3.0 ADS-B and Airborne Systems Definition and ~~Functional~~ Performance Requirements

This section defines, within the context of ASA operational applications, the ADS-B System and its functional and performance requirements. Section 3.1.2 describes the system scope and relates requirements to the operational applications discussed in Section 2. System, Subsystem, and Subsystem Functional Level definitions and requirements are defined in order to support these operational needs. The system description and user equipage classifications are summarized in Section 3.2. System requirements are given in Section 3.3, and ADS-B output report characteristics supporting application needs are described in Section 3.4. In Section 3.5, the system level requirements of Section 3.3 are allocated to the subsystem level for each equipage classification. Required characteristics are defined at each subsystem interface. Functional requirements supporting these capabilities are addressed in Section 3.6. Specification of testable requirements is completed in Section 3.4, so therefore, no new requirement reference numbers are assigned beyond that point.

3.1 System Scope and Definition of Terms

3.1.1 ASA System Scope and Definition of Terms

3.1.2 ADS-B System Scope and Definition of Terms

Figure 3-1 depicts the relationship between the application needs specified in Section 2 and the ADS-B System requirements of this section. Section 2 describes operational applications on an end-to-end basis for a number of typical operational scenarios. ADS-B System functional capabilities required to support these various scenarios are defined in this Section.

When practical, ADS-B System requirements have been examined parametrically based on operationally stressful examples of the general scenarios given in Section 2. This parametric study was based on varying the assumed quality of the input data from the source aircraft and evaluating the tolerable level of degradation permitted by the ADS-B System. The requirements in this Section are independent of the portion of the RF spectrum used for ADS-B transmissions, broadcast protocols, and ADS-B message formats, although some design tradeoff areas are identified.

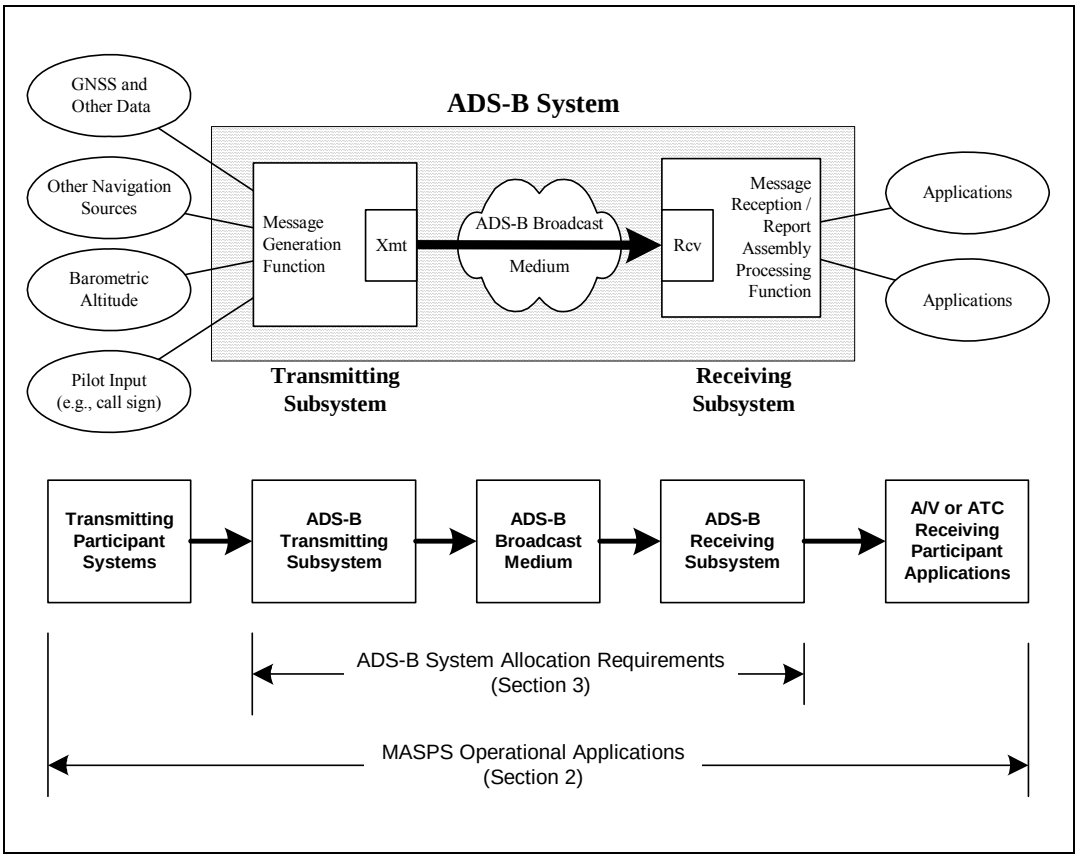


Figure 3-1: Relationship of MASPS Operational Requirements to ADS-B System Requirements

The following key terms are used within this section.

- **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 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.
- **ADS-B Application:** An operational application, external to the ADS-B System, which requires ADS-B Reports as input.
- **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 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 Report:** ADS-B Reports are specific information provided by the ADS-B receiving 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 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 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 Ground Subsystem:** The facility, including antenna(s) which perform ADS-B functionality for a ground-based, non-aircraft ADS-B Receiving Subsystem.
- **ADS-B Subsystem Function:** One element of the functionally partitioned ADS-B Subsystem, e.g. the message exchange function.

