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Minimum Aviation System Performance Standards For Automatic Dependent Surveillance Broadcast (ADS-B)

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RTCA/DO-242A

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This report was prepared by Special Committee 186 (SC-186) and approved by the RTCA Program Management Committee (PMC) on June 25, 2002. This document (RTCA/DO-242A) supersedes and replaces its first edition (RTCA/DO-242, dated February 19, 1998).

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1 Purpose and Scope

1.1 Introduction

This document contains Minimum Aviation System Performance Standards (MASPS) for Automatic Dependent Surveillance-Broadcast (ADS-B). These standards specify operational characteristics that should be useful to designers, manufacturers, installers, service providers and users of an ADS-B system intended for operational use on an international basis. This document provides a view of the system-wide operational use of ADS-B, but does not describe a specific technical implementation or design architecture meeting the operational and technical characteristics defined herein.

The diagram in Figure 1-1 shows the relationships between the ADS-B MASPS and other SC-186 documents, such as the ASA MASPS and the 1090 MHz extended squitter (1090ES) Link Minimum Operational Performance Standards (MOPS). Figure 1-1 also shows the functions under the auspices of SC-186 and those functions outside the scope of SC-186. The ADS-B MASPS accepts system level requirements allocated to the ADS-B link function and derives lower level link specific requirements allocated to the various link subsystems MOPS documents.

