aircraft/Vehicle ADS-B Subsystems (Class A)

Functional capabilities of interactive aircraft/vehicle subsystems are indicated in the context diagram of Figure 3.1.1.1.2c. These subsystems accept own-platform source data, exchange appropriate ADS-B messages with other interactive ADS-B System participants, and assemble ADS-B reports supporting own-platform applications. Such interactive aircraft subsystems, termed Class A subsystems, are further defined by equipage classification according to the provided user capability.

The following types of Class A subsystems are defined in (Table 3.1.1.3.2a):

Class A0: Supports minimum interactive capability for participants. Broadcast ADS-B messages are based upon own-platform source data. ADS-B messages received from other aircraft support generation of ADS-B reports that are used by on-board applications (e.g., CDTI for aiding visual acquisition of other-aircraft tracks by the own-aircraft's air crew). This equipage class may also support interactive ground vehicle needs on the airport surface.

Class A1 supports all class A0 functionality and additionally supports, e.g., ADS-B-based airborne conflict management and other applications at ranges < 20 NM. Class A1 is intended for operation in IFR designated airspace.

Class A2: Supports all class A1 functionality and additionally provides extended range to 40 NM and information processing to support longer range applications, e.g. oceanic climb to co-altitude.

Class A3: Supports all class A2 functionality and has additional range capability out to 90 NM, supporting, e.g., long range airborne applications.

3.1.1.3.2 Broadcast-Only Subsystems (Class B)

Some ADS-B system participants may not need to be provided information from other participants but do need to broadcast their state vector and associated data. Class B ADS-B subsystems meet the needs of these participants. Class B subsystems are defined as follows (Table 3.1.1.3.2a):

Class B0: Aircraft broadcast-only subsystem, as shown in Figure 3.1.1.1.2b. Class B0 subsystems require an interface with own-platform navigation systems. Class B0 subsystems require transmit powers and information capabilities equivalent to those of class A0.

Class B1: Aircraft broadcast-only subsystem, as shown in Figure 3.1.1.1.2b. Class B1 subsystems require an interface with own-platform navigation systems. Class B1 subsystems require transmit powers and information capabilities equivalent to those of class A1.

Class B2: Ground vehicle broadcast-only ADS-B subsystem. Class B2 subsystems require a high-accuracy source of navigation data and a nominal 5 NM effective broadcast range. Surface vehicles qualifying for ADS-B equipage are limited to those that operate within the surface movement area.

Class B3: Fixed obstacle broadcast-only ADS-B subsystem. Obstacle coordinates may be obtained from available survey data. Collocation of the transmitting antenna with the obstacle is not required as long as broadcast coverage requirements are met. Fixed obstacle qualifying for ADS-B are structures and obstructions identified by ATS authorities as a safety hazard.

Table 3.1.1.3.2a: Subsystem Classes and Their Features

Class	Subsystem	Description	Features	Comments
Interactive Aircraft/Vehicle Participant Subsystems (Class A)				
A0	Minimum Interactive Aircraft/Vehicle	Supports basic enhanced visual acquisition	Lower transmit power and less sensitive receive than Class A1 permitted.	Minimum interactive capability with CDTI.
A1	Basic Interactive Aircraft	A0 plus provides standard range	Standard transmit and receive	Provides standard range
A2	Enhanced Interactive Aircraft	A1 plus improved range	Standard transmit power and more sensitive receive. Interface with avionics source required for TS.	Supports longer range applications
A3	Extended Interactive Aircraft	A2 plus long range	Higher transmit power and more sensitive receive. Interface with avionics source required for TS	Extends range for advanced applications.
Broadcast-Only Participant Subsystems (Class B)				
B0	Aircraft Broadcast only	Supports A0 Applications for other participants	Transmit power may be matched to coverage needs.	Enables aircraft to be seen by Class A and Class C users.
B1	Aircraft Broadcast only	Supports A1 Applications for other participants	Transmit power may be matched to coverage needs.	Enables aircraft to be seen by Class A and Class C users.
B2	Ground vehicle Broadcast only	Supports airport surface situational awareness	Transmit power matched to surface coverage needs. High accuracy position input required.	Enables vehicle to be seen by Class A and Class C users.
B3	Fixed obstacle	Supports visual acquisition and airborne conflict management	Fixed coordinates. No position input required. Collocation with obstacle not required with appropriate broadcast coverage.	Enables NAV hazard to be detected by Class A users.
Ground Receive Subsystems (Class C)				
C1	ATS En route and Terminal Area Operations	Supports ATS cooperative surveillance	Requires ATS certification and interface to ATS sensor fusion system.	Supports provision of ATS Surveillance for ADS-B System Participants where adequate Air-Ground range and integrity have been demonstrated. Expected en route coverage out to 200 NM. Expected terminal coverage out to 60 NM.
C2	ATS Parallel Runway and Surface Operation	Supports ATS cooperative surveillance	Requires ATS certification and interface to ATS sensor fusion system.	Expected approach coverage out to 30 NM, or – if of lesser value - the point where the aircraft intercepts the final approach course. Expected surface coverage out to 5 NM.

C3	Flight Following Surveillance	Supports private user operations planning and flight following	Does not require ATS interface. Certification requirements determined by user application.	Coverage determined by application.

3.1.1.3.3 Ground Receive-Only Subsystems (Class C)

Surveillance state vector reports, mode-status reports, and on-condition reports are available from ADS-B system participants within the coverage domain of ground ADS-B receive-only, or Class C subsystems. The following Class C subsystems are defined (Table 3.1.1.3.2a):

Class C1: Ground ATS Receive-Only ADS-B Subsystems for En Route and Terminal area applications. Class C1 subsystems should meet continuity and availability requirements determined by the ATS provider.

Class C2: Ground ATS Receive-Only ADS-B Subsystems for approach monitoring and surface surveillance applications. Class C2 subsystems have more stringent accuracy and latency requirements than Class C1 systems. Class C2 systems may be required, depending upon the ADS-B System design, to recognize and process additional ADS-B message formats not processed by Class C1 subsystems.

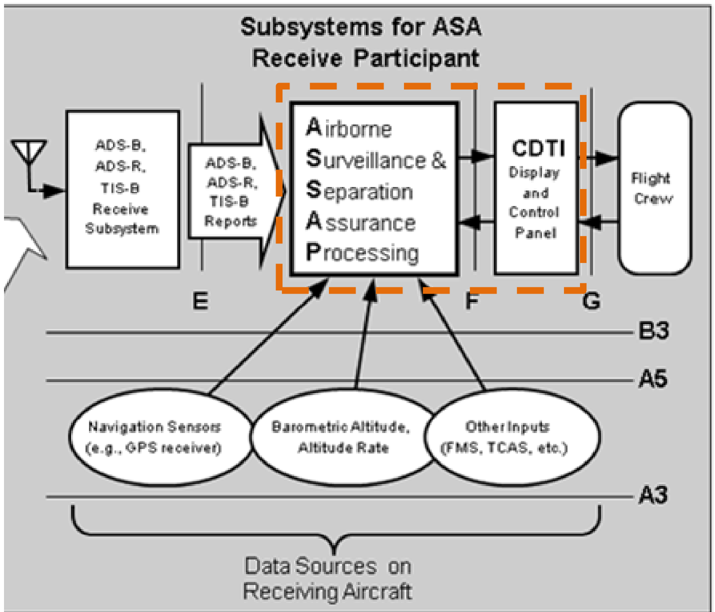
Class C3: Ground ATS Receive-Only ADS-B Subsystems for flight following surveillance is available from this equipage class for use by private operations planning groups or for provision of flight following and SAR.

3.1.2 ASSAP Subsystem Description (Dave Elliott)

The Airborne Surveillance and Separation Assurance Processing (ASSAP) subsystem represents the surveillance and application-specific processing functions of ASA. ASSAP surveillance processing consists of correlation, possible data fusion, and track processing of ADS-B, ADS-R, TIS-B, and TCAS traffic reports. ASSAP application processing provides the application-specific processing for all ASA applications. The extent of ASSAP application processing is dependent upon the aircraft's capabilities, as determined by each application's minimum performance requirements. ASSAP application processing may be minimal for airborne situational awareness applications (e.g., EvAcq or AIRB), or may require more significant processing for surface situational awareness applications (e.g., SURF) or future guidance applications (e.g., FIM-S). The ASSAP subsystem also monitors and processes flight crew inputs via the interface from the Cockpit Display of Traffic Information (CDTI) subsystem, and provides all traffic surveillance data and ASA application-specific data for visual and /or aural display to the CDTI for the flight crew.

3.1.2.1 ASSAP/CDTI System Boundaries

Figure 3.1.2.1 illustrate the ASSAP/CDTI system boundaries as two subsystems of the ASA System, and is based on Figure x.y in §x.y. The dashed line represents the system boundaries for the ASSAP and CDTI subsystems. The allocated requirements for ASSAP and the CDTI are found in §3.4.1 and §3.4.2, respectively.



<u>Figure 3.1.2.1:</u> Scope of ASA System MOPS

[Update with latest version, make sure to add the appropriate dashed line]

<u>Note:</u> *Detailed ASSAP and CDTI performance and subsystem requirements are addressed in the ASA System MOPS, the latest version of DO-317( ).*

ASSAP receives surveillance inputs from the ADS-B / ADS-R / TIS-B Receive Subsystem in the form of ADS-B and TIS-B reports. ASSAP may also receive surveillance inputs from installed TCAS systems. The ASSAP subsystem is integral to ASA application processing, providing surveillance processing on all available surveillance reports, and providing the application-specific processing associated with all ASA applications.

While ASSAP provides all application-specific processing for ASA, it also maintains the interfaces to and from the CDTI. It is due to the close association of the ASSAP and the CDTI, and their shared interface, that the ASSAP and CDTI MOPS was developed as a single requirements document. The two sub-systems, ASSAP and CDTI, constitute the “Aircraft Surveillance Application Systems“ and the Minimum Operational Performance Standards document for this system is termed the “ASA System MOPS” the latest version of DO-317( ).

As shown in Figure 3.1.2.1, the CDTI subsystem also serves as the ASA interface to the flight crew.

3.1.3 CDTI Subsystem Description

The CDTI subsystem includes the actual display media and the necessary controls to interface with the flight crew. Thus the CDTI consists of all displays and controls necessary to support the applications. The controls may be a dedicated CDTI control panel or it may be incorporated into other controls, (e.g., multifunction control display unit (MCDU) or Electronic Flight Bag (EFB)). Similarly, the CDTI display may be a stand-alone display or displays (dedicated display(s)) or the CDTI information may be present on an existing display(s) (e.g., multi-function display) or an EFB. At a minimum, CDTI includes a graphical plan-view (top down) traffic display (a "Traffic Display"), and the controls for the display and applications (as required). Additional graphical and non-graphical display surfaces may also be included. The CDTI receives position information of traffic and Own-ship from the airborne surveillance and separation assurance processing (ASSAP) function. The ASSAP receives such information from the surveillance sensors and Own-ship position sensors.

A physical display screen may have more than one instance of a CDTI Display on it. For example, a display with a split screen that has a Traffic Display on one half of the screen and a list of targets on the other half has two instances of CDTI Displays.

The Traffic Display is a graphical plan-view (top down) traffic display. Every CDTI installation includes a Traffic Display. The Traffic Display may be a stand-alone display or displays (dedicated display(s)) or the CDTI information may be present on an existing display(s) (e.g., multi-function display) or an EFB.

Specific requirements for the Traffic Display are shown in the ASA MOPS. The Traffic Display is required to indicate own-ship position and, to show the positions, relative to the own-ship, of traffic. The Traffic Display is also required to provide specific traffic information elements in associated data tag and traffic symbology.

3.1.4 ANSP Systems

3.1.4.1 ADS-B (Ground Receive) (RAD, NRA, APT)

(John Fisher)

3.1.4.2 TIS-B and ADS-R Service Description

This section defines the Automatic Dependent Surveillance-Rebroadcast (ADS-R) and Traffic Information Broadcast Services (TIS-B) services provided by the Surveillance and Broadcast Services System (SBS – Ground System). Together, ADS-R and TIS-B, provide the ADS-B user pilot's CDTI with aircraft/vehicle (A/V) position data that will compliment and complete the view of neighboring traffic.

ADS-R is an SBS service that receives ADS-B-OUT position broadcasts and rebroadcasts that information to aircraft in the vicinity equipped with a different ADS-B data link. ADS-R service provides for interoperability between ADS-B equipped aircraft with different data links.

TIS-B is a surveillance service that derives traffic information from FAA radar/sensor sources, and uplinks this traffic information to ADS-B-equipped aircraft. TIS-B enables ADS-B-equipped aircraft to receive position reports on non-ADS-B-equipped aircraft in the NAS.

Note: *TIS-B Service is intended for the transition period to full ADS-B equipage.*

Figure 3-8 illustrates the top-level architecture for the SBS – Ground System. It is composed of three segments: Radio Station, Control, and Network. ADS-R and TIS-B services are provided to aircraft at the air interface (top of figure). Surveillance and sensor data are provided to the TIS-B service as shown at the bottom of the figure (FAA TIS-B Data SDP). ADS-B surveillance data are provided to the ADS-R service within the Radio Segment, the determination of user need for ADS-R service and scheduling of ADS-R messages is performed within the Control Segment.

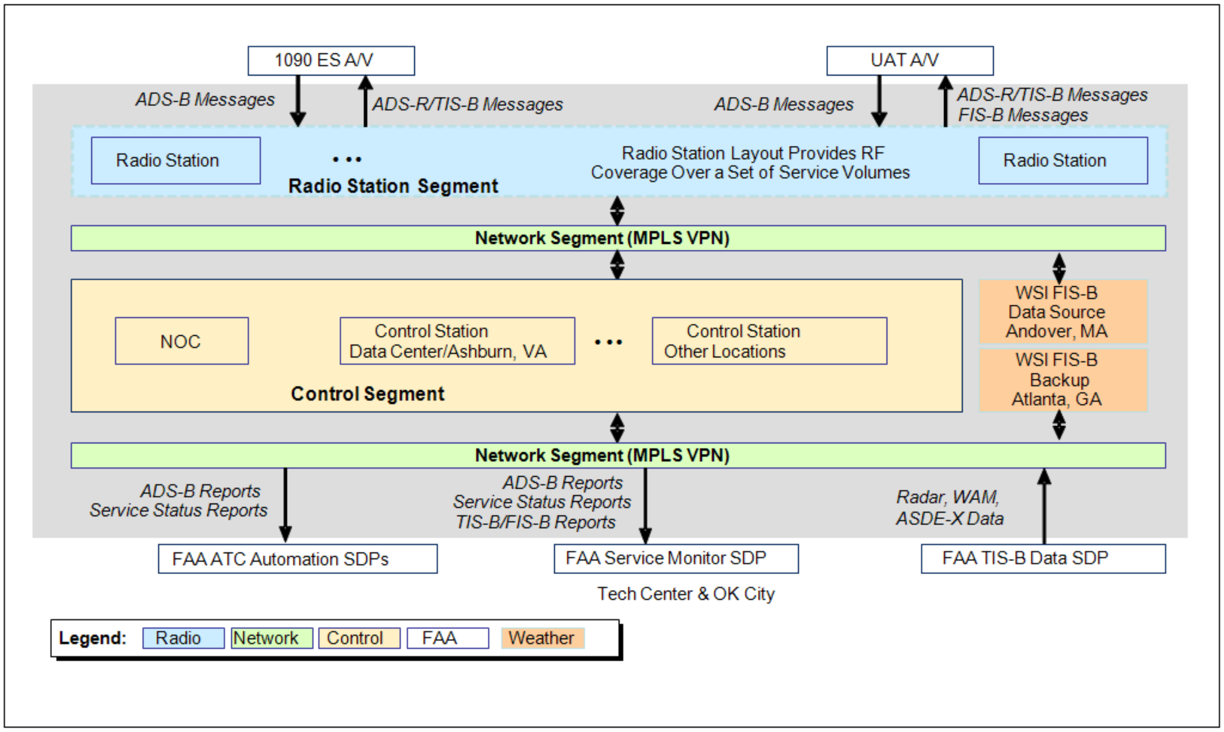


Figure 3-8: SBS System Reference Architecture

3.1.4.2.1 ADS-R Service

Automatic Dependent Surveillance–Rebroadcast (ADS-R) is a service that relays ADS-B information transmitted by an aircraft using one link technology to aircraft of an incompatible link technology. The high level data flows supporting ADS-R are illustrated in Figure 3-9. The SBS – Ground System control station infrastructure monitors ADS-B transmissions by active ADS-B equipped aircraft and continuously monitors the presence of proximate aircraft with incompatible link technologies (i.e., UAT and 1090ES). When such aircraft are in proximity of each other, the SBS – Ground System control station infrastructure instructs ground radio stations within range of both aircraft to rebroadcast surveillance information received on one link frequency to aircraft on the other link frequency. The ADS-R Service currently supports only advisory level surveillance applications.

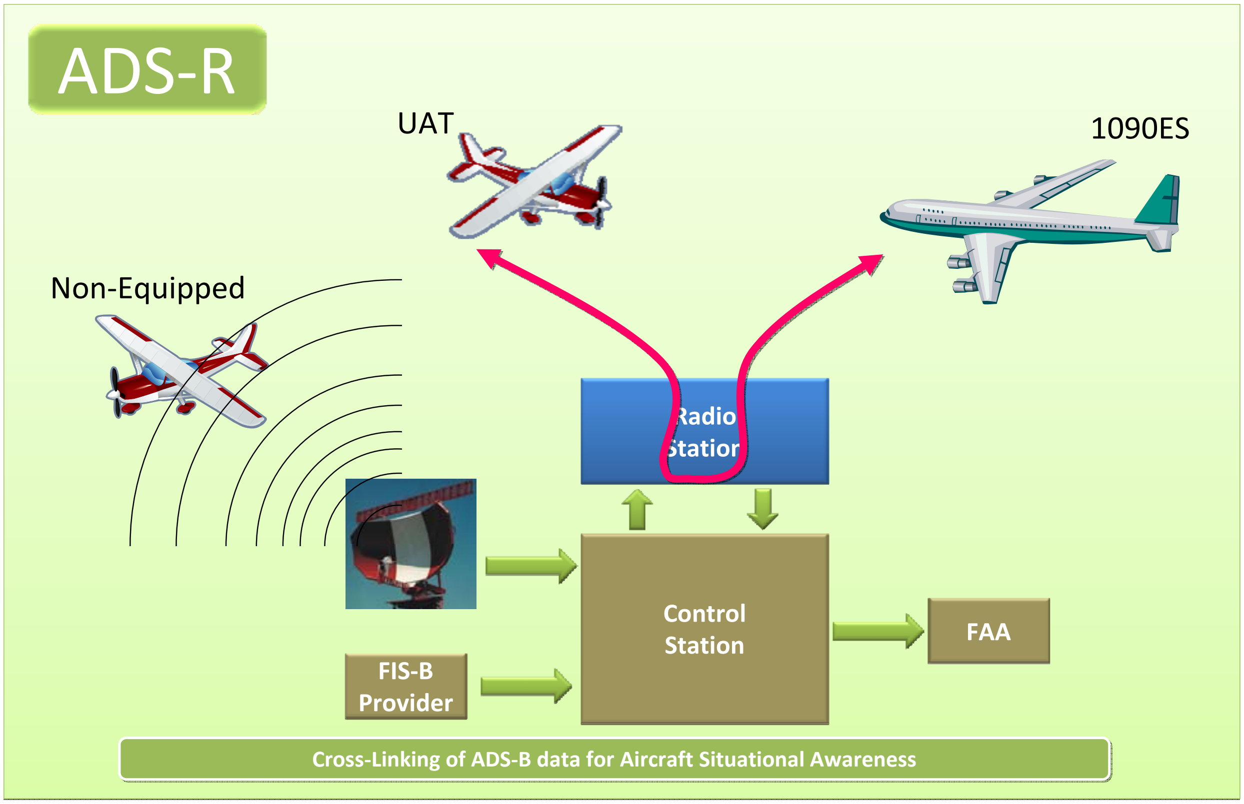


Figure 3-9: ADS-R Service Data Flows Data

3.1.4.2.1.1 ADS-R Concept of Operations

Since two incompatible ADS-B link technologies are allowed, aircraft equipped with a single link technology input will not be able to receive ADS-B transmissions from the other link technology, and therefore will be unable to receive all ADS-B transmissions. The ADS-R service closes this gap. In defined airspace regions, the ADS-R service will receive ADS-B transmissions on one link, and retransmit them on the complementary link when there is an aircraft of the complementary link technology in the vicinity.

An aircraft or vehicle that is an active ADS-B user and is receiving ADS-R service is known as an ADS-R Client. An ADS-B equipped aircraft or vehicle on the opposite link of the ADS-R Client that has its messages translated and transmitted by the SBS System is known as an ADS-R Target.

Figure 3-10 describes a more detailed ADS-R and TIS-B functional data flow. ADS-B dual data link equipped aircraft or vehicles (1090ES and UAT), shown at the top of the figure, do not require ADS-R service as they will receive ADS-B messages directly from single and dual data link equipped aircraft and vehicles.

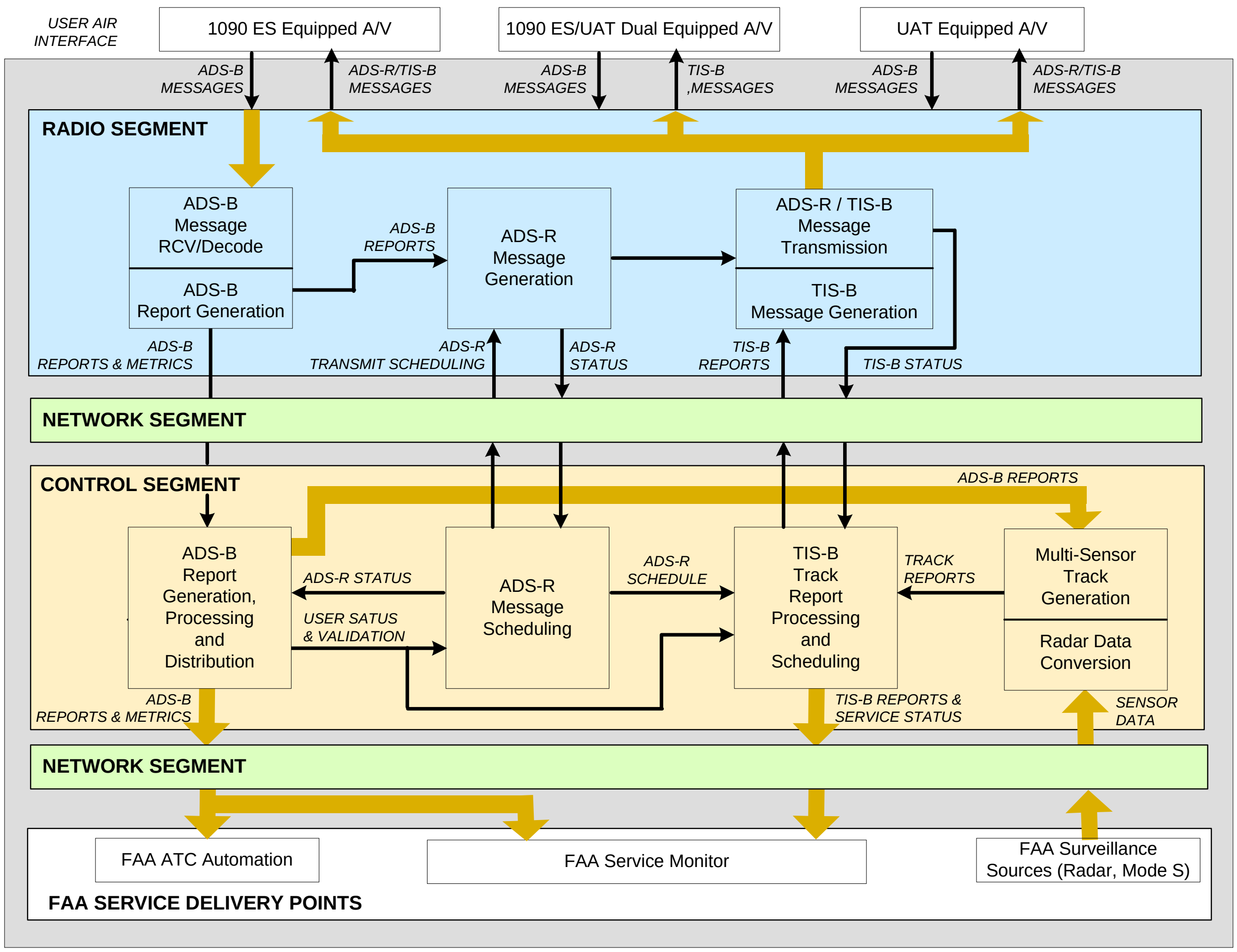


Figure 3-10: ADS-R and TIS-B Functional Architecture and Data Flows

3.1.4.2.1.2 ADS-R Client Identification

In order to receive ADS-R service an aircraft must be in an airspace region where the ADS-R service is offered, must be ADS-B-OUT, must have produced valid position data within the last 30 seconds to a SBS ground station, and must be ADS-B-IN on only one link (if ADS-B-IN on both links, ADS-R is not needed). The SBS – Ground System monitors the received ADS-B reports to identify active ADS-B users, and the ADS-B-IN link technologies operating on the aircraft.

Note: *With respect to the user aircraft/vehicle (A/V) data links; ADS-B-OUT indicates the A/V can transmit ADS-B messages, ADS-B-IN indicates the A/V can receive service messages such as ADS-R and TIS-B. A dual data link equipped A/V can transmit and receive both 1090ES and UAT services.*

ADS-R client identification is provided by the ADS-B Report Generation, Processing, and Distribution function shown in Figure 3-10 Control Segment block and sent to the ADS-R Message Scheduling function (User Status and Validation). The identification information contained in the "User Status and Validation" message includes:

1. A/V ICAO Address
2. Link Technology Indicator

In addition the ADS-B Report Generation, Processing, and Distribution function provides the A/V's:

1. Position data
2. Altitude
3. Validation Status

A/V validation status is referring to the capability of the SBS Control Station Segment providing an independent validation of the position information received in the ADS-B Messages. In certain Service Volumes, the FAA will require that the ADS-B Service provide independent validation. The validation capability may assure to a specified probability that each ADS-B Message, and the position information contained within, is from a real aircraft/vehicle with a valid position source rather than from a source broadcasting erroneous information or a spoofer. The validation methods are:

1) Comparison of ADS-B position data to radar position data,
2) Comparing a one way "passive range" with range to target indicated by ADS-B position data (available for UAT equipped targets), and
3) Use of time difference of arrival techniques.

3.1.4.2.1.3 ADS-R Target Identification

The SBS – Ground System identifies all aircraft that need to receive ADS-R transmissions for each active ADS-B transmitter. It does this by maintaining a list of all active ADS-B users, and their associated input link technologies. ADS-R target identification is provided by the ADS-B Report Generation, Processing, and Distribution function shown in Figure 3-10 Control Segment block and sent to the ADS-R Message Scheduling function. The identification information is contained in the targets ADS-B-OUT messages; the ID information includes:

1. A/V ICAO Address
2. Link Technology Indicator

For each transmitting ADS-B aircraft the SBS – Ground System determines all aircraft that do not have ADS-B-IN of the same link technology, that are within the vicinity, and need to receive ADS-R transmissions.

3.1.4.2.1.4 ADS-R in Enroute and Terminal Airspace Domains

To determine if a client requires ADS-R service, the SBS – Ground System will examine all candidate proximity aircraft, i.e., aircraft within a 15 NM horizontal range and ±5000 feet altitude of a client aircraft as shown in Figure 3-11. Aircraft that do not have ADS-B-IN of the same link technology as the client, and they are within the cylinder shown in Figure 3-11, are candidate ADS-R targets whose ID, position data, etc are required to be transmitted to the client.

In addition, ADS-B targets in a ground state are not provided to ADS-B-IN airborne clients, i.e., airborne clients within the Enroute or Terminal SVs.

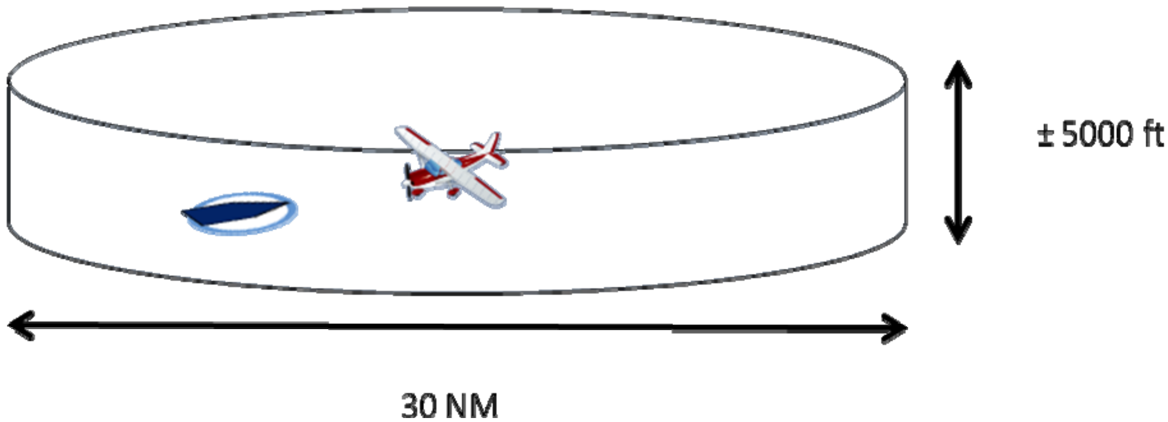


Figure 3-11: ADS-R Client Proximity Determination

3.1.4.2.1.5 ADS-R in Surface Domains

In a surface domain SV, a client is provided all applicable ADS-R targets in SV domain. This includes all targets in the ground state within the movement area (runways and taxiways) as well as all airborne targets within 5 NM and 2000 feet AGL of the airport reference point (ARP).

3.1.4.2.1.6 Transmission of ADS-R Targets over the Air Interface

Each ADS-R Target aircraft may have one or more client aircraft that need to receive ADS-R transmissions, possibly in different domains. The SBS – Ground System determines the ADS-R transmission rate required by the client in the most demanding domain. The SBS – Ground System also determines the radio or set of radios necessary to transmit ADS-R messages to all clients.

If a radio selected for transmissions to a client is also receiving transmissions from the client the ADS-R Message Scheduling function shown in Figure 3-10 prepares an ADS-R transmission schedule and submits it to the radio. The ADS-R transmission schedule identifies the 24-Bit address of the target aircraft, and an update interval. When the radio receives transmissions from the target aircraft it will retransmit the report on the opposite link, according to the provided schedule. Most ADS-R transmissions are of this type. In the uncommon case where a client and target are not served by a common radio, the SBS

– Ground System will receive the ADS-B report from the receiving radio, and forward the report to the transmitting radio.

A client aircraft that is receiving ADS-R service will receive reports for ADS-B aircraft on the opposite link within its vicinity. Since a single target may have multiple clients, sometimes in different domains, a client may receive ADS-R reports more frequently than required for the client's domain. An aircraft may also be in range of a ground radio station that is transmitting reports required by other aircraft. When this is the case the client aircraft will receive reports of aircraft that are outside the altitude and horizontal range of its vicinity.

The cumulative number of messages transmitted by all SBS – Ground System radio stations within reception range of any aircraft in the NAS will not exceed 1000 1090ES messages per second with received signal strength greater than -78 dBm. This limit applies to both the ADS-R and TIS-B Service combined. The cumulative maximum number of UAT messages received by an aircraft will not exceed 400 messages per second with received signal strength greater than -82 dBm.

3.1.4.2.2 TIS-B Service

3.1.4.2.2.1 TIS-B Service Concept of Operations

The TIS-B service provides active ADS-B users with a low-latency stream of position reports of non-ADS-B equipped aircraft. TIS-B service is available in supported Service Volumes when there is both adequate surveillance coverage from non-ADS-B ground sensors and adequate Radio Frequency (RF) coverage from SBS – Ground System radio stations. The high level data flows supporting TIS-B service are illustrated in Figure 3-12 below.