The distinction between ADS-B messages, which are ADS-B medium dependent, and ADS-B reports, which are ADS-B implementation independent, should be elaborated. ADS-B messages are transmitted over the ADS-B medium, while ADS-B reports are output by the ADS-B system to external applications supported by ADS-B. It may require the content of one or more ADS-B messages to provide the information for a single ADS-B report. The Report Formats described are intended to address a broad range of near term and future applications for ground and airborne systems. As discussed further in §3.4, a standardized ADS-B report content is specified in this document in order to facilitate early implementation in conjunction with interim ADS-B system implementations and ADS-B supported applications.

3.2 System Descriptions

3.2.1 Aircraft Systems

3.2.1.1 CDTI

3.2.1.2 ASSAP

3.2.1.3 ADS-B Subsystem Description

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

3.2.1.3.1 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.

3.2.1.3.1.1 System Level

ADS-B system level information exchange capabilities are illustrated in the top-level context diagram of Figure 3-2. 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 3.2, 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 Trajectory Change+0 and Trajectory Change+n reports for longer-term intent information, and Air Referenced Velocity reports, which include air speed and heading.

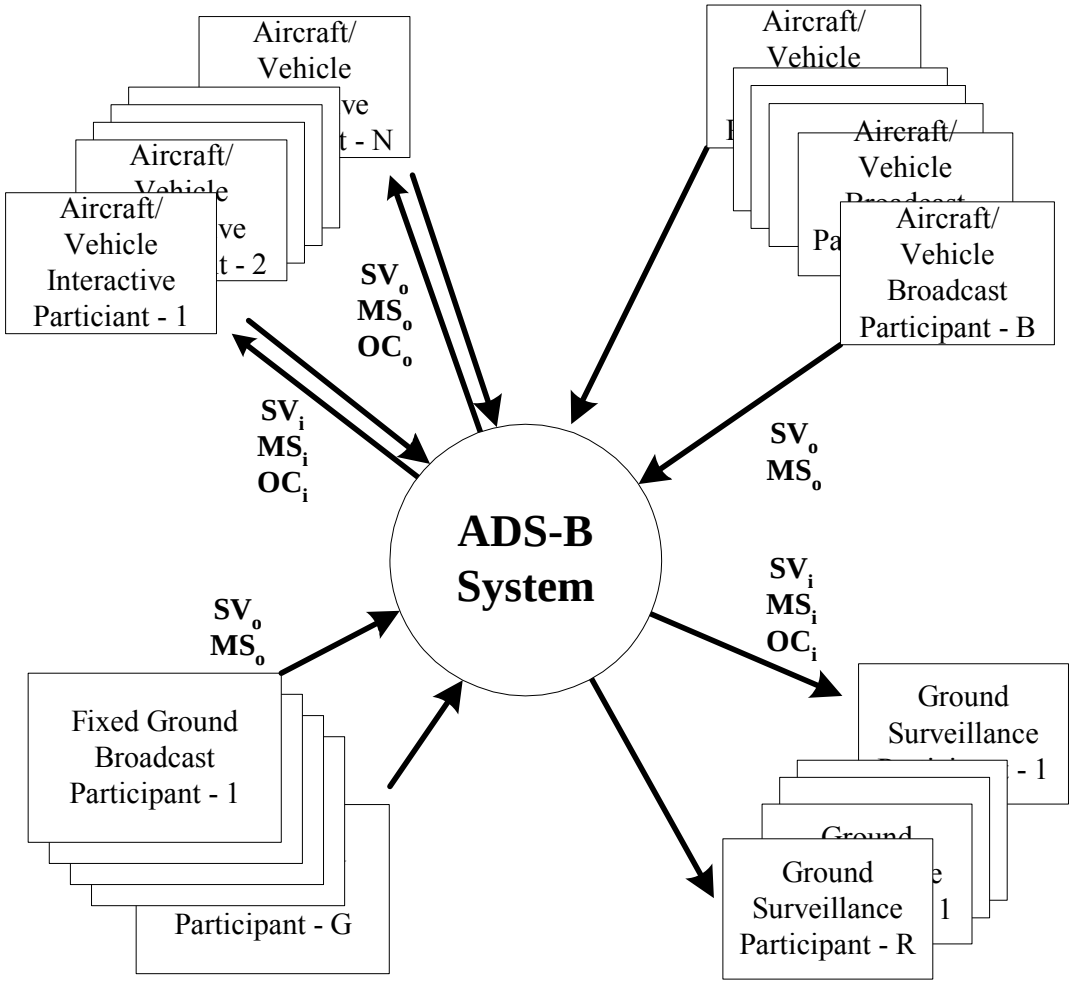
Data for on-condition or event-driven reports are accompanied as needed by appropriate control inputs (e.g., "transmit an ADS-B message under these conditions" as opposed to following a strictly periodic pattern of transmission). Messages transmitted by other ADS-B system participants are received by 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 §3.4.

