3.0 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. 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 3.4~~3~~, and ADS-B output report characteristics supporting application needs are described in Section 3.5~~4~~. In Section 3.6~~5~~, the system level requirements of Section 3.~~3~~4 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 3.7~~6~~. Specification of testable requirements is completed in Section 3.~~4~~5, 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.

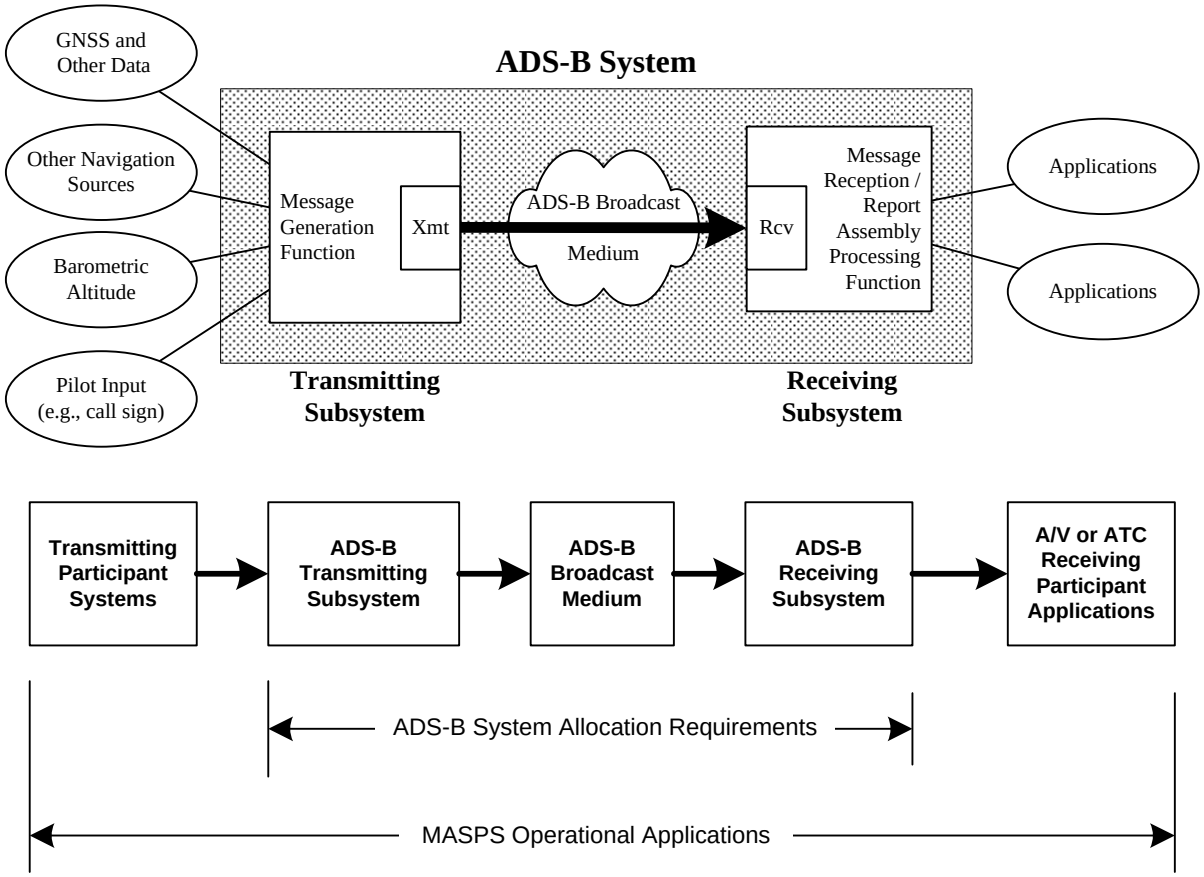

Figure 3-1: Relationship of MASPS Operational Requirements to ADS-B System Requirements

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 §3.54, 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~~3.2.1.3.1.1a. 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 3.2.1.3.1.1a~~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~~Target State reports containing selected altitude and selected heading ~~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~~ 4 and format characteristics associated with the required information exchanges are summarized in §3.~~.4~~5.

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 3.2.1.3.1.1b~~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 3.2.1.3.1.1a~~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 §3.2.1.4~~5~~.