An aircraft or vehicle that is an active ADS-B user and is receiving TIS-B service is known as a TIS-B Client. A non-ADS-B equipped aircraft or vehicle that has its position transmitted in TIS-B reports is known as a TIS-B Target.

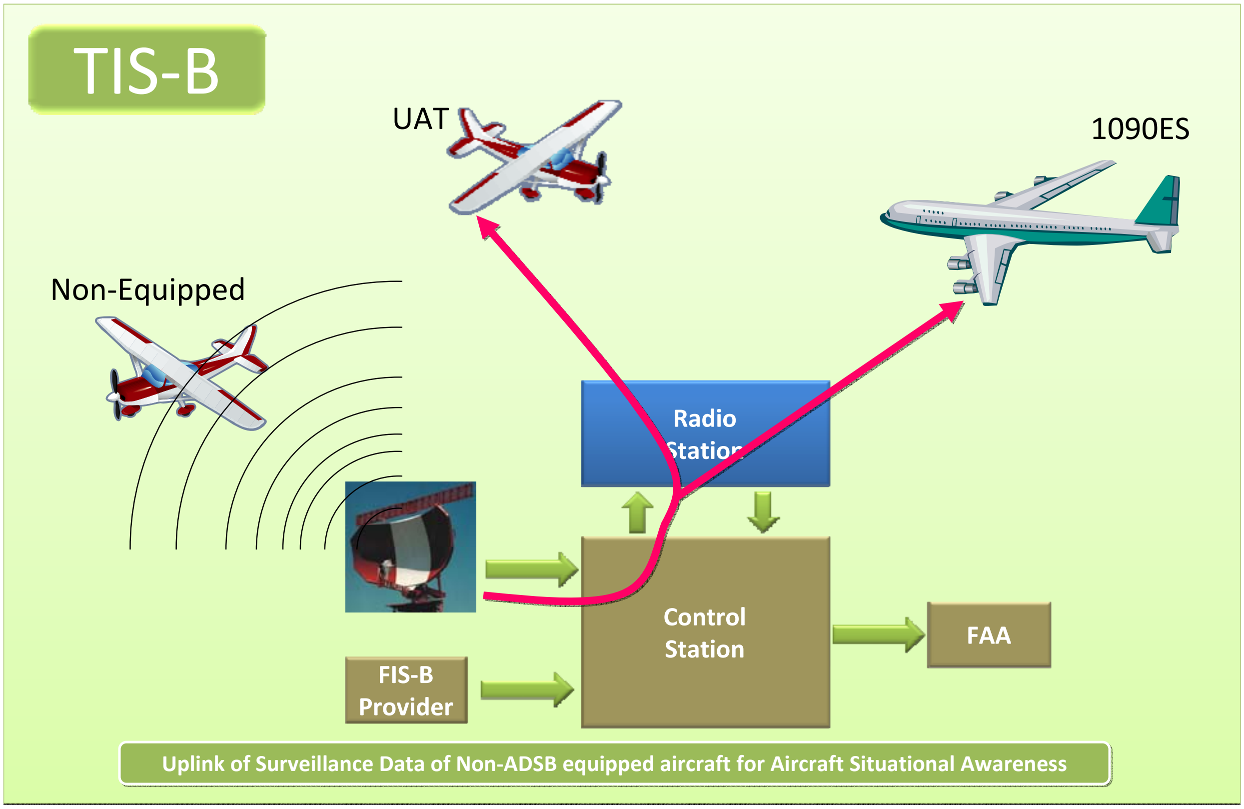


Figure 3-12: TIS-B Service Data Flow

3.1.4.2.2.2 TIS-B Client Identification

The SBS – Ground System control station monitors the ADS-B received reports to identify TIS-B Client aircraft. In order to be considered a TIS-B Client, an aircraft must be ADS-B-OUT, must have produced valid position data within the last 30s to a SBS ground station, must be under surveillance of at least one secondary radar and must be ADS-B-IN on at least one link. The TIS-B Service Status message is provided to UAT clients to indicate TIS-B service availability; this is considered to be a key safety benefit.

The SBS – Ground System monitors the received ADS-B reports to identify active ADS-B users, and the ADS-B-IN link technologies operating on the aircraft.

Note: *With respect to the user aircraft/vehicle (A/V) data links; ADS-B-OUT indicates the A/V can transmit ADS-B messages, ADS-B-IN indicates the A/V can receive service messages such as ADS-R and TIS-B. A dual data link equipped A/V can transmit and receive both 1090ES and UAT services.*

TIS-B client identification is provided by the ADS-B Report Generation, Processing, and Distribution function shown in Figure 3-10 Control Segment block and sent to the TIS-B Track Report Processing and Scheduling function (User Status and Validation). The identification information contained in the "User Status and Validation" message includes:

1. A/V ICAO Address
2. Link Technology Indicator

In addition the ADS-B Report Generation, Processing, and Distribution function provides the A/V's:

1. Position data
2. Altitude
3. Validation Status

A/V validation is referring to the capability of the SBS Control Station Segment providing an independent validation of the position information received in the ADS-B Messages. In certain Service Volumes, the FAA will require that the ADS-B Service provide independent validation. The validation capability may assure to a specified probability that each ADS-B Message, and the position information contained within, is from a real aircraft/vehicle with a valid position source rather than from a source broadcasting erroneous information or a spoofer. The validation methods are:

1) Comparison of ADS-B position data to radar position data
2) Comparing a one way "passive range" with range to target indicated by ADS-B position data (available for UAT equipped targets), and
3) Use of time difference of arrival techniques.

3.1.4.2.2.3 TIS-B Target Identification

The SBS – Ground System monitors surveillance information from the FAA; the surveillance data is correlated and merged from multiple surveillance sources into individual aircraft tracks. Aircraft tracks that cannot be correlated with an active ADS-B user track are potential TIS-B Targets.

The Multi-Sensor Tracker (MST) function is shown in Figure 3-10. The MST receives FAA sensor data from external sources and ADS-B messages from the ADS-B Report Generation, Processing and Distribution function. The MST establishes tracks from position data received. Track correlations are attempted with each position update of a track. FAA surveillance sensor tracks that cannot be correlated with ADS-B established tracks are candidate TIS-B targets.

Each ATCRBS and Mode S aircraft track identified by the tracker is assigned a unique ID when a 24-Bit address is unavailable for that target. When an ICAO address is available for a Mode S track (typically only in the surface service volumes), then this address is provided in the TIS-B messages. The SBS – Ground System has multiple trackers, deployed regionally such that there is an airborne tracker dedicated to the airspace of each FAA Enroute Center/Terminal Area. There is no correlation of track IDs between trackers, so as a TIS-B Target transitions across Service Volume boundaries between Enroute Centers, its Track ID will change, which may cause duplicate symbols to overlap while the old track ID times out on a CDTI. The avionics may need to be aware of the potential for track ID changes and perform correlation and association processing to associate aircraft across the track ID change in order to minimize duplicate symbols and perception of dropped tracks.

When ADS-R services are not offered in an airspace, the TIS-B service provides Client ADS-B equipped aircraft with proximity targets that are ADS-B equipped on the opposite link technology.

3.1.4.2.2.4 TIS-B in Enroute and Terminal Airspace Domains

The SBS – Ground System examines each potential TIS-B target to determine if it is within proximity of one or more TIS-B clients. In order to become a TIS-B target, a potential target must be contained in a cylinder defined by lateral and vertical distance from Client aircraft. The size of this cylinder depends on the airspace domain of the Client aircraft. TIS-B Service is provided to aircraft operating in the En Route and Terminal Service Volumes. There is a Service Ceiling of 24,000 feet, above which TIS-B clients will not be provided TIS-B service.

In the En Route and Terminal domains, proximity aircraft include all aircraft within a 15 NM radius and ±3500 feet of altitude. Aircraft or vehicles determined to be operating on the surface will not be considered valid TIS-B targets for aircraft operating in En Route and Terminal Service Volumes.

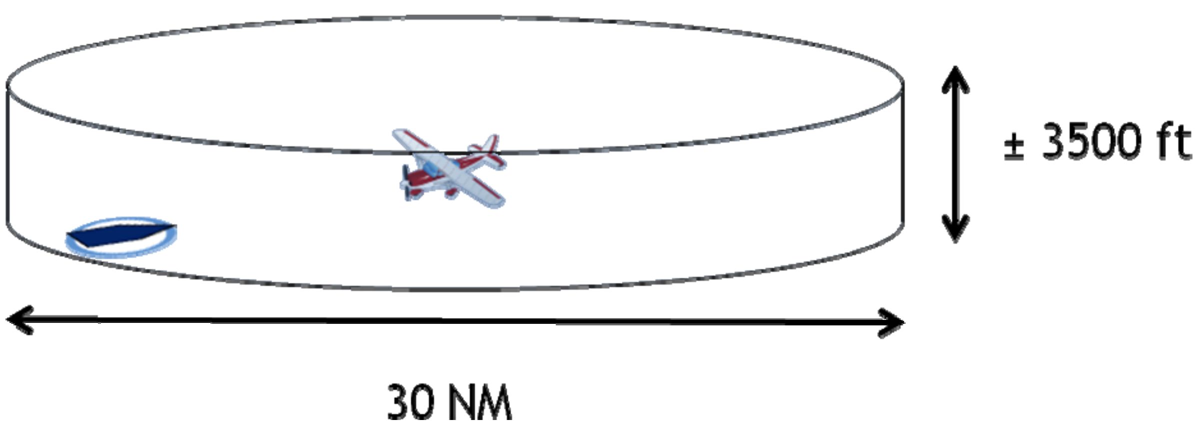


Figure 3-13: TIS-B Client Proximity Determination

3.1.4.2.2.5 TIS-B in Surface Domains

In a surface domain SV, a client is provided all applicable TIS-B targets in SV domain. This includes all targets in the ground state within the movement area as well as airborne targets within 5 NM and 2000 feet AGL of the airport reference point (ARP). Additionally, TIS-B in surface domains covers expanding volumes along the approach and departure corridors.

3.1.4.2.2.6 Transmission of TIS-B Target Messages

The SBS – Ground System transmits TIS-B reports for every TIS-B Target that is in proximity of one or more Clients. An individual Target may be in proximity of multiple Clients, with the potential for the Clients to be in separate airspace domains, with differing update rates. The SBS – Ground System will transmit TIS-B reports for a Target aircraft at the highest rate required by any of the clients of that aircraft. For example, if a Target aircraft has clients in both terminal and en route domains, TIS-B reports for that Target aircraft will be transmitted at the rate required for the terminal domain.

The cumulative number of messages transmitted by all SBS – Ground System radio stations within reception range of any aircraft in the NAS will not exceed 1000 1090ES messages per second with received signal strength greater than -78 dBm. This limit applies to both the ADS-R and TIS-B Service combined. The cumulative maximum number of UAT messages received by an aircraft will not exceed 400 messages per second with received signal strength greater than -82 dBm.

3.1.4.3 TIS-B and ADS-R Subsystem Requirements

(Mike Garcia)

3.1.5 Surface Vehicles

(UNASSIGNED)

3.2 Broadcast Information Elements Requirements

The ADS-B system **shall** (242AR2.3) be capable of transmitting messages and issuing reports containing the information specified in the following subsections. These MASPS do not specify a particular message structure or encoding technique. The information specified in the following subparagraphs can be sent in one or more messages in order to meet the report update requirements specified in Section §3.4.3.3.

3.2.1 Time of Applicability (TOA)

The time of applicability (TOA) of ADS-B reports indicates the time at which the reported values were valid. Time of applicability **shall** (242AR2.4) be provided in all reports. Requirements on the accuracy of the time of applicability are addressed in Section §3.4.3.3.2.2 and paraphrased in §3.5.1.3.3.

Note: *The required resolution of the Time of Applicability value is a function of the Report Type.*

3.2.2 Identification

The basic identification information to be conveyed by ADS-B **shall** (242AR2.5) include the following elements:

- Call Sign (§3.2.2.1)
- Participant Address (§3.2.2.2.1) and Address Qualifier (§3.2.2.2.2)
- ADS-B Emitter Category (§3.2.2.3)
- Mode 3/A Code (§3.2.2.4)

3.2.2.1 Call Sign

ADS-B **shall** (242AR2.6) be able to convey an aircraft call sign of up to 8 alphanumeric characters in length [6]. For aircraft/vehicles not receiving ATS services and military aircraft the call sign is not required.

Note: *The call sign is reported in the Mode Status (MS) report (§3.5.4 and §3.5.4.4).*

3.2.2.2 Participant Address and Address Qualifier

The ADS-B system design **shall** (242AR2.7) include a means (e.g., an address) to (a), correlate all ADS-B messages transmitted from the A/V and (b), differentiate it from other A/Vs in the operational domain.

Those aircraft requesting ATC services may be required in some jurisdictions to use the same 24 bit address for all CNS systems. Aircraft with Mode-S transponders using an ICAO 24 bit address **shall** (242AR2.8) use the same 24 bit address for ADS-B. All aircraft/vehicle addresses **shall** (242AR2.9) be unique within the applicable operational domain(s).

The ADS-B system design **shall** (242AR2.10) accommodate a means to ensure anonymity whenever pilots elect to operate under flight rules permitting an anonymous mode.

Notes:

1. *Some flight operations do not require one to fully disclose either the A/V call sign or address. This feature is provided to encourage voluntary equipage and operation of ADS-B by ensuring that ADS-B messages will not be traceable to an aircraft if the operator requires anonymity.*

2. *Correlation of ADS-B messages with Mode S transponder codes will facilitate the integration of radar and ADS-B information on the same aircraft during transition.*

3.2.2.2.1 Participant Address

The Participant Address field **shall** (242AR2.11) be included in all ADS-B reports. This 24-bit field contains either the ICAO 24-bit address assigned to the particular aircraft about which the report is concerned, or another kind of address that is unique within the operational domain, as determined by the Address Qualifier field.

3.2.2.2.2 Address Qualifier

The Address Qualifier field **shall** (242AR2.12) be included in all ADS-B reports. This field consists of one or more bits and describes whether or not the Address field contains the 24-bit ICAO address of a particular aircraft, or another kind of address that is unique within the operational domain.

Notes:

1. *The particular encoding used for the Address Qualifier is not specified in these MASPS, but is left for specification in lower level documents, such as the MOPS for a particular ADS-B data link. Experience in developing the MOPS for several proposed ADS-B data links suggests that 4 bits is sufficient for the Address Qualifier field.*

2. *Surface vehicles for a given airport need to have unique addresses only within range of the airport; vehicle addresses may be reused at other airports.*

3. *A participant's address and address qualifier are included as parts of all reports about that participant.*

3.2.2.3 ADS-B Emitter Category

An ADS-B participant's "emitter category" is conveyed in the Mode Status report (§3.5.4 and §3.5.4.5). The emitter category describes the type of A/V or other ADS-B participant. The ADS-B system **shall** (242AR2.13) provide for at least the following emitter categories:

a. Light (ICAO) – 7,000 kg (15,500 lbs) or less

b. Small aircraft – 7,000 kg to 34,000 kg (15,500 lbs to 75,000 lbs)

c. Large aircraft – 34,000 kg to 136,000 kg (75,000 lbs to 300,00 lbs)

d. High vortex large (aircraft such as B-757)

e. Heavy aircraft (ICAO) – 136,000 kg (300,000 lbs) or more

f. Highly maneuverable (> 5g acceleration capability) and high speed (> 400 knots cruise)

g. Rotorcraft

h. Glider/Sailplane

i. Lighter-than-air

j. Unmanned Aerial vehicle

k. Space/Trans-atmospheric vehicle

l. Ultralight / Hang glider / Paraglider

m. Parachutist/Skydiver

n. Surface Vehicle – emergency vehicle

o. Surface Vehicle – service vehicle

p. Point obstacle (includes tethered balloons)

q. Cluster obstacle

r. Line obstacle

Notes:

1. *ICAO Medium aircraft – 7,000 to 136,000 kg (15,500 to 300,000 lbs) can be represented as either small or large aircraft as defined above.*

2. *Obstacles can be either fixed or movable. Movable obstacles would require a position source.*

3. *Weights given for determining participant categories are maximum gross weights, not operating weights.*

4. *The following category code assignments should be considered for aircraft operating in the United States national air space (NAS).*

Light :	*Less than 7,000 kg (15,500 lb)*
Small:	*≥ 15,500 and < 41,000 lb*
Large:	*≥ 41,000 lb and < 255,000 lb and not in "High Vortex Large" category*
High Vortex Large:	*Certain other aircraft, including B-757*
Heavy:	*≥ 255,000 lb*

3.2.2.4 Mode 3/A Code

Since the Mode 3/A code is utilized by many Ground ATC systems for aircraft identification, it may continue to be necessary for ADS-B participants in certain airspace to transmit the Mode 3/A code. ADS-B **shall** (New Reqmt) have the capability to transmit the Mode 3/A code.

3.2.3 A/V Length and Width Codes

The A/V length and width codes describe the amount of space that an aircraft or ground vehicle occupies and are components of the Mode Status report (§3.5.4, §3.5.4.6). The aircraft length and width codes are not required to be transmitted by all ADS-B participants all of the time. However, they *are* required (§3.5.4.6) to be transmitted by aircraft above a certain size, at least while those aircraft are in the airport surface movement area.

3.2.4 Position

Position information **shall** (242AR2.14) be transmitted in a form that can be translated, without loss of accuracy and integrity, to latitude, longitude, geometric height, and barometric pressure altitude. The position report elements may be further categorized as geometric position and barometric altitude.

- The geometric position report elements are horizontal position (latitude and longitude), and geometric height. All geometric position elements **shall** (242AR2.15) be referenced to the WGS-84 ellipsoid.
- Barometric pressure altitude **shall** (242AR2.16) be reported referenced to standard temperature and pressure.

For any ADS-B participant that sets the "reporting reference point position" CC code (in MS report element #7g, §3.5.4.9.7) to ONE, the position that is broadcast in ADS-B messages as that participant's nominal position **shall** (242AR2.17) be the position of that participant's ADS-B position reference point (§3.3.4.1 below).

For any ADS-B participant that sets the "reporting reference point position" CC code (in MS report element #7g, §3.5.4.9.7) to ZERO, the position that is broadcast in ADS-B messages is not corrected from the position as given by the participant's navigation sensor to the position of that participant's ADS-B position reference point.

Note: *Surface movement and runway incursion applications will require high* NAC_P *values. To obtain those high values, it may be necessary to correct the reported position to that of the ADS-B Position Reference Point (§3.3.4.1) if the antenna of the navigation sensor is not located in very close proximity to the ADS-B reference point.*

3.2.4.1 ADS-B Position Reference Point

The nominal location of a transmitting ADS-B participant – the position that is reported to user applications in SV reports about that participant – is the location of the participant's ***ADS-B Position Reference Point***.

Note 1: *The "reporting reference point position" CC code (in MS report element #7g) indicates whether a transmitting ADS-B participant has corrected the position given by its navigation sensor (e.g., the position of the antenna of a GPS receiver) to the location of its ADS-B position reference point. (The process of correcting the position to that of the position reference point need not be done in the transmitting ADS-B subsystem; it might be applied in the navigation sensor, or in another device external to the ADS-B transmitting subsystem.) (See the description of MS report element #7g, §3.5.4.9.7)*

The ***ADS-B position reference point*** of an A/V **shall** (242AR2.18) be defined as the center of a rectangle (the "defining rectangle for position reference point") that has the following properties:

a. The defining rectangle for position reference point **shall** (242AR2.18-A) have length and width as defined in Table 3.2.4.1a below for the length and width codes that the participant is transmitting in messages to support the MS report.

b. The defining rectangle for position reference point **shall** (242AR2.18-B) be aligned parallel to the A/V's heading.

c. The ADS-B position reference point (the center of the defining rectangle for position reference point) **shall** (242AR2.18-C) lie along the axis of symmetry of the A/V. (For an asymmetrical A/V, the center of the rectangle should lie midway between the maximum port and starboard extremities of the A/V.)

d. The forward extremity of the A/V **shall** (242AR2.18-D) just touch the forward end of the defining rectangle for position reference point.

Table 3.2.4.1a: Dimensions of Defining Rectangle for Position Reference Point.

A/V – L/W Code (Decimal)	Length Code (binary)			Width Code (binary)	Upper-Bound Length and Width for Each Length/Width Code	
					Length (meters)	Width (meters)
0	0	0	0	0	No Data or Unknown	
1	0	0	0	1	15	23
2	0	0	1	0	25	28.5
3				1		34
4	0	1	0	0	35	33
5				1		38
6	0	1	1	0	45	39.5
7				1		45
8	1	0	0	0	55	45
9				1		52
10	1	0	1	0	65	59.5
11				1		67
12	1	1	0	0	75	72.5
13				1		80
14	1	1	1	0	85	80
15				1		90

Note 2: *The lengths and widths given in Table 3.2.4.1a are least upper bounds for the possible lengths and widths of an aircraft that reports the given length and width code as specified in Table TBD (§3.5.4.6). An exception, however, is made for the largest length and width codes, since there is no upper bound for the size of an aircraft that broadcasts those largest length and width codes.*

Figure 3.2.4.1a illustrates the location of the ADS-B reference point, for an example aircraft of length 31 m and width 29 m. Such an aircraft will have length code 2 (L < 35 m) and width code 0 (W < 33m). The ADS-B position reference point is then the center of a rectangle that is 35 m long and 33 m wide and positioned as given in the requirements just stated. As required in §2.1.2.3, this is the position that a transmitting ADS-B participant broadcasts when its "reporting reference point position" CC code is ONE.

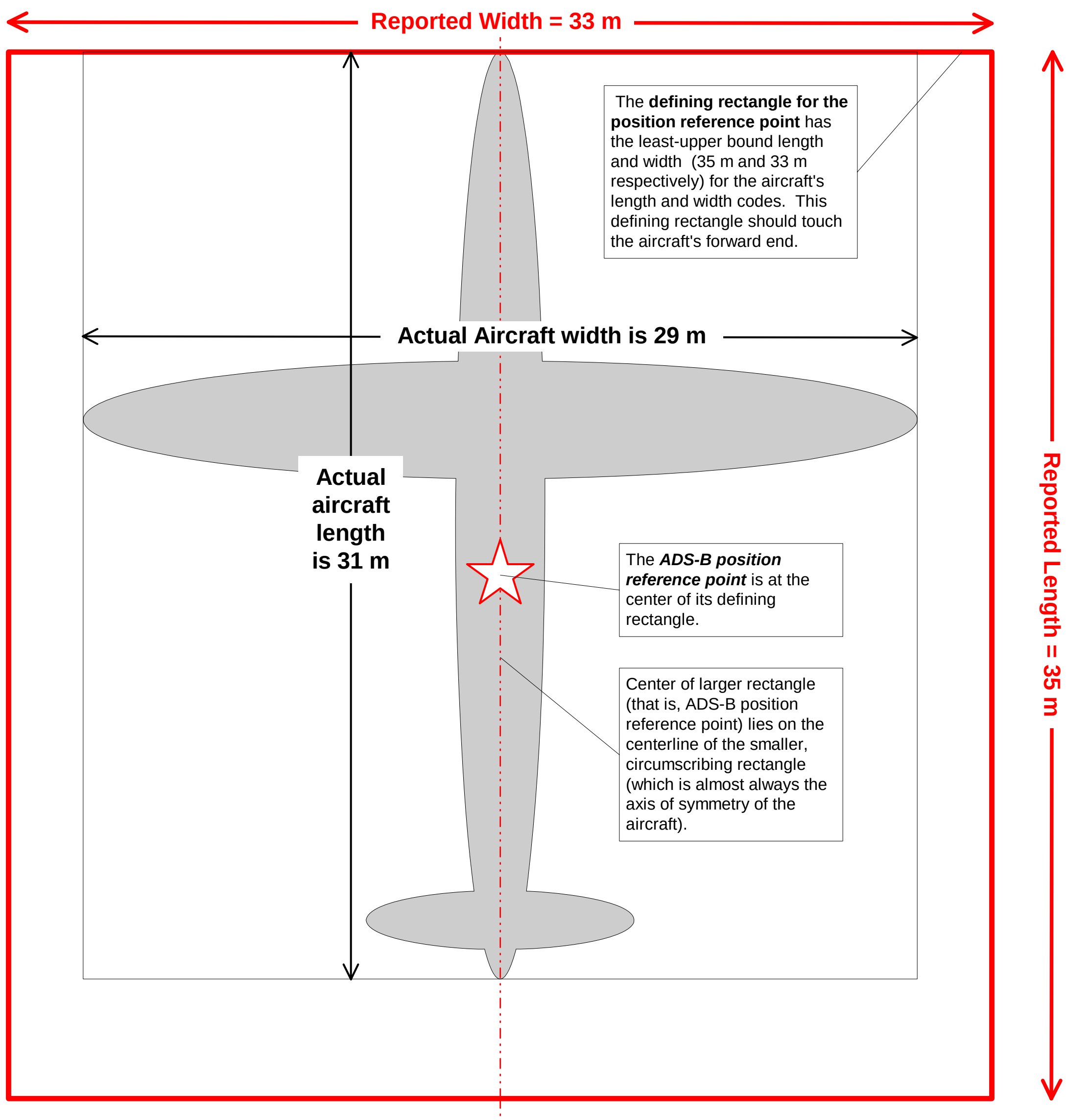


Figure 3.2.4.1a: Position Reference Point Definition.

Note 3: *When on the surface, the ability to correct for inaccuracies due to offsets in position between the navigation sensor and the ADS-B position reference point must be provided. If the navigation sensor or the transmitting ADS-B participant does not correct for this offset, the lateral distance from the lateral axis of the aircraft and the longitudinal distance from the nose of the aircraft must be conveyed so that the ADS-B application can account for this offset. A means to indicate that the position is corrected to the ADS-B reference point must be provided.* ➔ ***Editor's Note:*** *Add reference to the GPS Antenna Offset section below.* 🡐

Note 4: *There are operational applications where the ADS-B position being reported needs to be related to the extremities of large aircraft; such as, runway incursion alerting and other future surface applications. Therefore, for the aircraft size codes and* NAC_p *codes defined, the position being broadcast must be translated to a common reference point on the aircraft. The translation calculation on position sensor source data may be performed outside of the ADS-B transmitting subsystem, therefore, specific requirements for this function are not defined in these MASPS.*

3.2.4.2 Altitude

Both barometric pressure altitude and geometric altitude (height above the WGS-84 ellipsoid) **shall** (242AR2.19) be provided, if available, to the transmitting ADS-B subsystem. Some applications may have to compensate if only one source is available. However, when an A/V is operating on the airport surface, the altitude is not required to be reported, provided that the A/V indicates that it is on the surface.

Altitude **shall** (242AR2.20) be provided with a range from -1,000 ft up to +100,000 ft. For fixed or movable obstacles, the altitude of the highest point should be reported.

3.2.4.2.1 Pressure Altitude

ADS-B link equipment **shall** (242AR2.21) support a means for the pilot to indicate that the broadcast of altitude information from pressure altitude sources is invalid. This capability can be used at the request of ATC or when altitude is determined to be invalid by the pilot.

Barometric pressure altitude is the reference for vertical separation within the NAS and ICAO airspace. Barometric pressure altitude is reported referenced to standard temperature and pressure.

Pressure altitude, which is currently reported by aircraft in SSR Mode C and Mode S, will also be transmitted in ADS-B messages and reported to client applications in SV reports. The pressure altitude reported **shall** (242AR2.22) be derived from the same source as the pressure altitude reported in Mode C and Mode S for aircraft with both transponder and ADS-B.

3.2.4.2.2 Geometric Altitude

Geometric altitude is defined as the shortest distance from the current aircraft position to the surface of the WGS-84 ellipsoid, known as Height Above Ellipsoid (HAE). It is positive for positions above the WGS-84 ellipsoid surface, and negative for positions below that surface.

3.2.5 Horizontal Velocity

There are two kinds of velocity information:

- "Ground-referenced" or "geometric" velocity is the velocity of an A/V relative to the earth, or to a coordinate system (such as WGS-84) that is fixed with respect to the earth. Ground-referenced velocity is communicated in the SV report (§TBD).
- Air-referenced velocity is the velocity of an aircraft relative to the air mass through which it is moving. Airspeed, the *magnitude* of the air-referenced velocity vector, is communicated in the ARV report, §TBD. The ARV report also includes heading (§2.1.2.7), which is used in that report as an estimate of the *direction* of the air-referenced velocity vector. Conditions for when the broadcast of ARV data is required are specified in §TBD.

ADS-B geometric velocity information **shall** (242AR2.23) be referenced to WGS-84 [7]. Transmitting A/Vs that are not fixed or movable obstacles **shall** (242AR2.24) provide ground-referenced geometric horizontal velocity.

Note: *In this context, a "movable obstacle" means an obstacle that can change its position, but only slowly, so that its horizontal velocity may be ignored.*

3.2.6 Vertical Rate

Transmitting A/Vs that are not fixed or movable obstacles and that are not known to be on the airport surface **shall** (242AR2.25) provide vertical rate.

Note 1: *In this context, a "movable obstacle" means an obstacle that can change its position, but only slowly, so that its vertical rate may be ignored.*

Vertical Rate **shall** (242AR2.26) be designated as climbing or descending and **shall** (242AR2.27) be reported up to 32,000 feet per minute (fpm). Barometric altitude rate is defined as the current rate of change of barometric altitude. Likewise, geometric altitude rate is the rate of change of geometric altitude. At least one of the two types of vertical rate (barometric and geometric) **shall** (242AR2.28) be reported.

If only one of these two types of vertical rate is reported, it **shall** (242AR2.29) be obtained from the best available source of vertical rate information. (1) Inertial filtered barometric altitude rate will be the preferred source of altitude rate information. (2) If differentially corrected GPS (WAAS, LAAS, or other) is available, geometric altitude rate as derived from the GPS source should be transmitted. (3) If differentially corrected GPS is not available, unaugmented GNSS vertical rate should be used. (4) Pure barometric rate.

➔ **Question:** Is there a requirement to have vertical rate from the same source as the altitude broadcast?? ←

Note 2: *Future versions of these MASPS are expected to include requirements on the accuracy and latency of barometric altitude rate.*

Note 3: *Vertical rate is reported in the SV report (§TBD).*

3.2.7 Heading

Heading indicates the orientation of an A/V, that is, the direction in which the nose of the aircraft is pointing. Heading is described as an angle measured clockwise from true north or magnetic north. The heading reference direction (true north or magnetic north) is conveyed in the Mode Status report (§3.5.1.4).

Heading occurs not only in the SV report (§3.5.1.3) for participants on the airport surface, but also in the ARV report (§3.5.1.6) for airborne participants.

3.2.8 Capability Class (CC) Codes

A transmitting ADS-B participant broadcasts Capability Class (CC) codes (§3.5.1.4.9) so as to indicate capabilities that may be of interest to other ADS-B participants. The subfields of the CC codes field are described in the following subparagraphs.

3.2.8.1 TCAS/ACAS Operational

The CC code for "TCAS/ACAS operational" **shall** (242AR3.102-A) be set to ONE if the transmitting subsystem receives information from an appropriate interface that indicates that the TCAS/ACAS system is operational. Otherwise, this CC code **shall** (242AR3.102-C) be set to ZERO.

Notes:

1. *ADS-B does not consider TCAS/ACAS Operational equal to ONE (1) unless the TCAS/ACAS is in a state which can issue an RA (e.g., RI=3 or 4). RTCA DO-181E (EUROCAE ED-73E) Mode-S Transponders consider that the TCAS System is operational when "MB" bit 16 of Register 10_{16} is set to "ONE" (1). This occurs when the transponder / TCAS/ACAS interface is operational and the transponder is receiving TCAS RI=2, 3 or 4. (Refer to RTCA DO-181E (EUROCAE ED-73E), Appendix B, Table B-3-16.) RI=0 is STANDBY, RI=2 is TA ONLY and RI=3 is TA/RA.*

2. *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of these MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of these MASPS.*

3.2.8.2 1090 MHz ES Receive Capability

The CC Code for "1090ES IN" **shall** (242AR3.103-C) be set to ONE (1) if the transmitting aircraft also has the capability to receive ADS-B 1090ES Messages. Otherwise, this CC code subfield **shall** (242AR3.103-D) be set to ZERO (0).