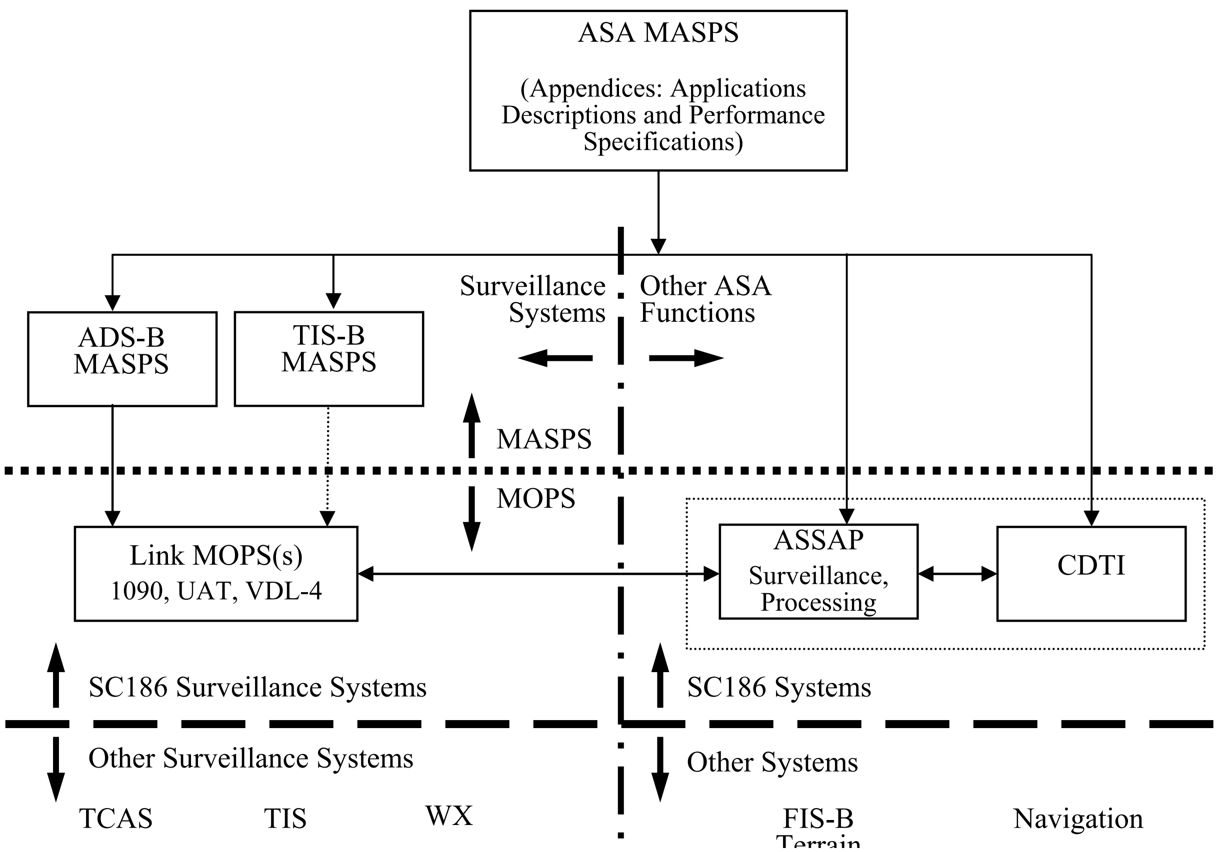

Figure 1-1: Relationship Between ADS-B MASPS And Other SC-186 Documents

Compliance with these standards is recommended as one means of assuring that the ADS-B system, a component of an end-to-end surveillance system, will perform its intended function satisfactorily. Analyses of proposed applications of ADS-B have focused on ADS-B system performance rather than end-to-end surveillance system requirements. The MASPS may be implemented by one or more regulatory documents and/or advisory documents (e.g., certifications, authorizations, approvals, commissionings, advisory circulars, notices, etc.) and may be implemented in part or in total. Any regulatory application of this document is the sole responsibility of appropriate governmental agencies.

The Long Term Intent material (§2.1.2.19.2 and §3.4.8) in this document represents best engineering judgment at the time of publication of this MASPS. This material is therefore necessarily subject to further validation and refinement. It is not intended that ADS-B link MOPS implement requirements for the broadcast of Long Term Intent based on this version of the ADS-B MASPS. However, this material is intended to be used:

- in link design considerations,
- to assess system capacity and performance, and
- as a basis for application development efforts.

ADS-B does not, by itself, guarantee the viability of the applications envisioned in this document. To support operational use of ADS-B, applications may require that appropriate additional systems be installed on aircraft and that appropriate operational procedures be in place.

Note: *ADS-B is a function on an aircraft or surface vehicle that periodically broadcasts its state vector and other information. (ADS-B functional requirements and scope are defined in Section 3.) ADS-B is not to be confused with the applications that it supports, some of which are identified and described conceptually within this MASPS. Specific requirements concerning individual applications will be found in other documents. The reader is advised to contact RTCA for the status and availability of those other documents.*

Section 1 of this document describes the ADS-B system and provides information needed to understand the rationale for system characteristics and requirements. It describes typical applications and operational goals, and establishes the basis for the standards stated in Sections 2 through 4. Definitions and assumptions essential to proper understanding of this document are also provided in Section 1.

Section 2 describes operational requirements. It provides specific scenarios for more detailed analysis based on the applications introduced in Section 1 and also sets forth the information exchange requirements for those applications. Beginning in Section 2 each testable requirement is given a number for reference purposes.

Section 3 defines system level performance requirements, defines subsystems, and allocates these requirements to subsystems. Interfaces and equipage classes are defined as well as specific ADS-B requirements, for example, information exchange content, exchange rates, coverage and capacity.

Section 4 describes the minimum system test procedures to verify that performance meets the system level performance requirements in Section 3. Section 4 lists by reference number each testable requirement contained in the preceding sections.

Acronyms and Definition of Terms are provided in Appendices A and B, respectively. Bibliography and References are provided in Appendix C.

1.2 System Overview

1.2.1 Definition of Automatic Dependent Surveillance Broadcast

ADS-B is a function on an aircraft or a surface vehicle operating within the surface movement area that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B supports improved use of airspace, reduced ceiling/visibility restrictions, improved surface surveillance, and enhanced safety such as conflict management.

When compared to ADS as currently employed in some oceanic regions, the key distinction of ADS-B is that it is a one-way *broadcast* in nature. Under ADS-B, an aircraft periodically broadcasts its own state vector and other information without knowing, a priori, what other aircraft or entities may be receiving it. In addition, the broadcast is made without the expectation of an acknowledgement or reply. With oceanic ADS, on the other hand, provision of such information is usually patterned after two-way Datalink protocols where the end participants are identified and acknowledgments are issued. Further rounding out the definition of ADS-B, it is *automatic* in the sense no pilot or controller action is required for the information to be issued. It is *dependent surveillance* in the sense that the surveillance-type information so obtained depends on the suitable navigation and broadcast capability in the source aircraft.