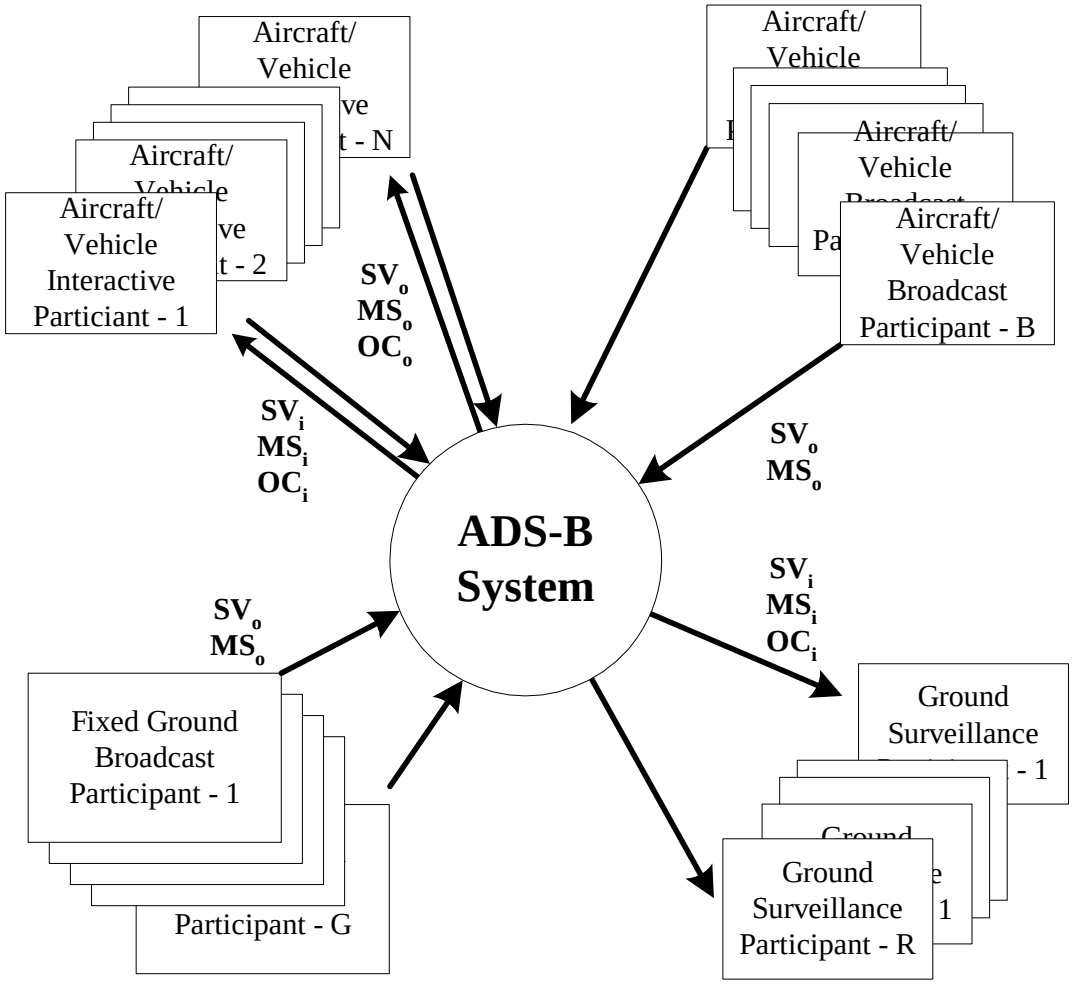

Figure 3.2.1.3.1.1a~~3-2~~: Illustrative ADS-B System Level Context Diagram

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