3.2.8.3 ARV Report Capability Flag

The Air Reference Velocity (ARV) Report Capability Flag is a one-bit field that **shall** (242AR3.106) be encoded as in Table 3.2.8.3.

Table 3.2.8.3: ARV Report Capability Flag

ARV Capability Flag	Meaning
0	No capability for Air Reference Velocity Reports.
1	Capability of sending Air Reference Velocity Reports.

3.2.8.4 TS Report Capability Flag

The Target State (TS) Report Capability Flag is a one-bit field that **shall** (242AR3.107) be encoded as in Table 3.2.8.4.

Table 3.2.8.4: TS Report Capability Flag

TS Report Capability Flag	Meaning
0	No capability for Target State Reports.
1	Capability of sending Target State Reports.

3.2.8.5 TC Report Capability Level

The Trajectory Change (TC) Report Capability Level is a two-bit field that **shall** (242AR3.108) be encoded as in Table 3.2.8.5.

Table 3.2.8.5: TC Report Capability Levels

TC Report Capability Level	Meaning
0	No capability for Trajectory Change Reports
1	Capability of sending information for TC+0 report only.
2	Capability of sending information for multiple TC reports.
3	(Reserved for future use.)

3.2.8.6 UAT Receive Capability

The "UAT IN" CC Code **shall** (242AR3.109-C) be set to ZERO (0) if the aircraft is NOT fitted with the capability to receive ADS-B UAT Messages. The "UAT IN" CC Code **shall** (242AR3.109-D) be set to ONE (1) if the aircraft has the capability to receive ADS-B UAT Messages.

3.2.8.7 Other Capability Codes

Other capability codes are expected to be defined in later versions of these MASPS.

3.2.9 Operational Mode (OM) Codes

Operational Mode (OM) codes are used to indicate the current operational modes of transmitting ADS-B participants. Specific operational mode codes are described in the following subparagraphs.

3.2.9.1 TCAS/ACAS Resolution Advisory Active Flag

The CC code for "TCAS/ACAS Resolution Advisory Active" **shall** (242AR3.110-A) be set to ONE if the transmitting aircraft has a TCAS II or ACAS computer that is currently issuing a Resolution Advisory (RA). Likewise, this CC code **shall** (242AR3.110-B) be set to ONE if the transmitting ADS-B equipment cannot ascertain whether the TCAS II or ACAS computer is currently issuing an RA. This CC code **shall** (242AR3.110-C) be ZERO only if it is explicitly known that a TCAS II or ACAS computer is not currently issuing a Resolution Advisory (RA).

Note: *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of this MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of this MASPS.*

3.2.9.2 IDENT Switch Active Flag

The "IDENT Switch Active" Flag is a one-bit OM code that is activated by an IDENT switch. Upon activation of the IDENT switch, this flag **shall** (242AR3.111-B) be set to ONE for a period of 20 ±3 seconds; thereafter, it **shall** (242AR3.111-C) be reset to ZERO.

Note: *These MASPS do not specify the means by which the "IDENT Switch Active" flag is set. That is left to lower-level documents, such as the MOPS for a particular ADS-B data link.*

3.2.9.3 Reserved for Receiving ATC Services Flag

The "Reserved for Receiving ATC Services" flag is a one-bit OM code. If implemented into future versions of these MASPS, when set to ONE, this code **shall** (242AR3.112) indicate that the transmitting ADS-B participant is receiving ATC services; otherwise this flag should be set to ZERO.

Note: *The means by which the "Reserved for Receiving ATC Services" flag is set is beyond the scope of this MASPS and is not specified in this document.*

3.2.9.4 Single Antenna Flag

The "Single Antenna Flag" is a 1-bit field that **shall** (242AR3.112-A) be used to indicate that the ADS-B Transmitting Subsystem is operating with a single antenna. The following conventions **shall** (242AR3.112-B) apply both to Transponder-Based and Stand Alone ADS-B Transmitting Subsystems:

a. Non-Diversity, i.e., those transmitting functions that use only one antenna, **shall** (242AR3.112-C) set the Single Antenna subfield to "ONE" at all times.

b. Diversity, i.e., those transmitting functions designed to use two antennas, **shall** (242AR3.112-D) set the Single Antenna subfield to "ZERO" at all times that both antenna channels are functional.

At any time that the diversity configuration cannot guarantee that both antenna channels are functional, then the Single Antenna Flag **shall** (242AR3.112-E) be set to "ONE."

Note: *Certain applications may require confirmation that each participant has functioning antenna diversity for providing adequate surveillance coverage.*

3.2.9.5 System Design Assurance (SDA)

The position transmission chain includes the ADS-B transmission equipment, ADS-B processing equipment, position source, and any other equipment that processes the position data and position quality metrics that will be transmitted.

The "System Design Assurance" (SDA) field is a 2-bit field that **shall** (242AR3.112-F) define the failure condition that the position transmission chain is designed to support as defined in Table 3.2.9.5.

The supported failure condition will indicate the probability of a position transmission chain fault causing false or misleading position information to be transmitted. The definitions and probabilities associated with the supported failure effect are defined in AC 25.1309-1A, AC 23-1309-1C, and AC 29-2C. All relevant systems attributes should be considered including software and complex hardware in accordance with RTCA DO-178B (EUROCAE ED-12B) or RTCA DO-254 (EUROCAE ED-80).

Table 3.2.9.5: "System Design Assurance" OM Subfield in Aircraft Operational Status Messages

SDA Value (decimal)	SDA Value (binary)	Supported Failure Condition Note 2	Probability of Undetected Fault causing transmission of False or Misleading Information Note 3,4	Software & Hardware Design Assurance Level Note 1,3
0	00	Unknown/ No safety effect	> $1x10^{-3}$ per flight hour or Unknown	N/A
1	01	Minor	≤ $1x10^{-3}$ per flight hour	D
2	10	Major	≤ $1x10^{-5}$ per flight hour	C
3	11	Hazardous	≤ $1x10^{-7}$ per flight hour	B

Notes:

1. *Software Design Assurance per RTCA DO-178B (EUROCAE ED-12B). Airborne Electronic Hardware Design Assurance per RTCA DO-254 (EUROCAE ED-80).*
2. *Supported Failure Classification defined in AC-23.1309-1C, AC-25.1309-1A, and AC 29-2C.*
3. *Because the broadcast position can be used by any other ADS-B equipped aircraft or by ATC, the provisions in AC 23-1309-1C that allow reduction in failure probabilities and design assurance level for aircraft under 6000 pounds do not apply.*
4. *Includes probability of transmitting false or misleading latitude, longitude, or associated accuracy and integrity metrics.*

3.2.9.6 GPS Antenna Offset

The "GPS Antenna Offset" field is an 8-bit field in the OM Code Subfield of surface format Aircraft Operational Status Messages that **shall** (242AR3.112-G) define the position of the GPS antenna in accordance with the following.

a. Lateral Axis GPS Antenna Offset:

The Lateral Axis GPS Antenna Offset **shall** (242AR3.112-H) be used to encode the lateral distance of the GPS Antenna from the longitudinal axis (Roll) axis of the aircraft. Encoding **shall** (242AR3.112-I) be established in accordance with Table 3.2.9.6A.

Table 3.2.9.6A: Lateral Axis GPS Antenna Offset Values

0 = left 1 = right	Values		Upper Bound of the GPS Antenna Offset Along Lateral (Pitch) Axis Left or Right of Longitudinal (Roll) Axis	
	Bit 1	**Bit 0**	**Direction**	**(meters)**
0	0	0	**LEFT**	**NO DATA**
	0	1		2
	1	0		4
	1	1		6
1	0	0	**RIGHT**	0
	0	1		2
	1	0		4
	1	1		6

Notes:

1. *Left means toward the left wing tip moving from the longitudinal center line of the aircraft.*
2. *Right means toward the right wing tip moving from the longitudinal center line of the aircraft.*
3. *Maximum distance left or right of aircraft longitudinal (roll) axis is 6 meters or 19.685 feet. If the distance is greater than 6 meters, then the encoding should be set to 6 meters.*
4. *The "No Data" case is indicated by encoding of "000" as above, while the "ZERO" offset case is represented by encoding of "100" as above.*
5. *The accuracy requirement is assumed to be better than 2 meters, consistent with the data resolution.*

b. Longitudinal Axis GPS Antenna Offset:

The Longitudinal Axis GPS Antenna Offset **shall** (242AR3.112-J) be used to encode the longitudinal distance of the GPS Antenna from the NOSE of the aircraft. Encoding **shall** (242AR3.112-K) be established in accordance with Table 3.2.9.6B. If the Antenna Offset is compensated by the Sensor to be the position of the ADS-B participant's ADS-B Position Reference Point (See §3.2.4.1), then the encoding is set to binary "00001" in Table 3.2.9.6B.

Table 3.2.9.6B: Longitudinal Axis GPS Antenna Offset Encoding

Longitudinal Axis GPS Antenna Offset Encoding					
Values					Upper Bound of the GPS Antenna Offset Along Longitudinal (Roll) Axis Aft From Aircraft Nose
Bit 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**(meters)**
0	0	0	0	0	**NO DATA**
0	0	0	0	1	Position Offset Applied by Sensor
0	0	0	1	0	2
0	0	0	1	1	4
0	0	1	0	0	6
*	*	*	*	*	***
*	*	*	*	*	***
*	*	*	*	*	***
1	1	1	1	1	60

Notes:

1. *Maximum distance aft from aircraft nose is 60 meters or 196.85 feet. If the distance is greater than 60 meters, then the encoding should be set to 60 meters.*
2. *The accuracy requirement is assumed to be better than 2 meters, consistent with the data resolution.*

3.2.9.7 Other Operational Mode Codes

Other operational mode (OM) codes may be defined in later versions of these MASPS.

3.2.10 Navigation Integrity Category

The Navigation Integrity Category (NIC) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable integrity containment region for the intended use. The Navigation Integrity Category is intimately associated with the SIL (Source Integrity Level) parameter described in §3.2.13. NIC specifies an integrity containment region. The SIL parameter specifies the probability of the reported horizontal position exceeding the containment radius defined by the NIC without alerting, assuming no avionics faults.

Note: *"NIC" and "NAC$_P$" as used in the current version of these MASPS replace the earlier term, "NUC$_P$", used in the first edition of the ADS-B MASPS (RTCA DO-242).*

The Navigation Integrity Category is reported in the State Vector (SV) report (§TBD).

Table 3.2.10a defines the navigation integrity categories that transmitting ADS-B participants **shall** (242AR2.30) use to describe the integrity containment radius, R_C, associated with the horizontal position information in ADS-B messages from those participants.

Table 3.2.10a: Navigation Integrity Categories (NIC).

NIC (Notes 1, 2)	**Horizontal Containment Bounds**	**Notes**
0	R_C Unknown	
1	R_C < 37.04 km (20 NM)	6
2	R_C < 14.816 km (8 NM)	3, 6
3	R_C < 7.408 km (4 NM)	6
4	R_C < 3.704 km (2 NM)	6
5	R_C < 1852 m (1 NM)	6
6	R_C < 1111.2 m (0.6 NM)	5, 6
6	R_C < 555.6 m (0.3 NM)	5, 6
7	R_C < 370.4 m (0.2 NM)	6
8	R_C < 185.2 m (0.1 NM)	6
9	R_C < 75 m	4
10	R_C < 25 m	4
11	R_C < 7.5 m	4

➔ **Editor's Question:** Is it appropriate to revise the NIC Table above to represent the NIC Supplements as they were defined in either DO-260B or DO-282B? DCM Proposal: Add the new "common" NIC = 6 w/Supplement Bit / Rc < 0.3 NM (Is in both DO-260B and DO-282B) Do not include NIC = 6 / Rc < 0.5 NM – this value is unique to DO-260B. (Research lost Note #6 and add a Note for Rc < 0.3 NM) ←

Notes for Table 3.2.10a:

1. *NIC is reported by an aircraft because there will not be a uniform level of navigation equipage among all users. Although GNSS is intended to be the primary source of navigation data used to report ADS-B horizontal position, it is anticipated that during initial uses of ADS-B or during temporary GNSS outages an alternate source of navigation data may be used by the transmitting A/V for ADS-B position information.*

2. *"NIC" in this column corresponds to "NUC_P" of Table 2-1(a) in the first version of these MASPS, DO-242, dated February 19, 1998.*

3. *The containment radius for NIC = 2 has been changed (from the corresponding radius for NUC_P = 2 in the first edition of these MASPS) so as to correspond to the RNP-4 RNAV limit of DO-236A, rather than the RNP-5 limit of the earlier DO-236. This is because RNP-5 is not a recognized ICAO standard RNP value.*

4. *HIL/HPL may be used to represent R_C for GNSS sensors.*

5. *R_C < 0.3 NM was added in this version of the MASPS and assigned NIC value of 6. It is left to the ADS-B data link to provide a means to distinguish between R_C < 0.3 NM and R_C < 0.6 NM.*

6. *RNP containment integrity refers to total system error containment including sources other than sensor error, whereas horizontal containment for NIC only refers to sensor position error containment.*

It is recommended that the coded representations of NIC should be such that:

a. Equipment that conforms to the current edition of these MASPS ("version 2" equipment) or to the previous, RTCA DO-242A, edition ("version 1" equipment) will recognize the equivalent NUC_P codes from the first edition of these MASPS (RTCA DO-242, version "0" equipment), and

b. Equipment that conforms to the initial, RTCA DO-242, edition of these MASPS ("version 0" equipment) will treat the coded representations of NIC coming from version 1 or 2 equipment as if they were the corresponding "NUC_P" values from the initial, RTCA DO-242, version of these MASPS.

3.2.11 Navigation Accuracy Category for Position (NAC_P)

The Navigation Accuracy Category for Position (NAC_P) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable level of accuracy for the intended use.

Table 3.2.11a defines the navigation accuracy categories that **shall** (242AR2.31) be used to describe the accuracy of positional information in ADS-B messages from transmitting ADS-B participants.

<u>Notes:</u>

1. *"NIC" and "NAC_P" as used in these MASPS replace the earlier term, "NUC_P", used in the initial, DO-242, edition of these MASPS .*

2. *It is likely that surface movement and runway incursion applications will require high NAC_P values. To obtain those high values, it may be necessary to correct the reported position to that of the ADS-B Position Reference Point (§3.2.4.1) if the antenna of the navigation sensor is not located in very close proximity to the ADS-B reference point.*

3. *The Estimated Position Uncertainty (EPU) used in Table 3.2.11a is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position being outside the circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).*

4. *The EPU limit for NAC_P = 2 has been changed (from the corresponding limit for NUC_P = 2 in the first edition of these MASPS) so as to correspond to the RNP-4 RNAV limit of DO-236A, rather than the RNP-5 limit of the earlier DO-236. This is because RNP-5 is not an ICAO standard RNP value.*

Table 3.2.11a: Navigation Accuracy Categories for Position (NAC_P).

NAC_P	95% Horizontal Accuracy Bounds (EPU)	Notes
0	EPU ≥ 18.52 km (10 NM)	
1	EPU < 18.52 km (10 NM)	1
2	EPU < 7.408 km (4 NM)	1
3	EPU < 3.704 km (2 NM)	1
4	EPU < 1852 m (1NM)	1
5	EPU < 926 m (0.5 NM)	1
6	EPU < 555.6 m (0.3 NM)	1
7	EPU < 185.2 m (0.1 NM)	1
8	EPU < 92.6 m (0.05 NM)	1
9	EPU < 30 m	2
10	EPU < 10 m	2
11	EPU < 3 m	2

Notes for Table 3.2.11a:

1. *RNP accuracy includes error sources other than sensor error, whereas horizontal error for NAC_P only refers to horizontal position error uncertainty.*

2. *A non-excluded satellite failure requires that the NAC_P and NAC_V parameters be set to ZERO along with R_C being set to Unknown to indicate that the position accuracy and integrity have been determined to be invalid. Factors such as surface multi-path, which has been observed to cause intermittent setting of Label 130 bit 11, should be taken into account by the ADS-B application and ATC.*

3.2.12 Navigation Accuracy Category for Velocity (NAC_V)

The velocity accuracy category of the least accurate velocity component being supplied by the reporting A/V's source of velocity data **shall** (242AR2.33) be as indicated in Table 3.2.12a.

Notes:

1. *NAC_V is another name for the parameter that was called NUC_R in the initial (DO-242) version of these MASPS.*

2. *Navigation sources, such as GNSS and inertial navigation systems, provide a direct measure of velocity which can be significantly better than that which could be obtained by position differences.*

3. *Refer to Appendix TBD for guidance material on determination of NAC_V. Appendix TBD describes the manner in which GNSS position sources, which do not output velocity accuracy, can be characterized so that a velocity accuracy value associated with the position source can be input into ADS-B equipment as part of the installation process.*

Table 3.2.12a: Navigation Accuracy Categories for Velocity (NAC_V).

NAC_V	Horizontal Velocity Error (95%)
0	Unknown or ≥ 10 m/s
1	< 10 m/s
2	< 3 m/s
3	< 1 m/s
4	< 0.3 m/s

Notes for Table 3.2.12a:

1. *When an inertial navigation system is used as the source of velocity information, error in velocity with respect to the earth (or to the WGS-84 ellipsoid used to represent the earth) is reflected in the NAC_V value.*

2. *When any component of velocity is flagged as not available the value of NAC_V will apply to the other components that are supplied.*

3. *A non-excluded satellite failure requires that the R_C be set to Unknown along with the NAC_V and NAC_P parameters being set to ZERO.*

3.2.13 Source Integrity Level (SIL)

The Source Integrity Level (SIL) defines the probability of the reported horizontal position exceeding the containment radius defined by the NIC (§3.2.10), without alerting, assuming no avionics faults. Although the SIL assumes there are no unannunciated faults in the avionics system, the SIL must consider the effects of a faulted Signal-in-Space, if a Signal-in-Space is used by the position source. The probability of an avionics fault causing the reported horizontal position to exceed the radius of containment defined by the NIC, without alerting, is covered by the System Design Assurance (SDA) parameter. The Source Integrity Limit encoding **shall** (242AR2.34) be as indicated in Table 3.2.13a. The SIL probability can be defined as either "per sample" or "per hour."

Note: *It is assumed that SIL is a static (unchanging) value that depends on the position sensor being used. Thus, for example, if an ADS-B participant reports a NIC code of 0 because four or fewer satellites are available for a GPS fix, there would be no need to change the SIL code until a different navigation source were selected for the positions being reported in the SV report.*

Table 3.2.13a: Source Integrity Level (SIL) Encoding.

SIL	Probability of Exceeding the NIC Containment Radius
0	Unknown or > 1 x 10^{-3} per flight hour or per sample
1	1×10^{-3} per flight hour or per sample
2	1×10^{-5} per flight hour or per sample
3	1×10^{-7} per flight hour or per sample

3.2.14 Barometric Altitude Integrity Code (NIC_{BARO})

The Barometric Altitude Integrity Code, NIC_{BARO}, is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude.

Note: *NIC_{BARO}, the barometric altitude integrity code, is reported in the Mode Status report (§TBD).*

3.2.15 Emergency/Priority Status

The ADS-B system **shall** (242AR2.36) be capable of supporting broadcast of emergency and priority status. Emergency/priority status is reported in the MS report (§TBD) and the emergency states are defined in the following Table 3.2.15a.

Table 3.2.15a: Emergency State Encoding

Value	Meaning
0	No Emergency
1	General Emergency
2	Lifeguard / Medical
3	Minimum Fuel
4	No Communications
5	Unlawful Interference
6	Downed Aircraft
7	Reserved

3.2.16 Geometric Vertical Accuracy (GVA)

The Geometric Vertical Accuracy subfield is a 2-bit field as specified in Table 3.2.16. The GVA field **shall** (new reqmt) be set by using the Vertical Figure of Merit (VFOM) (95%) from the GNSS position source used to report the geometric altitude.

Table 3.2.16: Geometric Vertical Accuracy (GVA) Parameter

GVA Encoding (decimal)	**Meaning** (meters)
0	Unknown or > 150 meters
1	≤ 150 meters
2	≤ 45 meters
3	Reserved

Note: *For the purposes of these MASPS, values for 0, 1 and 2 are encoded. Decoding values for 3 should be treated as < 45 meters until future versions of these MASPS redefine the value.*

3.2.17 TCAS/ACAS Resolution Advisory (RA) Data Block

For those aircraft equipped with TCAS/ACAS, in addition to the TCAS/ACAS Resolution Advisory Active broadcast flag, the RA Message Block is also required to be broadcast during an active RA and following termination so that ADS-B receiving systems can sense the termination of the RA. The message subfields are the data elements that are specified in RTCA DO-185B §2.2.3.9.3.2.3.1.1.

3.2.18 ADS-B Version Number

The ADS-B Version Number is a 3-bit field that specifies the ADS-B version of the transmitting ADS-B system. The ADS-B Version Number **shall** (242AR3.92) be defined as specified in Table 3.2.18 below.

Table 3.2.18: ADS-B Version Number

Value	**ADS-B Version**
0	DO-242
1	DO-242A
2	DO-260B & DO-282B
3-7	Reserved for future growth.

3.2.19 Selected Altitude Type

a. The "Selected Altitude Type" subfield is a 1-bit field that is used to indicate the source of Selected Altitude data. Encoding of the "Selected Altitude Type" **shall** (242AR3.132-A) be in accordance with Table 3.2.19.

b. Whenever there is no valid MCP / FCU or FMS Selected Altitude data available, then the “Selected Altitude Type” subfield **shall** (242AR3.132-B) be set to ZERO (0).

Note: *Users of this data are cautioned that the selected altitude value transmitted by the ADS-B Transmitting Subsystem does not necessarily reflect the true intention of the airplane during certain flight modes (e.g., during certain VNAV or Approach modes), and does not necessarily correspond to the target altitude (the next altitude level at which the aircraft will level off).*

In addition, on many airplanes, the ADS-B Transmitting Subsystem does not receive selected altitude data from the FMS and will only transmit Selected Altitude data received from a Mode Control Panel / Flight Control Unit (MCP / FCU).

Table 3.2.19: Selected Altitude Type Field Values

Coding	Meaning
0	Data being used to encode the Selected Altitude data field is derived from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment.
1	Data being used to encode the Selected Altitude data field is derived from the Flight Management System (FMS).

3.2.20 MCP/FCU or FMS Selected Altitude Field

a. The “MCP / FCU Selected Altitude or FMS Selected Altitude” subfield is an 11-bit field that **shall** (242AR3.133-A) contain either the MCP / FCU Selected Altitude or the FMS Selected Altitude data in accordance with the following subparagraphs.

b. Whenever valid Selected Altitude data is available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, such data **shall** (242AR3.133-B) be used to encode the Selected Altitude data field in accordance with Table 3.2.20. Use of MCP / FCU Selected Altitude **shall** (242AR3.133-C) then be declared in the “Selected Altitude Type” subfield as specified in Table 3.2.19.

c. Whenever valid Selected Altitude data is NOT available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, but valid Selected Altitude data is available from the Flight Management System (FMS), then the FMS Selected Altitude data **shall** (242AR3.133-D) be used to encode the Selected Altitude data field in accordance with Table 3.2.20 provided in paragraph “d.” Use of FMS Selected Altitude **shall** (242AR3.133-E) then be declared in the “Selected Altitude Type” subfield as specified in Table 3.2.19.

d. Encoding of the Selected Altitude data field **shall** (242AR3.133-F) be in accordance with Table 3.2.20. Encoding of the data **shall** (242AR3.133-G) be rounded so as to preserve accuracy of the source data within ±½ LSB.

e. Whenever there is NO valid MCP / FCU or FMS Selected Altitude data available, then the “MCP / FCU Selected Altitude or FMS Selected Altitude” subfield **shall** (242AR3.133-H) be set to ZERO (0) as indicated in Table 3.2.20.

Note: *Users of this data are cautioned that the selected altitude value transmitted by the ADS-B Transmitting Subsystem does not necessarily reflect the true intention of the airplane during certain flight modes (e.g., during certain VNAV or Approach modes), and does not necessarily correspond to the target altitude (the next altitude level at which the aircraft will level off).*

In addition, on many airplanes, the ADS-B Transmitting Subsystem does not receive selected altitude data from the FMS and will only transmit Selected Altitude data received from a Mode Control Panel / Flight Control Unit (MCP / FCU).

Table 3.2.20: "MCP/FCU Selected Altitude or FMS Selected Altitude" Field Values

Coding		Meaning
(Binary)	(Decimal)	
000 0000 0000	0	**NO Data *or* INVALID Data**
000 0000 0001	1	0 feet
000 0000 0010	2	32 feet
000 0000 0011	3	64 feet
*** **** ****	***	*** **** ****
*** **** ****	***	*** **** ****
*** **** ****	***	*** **** ****
111 1111 1110	2046	65440 feet
111 1111 1111	2047	65472 feet

3.2.21 Barometric Pressure Setting (Minus 800 millibars) Field

a. The "Barometric Pressure Setting (Minus 800 millibars)" subfield is a 9-bit field that **shall** (242AR3.136-A) contain Barometric Pressure Setting data that has been adjusted by subtracting 800 millibars from the data received from the Barometric Pressure Setting source.

b. After adjustment by subtracting 800 millibars, the Barometric Pressure Setting **shall** (242AR3.136-B) be encoded in accordance with Table 3.2.21.

c. Encoding of Barometric Pressure Setting data **shall** (242AR3.136-C) be rounded so as to preserve a reporting accuracy within ±½ LSB.

d. Whenever there is NO valid Barometric Pressure Setting data available, then the "Barometric Pressure Setting (Minus 800 millibars) subfield **shall** (242AR3.136-D) be set to ZERO (0) as indicated in Table 3.2.21.

e. Whenever the Barometric Pressure Setting data is greater than 1208.4 or less than 800 millibars, then the "Barometric Pressure Setting (Minus 800 millibars)" subfield **shall** (242AR3.136-E) be set to ZERO (0).

Note: *This Barometric Pressure Setting data can be used to represent QFE or QNH/QNE, depending on local procedures. It represents the current value being used to fly the aircraft.*

Table 3.2.21: Barometric Pressure Setting (Minus 800 millibars) Field Values

Value (Binary)	Value (Decimal)	Meaning
0 0000 0000	0	**NO Data *or* INVALID Data**
0 0000 0001	1	0 millibars
0 0000 0010	2	0.8 millibars
0 0000 0011	3	1.6 millibars
* **** ****	***	*** **** ****
* **** ****	***	*** **** ****
* **** ****	***	*** **** ****
1 1111 1110	510	407.2 millibars
1 1111 1111	511	408.0 millibars

3.2.22 Selected Heading Status Field

The "Selected Heading Status" is a 1-bit field that **shall** (242AR3.137-A) be used to indicate the status of Selected Heading data that is being used to encode the Selected Heading data in accordance with Table 3.2.22.

Table 3.2.22: Selected Heading Status Field Values

Value	Meaning
0	Data being used to encode the Selected Heading data is either **NOT** Available or is **INVALID**. See Table 3.5.1.7.9.
1	Data being used to encode the Selected Heading data is Available and is **VALID**. See Table 3.5.1.7.9.

3.2.23 Selected Heading Sign Field

The "Selected Heading Sign" is a 1-bit field that **shall** (242AR3.138-A) be used to indicate the arithmetic sign of Selected Heading data that is being used to encode the Selected Heading data in accordance with Table 3.2.23.

Table 3.2.23: Selected Heading Sign Field Values

Value	Meaning
0	Data being used to encode the Selected Heading data is Positive in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is positive or Zero for all values that are less than 180 degrees). See Table 3.2.24.
1	Data being used to encode the Delected Heading data is Negative in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is ONE for all values that are greater than 180 degrees). See Table 3.2.24.

3.2.24 Selected Heading Field

a. The "Selected Heading" is an 8-bit field that **shall** (242AR3.139-A) contain Selected Heading data encoded in accordance with Table 3.2.24.

b. Encoding of Selected Heading data **shall** (242AR3.139-B) be rounded so as to preserve accuracy of the source data within ±½ LSB.

c. Whenever there is NO valid Selected Heading data available, then the Selected Heading Status, Sign, and Data subfields **shall** (242AR3.139-C) be set to ZERO (0) as indicated in Table 3.2.24.

Note: *On many airplanes, the ADS-B Transmitting Subsystem receives Selected Heading from a Mode Control Panel / Flight Control Unit (MCP / FCU). Users of this data are cautioned that the Selected Heading value transmitted by the ADS-B Transmitting Subsystem does not necessarily reflect the true intention of the airplane during certain flight modes (e.g., during LNAV mode).*

Table 3.2.24: Selected Heading Status, Sign and Data Field Values

Values for Selected Heading:			Meaning
Status	**Sign**	**Data**	
0	0	0000 0000	**NO Data *or* INVALID Data**
1	0	0000 0000	0.0 degrees
1	0	0000 0001	0.703125 degrees
1	0	0000 0010	1.406250 degrees
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
1	0	1111 1111	179.296875 degrees
1	1	0000 0000	180.0 or -180.0 degrees
1	1	0000 0001	180.703125 or -179.296875 degrees
1	1	0000 0010	181.406250 or -178.593750 degrees
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
1	1	1000 0000	270.000 or -90.0000 degrees
1	1	1000 0001	270.703125 or -89.296875 degrees
1	1	1000 0010	271.406250 or -88.593750 degrees
1	1	1111 1110	358.593750 or -1.4062500 degrees
1	1	1111 1111	359.296875 or -0.7031250 degrees

3.2.25 Status of MCP/FCU Mode Bits

The "Status of MCP / FCU Mode Bits" is a 1-bit field that **shall** (242AR3.140-A) be used to indicate whether the mode indicator bits are actively being populated (e.g., set) in accordance with Table 3.2.25.

If information is provided to the ADS-B Transmitting Subsystem to set the Mode Indicator bits to either "0" or "1," then the "Status of MCP/FCU Mode Bits" **shall**

(242AR3.140-B) be set to ONE (1). Otherwise, the "Status of MCP/FCU Mode Bits" **shall** (242AR3.140-C) be set to ZERO (0).

Table 3.2.25: Status of MCP/FCU Mode Bits Field Values

Values	Meaning
0	No Mode Information is being provided in the Mode Indicator bits
1	Mode Information is deliberately being provided in the Mode Indicator bits

3.2.26 Mode Indicator: Autopilot Engaged Field

The "Mode Indicator: Autopilot Engaged" subfield is a 1-bit field that **shall** (242AR3.142-A) be used to indicate whether the autopilot system is engaged or not.

a. The ADS-B Transmitting Subsystem **shall** (242AR3.142-B) accept information from an appropriate interface that indicates whether or not the Autopilot is engaged.

b. The ADS-B Transmitting Subsystem **shall** (242AR3.142-C) set the Mode Indicator: Autopilot Engaged field in accordance with Table 3.2.26.

Table 3.2.26: Mode Indicator: Autopilot Engaged Field Values

Values	Meaning
0	Autopilot is NOT Engaged or Unknown (e.g., not actively coupled and flying the aircraft)
1	Autopilot is Engaged (e.g., actively coupled and flying the aircraft)

3.2.27 Mode Indicator: VNAV Mode Engaged Field

The "Mode Indicator: VNAV Mode Engaged" is a 1-bit field that **shall** (242AR3.146-A) be used to indicate whether the Vertical Navigation Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** (242AR3.146-B) accept information from an appropriate interface that indicates whether or not the Vertical Navigation Mode is active.

b. The ADS-B Transmitting Subsystem **shall** (242AR3.146-C) set the Mode Indicator: VNAV Mode Engaged field in accordance with Table 3.2.27.

Table 3.2.27: "Mode Indicator: VNAV Engaged" Field Values

Values	Meaning
0	VNAV Mode is NOT Active or Unknown
1	VNAV Mode is Active

3.2.28 Mode Indicator: Altitude Hold Mode Field

The "Mode Indicator: Altitude Hold Mode" is a 1-bit field that **shall** (242AR3.147-A) be used to indicate whether the Altitude Hold Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** (242AR3.147-B) accept information from an appropriate interface that indicates whether or not the Altitude Hold Mode is active.

b. The ADS-B Transmitting Subsystem **shall** (242AR3.147-C) set the Mode Indicator: Altitude Hold Mode field in accordance with Table 3.2.28.