For the purpose of this document, the term aircraft/vehicle (A/V) will refer to either 1) a machine or device capable of atmospheric flight, or 2) a vehicle on the airport surface movement area (i.e., runways and taxiways). For simplicity, the word *aircraft* is used to refer to aircraft and vehicles, where appropriate. In addition to A/Vs, ADS-B service may be extended to identify obstacles (e.g., an uncharted tower not identified by a current NOTAM). The full set of A/V categories, in the context of ADS-B, is provided in §2.1.2.3. While this section focuses on aviation applications, interoperability between different applications is desirable; for example, search and rescue operations.

ADS-B consists of the following components: a transmitting subsystem that includes a message generation and transmission functions at the source A/V, the propagation medium, and a receiving subsystem that includes message reception and report assembly functions at the receiving A/V or ground systems (Figure 1-2). As described later, some ADS-B participants may be able to transmit but not receive. In addition, some ground-based users may be able to receive but not transmit.

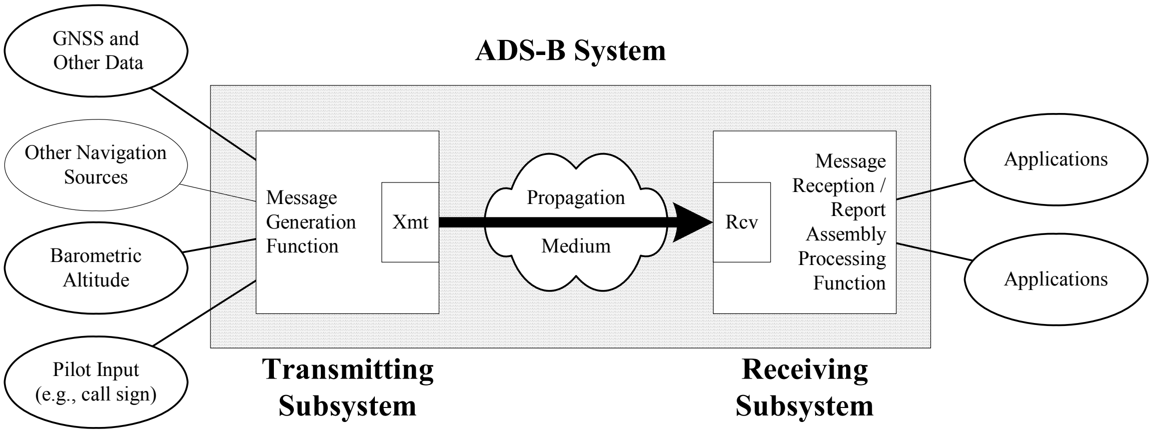

Figure 1-2: Functional Relationship between ADS-B and Surveillance Applications

The source of state vector and other transmitted information as well as user applications are not considered to be part of the ADS-B system.

The radio frequencies used for the ADS-B transmissions will operate in internationally allocated aeronautical radionavigation service band(s).

Although the emphasis of this document is on the application of ADS-B in the Air Traffic Service (ATS) environment, it is intended that the system be economical and useful under visual flight rules (VFR), where traffic conflict management is primarily air-to-air with ATS assistance, workload permitting. Satisfaction of this VFR need by ADS-B should result in the maximum voluntary equipage by the general aviation (GA) community.

1.2.1.1 Relationship to Primary and Secondary Surveillance Radar

Primary Surveillance Radar (PSR) is generally described as independent, non-cooperative surveillance. PSR is independent, because the user of the surveillance information derives the surveillance data on the subject aircraft by his/her own means (i.e., illumination of the target). PSR is non-cooperative, because the subject aircraft is not required to carry any commonly standardized surveillance-related equipment. Although the nature of the derived information is somewhat limited for ATS support (e.g., poor blip-scan-ratios, confusion with clutter, and lack of target altitude and ID), PSR is robust in the sense that surveillance outage failure modes are limited to those associated with the ground radar system.