3.2.1.3.1.2 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 3-3. 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 ($\underline{M}_o$). Similarly defined messages are received from other participants ($\underline{M}_i$), 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 3-2. 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 §3.5.



<u>Figure 3-2</u>: Illustrative ADS-B System Level Context Diagram

<u>Abbreviations:</u>

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

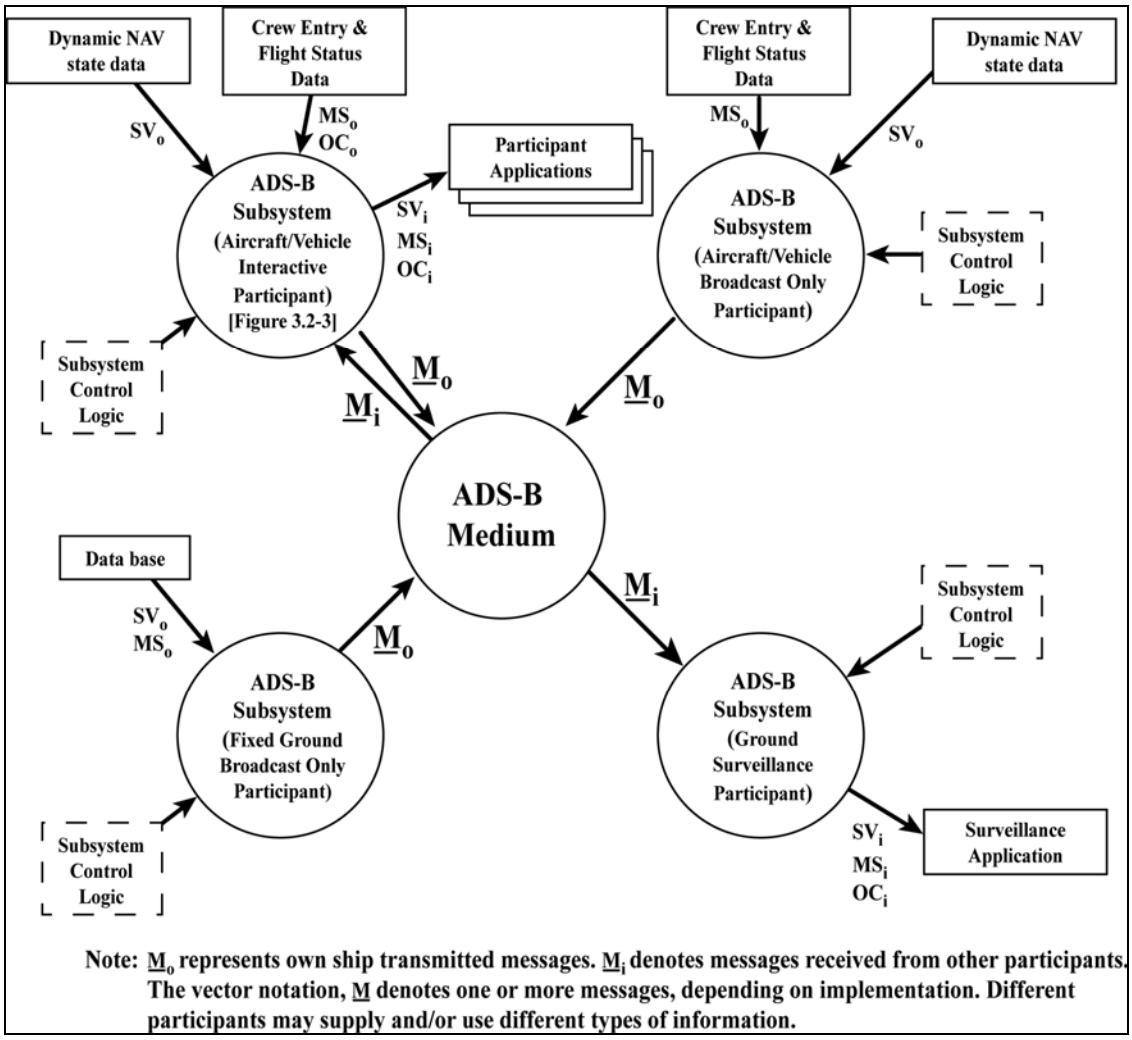


Figure 3-3: ADS-B Subsystem Level Context Diagram for ADS-B System

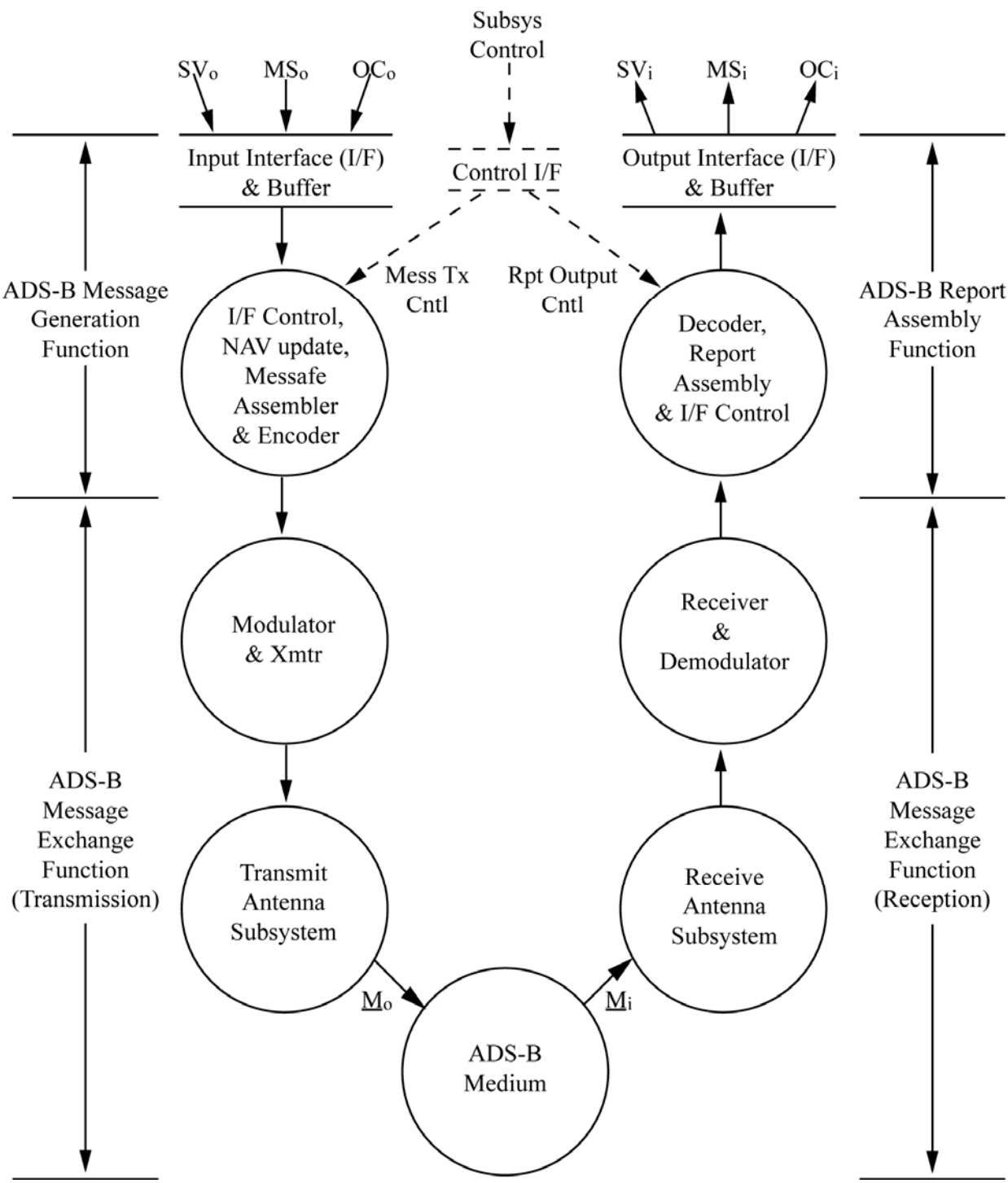


Figure 3-4: ADS-B Functional Level Context Diagram for Aircraft Interactive Subsystem

3.2.1.3.1.3 Functional Level

Subsystem functional partitioning and interfaces are illustrated for an interactive aircraft participant in the functional level context diagram of Figure 3-4. 