Table 3.2.28: "Mode Indicator: Altitude Hold Mode" Field Values

Values	Meaning
0	Altitude Hold Mode is NOT Active or Unknown
1	Altitude Hold Mode is Active

3.2.29 Mode Indicator: Approach Mode Field

The "Mode Indicator: Approach Mode" is a 1-bit field that **shall** (242AR3.148-A) be used to indicate whether the Approach Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** (242AR3.148-B) accept information from an appropriate interface that indicates whether or not the Approach Mode is active.

b. The ADS-B Transmitting Subsystem **shall** (242AR3.148-C) set the Mode Indicator: Approach Mode field in accordance with Table 3.2.29.

Table 3.2.29: "Mode Indicator: Approach Mode" Field Values

Values	Meaning
0	Approach Mode is NOT Active or Unknown
1	Approach Mode is Active

3.2.30 Mode Indicator: LNAV Mode Engaged Field

The "Mode Indicator: LNAV Mode Engaged" is a 1-bit field that **shall** (242AR3.149-A) be used to indicate whether the Lateral Navigation Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** (242AR3.149-B) accept information from an appropriate interface that indicates whether or not the Lateral Navigation Mode is active.

b. The ADS-B Transmitting Subsystem **shall** (242AR3.149-C) set the Mode Indicator: LNAV Mode Engaged field in accordance with Table 3.2.30.

Table 3.2.30: "Mode Indicator: LNAV Mode Engaged" Field Values

Values	Meaning
0	LNAV Mode is NOT Active
1	LNAV Mode is Active

3.3 System Application Requirements

3.4 Subsystem Requirements

3.4.1 Subsystem Requirements for ASSAP (Dave Elliott)

ASSAP is the surveillance and separation assurance processing component of ASA. ASSAP processes incoming data from own-ship, and other aircraft/vehicles (A/V), and derives information for display on the CDTI. Flight crew command and control inputs that affect application functions are also processed by ASSAP. In the future, ASSAP is expected to provide alerting and guidance information to the flight crew via the CDTI.

The two major functions of ASSAP are *surveillance processing* and *applications processing*. Functional requirements for ASSAP are described in §3.4.1.4.

Surveillance processing:

- Establishes tracks from ADS-B, ADS-R, and TIS-B traffic reports
- Cross-references traffic from different surveillance sources (ADS-B, ADS-R, TIS-B, and TCAS)
- Estimates track state (e.g., position, velocity), and track quality
- Deletes tracks that are beyond the maximum allowable coast time for any ASA applications

Applications processing:

- Determines the appropriateness of track information for various applications, and forwards the track data to the CDTI
- May performs alerting functions in future applications
- May derive guidance information in future applications

Each ASA transmit participant should input to ASSAP the highest quality state data that is available on-board; this information should be the same as that used for ADS-B transmission. ASSAP assesses own-ship performance and transmitted data quality as specified in Table x.y and assesses received traffic data quality as specified in Table x.y to determine if an active application can be supported.

Figure 3.4.1 summarizes ASSAP input / output interfaces to other subsystems and indicates the sections where the interface, functional, and performance requirements can be found in this document.

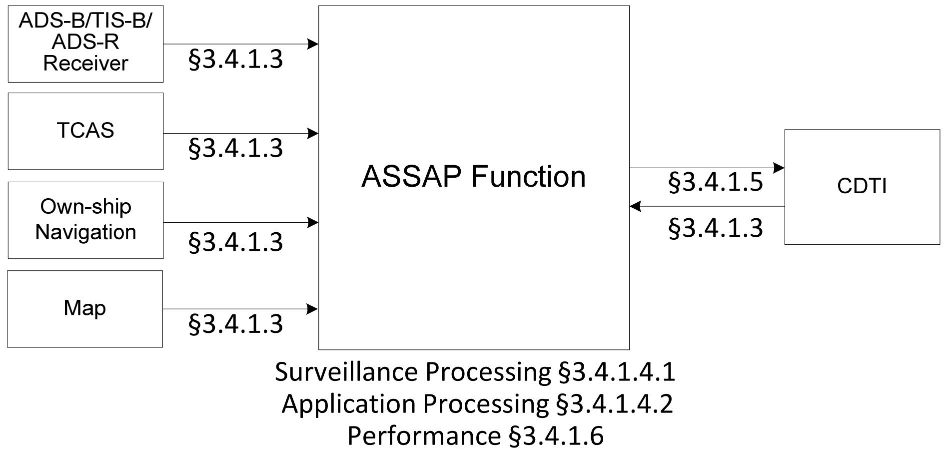


Figure 3.4.1: ASSAP Input / Output and Requirement Section Summary

3.4.1.1 Definitions

Key definitions used in this section include:

Correlation: The process of determining that a new measurement belongs to an existing track.

Estimation: The process of determining a track's state based on new measurement information

Extrapolation: The process of moving a track's state forward in time based on the track's last estimated kinematic state.

TCAS Target status: The status of the TCAS track, if applicable, from the TCAS system. The four states are: Resolution Advisory (RA), Traffic Advisory (TA), proximate, and other.

Track: A sequence of time-tagged measurements and state information relating to a particular aircraft or vehicle. The track may be a simple list file of A/V position and time data extrapolated to a common time for processing and display, or may include track estimation and Kalman filtering.

Track State: The basic kinematic variables that define the state of the aircraft or vehicle of a track, e.g., position, velocity, acceleration.

3.4.1.2 General Requirements

For systems integrated with TCAS, tracks with Resolution Advisories or Traffic Advisories shall (R3.xxx) be ordered as in the track priority assigned by TCAS.

When integrated with TCAS systems the ASSAP function shall (R3.xxx) not interfere with TCAS guidance to the flight crew.

For systems not integrated with TCAS, or for TCAS tracks without advisories, tracks shall (R3.xxx) be ordered by range within a priority level, or by an alternative criteria suited to the specific application.

3.4.1.3 Input Interface Requirements

ASSAP provides the central processing for ASA and interfaces with many other avionics subsystems. Depending on the class of aircraft, either EvAcq or AIRB defines the basic use of ASA for enhanced traffic situational awareness, and support for this application is the minimum requirement for all ASA implementations. The remaining applications (VSA, ITP, and SURF) are optional. Although VSA, ITP, and SURF applications are optional, when they are implemented, the requirements designated for these applications must be met.

ASSAP shall (R3.xxx) provide all input interfaces to support the minimum requirements for all installed applications as indicated in Table 3.4.1.3 by a dot (•).

ASSAP shall (R3.xxx) provide input interfaces for validation status information (e.g., valid bit) for each required information element input to the ASSAP from the ADS-B / ADS-R / TIS-B receiver. [need to make sure if valid bits are available for each]

Table 3.4.1.3: ASSAP Input Interface Requirements

Source	Info Category	Information Element[6]	EvAcq	AIRB	VSA	ITP	SURF
ADS-B / ADS-R / TIS-B Receiver	**Aircraft State Data**	Time Of Applicability	•	•	•	•	•
		Latitude (WGS-84)	•	•	•	•	•
		Longitude (WGS-84)	•	•	•	•	•
		Geometric Altitude[1]	•	•	•	•	•
		Air / Ground State	•	•	•	•	•
		North Velocity While Airborne	•	•	•	•	•
		East Velocity While Airborne	•	•	•	•	•
		Ground Speed While on the Surface		•	•	•	•
		Heading (true / mag) or Ground Track While on the Surface	•	•	•	•	•
		Pressure Altitude	•	•	•	•	•
		Vertical Rate	•	•	•	•	•
		Navigation Integrity Category (NIC)	•	•	•	•	•
ADS-B / ADS-R / TIS-B Receiver (continued)	**ID / Status**	ADS-B Link Version Number	•	•	•	•	•
		Participant Address	•	•	•	•	•
		Address Qualifier	•	•	•	•	•
		Call Sign / Flight ID		•	•	•	•
		A/V Length and Width Codes[8]					•
		Emitter Category		•	•	•	•
		Emergency / Priority Status[7]	•	•	•	•	•

Source	Info Category	Information Element[6]	EvAcq	AIRB	VSA	ITP	SURF
		Navigation Accuracy Category for Position (NAC_P)	●	●	●	●	●
		Navigation Accuracy Category for Velocity (NAC_V)	●	●	●	●	●
		Geometric Vertical Accuracy[1] (GVA)	●	●	●	●	●
		Surveillance Integrity Level (SIL)		●	●	●	
		System Design Assurance (SDA)	●	●	●	●	●
		True/Magnetic Heading [why not required?]					
		TIS-B / ADS-R Service Status[2]	●	●	●	●	●

Source	Info Category	Information Element[6]	EvAcq	AIRB	VSA	ITP	SURF
TCAS Target	TCAS related data[5]	Target Status	●	●	●	●	●
		Range	●	●	●	●	●
		Bearing	●	●	●	●	●
		Pressure Altitude[3]	●	●	●	●	●
		Altitude Rate	●	●	●	●	●
		Vertical Sense	●	●	●	●	●
		Mode S Address[3]	●	●	●	●	●
		Track ID	●	●	●	●	●
Navigation	**Own-ship state data**	Time of Applicability	●	●	●	●	●
		Horizontal Position	●	●	●	●	●
		Horizontal Velocity	●	●	●	●	●
		Geometric Altitude[1]	●	●	●	●	●
		Pressure Altitude	●	●	●	●	●
		Ground Speed (on surface)				●	
		Heading, True[4]	●	●	●	●	●
		Track Angle, True				●	
		A/V Length and Width Codes[8]					●
	Own-ship quality	Position Integrity Containment Region		●	●	●	
		Source Integrity Level		●	●	●	
		Horizontal Position Uncertainty	●	●	●	●	●
		Vertical Position Uncertainty[1]	●	●	●	●	●
		Velocity Uncertainty	●	●	●	●	●
	ID / Status	24 bit Address	●	●	●	●	●
		Air / Ground State	●	●	●	●	●
CDTI	**Flight Crew Inputs**	Application Selection	●	●	●	●	●
		Track ID of Selected Traffic	●	●	●	●	●
		Track ID of Designated Traffic [replaced coupled]	●	●	●	●	●
	Map Database	Airport Map Status	●	●	●	●	●

● = Required

Notes for Table 3.4.1.3:

1. *When geometric altitude is used to determine relative altitude.*
2. *For systems that don't receive information from TCAS.*
3. *This information requires a change to the standard TCAS bus outputs defined in ARINC 735A that currently does not provide the Mode S address code, nor does it necessarily output pressure altitude.*
4. *For systems that receive information from TCAS or determine relative bearing for traffic.*

5. *Required if TCAS is present in the configuration and an integrated TCAS/ASA traffic display is used. These outputs are expected to be supplied by current TCAS installation.*
6. *Each future application will add columns for minimum requirement.*
7. *When used to display the Emergency/Priority Status.*
8. *When used to display the physical extent of the aircraft.*

3.4.1.4 ASSAP Functional Requirements

ASSAP functional requirements are broken into surveillance processing requirements (§3.4.1.4.1) and applications processing requirements (§3.4.1.4.2).

3.4.1.4.1 ASSAP Surveillance Processing Requirements

ASSAP surveillance processing function receives information for traffic A/V's from various surveillance sources, correlates the data, registers the data, and outputs a track file consisting of state and other information about each A/V under track. Requirements for the surveillance sub-function follow. Note that the tracking and correlation functions make extensive use of the data that is provided in state data (Table 3.4.1.3).

ASSAP shall (R3.xxx) acquire all state data necessary to generate tracks for A/Vs and own-ship.

ASSAP may receive A/V data from different surveillance sources.

ASSAP shall (R3.xxx) perform a tracking function on each traffic A/V.

ASSAP shall (R3.xxx) extrapolate the target horizontal position (i.e., latitude and longitude), for tracks for which a position update has not been received, to a common time reference prior to providing information to the CDTI.

Note: *A linear extrapolation is expected to be used to compensate for any delays incurred leading up to the time of transmission. Extrapolation is only performed on targets determined to be airborne. The pressure altitude should not be extrapolated since the altitude rate accuracy may induce larger altitude errors than the provided in the original data.*

ASSAP shall (R3.xxx) not introduce any additional position error to that which might otherwise be introduced by a linear extrapolation using the instantaneous velocity reported for the target by other surveillance sources.

ASSAP shall (R3.xxx) maintain tracks for multiple A/Vs.

ASSAP may receive A/V data for the same A/V from different surveillance sources.

The ASSAP tracking function shall (R3.xxx) include a correlation function that associates traffic data from any surveillance sources that relate to the same A/V's track to minimize the probability of processing and displaying duplicate A/Vs.

When multiple source tracks correlate, the best quality source track shall (R3.xxx) be used.

The ASSAP tracking function shall (R3.xxx) terminate a track when the maximum coast interval (see §x.x, Table x.y) has been exceeded for all of the applications for which the track is potentially being used.

3.4.1.4.2 ASSAP Application Processing Requirements

The ASSAP will determine if the available data, quality, and track information is sufficient to support the minimum requirements display an A/V on the CDTI, and to run the installed applications.

If an A/V track is being surveilled by multiple sources, the determination of acceptability for applications should be based on the track quality as derived by ASSAP, rather than on quality of any individual source.

If the sole surveillance source of information is ADS-B, ADS-R, or TIS-B, the track quality assessment shall (R3.xxx) be based on the surveillance quality indicators (e.g. NIC, NAC_P, NAC_V, SIL) and the requirements specified in Table x.y.

ASSAP track quality (§3.3.2.1.1) shall (R3.xxx) be compared with minimum performance requirement values for each applications, as per Table x.y.

ASSAP shall (R3.xxx) assess the ability of own-ship and traffic targets to support the active applications.

ASSAP shall (R3.xxx) make ASSAP track reports available to the CDTI for all active applications.

ASSAP shall (R3.xxx) deliver track reports to the CDTI for all aircraft of sufficient quality for at least EvAcq, extrapolated to a common time.

Note: *Precise conditions under which airborne and surface traffic is to be displayed and filtered is developed in the ASA SYSTEM MOPS, the latest version of DO-317( ).*

The ASSAP track report shall (R3.xxx) indicate if the track's quality is insufficient for EvAcq.

3.4.1.5 Output Interface Requirements to CDTI

Information elements that are required as inputs to the ASSAP are also required to be available as outputs from the ASSAP to the CDTI to support the installed applications.

Some CDTIs may be implemented on existing NAV displays that already have their own-ship position data sources input directly. In that architecture, the interfaces from the ASSAP to the CDTI for those data sources are not a minimum requirement. In this case, the CDTI would have to make sure that the own-ship quality/integrity thresholds for the associated applications are met to perform each application. [this may lead to performance requirements for the CDTI section]

ASSAP shall (R3.xxx) propagate all ASSAP required input interface elements to the CDTI interfaces to support the minimum requirements for all installed applications as indicated in §3.4.1.3, Table 3.4.1.3 by a dot (•), except those that are provided directly to the CDTI from own-ship navigation sources.

Additionally, other information such as aircraft state information that is calculated or estimated is required to be output to the CDTI for the display of own-ship, traffic, or status to support the installed applications.

ASSAP shall (R3.xxx) provide all output interfaces to the CTDI to support the minimum requirements for all installed applications as indicated in Table 3.4.1.5 by a dot (•).

The ASSAP function shall (R3.xxx) provide validation status information (e.g., valid/invalid flags) for each data element provided to the CDTI.

Note: *No longer providing the data element (e.g., label or data word) may be another method of inferring valid/invalid status.*

Table 3.4.1.5: ASSAP to CDTI Information Elements

Category	Contents	EvAcq	AIRB	VSA	ITP	SURF
ID	Track ID	●	●	●	●	●
Traffic State Estimate	Horizontal Position	●	●	●	●	●
	Geometric Altitude[1]	●	●	●	●	●
	Pressure Altitude	●	●	●	●	●
	Track Angle / Heading	●	●	●	●	●
	North Velocity	●	●	●	●	●
	East Velocity	●	●	●	●	●
	Vertical Rate / Vertical Senses[2]	●	●	●	●	●
	Ground Speed		●	●	●	●
	ITP Distance				●	
	ITP Traffic Ahead / Behind				●	
Status	Traffic Air / Ground	●	●	●	●	●
	Traffic Application Capability			●	●	●
	Applications Status	●	●	●	●	●
	ASSAP Fault	●	●	●	●	●
	ITP Traffic Geometric Initialization Pass / Fail				●	
TCAS[3]	Correlation Status	●	●	●	●	●
Future	Alerts (TSAA)					
	Guidance (FIM-S)					

Notes for Table 3.4.1.5:

1. *Traffic Geometric Altitude is not needed for surface traffic.*
2. *When airborne.*
3. *The TCAS elements of the ASSAP to CDTI report are only required when the CDTI is also the TCAS Traffic Display.*

3.4.1.6 ASSAP Performance Requirements

The ASSAP function shall (R3.xxx) provide a traffic capacity of at least 60 tracks to the CDTI.

For systems integrated with TCAS, the ASSAP function shall (R3.xxx) be capable of receiving a traffic capacity of at least 30 tracks from TCAS.

ASSAP shall (R3.xxx) receive ADS B, ADS R and TIS B reports from the input interface and output correlated tracks to the CDTI within 2.0 seconds.

Note: *This requirement applies between the input (E) and output (F) of the ASSAP function per Figure 3.4.1.*

ASSAP outputs shall (R3.xxx) be sent to the CDTI at least once per second.

Total latency for the combination of ASSAP function, from interface E to interface F in Figure 3.4.1, shall (R3.xxx) be less than 2.5 seconds.

3.4.2 Subsystem Requirements for CDTI

Note: *The requirements in this section are extended in the latest version of the ASA MOPS, RTCA DO-317().*

3.4.2.1 General CDTI Requirements

The CDTI shall (R3.xxx) be presented on one or more of the following:

1. A standalone display dedicated to traffic information only.
2. A shared/multi-function display.
3. An Electronic Flight Bag (EFB).

The CDTI shall (R3.xxx) include a Traffic Display, as defined in Appendix A.

The CDTI shall (R3.xxx) satisfy all applicable requirements listed in this document in all flight environments (e.g.: expected temperatures and pressures) and operating areas (e.g. domestic and oceanic airspaces) for which it is intended.

Note: *For example, in order to satisfy this requirement fully, CDTI's intended for operation over or in the vicinity of the geographic poles would have to include an adequate provision for representing directionality of displayed traffic elements. A suitable coordinate transformation may be required and could be allocated to the ASSAP or the CDTI function.*

The operating range of display luminance and contrast shall (R3.xxx) be sufficient to ensure display readability through the full range of normally expected flight deck illumination conditions

CDTI information should be discernable, legible, and unambiguous within all flight environments (e.g., ambient illumination), even when displayed in combination with other information (e.g., electronic map).

The CDTI and associated alerting should be properly integrated with other display functions and should not interfere with critical functions or other alerting.

The CDTI should be designed so as to maximize usability, minimize flight crew workload, and reduce flight crew errors.

The CDTI display should be consistent with the requirements of current airborne display standards.

If non-traffic information is integrated with the traffic information on the display, the directional orientation, range, and own-ship position shall (R3.xxx) be consistent among the different information sets.

3.4.2.2 Latency

The maximum latency between the time the CDTI receives information from its input sources and the presentation of the information on the appropriate display(s) shall (R3.xxx) be as required by the installed applications.

3.4.2.3 Integrity

The CDTI shall (R3.xxx) display information with an integrity that meets the requirements of the installed applications.

3.4.2.4 Applications Supported

The CDTI shall (R3.xxx) support the AIRB or the EVAcq application.

Note: *Other applications are optional.*

The CDTI may support any subset of the following additional applications:

1. Basic Surface Situation Awareness (SURF).

2. Visual Separation on Approach (VSA).

3. In-Trail Procedures (ITP).

The CDTI shall (R3.xxx) not present conflicting information or guidance.

Note: *Installations supporting multiple applications or functional capabilities may require design considerations to ensure a clearly defined management of outputs from multiple applications or functional capabilities.*

3.4.2.5 Units of Measure

The CDTI should portray data using units of measure that are consistent with the design of the flight deck in which it is installed.

The CDTI shall (R3.xxx) portray all data using consistent units of measure and reference frames.

3.4.2.6 Information Exchange with ASSAP

The CDTI shall (R3.xxx) accept all information provided to it by ASSAP.

The CDTI shall (R3.xxx) provide ASSAP the information needed for the activation and deactivation of foreground applications, including those that operate on specifically designated traffic.

3.4.2.7 Traffic Symbols

The CDTI shall (R3.xxx) display one traffic symbol for each traffic report received from ASSAP that meets the traffic display criteria for the active applications subject to the maximum number of traffic symbols.

The CDTI shall (R3.xxx) be capable of displaying the minimum number of traffic symbols commensurate with the requirements of the installed applications.

3.4.2.8 TCAS Integration

On TCAS-integrated CDTI systems, the CDTI shall (R3.xxx) prioritize the display of TCAS information in such a manner as to preserve the integrity of the safety objectives for TCAS.

In order to provide more complete traffic situational awareness, the CDTI should, on aircraft also equipped with TCAS, integrate the display of TCAS information.

3.4.2.9 Multi-Function Display (MFD) Integration

Symbols, colors, and other encoded information that have a certain meaning in the traffic display function should not have a different meaning in another MFD function.

The MFD system should provide the capability to enable and disable display of traffic information (i.e., to overlay traffic or turn traffic information off).

3.4.2.10 Failure Annunciation

The CDTI shall (R3.xxx) be capable of annunciating all failure / abnormal conditions of the CDTI or its inputs that affect the proper operation of the CDTI or the ability to conduct applications, including the loss of surveillance data needed for an application.

3.4.2.11 Suitability of Traffic for Applications

If any additional applications are installed (beyond AIRB), the CDTI system shall (R3.xxx) have a means to determine the traffic's application capability with respect to each installed application.

3.4.2.12 Warnings and Alerts

The CDTI shall (R3.xxx) provide sufficiently and appropriately salient warnings and alerts for all warning and alert conditions.

The CDTI shall (R3.xxx) provide sufficient awareness as to the causes for the warnings and alerts.

Aural alerts shall (R3.xxx) be audible and distinguishable in all expected flight deck ambient noise conditions.

CDTI alerts should be consistent with, and capable of being integrated into the flight deck alerting system, giving proper priority to alerts with regard to safety of flight.

3.4.2.13 Display Configuration

The CDTI shall (R3.xxx) be configurable as necessary to support the installed applications.

The CDTI shall (R3.xxx) provide a sufficient set of controls to enable and disable all configurations, enable and disable all installed applications and to exercise all of its features.

The CDTI shall (R3.xxx) provide a sufficient set of indications to portray the CDTI's current configuration and the status of installed applications in a readily appreciable manner.

3.4.2.14 Accessibility of Controls

The CDTI shall (R3.xxx) be designed so that controls intended for use during flight cannot be operated in any position, combination or sequence that would result in a condition detrimental to the operation of the aircraft or the reliability of the equipment.

3.4.2.15 Information Displayed

The CDTI shall (R3.xxx) be capable of displaying the types of information needed for the execution of the installed applications.

Note: *Extensive, detailed requirements can be found in the latest version of the ASA MOPS, RTCA DO-317().*

3.4.2.16 Symbols

Each CDTI symbol shall (R3.xxx) be identifiable and distinguishable from other CDTI symbols.

The shape, color, dynamics, and other symbol characteristics should have the same meaning within the CDTI.

CDTI symbol modifiers should follow rules that are consistent across the symbol set.

If symbols are used to depict elements that have standard symbols (such as navigational fixes), the CDTI should use symbols that are consistent with established industry standards.

The CDTI system should be consistent with the rest of the flight deck in terms of color, standardization, automation, symbology, interaction techniques and operating philosophy.

3.4.2.17 Failure Protection

Any probable failure of the CDTI shall (R3.xxx) not degrade the normal operation of equipment or systems connected to it.

The failure of interfaced equipment or systems shall (R3.xxx) not degrade normal operation of the CDTI.

3.4.2.18 Interference Effects

The CDTI shall (R3.xxx) not be the source of harmful conducted or radiated interference nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

3.4.3 Subsystem Requirements for ADS-B

This section describes ADS-B system requirements. Specifications in this document are intended to be design independent. Assumptions and trade-off analyses used to define certain ADS-B requirements are presented in several appendices. Appendix D describes data sampling and encoding considerations, issues related to segmenting state vector information into multiple ADS-B messages, antenna implementation factors, and multipath propagation effects as they relate to the ADS-B medium and message format. Some enhancement in the aircraft-aircraft forward sector operational range may be feasible with the use of receive antenna pattern shaping; this topic is treated in Appendix E. Considerations involved in using the ADS-B System in very high integrity applications are discussed in Appendix F. ADS-B accuracy and update rate requirements are examined in Appendix O. Appendix G addresses report sample time and latency issues. Acquisition and tracking considerations are discussed in Appendix H.

3.4.3.1 ADS-B Surveillance Coverage

Air-to-air coverage requirements for illustrative operational scenarios were given in Table 2-8, and values associated with current ATS surveillance capabilities were summarized in Table 2-9(a). Transmitter and receiver requirements follow from these coverage requirements. Ideally, all airborne participants would have the same transmitter power and same receiver sensitivity. Recognizing, however, that lower equipage costs may be achieved with lower transmit power and receiver sensitivity, surveillance coverage requirements are based on minimum acceptable capability. Users interested in a certain level of operational capability can thus select an equipage class appropriate to their needs (see Table 3.1.1.3.2a).

ADS-B equipage classes summarized in Table 3.1.1.3.2a **shall** (242AR3.1) provide the air-to-air coverage specified in Table 3.4.3.1a. The stated ranges are the basis for the indicated relative effective radiated power (ERP) and the receiver sensitivity requirement for each transmit unit.

Since many users will share the same airspace, and all must be seen by ATS, all A, B, and C equipage classes must be interoperable. The ERP and minimum signal detection capabilities **shall** (242AR3.2) support the associated pair-wise minimum operational ranges listed in Table 3.4.3.1b. Broadcast only aircraft (class B0 and B1) **shall** (242AR3.3) have ERP values equivalent to those of class A0 and A1, respectively, as determined by own aircraft maximum speed, operating altitude, and corresponding coverage requirements. Ground vehicles operating on the airport surface (class B2) **shall** (242AR3.4) provide a 5 NM coverage range for class A receivers. If required due to spectrum considerations, ADS-B transmissions from ground vehicles (class B2) **shall** (242AR3.5) be automatically prohibited when those vehicles are outside the surface movement area (i.e., runways and taxiways). ERP for these vehicles may thus be as low as -12 dB relative to class A1. Fixed obstacle (class B3) broadcast coverage **shall** (242AR3.6) be sufficient to provide a 10 NM coverage range from the location of the obstacle.

Following is the rationale for the powers and ranges in Table 3.4.3.1a and Table 3.4.3.1b. Given the air-to-air ranges from Table 2-8, and repeated in Table 3.4.3.1a, an acceptable range of relative transmitter power was assumed, and appropriate receiver sensitivities were then derived. From these normalized transmitter power and receiver sensitivity values, the interoperability ranges shown in Table 3.4.3.1b were derived. An omni-directional aircraft transmit antenna is required for ATS support. While omni-directional receive antennas will generally be employed, a higher gain receive antenna may be used to increase coverage in the forward direction for extended range air-to-air applications (at the expense of reduced coverage in other directions). Appendix E discusses the impact of this directional antenna on alert time and shows that a directional aircraft receive antenna gain increase is limited to about 4 dB. When determining absolute power and sensitivity for the operational ranges given in Table 3.4.3.1a, it should be noted that the target should be acquired and under firm track at the indicated ranges. This implies that an additional margin for acquisition time is required. The ranges specified in Table 3.4.3.1a and Table 3.4.3.1b are minimum requirements; other applications may require longer ranges.

Ground receiver only subsystem (class C1) coverage examples are given in Table 2-9(a). Since en route air-ground ranges are longer than those for air-to-air, some ATS receivers must be more sensitive than airborne receivers. This need may be met with the aid of higher gain ground receive antennas. It is beyond the scope of these MASPS to specify ground receiver sensitivities (Class C).

Table 3.4.3.1a: Operational Range and Normalized Transmit/Receive Parameters by Interactive Aircraft Equipage Class

Equipage		Required Range (NM)	Transmit ERP relative to P_0 (dB)	Receive Sensitivity relative to S_0 (dB)
Class	Type			
A0	Minimum	10	>= -2.5	+3.5
A1	Basic	20	0	0
A2	Enhanced	40	+3	-3
A3	Extended	90	<=+6	-7
A3+	Extended Desired	120	<=+6	-9.5

Note: *For A3 equipment, the 90 NM range requirement applies in the forward direction. The required range aft is 40 NM. The required range 45 degrees port and starboard of the own aircraft's heading is 64 NM. The required range 90 degrees to port and starboard of own aircraft's heading is 45 NM (see Appendix E). [For A3+ equipment, the 120 NM desired range applies in the forward direction. The desired range aft is 42NM. The desired range 90 degrees to port and starboard is 85 NM.]*

Table 3.4.3.1b: Interoperability Ranges in NM for Aircraft Equipage Class Parameters Given in Table 3.4.3.1a

Rx Aircraft ➔ / Tx Aircraft	A0 Minimum (S_0+3.5dB)	A1 Basic (S_0)	A2 Enhanced (S_0-3dB)	A3 Expanded (S_0-7dB)	A3+ Expanded Desired (S_0-9.5dB)
A0: Minimum (P_0-2.5dB)	10	15	21	34	45
A1: Basic (P_0)	13	20	28	45	60
A2: Enhanced (P_0+3dB)	18	28	40	64	85
A3: Extended (P_0+6dB)	26	40	56	90	120
A3+: Extended Desired (P_0+6dB)	26	40	56	90	120

3.4.3.2 ADS-B Information Exchange Requirements by Equipage Class

Subsystems must be able to 1) broadcast at least the minimum set of data required for operation in airspace shared with others, and 2) receive and process pair-wise information required to support their intended operational capability. Each equipage class **shall** (242AR3.7) meet the required information broadcast and receiving capability at the indicated range to support the capability indicated in Table 3.4.3.2a and Table 3.4.3.2b.

The rationale for the requirements in Table 3.4.3.2a is as follows. Column 1 of Table 3.4.3.2a combines the equipage classes (which are based on user operational interests) from Table 3.1.1.3.2a with the required ranges given in Table 3.4.3.1a. Information exchange requirements by application were taken from Table 2-7 to determine the broadcast and receive data required for each equipage class (column 2 of Table 3.4.3.2a and Table 3.4.3.2b). A correlation between the equipage class and the ability of that class to support and perform that application was done next. (The determination of the information exchange ability of an equipage class to support a specific application is determined by the information transmitted by that equipage class, while the ability to perform a specific application is determined by the ability of that equipage class to receive and process the indicated information.)