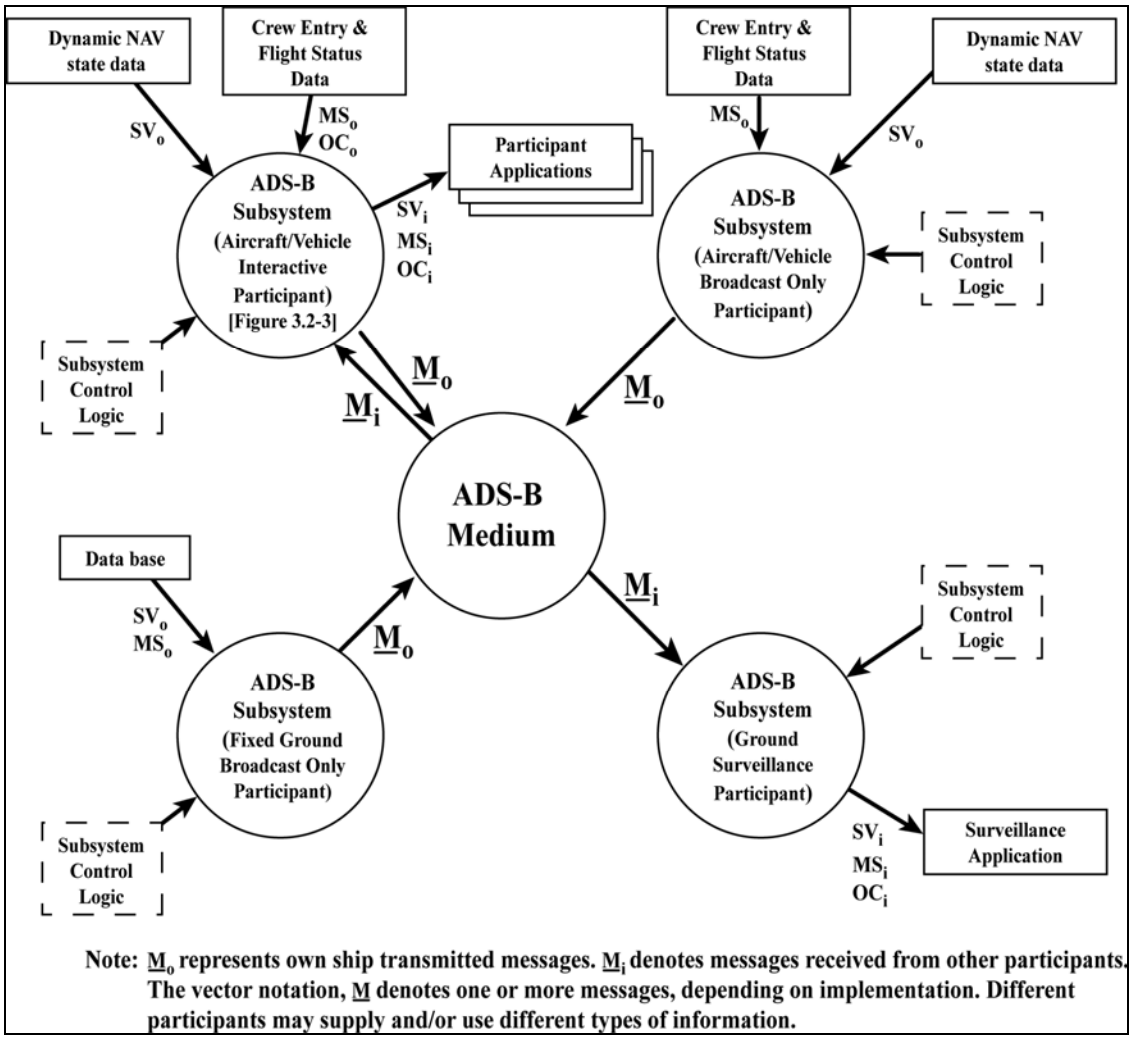

Figure ~~3-3~~3.2.1.3.1.1b.: ADS-B Subsystem Level Context Diagram for ADS-B System