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. Function level requirements supporting these capabilities are given in greater detail in §3.6. Subsystem functional partitioning and interfaces for broadcast-only and receive-only participants are described by an appropriate subset of this functionality.

3.2.1.3.2 Participant Architecture Examples

Examples of ADS-B subsystem architectures and their interactions are given in Figures 3-3, 3-6 and 3-7. Figure 3-5 illustrates the minimum capabilities on-board aircraft A to support aid to visual acquisition and ADS-B conflict avoidance on-board aircraft B.

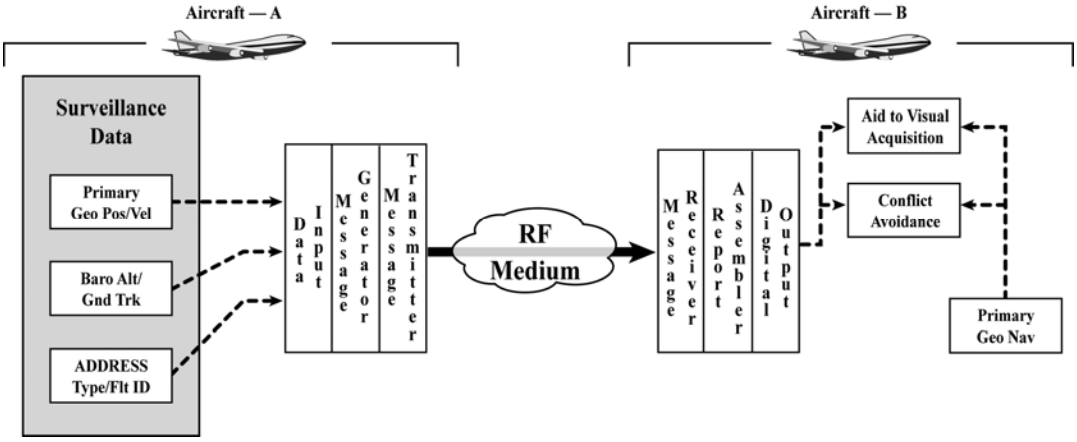


Figure 3-5: Example of A/C Pair Supporting Aid to Visual Acquisition and Conflict Avoidance Applications

Figure 3-6 illustrates expanded capabilities enabled by the more sophisticated onboard avionics. With addition of the ability to exchange intent data, and the ability to support appropriate user applications, each aircraft may be approved for future Free Flight operations.