Table 3.4.3.2a: Interactive Aircraft/Vehicle Equipage Type Operational Capabilities

	Domain →		**Terminal, En Route, Oceanic**								**Approach**		**Airport Surface**	
Equipage Class ↓	**Data Required to Support Operational Capability**		**R ≤10 NM** e.g., Enhanced Visual Acquisition		**R ≤20 NM**		**R ≤40 NM**		**R ≤90 NM**		**R ≤10 NM** e.g., Enhanced Visual Approach		**R ≤5 NM** e.g., Airport Surface Situation Awareness	
	Transmit	Receive	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Perform
A0 Minimum R≤10 NM	SV MS	SV MS	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes
A1 Basic R≤20 NM	SV MS	SV MS	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
A2 Enhanced R≤40 NM	SV MS TS	SV MS TS	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
A3 Extended R≤90 NM	SV MS TS	SV MS TS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

1. *SV= State Vector Report; MS = Mode Status Report; TS = Target State Report.*
2. *A transmitting ADS-B participant supports an application by broadcasting the required data that receiving ADS-B participants need for that application.*
3. *A receiving ADS-B participant performs an application by processing received messages from transmitting ADS-B participants that support that application.*
4. *Operation in airspace with high closure rates may require longer range.*
5. *Class A2 and A3 users may equip for low visibility taxi following.*
6. *Class A1 equipment may optionally support TS reports.*
7. *MS reports contain time-critical report elements that, when their values change, need to be updated at higher rates than that of the MS reports. See §3.5.4.1, §3.5.8.5, and §3.5.8.6 for details.)*

Table 3.4.3.2b: Broadcast and Receive Only Equipage Type Operational Capabilities

	Domain →		**Terminal, En Route, and Oceanic / Remote Non-Radar**								**Approach**		**Airport Surface**	
Equipage Class ↓	**Data Required to Support Operational Capability**		**R ≤ 10 NM** e.g., Enhanced Visual Acquisition		**R ≤ 20 NM**		**R ≤ 40 NM**		**R ≤ 90 NM**		**R ≤ 10 NM** e.g., Enhanced Visual Approach		**R ≤ 5 NM** e.g., Airport Surface Situation Awareness	
	Transmit	Receive	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form
B0 Aircraft R≤10 NM	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B1 Aircraft R≤20 NM	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B2 Ground Vehicle	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B3 Fixed Obstacle	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
C1 ATS En route & Terminal	No	SV MS TS	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No
C2 Approach & Surface	No	SV MS TS	No	Yes	No	Yes	No	No	No	No	No	Yes	No	Yes
C3 Flight Following	No	SV MS	No	Yes	No	No	No	No	No	No	No	No	No	No

Notes:

1. *SV= State Vector; MS = Mode Status; TS = Target State Report*
2. *A transmitting ADS-B participant supports an application by broadcasting the required data that receiving ADS-B participants need for that application.*
3. *A receiving ADS-B participant performs an application by processing received messages from transmitting ADS-B participants that support that application.*

3.4.3.3 ADS-B Data Exchange Requirements

3.4.3.3.1 Report Accuracy, Update Period and Acquisition Range

The subparagraphs below specify the report accuracy, update period, and acquisition range requirements for state vector, modes status, and specific on-condition reports. For each of these subparagraphs, report acquisition **shall** (242AR3.8) be considered accomplished when all report elements required for an operational scenario have been received by an ADS-B participant. In order to meet these requirements, the receiving participant must begin receiving messages at some range outside the minimum range for a given application. Appendix H illustrates examples of expected acquisition time for state vector, mode-status, and on-condition reports as a function of message period and probability of receipt. Appendix H also treats the necessary acquisition time for segmented state vector messages.

3.4.3.3.1.1 State Vector Report Acquisition, Update Interval and Acquisition Range

State vector (SV) report accuracy, update period and acquisition range requirements are derived from the sample scenarios of Chapter 2, and are specified in Table 3.4.3.3.1.1a. The state vector report **shall** (242AR3.9) meet the update period and 99 percentile update period requirements for each operational range listed. The rationale for these values is given in Appendix O. The formulation in Appendix O examines the loss of alert time resulting from data inaccuracies, report update interval, and probability of reception. The scope of the analysis was not sufficient to guarantee that the specific operations considered will be supported. Several range values are specified in the table because the alert time requirements are more demanding for short range than they are for surveillance of targets at longer ranges. The first value is based on minimum range requirements. Beyond this range, update period and/or receive probability may be relaxed for each sample scenario, as given by the other values.

For each of the scenarios included in Table 3.4.3.3.1.1a, the state vectors from at least 95% of the observable user population (radio line-of-sight) supporting that application **shall** (242AR3.10) be acquired and achieve the time and probability update requirements specified for the operational ranges. The state vector report is constantly changing and is important to all applications, including the safety critical ones. Algorithms designed to use the state vector reports will assume that the information provided is correct. (Some applications may even require that the information is validated before using it.)

Note: *For the remainder of the user population that has not been acquired at the specified acquisition range, it is expected that those ADS-B participants will be acquired at the minimum ranges needed for safety applications. It is anticipated that certain of these safety applications that are applicable in en route and potentially certain terminal airspace, may require that 99% of the airborne ADS-B equipped target aircraft in the surrounding airspace are acquired at least 2 minutes in advance of a predicted time for closest point of approach. This assumes that the target aircraft will have been transmitting ADS-B for some minutes prior to the needed acquisition time and are within line-on-sight of the receiving aircraft.*

Required ranges for acquisition **shall** (242AR3.11) be as specified in Table 3.4.3.3.1.1a: (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3).

Table 3.4.3.3.1.1a shows accuracy values in two ways: one describing the ADS-B report information available to applications, and the other presenting the error budget component allocated to ADS-B degradation of this information. The ADS-B system **shall** (242AR3.12) satisfy the error budget requirements specified in the table in order to assure satisfaction of ADS-B report accuracies. Degradation is defined here to mean additional errors imposed by the ADS-B system on position and velocity measurements above the inherent navigation source errors. The errors referred to in this section are specifically due to ADS-B quantization of state vector information, and other effects such as tracker lag. ADS-B timing and latency errors are treated as a separate subject under heading §3.4.3.3.2. The maximum errors specified in Table 3.4.3.3.1.1a are limited to contributions from the following two error sources:

- Quantization errors. The relationship between the quantization error and the number of bits required in the ADS-B message are described in Appendix D. This discussion also treats the effect of data sampling time uncertainties on report accuracy.
- Errors due to a tracker. The ADS-B system design may include a smoothing filter or tracker as described in Appendix D. If a smoothing filter or tracker is used in the ADS-B design, the quality of the reports **shall** (242AR3.13) be sufficient to provide equivalent track accuracy implied in Table 3.4.3.3.1.1a over the period between reports, under target centripetal accelerations of up to 0.5g with aircraft velocities of up to 600 knots. Tracker lag may be considered to be a latency (§3.4.3.3.2).

Table 3.4.3.3.1.1a: SV Accuracy, Update Interval and Acquisition Range Requirements

Operational Domain →	**Terminal, En Route, and Oceanic / Remote Non-Radar ↓**				**Approach ↓**	**Airport Surface ↓** (Note 4)
Applicable Range →	**R ≤ 10 NM**	**10 NM < R ≤ 20 NM**	**20 NM < R ≤ 40 NM**	**40 NM < R ≤ 90 NM**	**R ≤ 10 NM**	**(R ≤ 5 NM)**
Equipage Class →	**A0-A3 B0, B1, B3**	**A1-A3 B0, B1, B3**	**A2-A3**	**A3**	**A1-A3**	**A0-A3 B0, B1, B3**
Example Applications →	Airborne Conflict Management (ACM) Enhanced Visual Acquisition	Airborne Conflict Management (ACM) Standard Range	Long Range Applications	Extended Range Applications	AILS, Paired Approach	Surface Situational Awareness
Required 95th percentile SV Acquisition Range	10 NM	20 NM	40 NM (Note 12) (50 NM desired)	90 NM (Notes 3, 10) (120 NM desired)	10 NM	5 NM
Required SV Nominal Update Interval (95th percentile) (Note 5)	≤ 3 s (3 NM) ≤ 5 s (10 NM) (Note 11)	≤ 5 s (10 NM) (1 s desired, Note 2) ≤ 7 s (20 NM)	≤ 7 s (20 NM) ≤ 12 s (40 NM)	≤ 12 s	≤ 1.5 s (1000 ft runway separation) ≤ 3 s (1s desired) (2500 ft runway separation)	≤ 1.5 s
Required 99th Percentile SV Received Update Period (Coast Interval)	≤ 6s (3 NM) ≤ 10 s (10 NM) (Note 11)	≤ 10 s (10 NM) ≤ 14 s (20 NM)	≤ 14 s (20 NM) ≤ 24 s (40 NM)	≤ 24 s	≤ 3s (1000 ft runway separation) (1s desired, Note 2) ≤ 7s (2500 ft runway separation)	≤ 3 s
Example Permitted Total SV Errors Required To Support Application (1 sigma, 1D)	σ_{hp} = 200 m σ_{hv} = n/a σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 20 m / 50 m (Note 1) σ_{hv} = 0.6/ 0.75 m/s (Note 1) σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 20 / 50 m (Note 1) σ_{hv} = 0.3/ 0.75 m/s (Note 1) σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 200 m σ_{hv} = 5 m/s σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 20 m σ_{hv} = 0.3 m/s σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 2.5 m (Note 6) σ_{hv} = 0.3 m/sσ σ_{vp} = n/a σ_{vv} = n/a
Max. error due to ADS-B (1 sigma, 1D) (Note 7)	σ_{hp} = 20 m σ_{hv} = 0.25 m/s (Note 8) σ_{vp} = 30 ft σ_{vv} = 1 fps					σ_{hp} = 2.5 m (Note 6) σ_{hv} = 0.25 m/s σ_{vp} = n/a σ_{vv} = n/a

Definitions for Table 3.4.3.3.1.1a:

σ_{hp}: standard deviation of horizontal position error.

σ_{hv}: standard deviation of horizontal velocity error.

σ_{vp}: standard deviation of vertical position error.

σ_{vv}: standard deviation of vertical velocity error.

n/a: not applicable.

Notes for Table 3.4.3.3.1.1a:

1. *The lower number represents the desired accuracy for best operational performance and maximum advantage of ADS-B. The higher number, representative of GPS standard positioning service, represents an acceptable level of ADS-B performance, when combined with barometric altimeter.*

2. *The analysis in Appendix O indicates that a 3-second report received update period for the full state vector will yield improvements in both safety and alert rate relative to TCAS II, which does not measure velocity. Further improvement in these measures can be achieved by providing a one-second report received update rate. Further definition of ADS-B based separation and conflict avoidance system(s) may result in refinements to the values in the Table.*

3. *The 90 NM range requirement applies in the forward direction (that is, the direction of the own aircraft's heading). The required range aft is 40 NM. The required range 45 degrees to port and starboard of the own aircraft's heading is 64 NM (see Appendix E). The required range 90 degrees to port and starboard of the own aircraft's heading is 45 NM. [The 120 NM desired range applies in the forward direction. The desired range aft is 42 NM. The desired range 45 degrees to port and starboard of the own-aircraft's heading is 85 NM.]*

4. *Requirements apply to both aircraft and vehicles.*

5. *Supporting analyses for update period and update probability are provided in Appendices H and O.*

6. *The position error requirement for aircraft on the airport surface is stated with respect to the aircraft's ADS-B position reference point (§2.1.2.5).*

7. *This row represents the allowable contribution to total state vector error from ADS-B.*

8. *The requirements on horizontal velocity error (*σ_{hv}*,) apply to aircraft speeds of up to 600 knots. Accuracies required for velocities above 600 knots are TBD.*

9. *Specific system parameter requirements in Table 3.4.3.3.1.1a can be waived provided that the system designer shows that the application design goals stated in Appendix O or equivalent system level performance can be achieved.*

10. *Air-to-air ranges extending to 90 NM were originally intended to support the application of Flight Path Deconfliction Planning, Cooperative Separation in Oceanic/Low Density En Route Airspace, as described in §2.2.2.6. It is noted in Section 2.2.2.6, in connection with Table 2-8, that the operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.*

11. *Requirements for applications at ranges less than 10 NM are under development. The 3-second update period is required for aircraft pairs with horizontal separation less than [1.1 NM] and vertical separation less than [1000 feet]. The 3 second update period is also required to support ACM for aircraft pairs within 3 NM lateral separation and 6000 feet vertical separation that are converging at a rate of greater than 500 feet per minute vertically or greater than 6000 feet per minute horizontally. The update rate can be reduced to once per 5 seconds (95%) for aircraft pairs that are not within these geometrical constraints and for applications other than ACM. Requirements for ACM are under development. Requirements for future applications may differ from those stated here.*

12. *These values are based on the scenario in §2.2.2.5.2 which assumes a reduced horizontal separation standard of 2 NM. Separation standards of more than 2 NM may require longer acquisition ranges to provide adequate alerting times.*

3.4.3.3.1.2 Mode Status Acquisition, Update Interval and Acquisition Range

Mode Status (MS) acquisition range requirements are derived from the sample scenarios of Chapter 2, and are specified in Table 3.4.3.3.1.2a. For each of the equipage classes included in Table 3.4.3.3.1.2a, the Mode Status reports from at least 95% of the observable (radio line of sight) population **shall** (242AR3.14-A) be acquired at the range specified in the "Required 95th Percentile Acquisition Range" row of Table 3.4.3.3.1.2a (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3). Likewise, for each of the equipage classes included in Table 3.4.3.3.1.2a, the Mode Status reports from at least 99% of the observable (radio line of sight) population **shall** (242AR3.14-B) be acquired at the reduced range specified in the "Required 99th Percentile Acquisition Range" row of Table 3.4.3.3.1.2a.

Note: *As requirements mature for applications that require MS reports, the required probably of acquisition at specified ranges may change. It is possible that these requirements may be more stringent in later versions of these MASPS.*

Mode Status (MS) update intervals are not specified directly. Only the minimum acquisition ranges are specified. From these minimum ranges, combinations of update intervals and receive probabilities for MS can be derived for media specific ADS-B implementations.

Table 3.4.3.3.1.2a: MS Accuracy and Acquisition Range Requirements

Operational Domain →	Terminal, En Route, and Oceanic / Remote Non-Radar ↓				Approach ↓	Airport Surface ↓ (Note 1)
Applicable Range →	**R ≤ 10 NM**	**10 NM < R ≤ 20 NM**	**20 NM < R ≤ 40 NM**	**40 NM < R ≤ 90 NM**	**R ≤ 10 NM**	**(R ≤ 5 NM)**
Equipage Class →	**A0-A3 B0, B1, B3**	**A1-A3 B0, B1, B3**	**A2-A3**	**A3**	**A1-A3**	**A0-A3 B0, B1, B3**
Example Applications →	Airborne Conflict Management (ACM)		Long Range Applications	Extended Range Applications	AILS, Paired Approach	Surface Situational Awareness
	Enhanced Visual Acquisition	Standard Range				
Required 95th percentile MS Acquisition Range	10 NM	20 NM	40 NM (Note 6) (50 NM desired)	90 NM (Notes 2, 3) (120 NM desired)	10 NM	5 NM
Required 99th percentile MS Acquisition Range (Notes 4, 5)	8 NM	17 NM	34 NM (Note 6)	n/a	n/a	n/a

➔ WHY IS THIS NOT STATED IN TERMS OF SECONDS???? ➔

Definitions for Table 3.4.3.3.1.2a:

n/a: not applicable.

Notes for Table 3.4.3.3.1.2a:

1. *Requirements apply to both aircraft and vehicles. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.*

2. *The 90 NM range requirement applies in the forward direction (that is, the direction of the own aircraft's heading). The required range aft is 40 NM. The required range 45 degrees to port and starboard of the own aircraft's heading is 64 NM (see Appendix E). The required range 90 degrees to port and starboard of the own aircraft's heading is 45 NM. [The 120 NM desired range applies in the forward direction. The desired range aft is 42 NM. The desired range 45 degrees to port and starboard of the own-aircraft's heading is 85 NM.]*

3. *Air-to-air ranges extending to 90 NM are intended to support the application of Cooperative Separation in Oceanic/Low Density En Route Airspace, as described in §2.2.2.6. It is noted in Section 2.2.2.6, in connection with Table 2-8, that the operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary.*

4. *These requirements are to be met for essential level applications. As these applications are developed, these requirements may be further refined in terms of more stringent ranges and acquisition probability.*

5. *It is assumed that the population for which these acquisition requirements is to be met are aircraft that have been operating and broadcasting MS reports within radio line of sight at ranges significantly greater than the acquisition range.*

6. *These values are based on the scenario in §2.2.2.5.2 which assumes a reduced horizontal separation standard of 2 NM. Separation standards of more than 2 NM may require longer acquisition ranges to provide adequate alerting times.*

3.4.3.3.1.3 Target State Report Acquisition, Update Interval and Acquisition Range

➔ **Editor's Note:** We need to scrub this section and probably remove the performance derivation.

Target State (TS) report update periods and acquisition range requirements are summarized in Table 3.4.3.3.1.3a. These requirements are specified in terms of acquisition range and required update interval to be achieved by at least 95% of the observable user population (radio line of sight) supporting TS within the specified acquisition range or time interval.

Note: *For the remainder of the user population that has not been acquired at the specified acquisition range, it is expected that those ADS-B participants will be acquired at the minimum ranges needed for safety applications. It is anticipated that certain of these safety applications that are applicable in en route and potentially certain terminal airspace, may require that 99% of the airborne ADS-B equipped target aircraft in the surrounding airspace are acquired at least 2 minutes in advance of a predicted time for the when loss of required separation will occur. This assumes that the target aircraft will have been transmitting ADS-B for some minutes prior to the needed acquisition time and are within line-on-sight of the receiving aircraft.*

The requirements for the minimum update periods for TS reports are functions of range. Tighter requirements (smaller required update periods) are desired on these reports for a time period equal to two update periods immediately following any major change in the information previously broadcast as specified in §3.4.7.2 and §3.4.8.2. These requirements are specified in terms of acquisition range and required update interval to achieve a 95% confidence of receiving a TS within the specified acquisition range or time interval.

The nominal TS report update period for A2 equipage at ranges within 40 NM and for A3 equipage at ranges in the forward direction within 90 NM **shall** (242AR3.21) be T_U, such that

$$T_U = \max\left(12\,s, \quad 0.45\frac{s}{NM}\cdot R\right)$$

where R is the range to the broadcasting aircraft and T_U is rounded to the nearest whole number of seconds. If implemented, these requirements are applicable to TS report update rates for A1 equipment for ranges of 20 NM or less.

Notes:

1. *It is desired that requirement 242AR3.21 should be met by A2 equipment at ranges up to and including 50 NM and by A3 equipment up to and including 120 NM.*

2. *Future versions of these MASPS might include higher update rates when there is a major change in the intent information being broadcast. Rates in the order of* $T_U = \max\left(12\,s,\quad 0.22\frac{s}{NM}\cdot R\right)$ *are under investigation for future applications and should be considered desired design goals.*

Table 3.4.3.3.1.3a shows the values for the required minimum update periods as calculated by the above formulae at the ranges indicated as required and desired for A2 and A3 aircraft.

If the TS report is implemented in ADS-B systems of equipage class A1, such systems **shall** (242AR3.22) have a 20 NM acquisition range for TS Report. For equipage class A2, the acquisition range for TS reports **shall** (242AR3.23) be 40 NM, with 50 NM desired. For equipage class A3, the acquisition range for TC reports in the forward direction **shall** (242AR3.24) be 90 NM, with 120 NM desired. The range requirements in all other directions for A3 equipment **shall** (242AR3.25) be consistent with those stated in Note 3 of Table 3.4.3.3.1.1a.

Table 3.4.3.3.1.1a: Summary of TS Report Acquisition Range and Update Interval Requirements

Operational Domain →	**Terminal, En Route, and Oceanic / Remote Non-Radar ↓**				
Applicable Range →	**R ≤ 20 NM**	**R <= 40 NM**	**R <= 50 NM**	**R <= 90 NM**	**R <= 120 NM**
Equipage Class →	A1 optional A2 required	A2 required	A2 desired, A3 required	A3 required	A3 desired
TS Report Acquisition Range	20 NM (A1 optional)	40 NM (A2, A3 required)	50 NM (A2, A3 desired)	not required	not required
TS Report state change update period (note 3)	12 s	12 s desired (See note 2 above.)	12 s desired	not required	not required
TS Report nominal update period	12 s	18 s	23 s desired	not required	not required

➔ WE NEED TO DEFINE THE 95% OR 99% REQUIREMENTS HERE ➔

Notes for Table 3.4.3.3.1.1a:

1. *Table 3.4.3.3.1.1a is based on an air-air en route scenario between two aircraft closing at 1200 knots, which is considered a worst-case scenario for deriving range requirements for ADS-B conflict alerting. See Appendix O for scenario details.*

2. *The ranges shown in Table 3.4.3.3.1.1a are meant to represent operational airspace with aircraft densities equivalent to those defined in Table 2-8.*

3. *The trigger conditions for the desired broadcasting of TS reports at the "state change" update rate are specified in §3.4.7.2.*

3.4.3.3.2 State Vector Report Latency and Report Time Error Requirements

➔ **Editor's Note:** We need to review the re-purpose of text in the MOPS as a replacement for this analysis. Use only the common high level requirements from Appendices from DO-260B and DO-282B.

When ADS-B makes a SV report of aircraft/vehicle position and velocity to an application, this will occur at a time later than when the measurements were made. There are several sources of such delay or *latency* (defined below). Before the information reaches the ADS-B system, delays occur both in the navigation receiving system (a GNSS receiver for example) and in the data bus system that may be used to convey the information to ADS-B. Within the ADS-B system, delay can be caused by the computation time for preparing the transmission and for assembling the report. After the report leaves ADS-B, additional delays may occur.

Delays that occur prior to the information reaching ADS-B are not the subject of requirements in these MASPS. Delays occurring after the information is reported by ADS-B are likewise not considered in these MASPS.

Compensation may be applied to the reported information in order to adjust, at least approximately, for the changes in A/V state between the time of measurement and the time of the report. Compensation may be applied to position information while not being applied to velocity information. As a result, the position and velocity parts of a state vector report may apply to two different times. This produces a velocity lag error if the reporting aircraft is accelerating.

3.4.3.3.2.1 Latency Definitions

The following definitions are used in the requirements concerning latency.

- Latency: While the position and velocity of an A/V may be constantly changing, a particular measurement applies to the true state at a certain time, called the "time of measurement." Latency, for cases in which compensation is not used, is the time difference between the time of measurement and the time it is reported at the ADS-B output (the latter minus the former). For cases in which compensation is used, the time of applicability of position and velocity will differ in general, and the report contains the time of applicability of position. Position latency is the difference, if any, between the time of applicability and the time the information is reported at the ADS-B output (the latter minus the former). Velocity latency is defined in the same way, but will in general, have a different value. Latency includes the total time differences, whether it is constant with time or variable, and whether it is known by the application or uncertain.
- ADS-B Latency: This is the component of latency attributable to the ADS-B system. Typically the source will make measurements periodically, and will provide the information to ADS-B once per period. If the ADS-B timing structure is independent of the source timing, as is typical, there will be a waiting time (a contribution to latency) between when the information is provided by the source and when it is transmitted. The average value of this asynchronization wait is one half the source period. This contribution to latency is attributed to ADS-B. If a data bus is used to convey information from the source to ADS-B, it may contribute latency, but that contribution is not attributed to ADS-B latency. Similarly, a data bus may be used to convey information from ADS-B to an application, and any resulting latency is not attributed to ADS-B.

- Report time error: Each ADS-B report includes timing information. Report time error is defined as the reported time minus the true time of the measurement. The time in the report is taken to be the time of the position measurement. If the times of applicability of the position and velocity are different and are not reported separately, then the application can use the single reported time for both, with a resulting report time error.
- Differential Delay: The difference in adjacent aircraft report times used by a third party surveillance application. Differential delay, relative to the output of a separate surveillance system e.g., radar, will also influence position registration error when the two outputs are combined.

3.4.3.3.2.2 State Vector Latency Requirements

If NAC_P is less than 10 and NIC is less than 9, then ADS-B latency of the reported information **shall** (242AR3.26) be less than 1.2 s with 95 percent confidence. If either $NAC_P \geq 10$ or NIC ≥ 9, then ADS-B latency **shall** (242AR3.27) be less than 0.4 s with 95% confidence. The standard deviation of the report time error **shall** (242AR3.28) be less than 0.5 s (1 sigma). The mean report time error for position **shall** (242AR3.29) not exceed 0.5 s. The mean report time error for velocity **shall** (242AR3.30) not exceed 1.5 s. Differential delay errors should be considered and, if necessary, compensated for by the using application. ADS-B is not required to compensate for differential delays; however, all necessary information to perform such compensation is included in the ADS-B state vector report. Appendices G, J, and K provide a more detailed discussion of the different sources of latency, and provide the rationale for these numerical requirements.

3.4.3.4 ADS-B Network Capacity (Stan Jones)

(Stan Jones)

3.4.3.5 ADS-B Medium (Stan Jones)

(Stan Jones)

3.4.3.6 ADS-B System Quality of Service (Dean Miller)

(Dean Miller)

3.4.4 Subsystem Requirements for TIS-B and ADS-R (Mike Garcia)

(Mike Garcia)

3.5 Messages and Reports

The ADS-B/TIS-B and ADS-R Receive Subsystem receives ADS-B, TIS-B and ADS-R Messages, processes them, and converts them into ADS-B/TIS-B/ADS-R reports for ASSAP.

3.5.1 ADS-B Messages and Reports

This section provides requirements and definition of ADS-B reports and the relationship between these reports and the received messages. The ADS-B output report definitions establish the standard contents and conditions for outputting data qualified for user applications. Exchange of broadcast messages and report assembly considerations are discussed in §3.5.1.2. Report data elements are specified in §3.5.1.3 to §3.5.1.8 and standardized according to content, nomenclature, parameter type, applicable coordinate system, logical content, and operational conditions. Reports required for each Equipment Class and supporting message contents are defined in §3.4.3.2. Report contents and message requirements are based on the information requirements summarized in Table 2-6. These definitions provide the basis for:

- Independence between applications and broadcast link technologies
- Interoperability of applications utilizing different ADS-B technologies.

Specific digital formats are not defined since interface requirements will determine those details. Such interfaces may be internal processor buses or inter-system buses such as those described in ARINC, IEEE, and military standards. Additional information requirements may develop in the future and result in expansion to the report definitions specified in this document. ADS-B system designs should be sufficiently flexible to accommodate such future expansion.

3.5.1.1 Report Assembly Design Considerations

Four report types are defined as ADS-B outputs to applications. They provide flexibility in meeting delivery and performance requirements for the information needed to support the operations identified in Section 2. Report types are:

- Surveillance State Vector Report (SV, §3.5.1.3);
- Mode Status Report (MS, §3.5.1.4);
- Various On-Condition Reports (OC, §3.5.1.5) – a category that includes the following report types:
  - Air Referenced Velocity Report (ARV, §3.5.1.6),
  - Target State Report (TS, §3.5.1.7), and
  - Other On-Condition Reports, which may possibly be defined in future versions of this MASPS.

All interactive participants must receive messages and assemble reports specified for the respective equipage class (Table 3.4.3.2a). All transmitting participants must output at least the minimum data for the SV and MS reports. The minimum requirements for exchanged information and report contents applicable for equipage classes are provided in §3.4.3.2.

3.5.1.2 ADS-B Message Exchange Technology Considerations in Report Assembly

ADS-B participants can vary both in the information exchanged and in the applications supported. ADS-B reports are assembled from received ADS-B messages. Message formats are defined in MOPS or equivalent specifications for each link technology chosen for ADS-B implementation. Reports are independent of the particular message format and network protocol. In some ADS-B broadcast exchange technologies the information may be conveyed as a single message, while others may utilize multiple messages which require assembly in the receiving subsystem to generate the ADS-B report. The report assembly function must be performed by the ADS-B subsystem prior to disseminating the report to the application.

Broadcast technologies vary in broadcast rate and probability of message reception. The receiving subsystem, therefore, must process messages compatibly with the message delivery performance to satisfy required performance as observed in the ADS-B report outputs. Also, data compression techniques may be used to reduce the number of transmitted bits in message exchange designs.

The messages **shall** (242AR3.40) be correlated, collated, uncompressed, re-partitioned, or otherwise manipulated as necessary to form the output reports specifically defined in §3.5.1.3 to §3.5.1.8 below. The message and report assembly processing capability of the receiving subsystem **shall** (242AR3.41) support the total population of the participants within detection range provided by the specific data link technology.

Receiving subsystem designs must provide reports based on all decodable messages received, i.e., for each participant the report **shall** (242AR3.42) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is received from that participant with the exception that no type of report is required to be issued at a rate of greater than once per second. The Report Assembler function converts the received messages into the reports appropriate to the information conveyed from the transmitting participant. The applicable reports **shall** (242AR3.43) be made available to the applications on a continual basis in accordance with the local system interface requirements.

Each ADS-B report contains an address, for the purpose of enabling the receiver to associate the receptions into a single track. If the ADS-B design uses the ICAO 24-bit address, then there **shall** (242AR3.44) be agreement between the address currently being used by the Mode S transponder and the reported ADS-B address, for aircraft with both transponder and ADS-B.

3.5.1.3 ADS-B State Vector Report

Table 3.5.1.3 lists the report elements that comprise the State Vector (SV) report. The SV report contains information about an aircraft or vehicle's current kinematic state. Measures of the State Vector quality are contained in the NIC element of the SV report and in the NAC_P, NAC_V, NIC_{BARO} and SIL elements of the Mode Status Report (§3.5.1.4).

Table 3.5.1.3: State Vector Report Definition

	SV Elem. #	Contents	[Resolution or # of bits]	Required from airborne participants	Required from surface participants	Reference Section	Notes
ID	1	Participant Address	[24 bits]	•	•	3.3.2.2.1	
	2	Address Qualifier	[1 bit]	•	•	3.3.2.2.2	1
TOA	3	Time Of Applicability	[0.2 s]	•	•	3.5.1.3.3	
Geometric Position	4a	Latitude (WGS-84)		•	•	3.5.1.3.4	2, 3
	4b	Longitude (WGS-84)		•	•		
	4c	Horizontal Position Valid	[1 bit]	•	•	3.5.1.3.5	
	5a	Geometric Altitude		•		3.5.1.3.6	3, 4
	5b	Geometric Altitude Valid	[1 bit]	•		3.5.1.3.7	
Horizontal Velocity	6a	North Velocity while airborne		•		3.5.1.3.8	3
	6b	East Velocity while airborne		•			3
	6c	Airborne Horizontal Velocity Valid	[1 bit]	•		3.5.1.3.9	
	7a	Ground Speed while on the surface	[1 knot]		•	3.5.1.3.10	
	7b	Surface Ground Speed Valid	[1 bit]		•	3.5.1.3.11	
Heading	8a	Heading while on the Surface	[6° or better (6 bits)]		•	3.5.1.3.12	
	8b	Heading Valid	[1 bit]		•	3.5.1.3.13	
Baro Altitude	9a	Pressure Altitude		•		3.5.1.3.14	3, 4
	9b	Pressure Altitude Valid	[1 bit]	•		3.5.1.3.15	
Vertical Rate	10a	Vertical Rate (Baro/Geo)		•		3.5.1.3.16	3
	10b	Vertical Rate Valid	[1 bit]	•		3.5.1.3.17	
NIC	11	Navigation Integrity Category	[4 bits]	•	•	3.5.1.3.18	
Report Mode	12	SV Report Mode	[2 bits]			3.5.1.3.19	

Notes for Table 3.5.1.3:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links.*
2. *A horizontal position resolution finer than 20 m will be required if the NAC_P element of the MS report (§3.5.1.4) is 9 or greater (§3.3.11).*
3. *Resolution requirements of these elements must be sufficient to meet the error requirements specified in Table 3.4.3.3.1.1a.*
4. *Future revisions of this MASPS may not require that both geometric and pressure altitudes – if available – to be broadcast at the SV rate. Conditions will need to be specified as to when each altitude must be the "primary" altitude being sent at the SV rate.*

3.5.1.3.1 Air/Ground State

A transmitting ADS-B participant's air/ground state is an internal state in the transmitting ADS-B subsystem that affects which SV report elements are to be broadcast, but which is not required to be broadcast in ADS-B messages from that participant.

Notes:

1. *It is possible that a future edition of this MASPS would require a participant's air/ground state to be broadcast. This would occur if an operational concept for a user application that needs air/ground state were to be included in a future version of this MASPS.*

2. *A transmitting ADS-B participant's air/ground state also affects whether the aircraft size (length and width) codes in the MS report are to be broadcast (see §3.5.1.4.6).*

A transmitting participant's air/ground state has the following possible values:

- "Known to be airborne,"
- "Known to be on the surface," and
- "Uncertain whether airborne or on the surface."