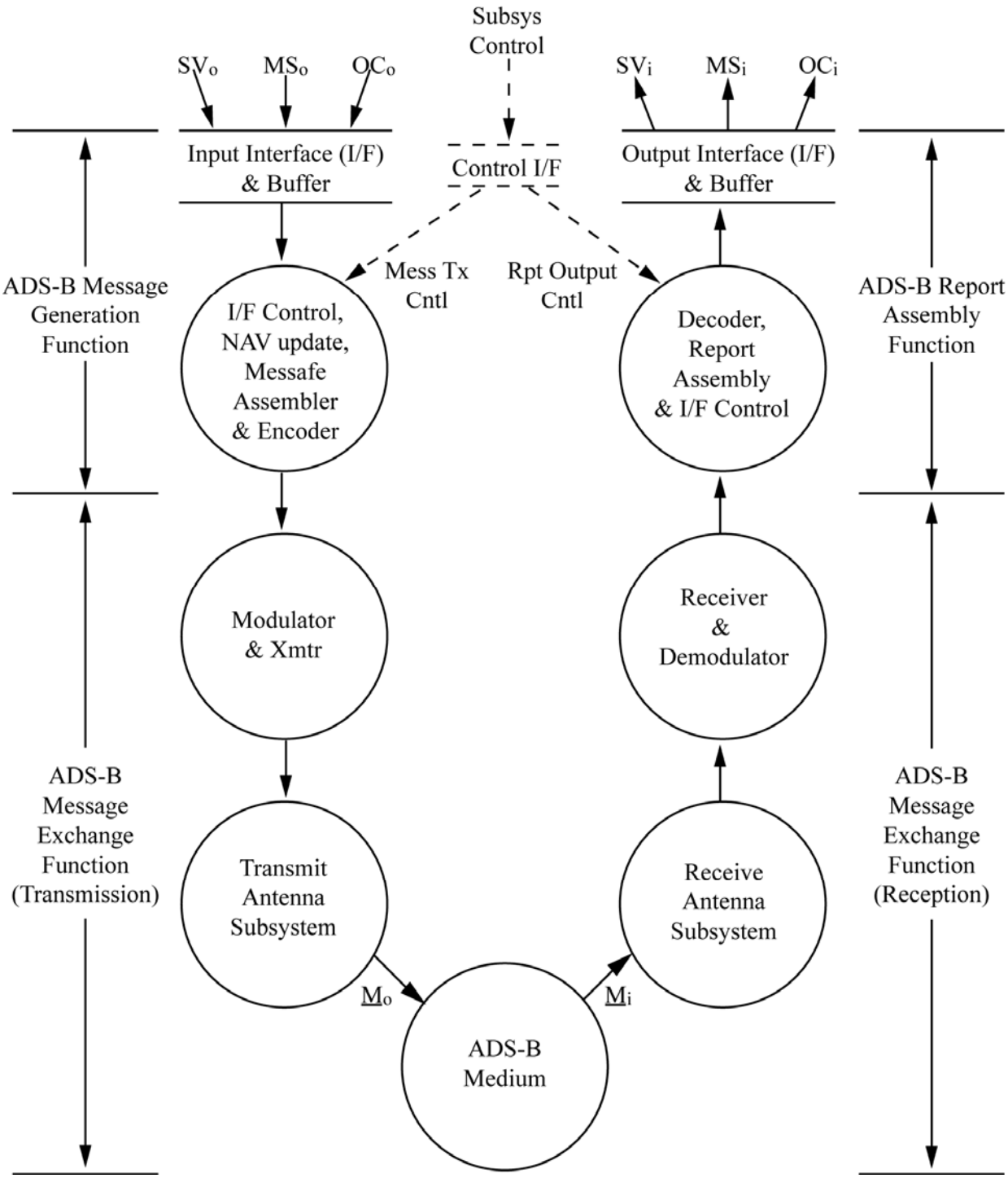

Figure 3-4: ADS-B Functional Level Context Diagram for Aircraft Interactive Subsystem

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~~3.2.1.3.2a, 3.2.1.3.2b ~~3-6~~ and 3.2.1.3.2c~~3-7~~. Figure 3.2.1.3.2a ~~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.

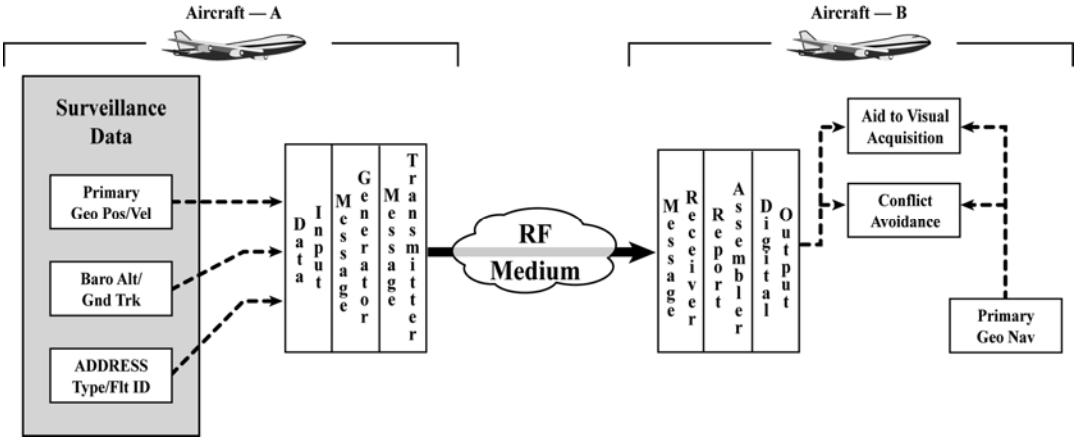

Figure ~~3-5~~3.2.1.3.2a: Example of A/C Pair Supporting Aid to Visual Acquisition and Conflict Avoidance Applications

Figure 3.2.1.3.2b~~3-6~~ illustrates expanded capabilities enabled by the more sophisticated onboard avionics. With ~~addition of the ability to exchange intent data~~more capable ADS-B transmit and receive avionics, and the ability to support appropriate user applications, each aircraft may be approved for ~~future Free Flight operations.~~more advanced ADS-B applications.

Figure 3.2.1.3.2c~~3-7~~ illustrates ADS-B applied to air-ground surveillance. The precise velocity, geometric and air mass data along with ~~intent~~ 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 ~~will~~ 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.