Figure 3-7 illustrates ADS-B applied to air-ground surveillance. The precise velocity, geometric and air mass data along with intent 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 will require 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.

3.2.1.3.3 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 ~~of this MASPS~~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 ~~discussed in Section 2 can be~~are divided into ~~four~~ 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~~ and TC+0 reports~~)

~~Flight Path De-confliction Planning: pair-wise assessment with strategic intent information (TS, TC+0, and TC+n reports)~~

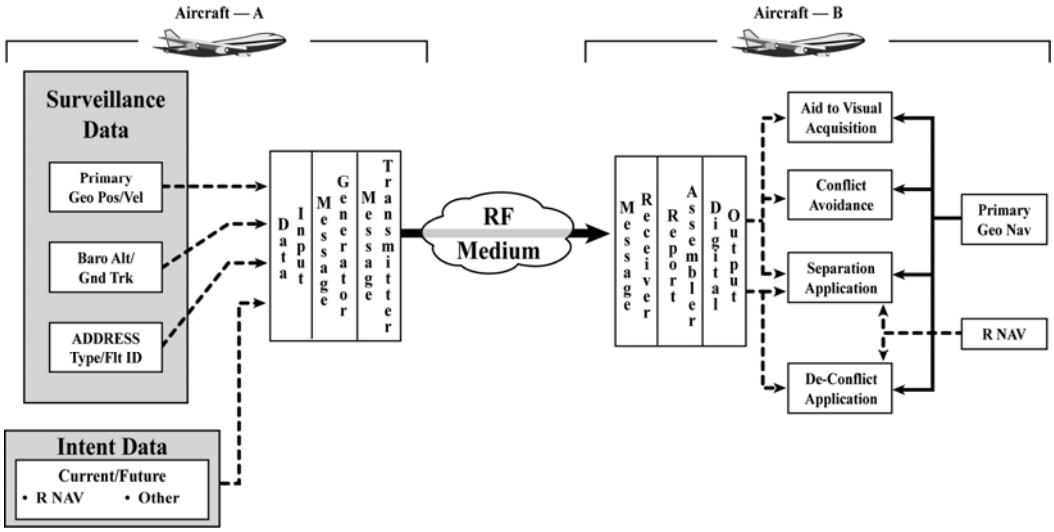


Figure 3-6: Example of A/C Pair Capable of Supporting Self Separation~~Free Flight~~ Applications

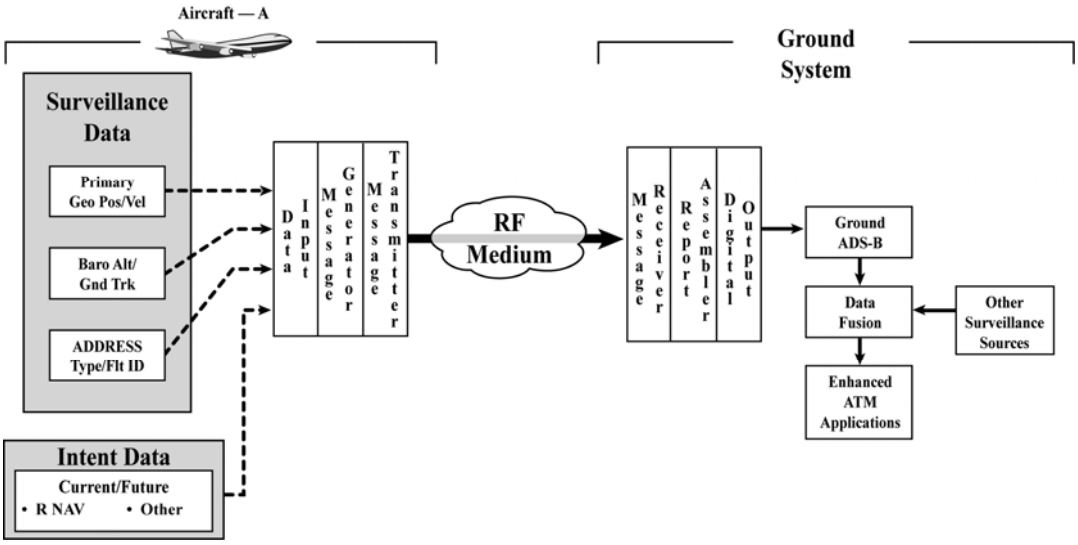


Figure 3-7: Example of ADS-B Support of Ground ATS Applications

ADS-B equipage is categorized according to the classes listed in Table 3-1. ADS-B equipage classes are defined in terms of the four 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 preclude transmission of ADS-B messages when outside the surface movement area.