3.5.1.3.1.1 Determination of Air/Ground State

A transmitting ADS-B participant applies the following tests to determine its air/ground state:

1. If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is one of the following, then it **shall** (242AR3.45) set its air/ground state to "known to be airborne:"

   a. Light Aircraft

   b. Glider or Sailplane

   c. Lighter Than Air

   d. Unmanned Aerial Vehicle

   e. Ultralight, Hang Glider, or Paraglider

   f. Parachutist or Skydiver

   g. Point Obstacle

   h. Cluster Obstacle

   i. Line Obstacle

   Note 1: *Because it is important for fixed ground or tethered obstacles to report altitude, Point Obstacles, Cluster Obstacles, and Line obstacles always report the "Airborne" state.*

2. If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that

participant's emitter category is one of the following, then that participant **shall** (242AR3.46) set its air/ground state to "known to be on the surface:"

a. Surface Vehicle – Emergency

b. Surface Vehicle – Service

3. If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is "rotorcraft," then that participant **shall** (242AR3.47) set its air/ground state to "uncertain whether airborne or on the surface."

Note 2: *Because of the unique operating capability of rotorcraft (i.e., hover, etc.) an operational rotorcraft always reports the "uncertain" air/ground state, unless the "surface" state is specifically declared. This causes the rotorcraft to transmit those SV elements that are required from airborne ADS-B participants.*

4. If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and its ADS-B emitter category is not one of those listed under tests 1, 2, and 3 above, then that participant's ground speed (GS), airspeed (AS) and radio height (RH) **shall** (242AR3.48-A) be examined, provided that some or all of those three parameters are available to the transmitting ADS-B subsystem. If GS < 100 knots, or AS < 100 knots, or RH < 50 feet, then the transmitting ADS-B participant **shall** (242AR3.48-B) set its Air/Ground state to "known to be on the surface."

5. If a transmitting ADS-B participant is equipped with a means, such as a weight-on-wheels switch, to determine automatically whether it is airborne or on the surface, and that automatic means indicates that the participant is airborne, then that participant **shall** (242AR3.49) set its air/ground state to "known to be airborne."

6. If a transmitting ADS-B participant is equipped with a means, such as a weight-on-wheels switch, to determine automatically whether it is airborne or on the surface, and that automatic means indicates that the participant is on the surface, then the following additional tests **shall** (242AR3.50) be performed to validate the "on-the-surface" condition:

   a. If the participant's ADS-B emitter category is any of the following:

      - "Small Aircraft" or
      - "Medium Aircraft" or
      - "High-Wake-Vortex Large Aircraft" or
      - "Heavy Aircraft" or
      - "Highly Maneuverable Aircraft" or
      - "Space or Trans-atmospheric Vehicle"

      AND one or more of the following parameters is available to the transmitting ADS-B system:

- Ground Speed (GS) or
- Airspeed (AS) or
- Radio height from radio altimeter (RH)

AND any of the following conditions is true:

- GS > 100 knots or
- AS > 100 knots or
- RH > 100 50 ft,

THEN, the participant **shall** (242AR3.51-A) set its Air/Ground state to "known to be airborne."

b. Otherwise, the participant **shall** (242AR3.51-B) set its Air/Ground state to "known to be on the surface."

3.5.1.3.1.2 Effect of Air/Ground State

The set of SV elements to be broadcast by ADS-B participants is determined by those participants' air/ground state as follows:

a. ADS-B participants that are known to be on the surface **shall** (242AR3.52) transmit those State Vector report elements that are indicated with bullets ("•") in the "required from surface participants" column of Table 3.5.1.3.

b. ADS-B participants that are known to be airborne **shall** (242AR3.53) transmit those SV report elements that are indicated by bullets ("•") in the "required from airborne participants" column of Table 3.5.1.3.

c. ADS-B participants for which the air/ground state is uncertain **shall** (242AR3.54) transmit those SV report elements that are indicated by bullets in the "required from airborne participants" column. It is recommended that such participants should also transmit those SV elements that are indicated with bullets in the "required from surface participants" column.

3.5.1.3.2 SV Report Update Requirements

Required SV report update rates, described by operating range, are given in Table 3.4.3.3.1.1a (§3.4.3.3.1.1).

a. A receiving ADS-B subsystem **shall** (242AR3.55) update the SV report that it provides to user applications about a transmitting ADS-B participant whenever it receives messages from that participant providing updated information about any of the SV report elements with the exception that SV reports are not required to be issued at a rate of greater than once per second.

b. For ADS-B systems that use segmented messages for SV data, time-critical SV report elements that are not updated in the current received message **shall** (242AR3.56) be estimated whenever the SV report is updated. The time-critical SV elements are defined as the following:

   i. Geometric position (latitude, longitude, geometric height, and their validity flags – elements 4a, 4b, 4c, 5a, 5b);

   ii. Horizontal velocity and horizontal velocity validity (elements 6a, 6b, 6c, 7a, 7b);

   iii. Heading while on the surface (elements 8a, 8b);

   iv. Pressure altitude (elements 9a, 9b);

   v. Vertical rate (elements 10a, 10b); and

   vi. NIC (element 11).

   Note 1: *Estimation of NIC is done by simply retaining the last reported value.*

c. For time-critical elements of the SV report, a ADS-B receiving subsystem's report assembly function **shall** (242AR3.57) indicate "no data available" if no data are received in the preceding coast interval specified in Table 3.4.3.3.1.1a (§3.4.3.3.1.1).

   Note 2: *An ADS-B receiving subsystem may mark data elements as "no data available" by setting the associated validity bit(s) to ZERO. For NIC this is done by setting the value of NIC to ZERO.*

3.5.1.3.3 Time of Applicability (TOA) Field for SV Report

The Time of Applicability (TOA) field in the SV report describes the time at which the elements of that report are valid.

Note: *As mentioned in the definition of latency in §3.4.3.3.2.1, the times of applicability of position and velocity may differ. The TOA field in the SV report contains the time of applicability of position.*

The time of applicability (TOA) relative to local system time **shall** (242AR3.58) be updated with each State Vector report update.

Requirements on the accuracy of the TOA field in the SV report are given in §3.4.3.3.2.2, and may be paraphrased as follows:

a. The standard deviation of the SV report time error is to be less than 0.5 s.

b. The mean report time error for the position elements of the SV report is not to exceed 0.5 s.

c. The mean report time error for the velocity elements of the SV report is not to exceed 1.5 s.

Note: *The recommended TOA resolution of 0.2 s specified in Table 3.5.1.3 will meet the specifications in items a, b, and c above.*

3.5.1.3.4 Horizontal Position

Horizontal position (§3.3.4) **shall** (242AR3.59) be reported as WGS-84 latitude and longitude. Horizontal position **shall** (242AR3.60) be reported with the full range of possible latitudes (-90° to +90°) and longitudes (-180° to +180°).

Horizontal position **shall** (242AR3.61) be communicated and reported with a resolution sufficiently fine so that it does not compromise the accuracy reported in the NAC_P field (§3.3.11) of the Mode Status report (§3.5.1.4). Moreover, horizontal position **shall** (242AR3.62) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to horizontal position error, σ_{hp}, listed in Table 3.4.3.3.1.1a 20 m for airborne participants, or σ_{hp} = 2.5 m for surface participants.

3.5.1.3.5 Horizontal Position Valid Field

The Horizontal Position Valid field in the SV report **shall** (242AR3.63-A) be set to ONE if a valid horizontal position is being provided in geometric position (latitude and longitude) fields of that report; otherwise, the Horizontal Position Valid field **shall** (242AR3.63-B) be ZERO.

3.5.1.3.6 Geometric Altitude Field

Geometric altitude **shall** (242AR3.64) be reported with a range from -1,000 feet up to +100,000 feet. If the NAC_P code (§3.3.11) reported in the MS report (§3.5.1.4) is 9 or greater, the geometric altitude **shall** (242AR3.65) be communicated and reported with a resolution sufficiently fine that it does not compromise the vertical accuracy reported in the NAC_P field. Moreover, geometric altitude **shall** (242AR3.66) be communicated and reported with a resolution sufficiently fine so that it does not compromise the one-sigma maximum ADS-B contribution to vertical position error, σ_{vp}, listed in Table 3.4.3.3.1.1a, σ_{vp} = 30 feet for airborne participants.

Note: *A resolution of 100 feet or finer is sufficient not to compromise the one-sigma (one standard deviation) ADS-B contribution to vertical position error listed in Table 3.4.3.3.1.1a. This is because the error introduced by rounding altitude to the nearest multiple of 100 feet has a uniform probability distribution, for which the standard deviation is 100 feet divided by the square root of 12, that is, about 28.9 feet.*

3.5.1.3.7 Geometric Altitude Valid Field

The Geometric Altitude Valid field in the SV report is a one-bit field which **shall** (242AR3.67) be ONE if valid data is being provided in the Geometric Altitude field (§3.5.1.3.6), or ZERO otherwise.

3.5.1.3.8 Geometric Horizontal Velocity

Geometric horizontal velocity is the horizontal component of the velocity of an A/V with respect to the earth (or with respect to an earth-fixed reference system, such as the WGS-84 ellipsoid). The range of reported horizontal velocity **shall** (242AR3.68) accommodate speeds of up to 250 knots for surface participants and up to 4000 knots for airborne participants. Horizontal velocity **shall** (242AR3.69) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode Status report. Moreover, horizontal velocity **shall** (242AR3.70) be communicated and reported with a resolution sufficiently fine so that it does not compromise the one-sigma maximum ADS-B contribution to horizontal velocity error, σ_{hv}, listed in Table 3.4.3.3.1.1a, that is, 0.5 m/s (about 1 knot) for airborne participants with speeds of 600 knots or less, or 0.25 m/s (about 0.5 knot) for surface participants.

Note: *The rounding of velocity to the nearest encoded representation may be modeled with a uniform probability distribution. As such, the standard deviation (one-sigma velocity error, σ_{hv}) due to rounding to the nearest possible encoded representation is the weight of the LSB divided by the square root of 12. Thus, σ_{hv} = 0.5 m/s (about 1 knot) for airborne participants implies a resolution of $res_{hv} = \sigma_{hv} \cdot \sqrt{12}$ = 1.73 m/s (about 3.4 knots), so even a horizontal velocity resolution of 2 knots is sufficiently fine to meet the constraint imposed by Table 3.4.3.3.1.1a on airborne participants with speeds up to 600 knots. Likewise, a horizontal velocity resolution of 1 knot is sufficiently fine to satisfy the constraint imposed by Table 3.4.3.3.1.1a for surface participants.*

3.5.1.3.9 Airborne Horizontal Velocity Valid Field

The Airborne Horizontal Velocity Valid field in the SV report is a one-bit field which **shall** (242AR3.71-A) be set to ONE if a valid horizontal geometric velocity is being provided in the “North Velocity while airborne” and “East velocity while airborne” fields of the SV report; otherwise, the “Airborne Horizontal Velocity Valid” field **shall** (242AR3.71-B) be ZERO.

3.5.1.3.10 Ground Speed While on the Surface Field

The ground speed (the magnitude of the geometric horizontal velocity) of an A/V that is known to be on the surface **shall** (242AR3.72) be reported in the “ground speed while on the surface” field of the SV report. For A/Vs moving at ground speeds less than 70 knots, the ground speed **shall** (242AR3.73) be communicated and reported with a resolution of 1 knot or finer. Moreover, the resolution with which the “ground speed while on the surface” field is communicated and reported **shall** (242AR3.74) be sufficiently fine so as not to compromise the accuracy of that speed as communicated in the NAC_V field of the MS report (§3.5.1.4).

3.5.1.3.11 Surface Ground Speed Valid Field

The Surface Ground Speed Valid field in the SV report is a one-bit field which **shall** (242AR3.75) be ONE if valid data is available in the Ground Speed While on the Surface field (§3.5.1.3.10), or ZERO otherwise.

3.5.1.3.12 Heading While on the Surface Field

Heading (§3.3.7) indicates the orientation of an A/V, that is, the direction in which the nose of an aircraft is pointing. ADS-B Participants are not required to broadcast heading if their length/width code (part of the aircraft size code, Table 3.3.4.1a) is Zero (0). However, each ADS B participant that reports a length code of 2 or greater **shall** (242AR3.76) transmit messages to support the heading element of the SV report when that participant is on the surface and has a source of heading available to its ADS-B transmitting subsystem.

Heading **shall** (242AR3.77-A) be reported for the full range of possible headings (the full circle, from 0° to nearly 360°). The heading of surface participants **shall** (242AR3.77-B) be communicated and reported with a resolution of 6 degrees of arc or finer.

Notes:

1. *If heading is encoded as a binary fraction of a circle, a resolution of 6° of arc or finer would require at least 6 binary bits.*

2. *The reference direction for heading (true north or magnetic north) is communicated in the True/Magnetic Heading Flag (§3.2.7) of the Mode Status report.*

3. *For operations at some airports, heading may be required to enable proper orientation and depiction of an A/V by applications supporting those surface operations.*

3.5.1.3.13 Heading Valid Field

The "heading valid" field in the SV report **shall** (242AR3.78-A) be ONE if a valid heading is provided in the "heading while on the surface" field of the SV report; otherwise, it **shall** (242AR3.78-B) be ZERO.

3.5.1.3.14 Pressure Altitude Field

Barometric pressure altitude **shall** (242AR3.79) be reported referenced to standard temperature and pressure (1013.25 hPa or mB, or 29.92 in Hg). Barometric pressure altitude **shall** (242AR3.80) be reported over the range of -1,000 feet to +100,000 feet.

If a pressure altitude source with 25 foot or better resolution is available to the ADS-B transmitting subsystem, then pressure altitude from that source **shall** (242AR3.81-A) be communicated and reported with 25 foot or finer resolution. Otherwise, if a pressure altitude source with 100 foot or better resolution is available, pressure altitude from that source **shall** (242AR3.81-B) be communicated and reported with 100 foot or finer resolution.

3.5.1.3.15 Pressure Altitude Valid Field

The “pressure altitude valid” field in the SV report is a one-bit field which **shall** (242AR3.82-A) be ONE if valid information is provided in the “pressure altitude” field; otherwise, the “pressure altitude valid” field **shall** (242AR3.82-B) be ZERO.

3.5.1.3.16 Vertical Rate Field

The “vertical rate” field in the SV report contains the altitude rate of an airborne ADS-B participant. This **shall** (242AR3.83) be either the rate of change of pressure altitude or of geometric altitude, as specified by the “vertical rate type” element in the MS report. The range of reported vertical rate **shall** (242AR3.84) accommodate up to ±32000 ft/min for airborne participants. Geometric vertical rate **shall** (242AR3.85) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode Status report. Moreover, vertical rate **shall** (242AR3.86) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to vertical rate error, σ_{vv}, listed in Table 3.4.3.3.1.1a, that is, 1.0 ft/s for airborne participants.

3.5.1.3.17 Vertical Rate Valid Field

The “vertical rate valid” field in the SV report is a one-bit field which **shall** (242AR3.87-A) be ONE if valid information is provided in the “vertical rate” field; otherwise, the “vertical rate valid” field **shall** (242AR3.87-B) be ZERO.

3.5.1.3.18 Navigation Integrity Category (NIC) Field

The NIC field in the SV report is a 4-bit field that **shall** (242AR3.88) report the Navigation Integrity Category described in Table 3.3.10a (§3.3.10).

3.5.1.3.19 Report Mode Field

The “Report Mode” provides a positive indication when SV and MS acquisition is complete and all applicable data sets and modal capabilities have been determined for the participant or that a default condition is determined by the Report Assembly function. The information for this SV element is not transmitted over the ADS-B data link, but is provided by the report assembly function at the receiving ADS-B participant. Table 3.5.1.3.19 lists the possible values for the SV Report Mode.

Table 3.5.1.3.19: SV Report Mode Values.

Value	Meaning
0	Acquisition
1	Track
2	Default

3.5.1.4 Mode Status Report

The mode-status (MS) report contains current operational information about the transmitting participant. This information includes participant type, mode specific parameters, status data needed for certain pair-wise operations, and assessments of the integrity and accuracy of position and velocity elements of the SV report. Specific requirements for a participant to supply data for and/or generate this report subgroup will vary according to the equipage class of each participant. §3.4.3.2 defines the required capabilities for each Equipage Class defined in §3.2.1.3.3. Equipage classes define the level of MS information to be exchanged from the source participant to support correct classification onboard the user system.

The Mode Status report for each acquired participant contains the unique participant address for correlation purposes, static and operational mode information and Time of Applicability. Contents of the Mode Status report are summarized in Table 3.5.1.4.

The static and operational mode data includes the following information:

- Capability Class (CC) Codes – used to indicate the capabilities of a transmitting ADS-B participant.
- Operational Mode (OM) Codes – used to indicate the current operating mode of a transmitting ADS-B participant.

For each participant the Mode-status report **shall** (242AR3.89) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is accepted from that participant.

Table 3.5.1.4: Mode Status (MS) Report Definition.

	MS Elem. #	Contents [Resolution or # of bits]	Elements That Require Rapid Update	Reference Section	Notes
ID	1	Participant Address [24 bits]		3.3.2.2.1	
	2	Address Qualifier [1 bit]		3.3.2.2.2	1
TOA	3	Time of Applicability [1 s resolution]		3.5.1.4.2	
Version	4	ADS-B Version Number [3 bits]		3.5.1.4.3	
ID, Continued	5a	Call Sign [up to 8 alpha-numeric characters]		3.5.1.4.4	
	5b	Emitter Category [5 bits]		3.5.1.4.5	
	5c	A/V Length and Width Codes [4 bits]		3.5.1.4.6	2
Status	6a	Mode Status Data Available [1 bit]		3.5.1.4.7	
	6b	Emergency/Priority Status [3 bits]		3.5.1.4.8	3
CC, Capability Codes	7	Capability Class Codes [16 bits]		3.5.1.4.9	
		7a: TCAS/ACAS operational [1 bit]	•	3.5.1.4.9	4
		7b: 1090 MHz ES Receive Capability [1 bit]		3.5.1.4.9	
		7c: ARV report Capability Flag [1 bit]		3.5.1.4.9	
		7d: TS report Capability Flag [1 bit]		3.5.1.4.9	
		7e: TC report Capability Level [2 bits]		3.5.1.4.9	
		7f: UAT Receive Capability [1 bit]		3.5.1.4.9	
		(CC Codes reserved for future growth) [3 bits]		3.5.1.4.9	
OM, Operational Mode	8	Operational Mode Parameters [16 bits]		3.5.1.4.10	
		8a: TCAS/ACAS resolution advisory active [1 bit]	•	3.5.1.4.10	4
		8b: IDENT Switch Active [1 bit]		3.5.1.4.10	3
		8c: Reserved for Receiving ATC services [1 bit]		3.5.1.4.10	
		8d: Single Antenna Flag [1 bit]		3.5.1.4.10	
		8e: System Design Assurance [2 bits]		3.5.1.4.10	
		8f: GPS Antenna Offset [8 bits]		3.5.1.4.10	
		(Reserved for future growth) [2 bits]		3.5.1.4.10	
SV Quality	9a	Nav. Acc. Category for Position (NAC_P) [4 bits]	•	3.5.1.4.11	4
	9b	Nav. Acc. Category for Velocity (NAC_V) [3 bits]	•	3.5.1.4.12	4
	9c	Source Integrity Level (SIL) [2 bits]	•	3.5.1.4.13	4
	9d	NIC_{BARO} - Altitude Cross Checking Flag [1 bit]		3.5.1.4.14	
	9e	Geometric Vertical Accuracy (GVA) [2 bits]		3.5.1.4.15	
	9f	(Reserved for future growth) [2 bits]		3.5.1.4.16	
Data Reference	10a	True/Magnetic Heading [1 bit]		3.5.1.4.17	
	10b	Vertical Rate Type (Baro./Geo.) [1 bit]		3.5.1.4.18	
Other	11	Reserved for Flight Mode Specific Data [3 bits]		3.5.1.4.19	

Notes for Table 3.5.1.4:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. For example, address qualifier bits might be needed to distinguish reports about TIS-B targets from reports about ADS-B targets. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links.*

2. *The aircraft size code only has to be transmitted by aircraft above a certain size, and only while those aircraft are on the ground. (See §3.5.1.4.6 for details.)*

3. *These elements are primarily for air-to-ground use. Update rate requirements for ground applications are not defined in these MASPS. If higher rates are later deemed to be required, they will be addressed in a future revision of these MASPS.*

4. *Changes to the values of these elements may trigger the transmission of messages conveying the changed values at higher than nominal update rates. (Only those elements whose values have changed need be updated, not the entire MS report.) These update rates, the duration for which those rates must be maintained, and the operational scenario to be used to evaluate these requirements are to be defined in a future revision of these MASPS.*

3.5.1.4.1 MS Report Update Requirements

The report assembly function **shall** (242AR3.90-A) provide update when received. For those elements indicated in Table 3.5.1.4 as "elements that require rapid update", the report assembly function **shall** (242AR3.90-B) indicate the data has not been refreshed with the "Mode Status Data Available" bit (§3.5.1.4.7) if no update is received in the preceding 24 second period.

Note: *The 24-second period before which the "Mode Status Data Available" bit is cleared was chosen as being the longest coast interval for SV reports, as indicated in Table 3.4.3.3.1.1a.*

3.5.1.4.2 Time of Applicability (TOA) Field for MS Report

The time of applicability relative to local system time **shall** (242AR3.91) be updated with every Mode Status report update.

3.5.1.4.3 ADS-B Version Number

The ADS-B Version Number conveyed in the MS report specifies the ADS-B version of the ADS-B transmitting system as specified in Table 3.3.20.

Note: *Messages transmitted to support this report element might signify lower level document (i.e., MOPS) version. However, ADS-B reports need to – at a minimum – signify the MASPS version so that applications can appropriately interpret received ADS-B data.*

3.5.1.4.4 Call Sign Field

An ADS-B participant's call sign (§3.3.2.1) is conveyed in the Call Sign field of the MS report. The call sign **shall** (242AR3.93) consist of up to 8 alphanumeric characters. The characters of the call sign **shall** (242AR3.94) consist only of the capital letters A-Z, the decimal digits 0-9, and – as trailing pad characters only – the "space" character.

3.5.1.4.5 Emitter Category Field

An ADS-B participant's category code (§3.3.2.3) is conveyed in the Emitter Category field of the MS report. The particular encoding of the emitter category is not specified in these MASPS, being left for lower level specification documents, such as the MOPS for a particular ADS-B data link. Provision in the encoding **shall** (242AR3.95) be made for at least 24 distinct emitter categories, including the particular categories listed in §3.3.2.3 above.

3.5.1.4.6 A/V Length and Width Codes

The "A/V Length and Width Codes" field in the MS field is a 4-bit field that describes the amount of space that an aircraft or ground vehicle occupies. The aircraft/vehicle length and width codes **shall** (242AR3.96) be as described in Table 3.3.4.1a. The aircraft size code is a four-bit code, in which the 3 most significant bits (the length code) classify the aircraft into one of eight length categories, and the least significant bit (the width code) classifies the aircraft into a "narrow" or "wide" subcategory.

Each aircraft **shall** (242AR3.97) be assigned the smallest length and width codes for which its overall length and wingspan qualify it.

Note: *For example, consider a powered glider with overall length of 24 m and wingspan of 50 m. Normally, an aircraft of that length would be in length category 1. But since the wingspan exceeds 34 m, it will not fit within even the "wide" subcategory of length category 1. Such an aircraft would be assigned length category 4 and width category 1, meaning "length less than 55 m and wingspan less than 52 m."*

Each aircraft ADS-B participant for which the length code is 2 or more (length greater than or equal to 25 m or wingspan greater than 34 m) **shall** (242AR3.98) transmit its aircraft size code while it is known to be on the surface. For this purpose, the determination of when an aircraft is on the surface **shall** (242AR3.99) be as described in §3.5.1.3.1.1.

3.5.1.4.7 Mode Status Data Available Field

The Mode Status Data Available field is a one-bit field in the MS report. The report assembly function **shall** (242AR3.100-A) set this field to ZERO if no data has been received within 24 seconds under the conditions specified in §3.5.1.4.1; otherwise the report assembly function **shall** (242AR3.100-B) set this bit to ONE.

3.5.1.4.8 Emergency/Priority Field

The emergency/priority status field in the MS report is a 3-bit field which **shall** (242AR3.101) be encoded as indicated in Table 3.3.15a.

3.5.1.4.9 Capability Class (CC) Code Fields

Capability Class (CC) codes are used to indicate the capability of a participant to support engagement in various operations. Known specific capability class codes that are included in the MS report are listed below. However, this is not an exhaustive set and provision should be made for future expansion of available class codes, including appropriate combinations thereof.

Airborne Capability Class Codes

- TCAS/ACAS operational (§TBD)
- 1090ES IN & UAT IN
- ARV report capability (§TBD)
- TS report capability (§TBD)
- TC report capability level (§TBD)
- Other capabilities, to be defined in later versions of these MASPS
-

Surface Capability Class Codes

- 1090ES IN & UAT IN
- Service Level of the transmitting A/V (B2 Low) (§TBD)(unique to 1090ES)
- NAC_V (§TBD)
- Other capabilities, to be defined in later versions of these MASPS

3.5.1.4.10 Operational Mode (OM) Codes

Operational Mode (OM) codes are used to indicate the current operational mode of transmitting ADS-B participants. Specific operational mode codes included in the MS report are listed below. Unless noted, these parameters **shall** (New Reqmt) be broadcast in both airborne and surface operational status messages. However, this is not an exhaustive set and provision should be made for future expansion of available OM codes, including appropriate combinations thereof.

- TCAS/ACAS resolution advisory active (§TBD).
- IDENT switch active flag (§TBD)
- Reserved for Receiving ATC services (§TBD)
- Single Antenna Flag
- System Design Assurance (SDA) (§TBD)
- GPS Antenna Offset (Surface OM Messages Only, §3.3.9.6)
- Other operational modes, to be defined in later versions of these MASPS.

3.5.1.4.11 Navigation Accuracy Category for Position (NAC_P) Field

The Navigation Accuracy Category for Position (NAC_P, §3.3.11) is reported so that surveillance applications may determine whether the reported position has an acceptable level of accuracy for the intended use. The NAC_P field in the MS report is a 4-bit field which **shall** (242AR3.113) be encoded as described in Table 3.3.11a in §3.3.11.

Note: *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of this MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of these MASPS.*

3.5.1.4.12 Navigation Accuracy Category for Velocity (NAC_V) Field

The Navigation Accuracy Category for Velocity (NAC_V, §3.3.12) is reported so that surveillance applications may determine whether the reported velocity has an acceptable level of accuracy for the intended use. The NAC_V field in the MS report is a 3-bit field which **shall** (242AR3.114) be encoded as described in Table 3.3.12a (§3.3.12).

Note: *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of these MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of these MASPS.*

3.5.1.4.13 Source Integrity Level (SIL) Field

The SIL field in the MS report is a 2-bit field which **shall** (242AR3.115) be coded as described in Table 3.3.13a (§3.3.13).

Note: *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of this MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of this MASPS.*

3.5.1.4.14 NIC_{BARO} Field

The NIC_{BARO} field in the MS report is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude. A transmitting ADS B participant **shall** (242AR3.117-A) set NIC_{BARO} to ONE in the messages that it sends to support the MS report only if there is more than one source of barometric pressure altitude data and cross-checking of one altitude source against the other is performed so as to clear the "barometric altitude valid" flag in the SV report if the two altitude sources do not agree. Otherwise, it **shall** (242AR3.117-B) set this flag to ZERO.

3.5.1.4.15 Geometric Vertical Accuracy (GVA)

The Geometric Vertical Accuracy parameter in the MS report is an encoded representation of the 95% accuracy estimate of the geometric altitude (HAE) as output by the GNSS position source. In some GNSS position sources this output parameter is known as the Vertical Figure of Merit (VFOM).

3.5.1.4.16 Reserved for MS Report

A 2-bit field in the MS Report **shall** (242AR3.116) is be reserved for future use.

3.5.1.4.17 True/Magnetic Heading Flag

The True/Magnetic Heading Flag in the Mode Status report is a one-bit field which **shall** (242AR3.118) be ZERO to indicate that heading is reported referenced to true north, or ONE to indicate that heading is reported referenced to magnetic north.

Note: *The True/Magnetic Heading Flag applies to the heading being reported in the SV report while on the surface (§3.5.1.3.12), heading reported in the ARV report while airborne (§3.5.1.6.6), and the selected target heading reported in the TS report (§3.5.1.7.9).*

3.5.1.4.18 Vertical Rate Type Field

The Primary Vertical Rate Type field in the MS report is a one-bit flag which **shall** (242AR3.119) be ZERO to indicate that the vertical rate field in the SV report §3.5.1.3.16 holds the rate of change of barometric pressure altitude, or ONE to indicate that the vertical rate field holds the rate of change of geometric altitude.

3.5.1.4.19 (Reserved for) Flight Mode Specific Data Field

A 3-bit field in the MS Report is reserved for future use as a "Flight Mode Specific Data" field. In the current version (RTCA DO-3xx) of these MASPS, the "Reserved for Flight Mode Specific Data" field **shall** (242AR3.120) be ZERO.

3.5.1.5 On-Condition Reports

The following paragraphs (§3.5.1.6 to §3.5.1.7) describe various On Condition (OC) reports. The OC reports are those for which messages are not transmitted all the time, but only when certain conditions are satisfied. Those OC report types currently defined are as follows:

ARV: Air Referenced Velocity (ARV) Report (§3.5.1.6).

TS: Target State (TS) Report (§3.5.1.7).

Other On-Condition reports may be defined in future versions of these MASPS.

3.5.1.6 Air Referenced Velocity (ARV) Report

The Air Referenced Velocity (ARV) report contains velocity information that is not required from all airborne ADS-B transmitting participants, and that may not be required at the same update rate as the position and velocity elements in the SV report. Table 3.5.1.6 lists the elements of the ARV Report.

Table 3.5.1.6: Air Referenced Velocity (ARV) Report Definition

	ARV Elem. #	Contents [Resolution or # of bits]	Reference Section	Notes
ID	1	Participant Address [24 bits]	3.3.2.2.1	
	2	Address Qualifier [1 bit]	3.3.2.2.2	1
TOA	3	Time of Applicability [1 s resolution]	3.5.1.6.3	
Airspeed	4a	Airspeed [1 knot or 4 knots]	3.5.1.6.4	
	4b	Airspeed Type and Validity [2 bits]	3.5.1.6.5	
Heading	5a	Heading while airborne [1 degree]	3.5.1.6.6	2
	5b	Heading Valid [1 bit]	3.5.1.6.7	

Notes for Table 3.5.1.6:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links.*
2. *The heading reference direction (true north or magnetic north) is given in the MS report (§3.5.1.4).*

3.5.1.6.1 Conditions for Transmitting ARV Report Elements

There are no conditions specified in this MASPS for which it is required to transmit messages supporting ARV reports. Possible future conditions being considered for requiring ARV reports are discussed in Appendix I.

Notes:

1. *Uses of the ARV report are anticipated for future applications such as in-trail spacing, separation assurance when the transmitting aircraft is being controlled to an air-referenced heading, and for precision turns. For example, ARV report information allows wind conditions encountered by the transmitting aircraft to be derived. Current heading also provides a consistent reference when the aircraft is being controlled to a target heading. Such anticipated uses for ARV information are described in Appendix I.*

2. *Such uses will be associated with conditions for transmitting messages to support the ARV report. It is anticipated that when the requirements for such future applications are better understood, that additional conditions for transmitting the ARV report information may be included in a future revision of this MASPS.*

3.5.1.6.2 ARV Report Update Requirements

This section is reserved for update rate requirements when future versions of this MASPS define conditions under which the support of ARV reports is required.

Note: *It is expected that required ARV report update rates will not exceed those for State Vector (SV) reports.*

3.5.1.6.3 Time of Applicability (TOA) Field for ARV Report

The time of applicability relative to local system time **shall** (242AR3.121) be updated with every Air-Referenced Velocity report update.

3.5.1.6.4 Airspeed Field

Reported airspeed ranges **shall** (242AR3.122) be 0-4000 knots airborne. Airspeeds of 600 knots or less **shall** (242AR3.123) be reported with a resolution of 1 knot or finer. Airspeeds between 600 and 4000 knots **shall** (242AR3.124) be reported with a resolution of 4 knots or finer.