3.2.1.3.3 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 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)

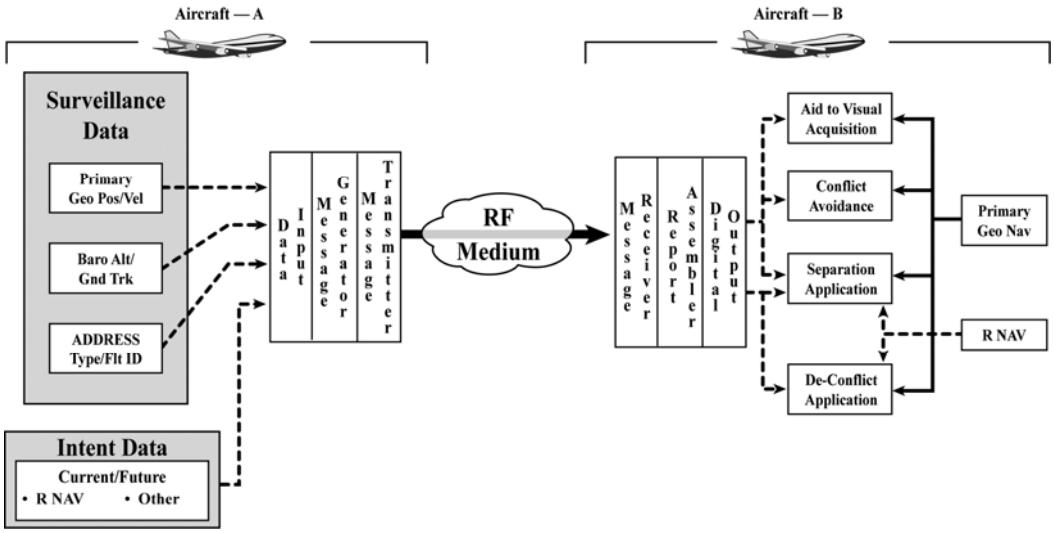

Figure 3.2.1.3.2b~~3-6~~: Example of A/C Pair Capable of Supporting Advanced ~~Self Separation~~ADS-B Applications

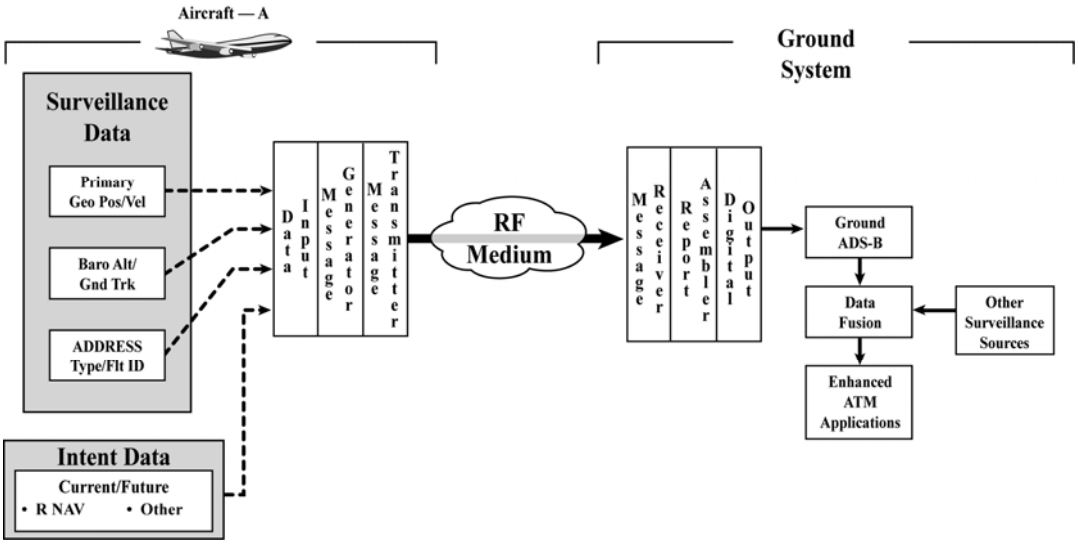

Figure 3-7: Example of ADS-B Support of Ground ATS Applications

ADS-B equipage is categorized according to the classes listed in Table 3.2.1.3.3a ~~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~~ disable 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 3.2.1.3.3a ~~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.

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

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 3.2.1.3.3a ~~Table 3-1~~):

Class B0: Aircraft broadcast-only subsystem, as shown in Figure 3.2.1.3.1.1b~~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 3.2.1.3.1.1b~~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 3.2.1.3.3a~~Table 3-1~~: **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. 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 3.2.1.3.3a ~~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.