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

Functional capabilities of interactive aircraft/vehicle subsystems are indicated in the context diagram of Figure 3-4. 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):

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. ~~This service requires the broadcast and receipt of intent information contained in TS and TC+0 reports~~.

Class A3: Supports all class A2 functionality and has additional range capability out to 90 nmi, supporting, e.g., long range airborne applications~~conflict management~~. ~~Class A3 has the ability to broadcast and receive multiple TC reports.~~

3.2.1.3.3.2 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):

Class B0: Aircraft broadcast-only subsystem, as shown in Figure 3-3. 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 3-3. 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: Subsystem Classes and Their Features

Class	Subsystem	~~Example Applications~~Description	Features	Comments
Interactive Aircraft/Vehicle Participant Subsystems (Class A)				
A0	Minimum Interactive Aircraft/Vehicle	Supports basic enhanced visual acquisition~~, conflict detection~~	Lower transmit power and less sensitive receive than Class A1 permitted.	Minimum interactive capability with CDTI.
A1	Basic Interactive Aircraft	A0 plus ~~airborne conflict management, station keeping~~provides standard range	Standard transmit and receive	Provides ~~ADS-B based conflict avoidance and interface to current TCAS surveillance algorithms/ display~~standard range
A2	Enhanced Interactive Aircraft	A1 plus ~~merging, conflict management, in-trail climb~~improved range	Standard transmit power and more sensitive receive. Interface with avionics source required for TS ~~and TC+0 report data~~.~~.~~	~~Baseline for separation management employing intent information.~~Supports longer range applications
A3	Extended Interactive Aircraft	A2 plus long range ~~conflict management~~	Higher transmit power and more sensitive receive. Interface with avionics source required for TS~~, TC+0, and TC+n report data~~	Extends ~~planning horizon for strategic separation employing intent information~~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. NAV input required.	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. NAV input required.	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 NAV 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 NAV 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.

3.2.1.3.3.3 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):

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.

3.3.32.1.4 ADS-B Subsystem Requirements

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 G 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.; t This topic is treated in Appendix H. Considerations involved in using the ADS-B System in very high integrity applications are discussed in Appendix I. ADS-B accuracy and update rate requirements are examined in Appendix J. Appendix K addresses report sample time and latency issues. Acquisition and tracking considerations are discussed in Appendix L.

3.3.32.1.4.1 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) and Table 2-9(b). 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).

ADS-B equipage classes summarized in Table 3-1 **shall** (242AR3.1) provide the air-to-air coverage specified in Table 3.~~3.3~~2.1.4.1a~~3-2(a)~~. 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.~~3.3~~2.1.4.1b~~3-2(b)~~. 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 3-2(a)~~Table 3.~~3.3~~2.1.4.1a and ~~Table 3-2(b)~~Table 3.~~3.3~~2.1.4.1b. Given the air-to-air ranges from Table 2-8, and repeated in ~~Table 3-2(a)~~Table 3.~~3.3~~2.1.4.1a, 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 3-2(b)~~Table 3.~~3.3~~2.1.4.1b 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 H 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 3-2(a)~~Table 3.~~3.3~~2.1.4.1a, 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 3-2(a)~~Table 3.~~3.3~~2.1.4.1a and ~~Table 3-2(b)~~Table 3.~~3.3~~2.1.4.1b are minimum requirements; other applications may require longer ranges.

Ground receiver only subsystem (class C1) coverage examples are given in Table 2-9(a) and Table 2-9(b). 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 this MASPS to specify ground receiver sensitivities (Class C).

Table 3.~~3.3~~2.1.4.1a~~Table 3-2(a)~~: 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 H). [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.~~3.3~~2.1.4.1b ~~3-2(b)~~ Interoperability Ranges in NM for Aircraft Equipage Class Parameters Given in ~~Table 3-2(a)~~Table 3.~~3.3~~2.1.4.1a

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.~~3.3~~2.1.4.2 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 ~~applications~~ capability indicated in ~~Table 3-3(a)~~Table 3.3.~~3~~2.1.4.2a and ~~Table 3-3(b)~~Table 3.~~3.3~~2.1.4.2b.

The rationale for the requirements in ~~Table 3-3(a)~~Table 3.~~3.3~~2.1.4.2a is as follows. Column 1 of ~~Table 3-3(a)~~Table 3.~~3.3~~2.1.4.2a combines the equipage classes (which are based on user operational interests) from Table 3-1 with the required ranges given in ~~Table 3-2(a)~~Table 3.~~3.3~~2.1.4.1a. 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 3-3(a)~~Table 3.~~3.3~~2.1.4.2a and ~~Table 3-3(b)~~Table 3.~~3.3~~2.1.4.2b). 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 3-3(a)~~Table 3.~~3.3~~2.1.4.2a: 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., ~~Conflict Detection,~~ Enhanced V~~v~~isual Acquisition		**R ≤20 NM** ~~e.g., Airborne Conflict management, station keeping~~		**R ≤40 NM** ~~e.g., Merging, conflict management, in-trail climb~~		**R ≤90 NM** ~~e.g., Long range conflict management~~		**R ≤10 NM** **e.g., Enhanced Visual Approach**~~e.g., AILS, paired 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
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 ~~ARV~~	SV MS ~~ARV~~	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
A2 Enhanced R=>40 NM	SV MS ~~ARV~~ TS ~~TC+0~~	SV MS ~~ARV~~ TS ~~TC+0~~	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
A3 Extended R=>90 NM	SV MS ~~ARV~~ TS ~~TC+n~~	SV MS ~~ARV~~ TS ~~TC+n~~	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