3.5.1.6.5 Airspeed Type and Validity

The Airspeed Type and Validity field in the ARV report is a 2-bit field that **shall** (242AR3.125) be encoded as specified in Table 3.5.1.6.5.

Table 3.5.1.6.5: Airspeed Type Encoding

Airspeed Type	Meaning
0	Airspeed Field Not Valid
1	True Airspeed (TAS)
2	Indicated Airspeed (IAS)
3	Reserved for Mach

3.5.1.6.6 Heading While Airborne Field

An aircraft's heading (§3.3.7) is reported as the angle measured clockwise from the reference direction (magnetic north or true north) to the direction in which the aircraft's nose is pointing. If an ADS B participant broadcasts messages to support ARV reports, and heading is available to the transmitting ADS-B subsystem, then it **shall** (242AR3.126) provide heading in those messages. Reported heading range **shall** (242AR3.127) cover a full circle, from 0 degrees to (almost) 360 degrees. The heading field in ARV reports **shall** (242AR3.128) be communicated and reported with a resolution at least as fine as 1 degree of arc.

Note: *The reference direction for heading (true north or magnetic north) is reported in the True/Magnetic Heading Flag of the Mode Status report §3.5.1.4.16 above).*

3.5.1.6.7 Heading Valid Field

The "Heading Valid" field in the ARV report **shall** (242AR3.129) be ONE if the "Heading While Airborne" field contains valid heading information, or ZERO if that field does not contain valid heading information.

3.5.1.7 Target State (TS) Report

The Target State (TS) Report provides information on the current status of the MCP/FCU or FMS Selected Altitude and the Selected Heading. Table 3.5.1.7 lists the elements of this report.

Table 3.5.1.7: Target State (TS) Report Definition

	TS Report Elem. #	Contents [Resolution or # of bits]	Reference Section
ID	1	Participant Address [24 bits]	3.3.2.1
	2	Address Qualifier [1 bit]	3.3.2.2
TOA	3	Time of Applicability [1 s resolution]	3.5.1.7.3
Selected Altitude	4a	Selected Altitude Type [1 bit]	3.5.1.7.4
	4b	MCP/FCU or FMS Selected Altitude [16 bits]	3.5.1.7.5
	4c	Barometric Pressure Setting (minus 800 millibars) [16 bits]	3.5.1.7.6
Selected Heading	5	Selected Heading [16 bits]	3.5.1.7.9
Mode Indicators	6a	Autopilot Engaged [1 bit]	3.5.1.7.11
	6b	VNAV Mode Engaged [1 bit]	3.5.1.7.12
	6c	Altitude Hold Mode [1 bit]	3.5.1.7.13
	6d	Approach Mode [1 bit]	3.5.1.7.14
	6e	LNAV Mode Engaged [1 bit]	3.5.1.7.15
Reserved		(Reserved for Future Growth) [4 bits]	

3.5.1.7.1 Conditions for Transmitting TS Report Information

An airborne ADS-B participant of equipage class A2 or A3 **shall** (242AR3.130) transmit messages to support the TS report when airborne and target state information is available.

Note: *TS Reports are also optional for A1 equipment. If A1 equipment chooses to support TS reports those reports must meet the requirements specified in §3.5.1.7 and all of its subsections.*

3.5.1.7.2 TS Report Update Requirements

The nominal update interval for TS Report information is specified in §3.4.3.3.1.4 and Table 3.4.3.3.1.1d.

The higher "state change" update interval requirements specified for TS report information in §3.4.3.3.1.4 and Table 3.4.3.3.1.1d **shall** (242AR3.131) be met whenever there is a change in the value of any of the TS report fields. Editor's Note: ➔ We should talk about this. ➔

3.5.1.7.3 Time of Applicability (TOA) field for TS Report

The time of applicability relative to local system time **shall** (242AR3.132) be updated with every Target State report update.

3.5.1.7.4 Selected Altitude Type

The "Selected Altitude Type" subfield is a field in the TS report that is used to indicate the source of Selected Altitude data. Encoding of the "Selected Altitude Type" is specified in Table 3.3.19.

3.5.1.7.5 MCP/FCU or FMS Selected Altitude Field

The "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield is a field in the TS report that contains either the MCP / FCU Selected Altitude or the FMS Selected Altitude data as specified in Table 3.3.20.

3.5.1.7.6 Barometric Pressure Setting (Minus 800 millibars) Field

The "Barometric Pressure Setting (Minus 800 millibars)" subfield is a field in the TS report that contains Barometric Pressure Setting data that has been adjusted by subtracting 800 millibars from the data received from the Barometric Pressure Setting source. After adjustment by subtracting 800 millibars, the Barometric Pressure Setting is encoded as specified in Table 3.3.21.

3.5.1.7.7 Selected Heading Field

The "Selected Heading" is a field in the TS report that contains Selected Heading data encoded as specified in Table 3.3.24.

3.5.1.7.8 MCP/FCU Mode Indicator: Autopilot Engaged Field

The "Mode Indicator: Autopilot Engaged" subfield is a field in the TS report that is used to indicate whether the autopilot system is engaged or not, as specified by Table 3.3.26.

3.5.1.7.9 MCP/FCU Mode Indicator: VNAV Mode Engaged Field

The "Mode Indicator: VNAV Mode Engaged" is a field in the TS report that is used to indicate whether the Vertical Navigation Mode is active or not, as specified in Table 3.3.27.

3.5.1.7.10 MCP/FCU Mode Indicator: Altitude Hold Mode Field

The "Mode Indicator: Altitude Hold Mode" is a field in the TS report that is used to indicate whether the Altitude Hold Mode is active or not, as specified in Table 3.3.28.

3.5.1.7.11 MCP/FCU Mode Indicator: Approach Mode Field

The "Mode Indicator: Approach Mode" is a field in the TS report that is used to indicate whether the Approach Mode is active or not, as specified in Table 3.3.29.

3.5.1.7.12 MCP/FCU Mode Indicator: LNAV Mode Engaged Field

The "Mode Indicator: LNAV Mode Engaged" is a field in the TS report that is used to indicate whether the Lateral Navigation Mode is active or not, as specified in Table 3.3.30.

3.5.2 Traffic Information Services – Broadcast (TIS-B) Messages and Reports

3.5.2.1 Introduction to TIS-B

The formats and coding for a Traffic Information Service Broadcast (TIS-B) are based on the same ADS-B signal transmission.

TIS-B complements the operation of ADS-B by providing ground-to-air broadcast of surveillance data on aircraft that are not equipped for ADS-B. The basis for this ground surveillance data may be an ATC Mode S radar, a surface or approach multi-lateration system or a multi-sensor data processing system. The TIS-B ground-to-air transmissions use the same signal formats as ADS-B broadcasts and can therefore be accepted by an ADS-B receiver.

TIS-B data content on the signal does not include all of the parameters, such as the System Design Assurance (SDA) and the SIL Supplement, which are normally associated with ADS-B transmissions from aircraft. Those parameters that are not broadcast will need to be provided by the TIS-B Service Provider.

TIS-B service is the means for providing a complete surveillance picture to ADS-B users during a transition period. After transition, it also provides a means to cope with a user that has lost its ADS-B capability, as well as a means to provide ADS-B users with information from surface or approach multi-lateration systems.

3.5.2.2 TIS-B Message Processing and Report Generation

The information received in TIS-B Messages is reported directly to applications. In the most common case, a particular target will result in TIS-B Message receptions or ADS-B Message receptions, but not both. It is possible, however, for both types of messages to be received for a single target. If this happens, the TIS-B information is processed and reported independently of the ADS-B receptions and reporting.

Whereas ADS-B reports are classified as to "State Vector Reports" and certain other defined types, TIS-B reports are not. Instead, TIS-B reporting follows the general principle that all received information is reported directly upon reception.

In the absence of TIS-B Message receptions, it is possible for reports to be generated, but this is not required. Such additional reports might be useful as a means of counteracting possible flaws in an on-board data bus between ADS-B and an application.

3.5.3 ADS-B Rebroadcast Service (ADS-R) Messages and Reports

The formats and coding for an ADS-B Rebroadcast Service (ADS-R) are based on the same ADS-B signal transmission characteristics as are defined for each individual ADS-B data link.

The ADS-B Rebroadcast Service complements the operation of ADS-B and the Fundamental TIS-B Service (see the TIS-B MASPS, RTCA DO-286B, §1.4.1) by providing ground-to-air rebroadcast of ADS-B data about aircraft that are not equipped for ADS-B-1, but are equipped with an alternate form of ADS-B (e.g., ADS-B-2). The basis for the ADS-R transmission is the ADS-B Report received at the Ground Station using a receiver compatible with the alternate ADS-B data link.

The ADS-R ground-to-air transmissions use the same signal formats as the respective ADS-B data links and can therefore be accepted by an alternate ADS-B Receiving Subsystem.

3.6 Subsystem Requirements and Assumptions

(Rudy Johnson)

3.7 Functional Level Requirements

(UNASSIGNED)

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4 ADS-B IN System Applications Requirements

4.1 Enhanced Visual Acquisition (EVACQ) / ATSA-AIRB (Eric Vallauri)

(Eric Vallauri)

4.2 Enhanced Visual Approach (EVAPP) / ATSA-VSA (Eric Vallauri)

(Eric Vallauri)

4.3 ATSA-SURF (Eric Vallauri)

(Eric Vallauri)

4.4 In Trail Procedures (ITP)

The objective of the In-Trail Procedure (ITP) is to enable aircraft that desire flight level changes in procedural airspace to achieve these changes on a more frequent basis, thus improving flight efficiency and safety. The ITP achieves this objective by permitting a climb-through or descend-through maneuver between properly equipped aircraft, using a new distance-based longitudinal separation minimum during the maneuver. The ITP requires the flight crew to use information derived on the aircraft to determine if the initiation criteria required for an ITP are met. The initiation criteria are designed such that the spacing between the estimated positions of own ship and surrounding aircraft is no closer than an approved distance throughout the maneuver. ITP requires specific application-unique processing and display parameters. Refer to RTCA DO-312 [EUROCAE ED-159] for a complete ITP description.

4.5 Interval Management

4.5.1 FIM

Airborne Spacing - Flight Deck Interval Management (ASPA-FIM) (as defined in RTCA DO-328) describes a set of airborne (i.e., flight deck) capabilities designed to support a range of Interval Management (IM) Operations whose goal is precise inter-aircraft spacing. IM is defined as the overall system that enables the improved means for managing traffic flows and aircraft spacing. This includes both the use of ground and airborne tools, where ground tools assist the controller in evaluating the traffic picture and determining appropriate clearances to merge and space aircraft efficiently and safely, and airborne tools allow the flight crew to conform to the IM Clearance.

IM requires a controller using IM to provide an IM Clearance. While some IM Clearances will keep the IM Aircraft on its current route and result only in speed management, other clearances may include a turn for path lengthening or shortening. The objective of the IM Clearance is for the IM Aircraft to achieve and/or maintain an Assigned Spacing Goal relative to a Target Aircraft. The key addition to current operations is the provision of precise guidance within the flight deck to enable the flight crew to actively manage the spacing relative to the Target Aircraft. During IM Operations, the controller retains responsibility for separation, while the flight crew is responsible for using the FIM Equipment to achieve and/or maintain the ATC Assigned Spacing Goal. This does not differ greatly from current operations when controllers provide speed and turn clearances to manage traffic. With ASPA-FIM, however, the flight crew has the capabilities and responsibility to actively manage the speed of the aircraft to meet the operational goals set by the controller. Enabling flight crews to manage their spacing using the FIM Equipment is expected to reduce controller workload related to the IM Aircraft by relieving the controller of the need to communicate several speed and/or vector instructions.

4.5.2 GIM-S

In response to projected increases in air traffic volume and complexity for the National Airspace System (NAS), applications for Interval Management (IM) are being developed to enhance interval management, including merging and spacing operations in en route and terminal areas for the near-term and mid-term timeframes. These applications include Flight deck-based IM (FIM), in which the flight crew makes use of specialized avionics that provides speed and turn commands. The utilization of FIM in the NAS presupposes the existence of appropriate and integrated Ground-based IM (GIM) capabilities that provides controllers the capabilities to initiate, monitor, and terminate FIM-S operations as well as manage non FIM equipped flights. During IM operations, responsibility for separation may reside with the controller (referred to as spacing applications or GIM/FIM-S) or with the flight crew (referred to as delegated separation applications or GIM/FIM-DS). Figure 4.5.2 provides an overview of the various applications that can be part of IM.

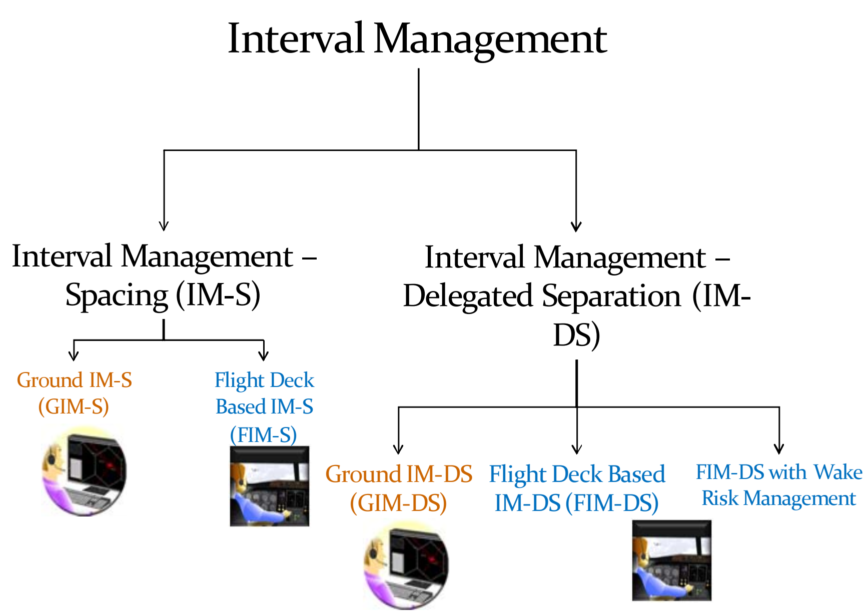


Figure 4.5.2a: Overview of IM Applications

GIM-S applications, either together with the use of FIM-S or by itself, improve aircraft spacing during departure, arrival, and cruise phase of flight. The GIM-S applications assist in reducing the effect of airborne congestion, while increasing runway throughput, and increase the efficiency and capacity of interval management, including merging and spacing operations. The GIM-S application utilizes Automatic Dependent Surveillance –

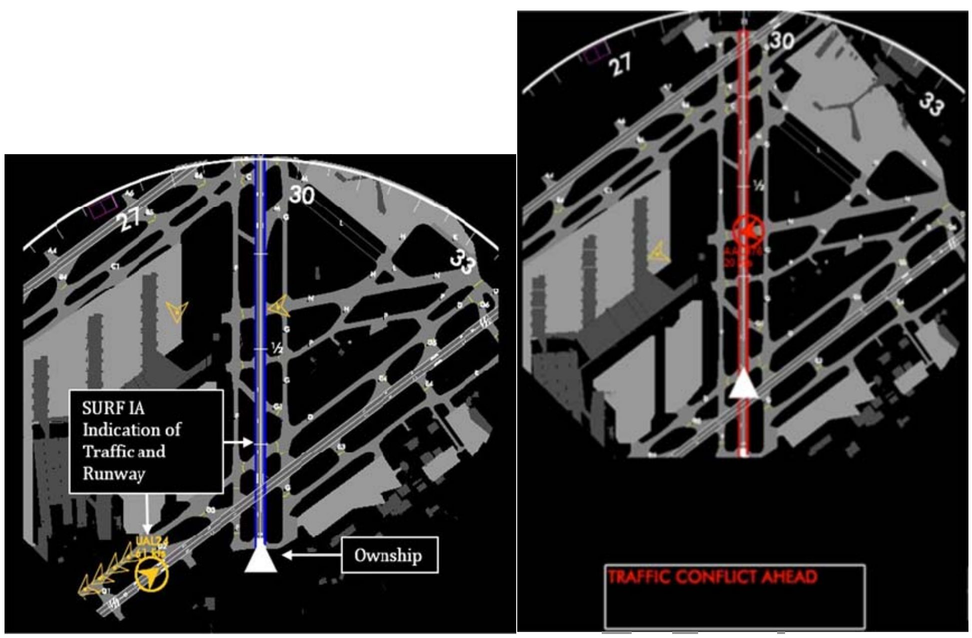
Broadcast (ADS-B) that increases accuracy in trajectory prediction and facilitates more efficient spacing control through the use of speed advisories. While GIM-S can be operated without FIM-S, benefits are expected to increase with the participation of FIM-S aircraft to deliver aircraft at higher accuracy, consistency, and at comparable or lower controller workload.

4.6 Future Applications

(We agreed to put in a paragraph on Conflict Detection)

4.6.1 SURF-IA

The Airport Surface with Indications and Alerts (SURF IA) application enhances the ATSA SURF application (as described in RTCA DO-322) to increase its effectiveness in preventing runway incursions. The SURF IA application adds two distinct components to ATSA SURF for that purpose, SURF IA indications and SURF IA alerts. SURF IA indications identify the runway status and traffic status that could represent a safety hazard. SURF IA indications are presented under normal operational conditions, do not require immediate flight crew awareness, and do not include auditory and visual attention getters. Secondly, SURF IA alerts are displayed to attract the flight crews' attention to non-normal surface traffic conditions. SURF IA alerts facilitate a timely response via auditory and visual attention getters. SURF IA alerts are non-directive and do not provide guidance about how to respond to the alert. See Figure 4.6.1 for a notional example of displays. SURF IA indications and alerts include the display of off-scale indications for safety relevant traffic that would otherwise not be visible on the display.



<u>Figure 4.6.1:</u> Example for SURF IA Indication (left) and A SURF IA warning alert (right)

SURF IA is applicable for operations at controlled and uncontrolled airports and designed for installation on airplanes. SURF IA indications and alerts are supplemental to existing means and procedures of maneuvering aircraft on and near an airport.

SURF IA is described in RTCA DO-323, which contains the detailed safety, performance, and interoperability requirements for the application. RTCA DO-323 requires ADS-B IN, but does not require ground infrastructure such as Traffic Information Service – Broadcast (TIS-B) or Automatic Dependent Surveillance Rebroadcast (ADS-R). However, SURF IA will utilize that surveillance information if available at sufficient quality and integrity.

4.6.2 TSAA

The intended function of Traffic Situational Awareness with Alerts (TSAA) application is to increase flight crew traffic situation awareness by providing timely alerts of airborne traffic in the vicinity. TSAA is intended to reduce the risk of a near mid-air or mid-air collision by aiding in visual acquisition as part of the flight crew's existing see-and-avoid capability.

TSAA provides alerts using the Traffic Display and aural messages to direct attention out the window, assisting the pilot or flight crew with visual acquisition in both Visual Meteorological Conditions and Instrument Meteorological Conditions, if possible. The application functions under both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). When a Traffic Display is available, it builds on the Enhanced Visual Acquisition, or AIRB application. TSAA is also capable of providing alerts without a Traffic Display. These alerts are for predicted airborne conflicts or relevant nearby traffic.

The alert acts as an attention-getting mechanism that reduces the effort used to scan the Traffic Display (if installed) while still permitting the pilot or flight crew to determine if a conflict exists and which aircraft are in conflict. After receiving the alert, the pilot or flight crew will take the necessary action in accordance with the operational rules in effect at the time.

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Appendix A
Acronyms and Definitions of Terms

A Acronyms and Definitions of Terms

A.1 Acronyms

The following acronyms and symbols for units of measure are used in this document.

1090ES	1090 MHz Extended Squitter
A/S	Adjacent Ship
A/V	Aircraft/Vehicle
AC	Aviation Circular (FAA)
AC	Aircraft
ACAS	Airborne Collision Avoidance System. (ACAS is the ICAO standard for TCAS)
ACL	ASA Capability Level
ACM	Airborne Conflict Management
ADS	Automatic Dependent Surveillance
ADS-A	Addressed ADS
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	ADS-Contract
ADS-R	ADS-B – Rebroadcast
AGC	Automatic Gain Control
AGL	Above Ground Level
AIC	Aeronautical Information Circular
AILS	Airborne Information for Lateral Spacing
AIM	Aeronautical Information Manual, (FAA publication)
ALPA	Air Line Pilots Association
AMASS	Airport Movement Area Safety Systems
AMMD	Aerodrome Moving Map Display (an acronym from [DO-257A])
ANSD	Assured Normal Separation Distance
AOC	Aeronautical Operational Control
AOC	Airline Operations Center
AOPA	Aircraft Owners and Pilots Association
APU	Auxiliary Power Unit
ARFF	Aircraft Rescue and Fire Fighting
ARTCC	Air Route Traffic Control Center
ARV	Air Referenced Velocity
ASA	Aircraft Surveillance Applications (to be distinguished from Airborne Surveillance Applications which not referenced as ASA in this document)
ASAS	(1) Airborne Separation Assurance System (an acronym used in [PO-ASAS]) or (2) Aircraft Surveillance Applications System (an acronym used in these MASPS). The two terms are equivalent.
ASDE-3	Airport Surveillance Detection Equipment version 3
ASDE-X	Airport Surveillance Detection Equipment X-band
ASF	Air Safety Foundation (AOPA organization)
ASIA	Approach Spacing for Instrument Approaches
ASOR	Allocation of Safety Objectives and Requirements
ASRS	Aviation Safety Reporting Service
ASSA	Airport Surface Situational Awareness
ASSAP	Airborne Surveillance and Separation Assurance Processing
AT	Air Traffic

ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATIS	Automated Terminal Information System
ATM	Air Traffic Management
ATP	Airline Transport Pilot (rating)
ATS	Air Traffic Services
ATSA	Airborne Traffic Situational Awareness
ATSP	Air Traffic Service Provider
A/V	Aircraft or Vehicle
BAQ	Barometric Altitude Quality
Bps	Bits per Second
CAASD	Center for Advanced Aviation System Development
CARE	Co-operative Actions of R&D in EUROCONTROL
CAZ	Collision Avoidance Zone
CC	Capability Class
CD	Conflict Detection
CD&R	Conflict Detection and Resolution
CDTI	Cockpit Display of Traffic Information
CDU	Control and Display Unit
CDZ	Conflict Detection Zone
CFR	Code of Federal Regulations
CNS	Communications, Navigation, Surveillance
CP	Conflict Prevention
CPA	Closest Point of Approach
CPDLC	Controller Pilot Data Link Communications
CR	Conflict Resolution
CRC	Cyclic Redundancy Check
CRM	Crew Resource Management
CSPA	Closely Spaced Parallel Approaches
CTAF	Common Traffic Advisory Frequency
CTAS	Center TRACON Automation System
DAG	Distributed Air Ground
DGPS	Differential GPS
DH	Decision Height
DME	Distance Measuring Equipment
DMTL	Dynamic Minimum Trigger Level
dps	Degree per Second
DOT	Department of Transportation, U. S. Government
ECAC	European Civil Aviation Conference
ELT	Emergency Locator Transmitter
EMD	Electronic Map Display
EPU	Estimated Position Uncertainty
ERP	Effective Radiated Power
ES	Extended Squitter
ETA	Estimated Time of Arrival
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTROL	European Organization for the Safety of Air Navigation
EVAcq	Enhanced Visual Acquisition
EVApp	Enhanced Visual Approach

FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAR	Federal Aviation Regulation
FAROA	Final Approach and Runway Occupancy Awareness
FAST	Final Approach Spacing Tool
FEC	Forward Error Correction
FFAS	Free Flight Airspace
FIS-B	Flight Information Services - Broadcast
FL	Flight Level
FMEA	Failure Modes and Effects Analysis
FMS	Flight Management System
fpm	Feet Per Minute
FRUIT	False Replies Unsynchronized in Time (also see Garble)
FSDO	Flight Standards District Office (FAA)
FSS	Flight Service Station
ft	Feet
g	Acceleration due to earth's gravity
GA	General Aviation
GBAS	Ground-Based Augmentation System
GHz	Giga Hertz
GLONASS	Global Orbiting Navigation Satellite System
GLS	GNSS Landing System
gnd	Ground
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	Ground-based Surveillance Application
GVA	Geometric Vertical Accuracy
HFOM	Horizontal Figure Of Merit
HGS	Head-Up Guidance System
HIRF	High Intensity Radiated Field
HMI	Hazardously Misleading Information
HPL	Horizontal Protection Limit
HUD	Head-Up Display
Hz	Hertz
IAC	Instantaneous Aircraft Count
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
ICR	Integrity Containment Risk
ICSPA	Independent Closely Spaced Parallel Approaches
ID	Identification
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
ITC	In-Trail Climb
ITD	In-Trail Descent
ITU	International Telecommunication Union

JTIDS	Joint Tactical Information Distribution System
kg	Kilogram
LA	Los Angeles
LAAS	Local Area Augmentation System
LAHSO	Land And Hold Short Operations
lb	Pound
LL	Low Level
LOS	Loss of Separation
LSB	Least Significant Bit
m	meter (or “metre”), the SI metric system base unit for length
MA	Maneuver Advisory
MAC	Midair Collision
MACA	Midair Collision Avoidance
MAS	Managed Airspace
MASPS	Minimum Aviation System Performance Standards
MCP	Mode Control Panel
MFD	Multi-Function Display
MHz	Mega Hertz
mm	Millimeter
MOPS	Minimum Operation Performance Standards (RTCA documents)
mrad	milliradian. 1 mrad = 0.001 radian
MS	Mode status
MSL	Minimum Signal Level
MTL	Minimum Trigger Level
MTBF	Mean-Time-Between-Failures
MTR	Military Training Route
MTTF	Mean Time To Failure
MTTR	Mean-Time To Restore
N/A	Not Applicable or No Change
NAC	Navigation Accuracy Category (sub “p” is for position and sub “v” is for velocity)
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NIC	Navigation Integrity Category
NIC_{BARO}	Barometric Altitude Integrity code
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium - National Aerospace Laboratory in the Netherlands
NM	Nautical Mile
NMAC	Near Mid Air Collision
NMPH	Nautical Miles Per Hour
NOTAM	NOTice to AirMen
NPA	Non-Precision Approach
NSE	Navigation System Error
NTSB	National Transportation Safety Board
NUC	Navigation Uncertainty Category
O/S	Own Ship
OC	On Condition

OH	Operational Hazard
OHA	Operational Hazard Assessment
OPA	Operational Performance Assessment
OSA	Operational Safety Analysis
OSED	Operational Services and Environment Description
OTW	Out-the-Window
PA	Prevention Advisory
PAPI	Precision Approach Path Indicator
PAZ	Protected Airspace Zone
PF	Pilot Flying
PFD	Primary Flight Display
PIREP	Pilot Report
PNF	Pilot Not Flying
PO-ASAS	Principles of Operation for the Uses of ASAS (See the entry in Appendix B for [PO-ASAS])
PRM	Precision Runway Monitor
PSR	Primary Surveillance Radar
R&D	Research and Development
RA	Resolution Advisory (TCAS II),
rad	radian, an SI metric system derived unit for plane angle
RAIM	Receiver Autonomous Integrity Monitoring
R_C	Radius of Containment
RCP	Required Communications Performance
Rcv	Receive
REQ No.	Requirement Number
RIPS	Runway Incursion Prevention System
RMP	Required Monitoring Performance
RMS	Root Mean Square
RNAV	Area Navigation
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTA	Required Time of Arrival
RVR	Runway Visual Range
RVSM	Reduced Vertical Separation Minimum
Rx	receive, receiver
s	second, the SI metric system base unit for time or time interval
SA	Selective Availability
SAE	Society of Automotive Engineers
SAR	Search and Rescue
SARPs	Standards and Recommended Practices
SBAS	Satellite-Based Augmentation System
SC	Special Committee
SDA	System Design Assurance
SF21	Safe Flight 21
SGS	Surface Guidance System
SI	Système International d'Unités (International System of Units not to be confused with the Mode Select Beacon system SI function)
SIL	Source Integrity Level
SIRO	Simultaneous Intersecting Runway Operations

SM	Statute Miles
SMM	Surface Moving Map
SNR	Signal-to-Noise Ratio
SPR	Surveillance Position Reference point
SPS	Standard Positioning Service
SSR	Secondary Surveillance Radar
STP	Surveillance Transmit Processing
SUA	Special Use Airspace
SV	State Vector
SVFR	Special Visual Flight Rules
TA	Traffic Advisory (TCAS II)
TAS	True Airspeed
TAWS	Terrain Awareness and Warning System
TBD	To Be Defined
TC	Trajectory Change (for Trajectory Change report)
TCAS	Traffic Alert and Collision Avoidance System (See ACAS)
TCAS I	TCAS system that does not provide resolution advisories
TCAS II	TCAS system that provides resolution advisories
TCMI	Trajectory Change Management Indicator
TCP	Trajectory Change Point
TCV	Test Criteria Violation
TESIS	Test and Evaluation Surveillance and Information System
TIS	Traffic Information Service
TIS-B	Traffic Information Service – Broadcast
TLAT	Technical Link Assessment Team
TLS	Target Level Safety
TMA	Traffic Management Area
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TOA	Time of Applicability
TORCH	Technical ecOnomical and opeRational assessment of an ATM Concept acHiveable from the year 2005
TQL	Transmit Quality Level
TRACON	Terminal Area CONtrol
TS	Target State (for Target State report)
TSD	Traffic Situation Display
TSE	Total System Error
TTF	Traffic To Follow
TTG	Time to Go
Tx	Transmit
U.S.	United States of America
UAT	Universal Access Transceiver
UHF	Ultra High Frequency: The band of radio frequencies between 300 MHz and 3 GHz, with wavelengths between 1 m and 100 mm.
UMAS	Unmanaged Airspace
UPT	User Preferred Trajectory
USAF	United States Air Force.
UTC	Universal Time, Coordinated, formerly Greenwich Mean Time
Vapp	Final Approach Speed
VDL-4	Very High Frequency Data Link Mode 4

VEPU	Vertical Position Uncertainty
VFOM	Vertical Figure Of Merit
VFR	Visual Flight Rules
VHF	Very High Frequency: The band of radio frequencies between 30 MHz and 300 MHz, with wavelengths between 10 m and 1 m.
VMC	Visual Meteorological Conditions
VOR	Very High Frequency Omni-directional Radio
VPL	Vertical Protection Limit
Vref	Reference Landing Velocity
WAAS	Wide Area Augmentation System
WCB	Worst Case Blunder
WG	Working Group
WGS-84	World Geodetic System - 1984
xmit	transmit, transmitter

A.2 Definitions of Terms

The following are definitions of terms used in this document. Square brackets, e.g. [RTCA DO-242A], refer to entries in the bibliography in Appendix B.

Accuracy – A measure of the difference between the A/V position reported in the ADS-B message field as compared to the true position. Accuracy is usually defined in statistical terms of either: 1) a mean (bias) and a variation about the mean as defined by the standard deviation (sigma) or a root mean square (rms) value from the mean. The values given in this document are in terms of the two sigma variation from an assumed zero mean error.

Active Waypoint – A waypoint to or from which navigational guidance is being provided. For a parallel offset, the active waypoint may or may not be at the same geographical position as the parent waypoint. When not in the parallel offset mode (operating on the parent route), the active and parent waypoints are at the same geographical position.

ADS-B Aircraft Subsystem – The set of avionics, including antenna(s), which perform ADS-B functionality in an aircraft. Several Equipage Classes of ADS B Aircraft Subsystems are specified, with different performance capabilities.

ADS-B Application – An operational application, external to the ADS B System, which requires ADS B Reports as input.

ADS-B Participant – An ADS-B network member that is a supplier of information to the local ADS-B subsystem and/or a user of information output by the transmitting subsystem. This does not include the ADS-B subsystem itself.

ADS-B Participant Subsystem – An entity which can either receive ADS B messages and recover ADS-B Reports (Receiving Subsystem) and/or generate and transmit ADS-B messages (Transmitting Subsystem).

ADS-B Message – An ADS-B Message is a block of formatted data which conveys information used in the development of ADS B reports in accordance with the properties of the ADS B Data Link.

ADS-B Message Assembly Function – Takes as inputs ADS B source data. Prepares contents of, but not envelope for, ADS-B messages and delivers same to the ADS B Message Exchange Function.

ADS-B Message Exchange Function – Takes as inputs the message data to be transmitted, packages the data within implementation specific envelopes to form messages to be transmitted. Messages are transmitted and received. Received messages are validated and accepted and the implementation specific envelope is discarded. The received message data is provided to the ADS-B Report Assembly Function. Some subsystems transmit only; some subsystems receive only. The message exchange function includes the transmit and receive antennas along with any diversity mechanisms.

ADS-B Position Reference Point – The ADS-B position reference point is the position on an A/V that is broadcast in ADS-B messages as the nominal position of that A/V. For aircraft and ground vehicles, this position is the center of a rectangle that is aligned parallel to the A/V's heading and has length and width equal to the longest possible length and width for an aircraft with the same length and width codes as that element transmits while on the surface. The ADS-B position reference point is located such that the actual extent of the A/V is contained entirely that rectangle centered on the ADS-B position reference point.

ADS-B Report – ADS-B Reports are specific information provided by the ADS B receive subsystem to external applications. Reports contain identification, state vector, and status/intent information. Elements of the ADS B Report that are used and the frequency with which they must be updated will vary by application. The portions of an ADS B Report that are provided will vary by the capabilities of the transmitting participant.

ADS-B Report Assembly Function – Takes as inputs the received message data provided from the ADS-B Message Exchange Function. Develops ADS B reports using the received message data to provide an ADS-B report as output to an ADS-B application.

ADS-B Source Data – The qualified source data provided to the ADS B Message Generation Function and ultimately used in the development of ADS B Reports.

ADS-B System – A collection of ADS-B subsystems wherein ADS B messages are broadcast and received by appropriately equipped Participant Subsystems. Capabilities of Participant Subsystems will vary based upon class of equipage.

Aeronautical Radionavigation Service – A radionavigation service intended for the benefit and safe operation of aircraft.

Airborne Collision – This occurs when two aircraft that are in flight come into contact. The word "collision" is not an antonym of the word "separation."

Airborne Separation Assistance System (ASAS) – An aircraft system based on airborne surveillance that provides assistance to the flight crew supporting the separation of their aircraft from other aircraft.

Airborne Separation Assistance Application – A set of operational procedures for controllers and flight crews that makes use of an Airborne Separation Assistance System to meet a defined operational goal.**Airborne Surveillance and Separation Assurance Processing (ASSAP) –** ASSAP is the processing subsystem that accepts surveillance inputs, (e.g., ADS-B reports), performs surveillance processing to provide reports and tracks, and performs application-specific processing. Surveillance reports, tracks, and any application-specific alerts or guidance are output by ASSAP to the CDTI function. ASSAP surveillance processing consists of track processing and correlation of ADS-B, TIS-B, ADS-R, and TCAS reports).

Airborne Traffic Situational Awareness applications (ATSA applications) – These 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 are required for these applications." [PO-ASAS, p.1]**Aircraft Surveillance Applications (ASA) –** Airborne and surface functions that use ADS-B data and on board processing to be displayed to the flight crew to enhance their situational awareness, identify potential conflicts and/or collisions, and in the future to change the own-ship's spacing from other aircraft.

Aircraft/Vehicle (A/V) – Either: 1) a machine or service capable of atmospheric flight, or 2) a vehicle on the airport surface movement area.

A/V Address – The term "address" is used to indicate the information field in an ADS-B Message that identifies the A/V that issued the message. The address provides a convenient means by which ADS-B receiving units, or end applications, can sort messages received from multiple issuing units.

Air/Ground State – An internal state in the transmitting ADS-B subsystem that affects which SV report elements are to be broadcast, but which is not required to be broadcast in ADS-B messages from that participant.

Air Mass Data – Air mass data includes barometric altitude, air speed, and heading.

Air Referenced Velocity (AVR) Report

Alert – A general term that applies to all advisories, cautions, and warning information, can include visual, aural, tactile, or other attention-getting methods.

Alert Zone – In the Free Flight environment, each aircraft will be surrounded by two zones, a protected zone and an alert zone. The alert zone is used to indicate a condition where intervention may be necessary. The size of the alert zone is determined by aircraft speed, performance, and by CNS/ATM capabilities.

Applications – Specific use of systems that address particular user requirements. For the case of ADS-B, applications are defined in terms of specific operational scenarios.

Approach Spacing for Instrument Approaches (ASIA) – An application, described in Appendix I, in which, when approaching an airport, the flight crew uses the CDTI display to help them control their own-ship distance behind the preceding aircraft.

ASAS application – A set of operational procedures for controllers and flight crews that makes use of the capabilities of ASAS to meet a clearly defined operational goal. [PO-ASAS, p. 1]

Assured Collision Avoidance Distance (ACAD) – The minimum assured vertical and horizontal distances allowed between aircraft geometric centers. If this distance is violated, a collision or dangerously close spacing will occur. These distances are fixed numbers calculated by risk modeling.

Assured Normal Separation Distance (ANSD) – The normal minimum assured vertical and horizontal distances allowed between aircraft geometric centers. These distances are entered by the pilot or set by the system. Initially the ANSD will be based on current separation standards (and will be larger than the ACAD). In the long term, collision risk modeling will set the ANSD. Ultimately the ANSD may be reduced toward the value of the ACAD.

Automatic Dependent Surveillance-Broadcast (ADS-B) – ADS-B is a function on an aircraft or surface vehicle operating within the surface movement area that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B is automatic because no external stimulus is required to elicit a transmission; it is dependent because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance information to other users.

Automatic Dependent Surveillance – Rebroadcast (ADS-R) – ADS-R is a "gateway" function on ground systems that rebroadcasts an ADS-B-like message from traffic (including surface vehicles) that utilizes one broadcast link (RF medium) to users such as airborne receive systems that utilize a different ADS-B broadcast link.

Availability – Availability is an indication of the ability of a system or subsystem to provide usable service. Availability is expressed in terms of the probability of the system or subsystem being available at the beginning of an intended operation.

Background Application – An application that applies to all surveilled traffic of operational interest. One or more background applications may be in use in some or all airspace (or on the ground), but without flight crew input or automated input to select specific traffic. Background applications include: Enhanced Visual Acquisition (EV Acq), Conflict Detection (CD), Airborne Conflict Management (ACM), Airport Surface Situational Awareness (ASSA), and Final Approach and Runway Occupancy Awareness (FAROA).

Barometric altitude – Geopotential altitude in the earth's atmosphere above mean standard sea level pressure datum plane, measured by a pressure (barometric) altimeter.

Barometric altitude error – For a given true barometric pressure, P0, the error is the difference between the transmitted pressure altitude and the altitude determined using a standard temperature and pressure model with P0.

Barometric Altitude Integrity Code (NIC_{BARO}) – NIC_{BARO} is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude.

Call Sign – The term "aircraft call sign" means the radiotelephony call sign assigned to an aircraft for voice communications purposes. (This term is sometimes used interchangeably with "flight identification" or "flight ID"). For general aviation aircraft, the aircraft call sign is normally its national registration number; for airline and commuter aircraft, it is usually comprised of the company name and flight number (and therefore not linked to a particular airframe); and for the military, it usually consists of numbers and code words with special significance for the operation being conducted.

Capability Class Codes – Codes that indicate the capability of a participant to support engagement in various operations.

Closest Point of Approach (CPA) – The minimum horizontal distance between two aircraft during a close proximity encounter, also know as miss distance.

Coast Interval – The maximum time interval allowed for maintaining an ADS-B report when no messages supporting that report are received. Requirements for coast interval are typically specified in terms of 99% probability of reception at a given range.

Cockpit Display of Traffic Information (CDTI) – The pilot interface portion of a surveillance system. This interface includes the traffic display and all the controls that interact with such a display. The CDTI receives position information of traffic and own-ship from the airborne surveillance and separation assurance processing (ASSAP) function. The ASSAP receives such information from the surveillance sensors and own-ship position sensors.

Cockpit Display of Traffic Information (CDTI) Display – A single CDTI display format. A physical display screen may have more than one instance of a CDTI Display on it. For example, a display with a split screen that has a Traffic Display on one half of the screen and a list of targets on the other half has two instances of CDTI Displays.

Collision Avoidance – An unplanned maneuver to avoid a collision.

Collision Avoidance Zone (CAZ) – Zone used by the system to predict a collision or dangerously close spacing. The CAZ is defined by the sum of Assured Collision Avoidance Distance (ACAD) and position uncertainties.

Collision Avoidance Zone (CAZ) Alert – An alert that notifies aircraft crew that a CAZ penetration will occur if immediate action is not taken. Aggressive avoidance action is essential.

Conflict – A predicted violation of parameterized minimum separation criteria for adverse weather, aircraft traffic, special use airspace, other airspace, turbulence, noise sensitive areas, terrain and obstacles, etc. There can be different levels or types of conflict based on how the parameters are defined. Criteria can be either geometry based or time-based. This document only addresses aircraft traffic. See *Traffic Conflict*.

Conflict Detection – The discovery of a conflict as a result of a computation and comparison of the predicted flight paths of two or more aircraft for the purpose of determining conflicts (ICAO).

Conflict Detection Zone (CDZ) Alert – An alert issued at the specified look ahead time prior to CDZ penetration if timely action is not taken. Timely avoidance action is required.

Conflict Detection Zone (CDZ) Penetration Notification – Notification to the crew when the measured separation is less than the specified CDZ.

Conflict Detection Zone (CDZ) – Zone used by the system to detect conflicts. The CDZ is defined by the sum of ANSD, position uncertainties, and trajectory uncertainties. By attempting to maintain a measured separation no smaller than the CDZ, the system assures that the actual separation is no smaller than the ANSD.

Conflict Management – Process of detecting and resolving conflicts.

Conflict Prevention – The act of informing the flight crew of flight path changes that will create conflicts.

Conflict Probe – The flight paths are projected to determine if the minimum required separation will be violated. If the minima are not [projected to be] violated, a brief preventive instruction will be issued to maintain separation. If the projection shows the minimum required separation will be violated, the conflict resolution software suggests an appropriate maneuver.

Conflict Resolution – A maneuver that removes all predicted conflicts over a specified "look-ahead" horizon. (ICAO - The determination of alternative flight paths, which would be free from conflicts and the selection of one of these flight paths for use.)

Conformal – A desirable property of map projections. A map projection (a function that associate points on the surface of an ellipsoid or sphere representing the earth to points on a flat surface such as the CDTI display) is said to be *conformal* if the angle between any two curves on the first surface is preserved in magnitude and sense by the angle between the corresponding curves on the other surface.

Cooperative Separation – This concept envisions a transfer of responsibility for aircraft separation from ground based systems to the air-crew of appropriately equipped aircraft, for a specific separation function such as In-trail merging or separation management of close proximity encounters. It is cooperative in the sense that ground-based ATC is involved in the handover process, and in the sense that all involved aircraft must be appropriately equipped, e.g., with RNAV and ADS-B capability, to perform such functions.

Cooperative Surveillance – Surveillance in which the target assists by cooperatively providing data using on-board equipment.

Correlation – The process of determining that a new measurement belongs to an existing track.

Coupled Application – Coupled applications are those applications that operate only on specifically-chosen (either by the flight crew or automation) traffic. They generally operate only for a specific flight operation. Coupled applications include Enhanced Visual Approach, Approach Spacing for Instrument Approaches, and Independent Closely Spaced Parallel Approaches.

Coupled Target – A coupled target is a target upon which a coupled application is to be conducted.

Covariance – A two dimensional symmetric matrix representing the uncertainty in a track's state. The diagonal entries represent the variance of each state; the off-diagonal terms represent the covariances of the track state.

Cross-link – A cross-link is a special purpose data transmission mechanism for exchanging data between two aircraft—a two-way addressed data link. For example, the TCAS II system uses a cross-link with another TCAS II to coordinate resolution advisories that are generated. A cross-link may also be used to exchange other information that is not of a general broadcast nature, such as intent information.

Data Block – A block of information about a selected target that is displayed somewhere around the edge of the CDTI display, rather than mixed in with the symbols representing traffic targets in the main part of the display.

Data Tag – A block of information about a target that is displayed next to symbol representing that target in the main part of the CDTI display.

Desirable – The capability denoted as *Desirable* is not required to perform the procedure but would increase the utility of the operation.

Display range – The maximum distance from own-ship that is represented on the *CDTI* display. If the *CDTI* display is regarded as a map, then longer display ranges correspond to smaller map scales, and short display ranges correspond to larger map scales.

Domain – Divisions in the current airspace structure that tie separation standards to the surveillance and automation capabilities available in the ground infrastructure. Generally there are four domains: surface, terminal, en route, and oceanic/remote and uncontrolled. For example, terminal airspace, in most cases comprises airspace within 30 miles and 10,000 feet AGL of airports with a terminal automation system and radar capability. Terminal IFR separation standards are normally 3 miles horizontally and 1000 feet vertically.

Enhanced Visual Acquisition (EV Acq) – The enhanced visual acquisition application is an enhancement for the out-the-window visual acquisition of aircraft traffic and potentially ground vehicles. Pilots will use a *CDTI* to supplement and enhance out-the-window visual acquisition. Pilots will continue to visually scan out of the window while including the *CDTI* in their instrument scan,***Note:*** *An extended display range capability of at least 90 NM from own-ship is desirable for the ACM application.*

Estimation – The process of determining a track's state based on new measurement information.

Explicit Coordination – Explicit coordination of resolutions requires that the aircraft involved in a conflict communicate their intentions to each other and (in some strategies) authorize/confirm each other's maneuvers. One example of an explicit coordination technique would be the assignment of a 'master' aircraft, which determines resolutions for other aircraft involved in the conflict. Another is the crosslink used in *ACAS*.

Extended Display Range – Extended display range is the capability of the CDTI to depict traffic at ranges beyond the standard display range maximum of 40 NM.

Note: *An extended display range capability of at least 90 NM from own-ship is desirable for the ACM application.*

Extended Runway Center Line – An extension outwards of the center line of a runway, from one or both ends of that runway.

Extrapolation – The process of predicting a track's state forward in time based on the track's last kinematic state.

Field of View – The *field of view* of a *CDTI* is the geographical region within which the *CDTI* shows *traffic targets*. (Some other documents call this the field of regard.)

Flight Crew – One or more cockpit crew members required for the operation of the aircraft.

Foreground Application – An ASA application that the crew can activate and/or deactivate, the foreground applications is not intended to run full-time or activate automatically without crew interaction.

Garble – Garble is either nonsynchronous, in which reply pulses are received from a transponder being interrogated by some other source (see FRUIT), or synchronous, in which an overlap of reply pulses occurs when two or more transponders reply to the same interrogation.

Generic Conflict – A violation of parameterized minimum separation criteria for adverse weather, aircraft traffic, special use airspace, other airspace, turbulence, noise sensitive areas, terrain and obstacles, etc. There can be different levels or types of conflict based on how the parameters are defined. Criteria can be either geometry based or time-based.

Geometric height – The minimum altitude above or below a plane tangent to the earth's ellipsoid as defined by WGS-84.

Geometric height error – Geometric height error is the error between the true geometric height and the transmitted geometric height.

Geometric Vertical Accuracy (GVA) – The GVA parameter is a quantized 95% bound of the error of the reported geometric altitude, specifically the Height Above the WGS-84 Ellipsoid (HAE). This parameter is derived from the Vertical Figure of Merit (VFOM) output by the position source.

GNSS sensor integrity risk – The probability of an undetected failure that results in NSE (navigation system error) that significantly jeopardizes the total system error (TSE) exceeding the containment limit. [DO-247, §5.2.2.1]

Global Positioning System (GPS) – A space-based positioning, velocity and time system composed of space, control and user segments. The space segment, when fully operational, will be composed of 24 satellites in six orbital planes. The control segment consists of five monitor stations, three ground antennas and a master control station. The user segment consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user.

Ground Speed – The magnitude of the horizontal velocity vector (see *velocity*). In these MASPS it is always expressed relative to a frame of reference that is fixed with respect to the earth's surface such as the WGS-84 ellipsoid.

Ground Track Angle – The direction of the horizontal velocity vector (see *velocity*) relative to the ground as noted in Ground Speed.

Hazard Classification – An index into the following table:

Hazard	Class	Acceptable failure rate
1	"Catastrophic" consequences	10^{-9} per flight hour
2	"Hazardous/Severe Major" consequences	10^{-7} per flight hour
3	"Major" consequences	10^{-5} per flight hour
4	"Minor" consequences	10^{-3} per flight hour
5	Inconsequential, no effect	

Hertz (Hz) – A rate where 1 Hz = once per second.

Horizontal Protection Limit (HPL) – The radius of a circle in the horizontal plane (i.e. the plane tangent to the WGS-84 ellipsoid), with its center being the true position, which describes the region which is assured to contain the indicated horizontal position. This computed value is based upon the values provided by the augmentation system.

Horizontal velocity – The horizontal component of velocity relative to a ground reference (see *Velocity)*.

Implicit Coordination – Implicitly coordinated resolutions are assured not to conflict with each other because the responses of each pilot are restricted by common rules. A terrestrial example of an implicit coordination rule is "yield to the vehicle on of conflict based on how the parameters are defined." Criteria can be either geometry based or time-based.

Integrity Containment Risk (ICR) – The per-flight-hour probability that a parameter will exceed its containment bound without being detected and reported within the required time to alert. (See also *Integrity* and *Source Integrity Level*.)

In-Trail Climb – In-trail climb (ITC) procedures enables trailing aircraft to climb to more fuel-efficient or less turbulent altitude.

In-Trail Descent – In-trail descent (ITD) procedures enables trailing aircraft to climb to more fuel-efficient or less turbulent altitude.

Interactive Participants – An ADS-B network member that is a supplier of information to the local ADS-B subsystem and a user of information output by the subsystem. Interactive participants receive messages and assemble reports specified for the respective equipage class.

International Civil Aviation Organization (ICAO) – A United Nations organization that is responsible for developing international standards, recommended practices, and procedures covering a variety of technical fields of aviation.

Latency – Latency is the time incurred between two particular interfaces. Total latency is the delay between the true time of applicability of a measurement and the time that the measurement is reported at a particular interface (the latter minus the former). Components of the total latency are elements of the total latency allocated between different interfaces. Each latency component will be specified by naming the interfaces between which it applies.

Latency Compensation – High accuracy applications may correct for system latency introduced position errors using ADS-B time synchronized position and velocity information.

Low Level Alert – An optional alert issued when CDZ penetration is predicted outside of the CDZ alert boundary.

Mixed Equipage – An environment where all aircraft do not have the same set of avionics. For example, some aircraft may transmit ADS-B and others may not, which could have implications for ATC and pilots. A mixed equipage environment will exist until all aircraft operating in a system have the same set of avionics.

Nautical mile (NM) – A unit of length used in the fields of air and marine navigation. In this document, a nautical mile is always the international nautical mile of 1852 meters exactly.

Navigation Accuracy Category - Position (NAC_P) – The NAC_P parameter describes the accuracy region about the reported position within which the true position of the surveillance position reference point is assured to lie with a 95% probability at the reported time of applicability.

Navigation Accuracy Category - Velocity (NAC_V) – The NAC_V parameter describes the accuracy about the reported velocity vector within which the true velocity vector is assured to be with a 95% probability at the reported time of applicability.

Navigation Integrity Category (NIC) – NIC describes an integrity containment region about the reported position, within which the true position of the surveillance position reference point is assured to lie at the reported time of applicability.

Navigation sensor availability – An indication of the ability of the guidance function to provide usable service within the specified coverage area, and is defined as the portion of time during which the sensor information is to be used for navigation, during which reliable navigation information is presented to the crew, autopilot, or other system managing the movement of the aircraft. Navigation sensor availability is specified in terms of the probability of the sensor information being available at the beginning of the intended operation. [RTCA DO-247, §5.2.2.3]

Navigation sensor continuity – The capability of the sensor (comprising all elements generating the signal in space and airborne reception) to perform the guidance function without non-scheduled interruption during the intended operation. [RTCA DO-247, §5.2.2.2]

Navigation sensor continuity risk – The probability that the sensor information will be interrupted and not provide navigation information over the period of the intended operation. [RTCA DO-247, §5.2.2.2]

Navigation System Integrity – This relates to the trust that can be placed in the correctness of the navigation information supplied. Integrity includes the ability to provide timely and valid warnings to the user when the navigation system must not be used for navigation.**Navigation Uncertainty Category (NUC) –** Uncertainty categories for the state vector navigation variables are characterized by a NUC data set provided in the ADS-B sending system. The NUC includes both position and velocity uncertainties. (This term was used in DO-242. DO-242A separated the integrity and accuracy components of NUC into NIC, NAC, and SIL parameters.)

Operational Mode Code – A code used to indicate the current operational mode of transmitting ADS-B participants.

Own-ship – From the perspective of a flight crew, or of the ASSAP and CDTI functions used by that flight crew, the own-ship is the ASA participant (aircraft or vehicle) that carries that flight crew and those ASSAP and CDTI functions.

Passing Maneuvers – Procedures whereby pilots use: 1) onboard display of traffic to identify an aircraft they wish to pass; 2) traffic display and weather radar to establish a clear path for the maneuver; and 3) voice communication with controllers to positively identify traffic to be passed, state intentions and report initiation and completion maneuver.

Persistent Error – A persistent error is an error that occurs regularly. Such an error may be the absence of data or the presentation of data that is false or misleading. An unknown measurement bias may, for example, cause a persistent error.

Positional Uncertainty – Positional uncertainty is a measure of the potential inaccuracy of an aircraft's position-fixing system and, therefore, of ADS-B-based surveillance. Use of the Global Positioning System (GPS) reduces positional inaccuracy to small values, especially when the system is augmented by either space-based or ground-based subsystems. However, use of GPS as the position fixing system for ADS-B cannot be assured, and positional accuracy variations must be take into account in the calculation of CDZ and CAZ. When aircraft are in close proximity and are using the same position-fixing system, they may be experiencing similar degrees of uncertainty. In such a case, accuracy of relative positioning between the two aircraft may be considerably better than the absolute positional accuracy of either. If, in the future, the accuracy of relative positioning can be assured to the required level, it may be possible to take credit for the phenomenon in calculation of separation minima. For example, vertical separation uses this principle by using a common barometric altitude datum that is highly accurate only in relative terms.

Primary Surveillance Radar (PSR) – A radar sensor that listens to the echoes of pulses that it transmits to illuminate aircraft targets. PSR sensors, in contrast to secondary surveillance radar (SSR) sensors, do not depend on the carriage of transponders on board the aircraft targets.

Proximity Alert – An alert to the flight crew that something is within pre-determined proximity limits (e.g., relative range, or relative altitude difference) of own vehicle.

Range reference – The CDTI feature of displaying range rings or other range markings at specified radii from the own-ship symbol.

Received Update Rate – The sustained rate at which periodic ADS-B messages are successfully received, at a specified probability of reception.

Regime – Divisions in the future airspace structure in contrast to the current concept of domains. Based on the European concept the three regimes are:

1. **Managed Airspace (MAS)**
    - Known traffic environment
    - Route network 2D/3D and free routing
    - Separation responsibility on the ground, but may be delegated to the pilots in defined circumstances
2. **Free Flight Airspace (FFAS)** – FFAS is also known as Autonomous Airspace.
    - Known traffic environment
3. **Autonomous operations Separation responsibility in the air Unmanaged Airspace (UMAS**)
    - Unknown traffic environment
    - See [Rules of the air].

Registration – The process of aligning measurements from different sensors by removing systematic biases.

Required – The capability denoted as Required is necessary to perform the desired application.

Resolution – The smallest increment reported in an ADS-B message field. The representation of the least significant bit in an ADS-B message field.

Safe Flight 21 – The Safe Flight 21 Program was a joint government/industry initiative designed to demonstrate and validate, in a real-world environment, the capabilities of advanced surveillance systems and air traffic procedures. The program is demonstrating nine operational enhancements selected by RTCA, and providing the FAA and industry with valuable information needed to make decisions about implementing applications that have potential for significant safety, efficiency, and capacity benefits.

Seamless – A "chock-to-chock" continuous and common view of the surveillance situation from the perspective of all users.

Secondary Surveillance Radar (SSR) – A radar sensor that listens to replies sent by transponders carried on board airborne targets. SSR sensors, in contrast to *primary surveillance radar* (PSR*)* sensors, require the aircraft under surveillance to carry a *transponder*.

Selected Target – A selected target is a target for which additional information is requested by the flight crew.

Sensor – A measurement device. An air data sensor measures atmospheric pressure and temperature, to estimate pressure altitude, and pressure altitude rate, airspeed, etc. A *primary surveillance radar* (PSR) sensor measures its antenna direction and the times of returns of echoes of pulses that it transmits to determine the ranges and bearings of airborne targets. A *secondary surveillance radar* (SSR) sensor measures its antenna direction and the times of returns of replies from airborne transponders to estimate the ranges and bearings of airborne targets carrying those transponders.

Separation – Requirements or Separation Standards – The minimum distance between aircraft/vehicles allowed by regulations. Spacing requirements vary by various factors, such as radar coverage (none, single, composite), flight regime (terminal, en route, oceanic), and flight rules (instrument or visual).

Separation Violation – Violation of appropriate separation requirements.

Source Integrity Level (SIL) – The Source Integrity Level (SIL) defines the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. Although the SIL assumes there are no unannunciated faults in the avionics system, the SIL must consider the effects of a faulted Signal-in-Space, if a Signal-in-Space is used by the position source. The probability of an avionics fault causing the reported horizontal position to exceed the radius of containment defined by the NIC, without alerting, is covered by the System Design Assurance (SDA) parameter.

Spacing – A distance maintained from another aircraft for specific operations.

State (vector) – An aircraft's current horizontal position, vertical position, horizontal velocity, vertical velocity, turn indication, and navigational accuracy and integrity.

Station-keeping – Station-keeping provides the capability for a pilot to maintain an aircraft's position relative to the designated aircraft. For example, an aircraft taxiing behind another aircraft can be cleared to follow and maintain separation on a lead aircraft. Station-keeping can be used to maintain a given (or variable) separation. An aircraft that is equipped with an ADS-B receiver could be cleared to follow an FMS or GNSS equipped aircraft on a GNSS/FMS/RNP approach to an airport. An aircraft doing station-keeping would be required to have, as a minimum, some type of CDTI.

Subsystem Availability Risk – The probability, per flight hour, that an ASA subsystem is not available, that is, that it is not meeting its functional and performance requirements.

was operating at the start of the hour or operation, that the subsystem will continue to be available through the remainder of the hour or operation.

System Design Assurance (SDA) – Defines the failure condition that the position transmission chain is designed to support. The position transmission chain includes the ADS-B transmission equipment, ADS-B processing equipment, position source, and any other equipment that processes the position data and position quality metrics that will be transmitted.

Target Selection – Manual process of flight crew selecting a target.

Target – Traffic of particular interest to the flight crew.

Target Altitude – The aircraft's next intended level flight altitude if in a climb or descent or its current intended altitude if commanded to hold altitude.

Target Heading – The aircraft's intended heading after turn completion or its current intended heading if in straight flight.

Target State Report (TS Report) – An on-condition report specifying short-term intent information.

Target Track Angle – The aircraft's intended track angle over the ground after turn completion or its current intended track angle if in straight flight.

TCAS Potential Threat – A traffic target, detected by TCAS equipment on board the own-ship, that has passed the Potential Threat classification criteria for a TCAS TA (traffic advisory) and does not meet the Threat Classification criteria for a TCAS RA (resolution advisory). ([DO-185A, §1.8) (If the ASAS own-ship CDTI display is also used as a TCAS TA display, then information about TCAS potential threats will be conveyed to the CDTI, possibly via the ASSAP function.)

TCAS Proximate Traffic – A traffic target, detected by TCAS equipment on board the own-ship, that is within 1200 feet and 6 NM of the own-ship. ([DO-185A]. §1.8) (If the ASAS own-ship CDTI display is also used as a TCAS TA display, then information about TCAS proximate traffic targets will be conveyed to the CDTI, possibly via the ASSAP function.)

TCAS-Only Target – A traffic target about which TCAS has provided surveillance information, but which the ASSAP function has not correlated with targets from other surveillance sources (such as ADS-B, TIS, or TIS-B).

Time of Applicability – The time that a particular measurement or parameter is (or was) relevant.

TIS-B – Traffic Information Services – Broadcast (TIS-B) is a function on ground systems that broadcasts an ADS-B-like message that includes current position information of aircraft/vehicles within its surveillance volume. The aircraft/vehicle position information may be measured by a ground surveillance system such as a secondary surveillance radar (SSR) or a multilateration system.

Track – (1) A sequence of reports from the ASSAP function that all pertain to the same *traffic target*. (2) Within the ASSAP function, a sequence of estimates of traffic target state that all pertain to the same traffic target.

Track angle – See *ground track angle*.

Track State – The basic kinematic variables that define the state of the aircraft or vehicle of a track, e.g., position, velocity, acceleration.

Traffic – All aircraft/vehicles that are within the operational vicinity of own-ship.

Traffic Conflict – Predicted converging of aircraft in space and time, which constitutes a violation of a given set of separation minima. (ICAO).

Traffic Display – The Traffic Display is a graphical plan-view (top down) traffic display. The Traffic Display may be a stand-alone display or displays (dedicated display(s)) or the CDTI information may be present on an existing display(s) (e.g., multi-function display) or an EFB.

Traffic Display Criteria (TDC) – The surveillance range of ASA will frequently include more traffic than is of interest to the flight crew. Displaying too many traffic elements on the Traffic Display may result in clutter, and compromise the intended function of the CDTI. To determine the traffic of interest to the flight crew, a set of TDC is used to filter the traffic. Criteria generally include range and altitude. Additional criteria may also be used. The flight crew may change the TDC.

Traffic Information Service – Broadcast – A surveillance service that broadcasts traffic information derived from one or more ground surveillance sources to suitably equipped aircraft or surface vehicles, with the intention of supporting ASA applications.

Traffic Situation Display (TSD) – A TSD is a cockpit device that provides graphical information on proximate traffic as well as having a processing capability that identifies potential conflicts with other traffic or obstacles. The TSD may also have the capability to provide conflict resolutions.

Traffic symbol – A depiction on the CDTI display of an aircraft or vehicle other than the *own-ship*.

Traffic target – This is an aircraft or vehicle under surveillance. In the context of the ASA subsystems at a receiving ASA participant, traffic targets are aircraft or vehicles about which information is being provided (by ADS-B, TIS-B, TCAS, etc.) to the ASSAP.

Transmission Rate – The sustained rate at which periodic ADS-B messages are transmitted.

Transponder – A piece of equipment carried on board an aircraft to support the surveillance of that aircraft by *secondary surveillance radar* sensors. A transponder receives on the 1030 MHz and replies on the 1090 MHz downlink frequency.

Trajectory Uncertainty – Trajectory uncertainty is a measure of predictability of the future trajectory of each aircraft. There are a number of factors involved in trajectory predictability. These include knowledge of a valid future trajectory, capability of the aircraft to adhere to that trajectory, system availability (e.g., ability to maintain its intended trajectory with a system failure in a non redundant system versus a triple redundant system), and others.

Update Interval – The time interval between successful message receipt with a given probability of successful reception at a specified range. (Nominal Update Interval is considered 95% probability of successful reception at a specified range.)

Update Rate – The reciprocal of update interval (e.g. if the update interval is 5 s, the update rate = 1/5 ~ 0.20 Hz for the example above).

User-Preferred Trajectories (UPT) – A series of one or more waypoints that the crew has determined to best satisfy their requirements.

Velocity – The rate of change of position. Horizontal velocity is the horizontal component of velocity and vertical velocity is the vertical component of velocity. In these MASPS, velocity is always expressed relative to a frame of reference, such as the WGS-84 ellipsoid**Vref –** The reference landing air speed for an aircraft. It is weight dependent. Flight crews may vary their actual landing speed based on winds, etc.

Appendix B
Bibliography

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B Bibliography

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