1. *SV= State Vector Report; MS = Mode-Status Report~~; ARV = Air Referenced Velocity Report~~; TS = Target State Report.~~; TC+0 = Single Trajectory Change Report capability; TC+n = Multiple TC report capability, n = 1 to TBD~~*
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 ~~and TC+n~~ reports ~~each~~ contain time-critical report elements that, when their values change, need to be updated at higher rates than that of the MS ~~and TC+n~~ reports. See §3.4.4.1, §3.4.8.5, and §3.4.8.6 for details.)*

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~~Table 3-3(b)~~Table 3.~~3.3~~2.1.4.2b: 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., ~~Conflict Detection,~~ Enhanced V~~v~~isual Acquisition		**R ≤ 20 NM** ~~e.g., Airborne Conflict management, station keeping~~		**R ≤ 40 NM** ~~e.g., Merging, conflict management, in-trail climb~~		**R ≤ 90 NM** ~~e.g., Long-range conflict management~~		**R ≤ 10 NM** **e.g., Enhanced Visual Approach**~~e.g., AILS, paired 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 ~~ARV~~ TS~~, TC+n~~	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No
C2 Approach & Surface	No	SV MS ~~ARV~~ TS~~, TC+n~~	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; ~~ARV = Air-Referenced Velocity;~~ TS = Target State Report~~; TC+0 = Single Trajectory Change Report; TC+n = Multiple TC reports, n = 1 to TBD~~*
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.~~3.3~~2.1.4.3 ADS-B Data Exchange Requirements

3.~~3.3~~2.1.4.3.1 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 L 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 L also treats the necessary acquisition time for segmented state vector messages.

3.~~3.3~~2.1.4.3.1.1 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(a)~~Table 3.~~3.3~~2.1.3.3.1.1a. 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 J. The formulation in Appendix J 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(a)~~Table 3.~~3.3~~2.1.4.3.1.1a, 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(a)~~Table 3.~~3.3~~2.1.4.3.1.1a: (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3). ➔ Editor's NOTE: Where do we place information on restrictions on altitude based on Equipment class?? See DO-260B §2.2.2.2.10.1??

~~Table 3-4(a)~~Table 3.~~3.3~~2.1.4.3.1.1a 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.~~3.3~~2.1.4.3.2~~3.3.3.2~~. The maximum errors specified in ~~Table 3-4(a)~~Table 3.~~3.3~~2.1.4.3.1.1a 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 G. 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 G. 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(a)~~Table 3.~~3.3~~2.1.4.3.1.1a 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.~~3.3~~2.1.4.3.2~~3.3.3.2~~).

~~Table 3-4(a)~~Table 3.~~3.3~~2.1.~~4~~.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)		Long Range Applications~~Merging, Conflict Management, In-Trail Climb~~	Extended Range Applications ~~Long Range Conflict Management~~	AILS, Paired Approach	Surface Situational Awareness
	Enhanced Visual Acquisition	Standard Range~~Station Keeping~~				
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(a)~~Table 3.~~3.3~~2.1.4.3.1.1a:

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(a)~~Table 3.~~3.3~~2.1.4.3.1.1a:

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 J 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 H). 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 J and L.*

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(a)~~Table 3.~~3.3~~2.1.4.3.1.1a can be waived provided that the system designer shows that the application design goals stated in Appendix J or equivalent system level performance can be achieved.*

10. *Air-to-air ranges extending to 90 NM are 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.~~3.3~~2.1.4.3.1.2 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(b)~~Table 3.~~3.3~~2.1.4.3.1.1b. For each of the equipage classes included in ~~Table 3-4(b)~~Table 3.~~3.3~~2.1.4.3.1.1b, 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(b)~~Table 3.~~3.3~~2.1.4.3.1.1b. (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(b)~~Table 3.~~3.3~~2.1.4.3.1.1b, 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(b)~~Table 3.~~3.3~~2.1.4.3.1.1b.

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 this 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(b)~~Table 3.~~3.3~~2.1.4.3.1.1b: 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~~Merging, Conflict Management, In-Trail Climb~~	~~Long~~ Extended Range ~~Conflict Management~~Applications	AILS, Paired Approach	Surface Situational Awareness
	Enhanced Visual Acquisition	Standard Range~~Station Keeping~~				
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

Definitions for ~~Table 3-4(b)~~Table 3.3.~~3~~2.1.4.3.1.1b:

n/a: not applicable.

Notes for ~~Table 3-4(b)~~Table 3.~~3.3~~2.1.4.3.1.1b:

1. *Requirements apply to both aircraft and vehicles.*
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 H). 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 ~~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.*
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 ~~are~~ 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.~~3.3~~2.1.4.3.1.3 Air Referenced Velocity Acquisition, Update Interval and Acquisition Range

➔ Editor's Note: After discussion, it was agreed that this entire section will be extracted and put into an Appendix.

Air referenced velocity (ARV) update periods and acquisition range requirements are summarized in ~~Table 3-4(c)~~Table 3.~~3.3~~2.1.4.3.1.1c. 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 ARV on-condition reports 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 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.*

~~Table 3-4(c)~~Table 3.~~3.3~~2.1.4.3.1.1c Summary of Air Referenced Velocity Report Acquisition Range and Update Interval Requirements

Operational Domain →	**Terminal, En Route, and Oceanic / Remote Non-Radar ↓**			
Applicable Range →	**R ≤ 10 NM**	**10 NM < R ≤ 20 NM**	**20 NM < R ≤ 40 NM**	**40 NM < R ≤ 90 NM**
Equipage Class →	A1 required	A1 required	A2 required	A3 required
ARV Acquisition Range	n/a (see note)	20 NM	40 NM	90 NM
ARV Nominal Update Period (95%) when ground referenced velocity data not available	5 s	7 s	12 s	12 s

Note for ~~Table 3-4(c)~~Table 3.~~3.3~~2.1.4.3.1.1c:

This row is meant to specify the minimum acquisition ranges for all class A equipage classes. Since A1, A2, and A3 equipment all have minimum acquisition ranges greater than 0 NM, no requirement is specified in this cell.

The Air Referenced Velocity (ARV) report must be broadcasted under the conditions defined in §3.4.6.1.

Note: *If messages to support the ARV report are being transmitted under other conditions than those which require its update as specified in §3.4.6.1, acquisition ranges and update periods do not have to meet the above requirements.*

When the ARV report is required as defined in §3.4.6.1:

a. The ARV report's nominal update interval **shall** (242AR3.15) be 5 seconds for A1, A2, and A3 equipment at ranges of 10 NM and closer.

b. The ARV report's nominal update interval **shall** (242AR3.16) be 7 seconds for A1, A2, and A3 equipment at ranges greater than 10 NM and less than or equal to 20 NM.

c. The ARV report's nominal update interval **shall** (242AR3.17) be 12 seconds for A2 equipment at ranges greater than 20 NM and less than or equal to 40 NM.

d. The ARV report's nominal update interval **shall** (242AR3.18) be 12 seconds for A3 equipment at ranges greater than 40 NM and less than or equal to 90 NM.

When the ARV report is required as defined in §3.4.6.1, its acquisition range in the forward direction **shall** (242AR3.19) be:

a. 20 NM for equipage class A1,

b. 40 NM for equipage class A2, and

c. 90 NM for equipage class A3.

The acquisition range requirements in directions other than forward **shall** (242AR3.20) be consistent with those stated in Note 3 of ~~Table 3-4(a)~~Table 3.~~3.3~~2.1.4.3.1.1a.

3.~~3.3~~2.1.4.3.1.4 Target State~~ and Trajectory Change~~ Report Acquisition, Update Interval and Acquisition Range

Target State~~ and Trajectory Change~~(TS) report update periods and acquisition range requirements are summarized in ~~Table 3-4(d)~~Table 3.~~3.3~~2.1.4.3.1.1d. 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~~ and TC on-condition reports~~ 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~~arget State (TS) and Trajectory Change (TC)~~ 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 ~~intent~~ 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 TSS ~~or TC report~~ 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 R3.21 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 this 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(d)~~Table 3.~~3.3~~2.1.4.3.1.1d 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 ~~and TC 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(a)~~Table 3.~~3.3~~2.1.4.3.1.1a.

~~Table 3-4(d)~~Table 3.~~3.3~~2.1.4.3.1.1d: 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

Notes for ~~Table 3-4(d)~~Table 3.~~3.3~~2.1.4.3.1.1d:

1. *~~Table 3-4(d)~~Table 3.~~3.3~~2.1.4.3.1.1d 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(d)~~Table 3.~~3.3~~2.1.4.3.1.1d 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 ~~Target State~~TS reports at the "state change" update rate are specified in §3.4.7.2.*

~~Table 3-4(e): Summary of TC 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~~
~~TC Report Acquisition Range~~	~~20 NM (A1 optional)~~	~~40 NM~~	~~50 NM (A2 desired)~~	~~90 NM~~	~~120 NM (A3 desired)~~
~~TC+0 state change update period (note 3)~~	~~TBD (See note 4)~~	~~TBD (See note 4)~~	~~TBD (See note 4)~~	~~TBD (See note 4)~~	~~TBD (See note 4)~~
~~TC+0 report nominal update period~~	~~TBD (See note 4)~~	~~TBD (See note 4)~~	~~TBD (See note 4)~~	~~TBD (See note 4)~~	~~TBD (See note 4)~~

~~*Notes for Table 3-4(e):*~~

~~1. *Table 3-4(d) 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(e) 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 Target Change reports at the "state change" update rate are specified in §3.4.8.2.*~~

~~4. *Refer to Appendix N for preliminary estimates of these requirements.*~~

3.~~3.3~~2.1.4.3.2 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.

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 this MASPS. Delays occurring after the information is reported by ADS-B are likewise not considered in this 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.~~3.3~~2.1.4.3.2.1 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.~~3.3~~2.1.4.3.2.2 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 $\geq$ 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.