Except for barometric altitude, Secondary Surveillance Radar (SSR) is considered to be an independent, cooperative surveillance system. With SSR, the ground-based interrogator makes the target range and azimuth estimates based on the interrogation and subsequent reply of a cooperating beacon (or transponder) carried by the aircraft. Mode-S augments SSR with an aircraft addressing and two-way data link capability. SSR provides more detailed information than PSR, but SSR does not provide information on unequipped aircraft or where the aircraft component has failed. For this reason, SSR considerations must include availability of the transponder as well as the interrogation.

ADS-B is a dependent cooperative surveillance system. As with SSR, common equipage is required for participation in the system. In addition to position information, ADS-B provides other types of information, including velocity, and aircraft intent. Unlike ground based radar, ADS-B information is directly available to airborne as well as ground receivers. ADS-B surveillance failure modes, however, include both the navigation source of the reported state vector information as well as operation of the ADS-B transmitter units or the ADS-B receiver units. The use of a navigation unit output for both navigation and cooperative surveillance introduces a common failure mode that must be accommodated in ATS systems.

1.2.1.2 Relationship to Addressed ADS

ADS-B is inherently different from the addressed form of ADS that is being implemented (i.e., per "Minimum Operational Performance Standards for Airborne ADS Equipment," RTCA DO-212[1]) in support of oceanic aeronautical operations. Addressed ADS (ADS-A) is based on a negotiated one-to-one peer relationship between an aircraft providing ADS information and a ground facility requiring receipt of the ADS messages. In some parts of the world this is known as ADS Contract (ADS-C).

1.2.1.3 Relationship to Other Broadcast Services

Other services may also be provided to aircraft via broadcast, typically from the ground, such as delivery of flight information services (e.g., weather text, weather graphics, NOTAMs and ATIS). The broadcast of this information is referred to as Flight Information Service Broadcast (FIS-B). FIS-B is inherently different from ADS-B in that it requires sources of data external to the aircraft or broadcasting unit, and has different performance requirements such as periodicity of broadcast. There may also be other aircraft-based broadcast capabilities, e.g., to transmit aircraft measurements of meteorological data. Another potential application of broadcast services is the dissemination of aircraft position reports as collected by the ground-based radar surveillance system to participating users for cockpit display of traffic information. This broadcast service is called Traffic Information Service-Broadcast (TIS-B). All of these other broadcast services are outside the scope of this document.

Whereas ADS-B supports the transmission of state vector and intent information, a technology implementing ADS-B may also support transmission of other types of messages, such as request/reply messages. This document does not address whether the architecture for providing ADS-B also supports the delivery of other aeronautical broadcast or addressed services. Tradeoffs, including whether more than one service shares the same link, are outside the scope of this MASPS.

1.2.2 Operational Goals, Limitations and Considerations

It is conceivable that an ADS-B implementation may support only a subset of applications. A major goal for ADS-B is to have a single standardized system that supports all applications, if this can be achieved at low cost and low risk with a reasonable implementation schedule. A single system will eliminate the need for A/V owners and ATS service providers to equip with multiple ADS-B systems and technologies. On the other hand, some separation of functions may ease transition and minimize risk, and may allow users to equip with varying levels of capability depending on need. The optimum ADS-B architecture is not known. As a result, the MASPS specifies functional requirements associated with various candidate applications, without prejudice as to which applications may be supported by an ADS-B system.

1.2.2.1 Operational Performance Considerations

This MASPS defines performance specifications for a range of potential applications. There are considerable variations in performance requirements based on the application and environment. There are even performance requirement variations within an application. For example, conflict management may need a higher update rate for close targets, but a lower rate for distant targets. Similarly, the effective update rate of an ADS-B system may exceed requirements for a CDTI see and avoid capability, but may be appropriate for conflict management.

The ADS-B subsystem on an A/V should support anticipated applications in the expected operational environment. Certain ADS-B installations, however, may not support the full message content and/or navigation accuracy required by some applications. In these cases, it is the responsibility of the receiving application to accommodate these limitations.

User configurations may differ. For example, ground systems may extend range through the use of sectorized antennas or enhanced receiver sensitivity. Aircraft antenna systems, on the other hand, have less flexibility, but may not need the same performance as a ground system. For instance an ATS facility may monitor 1000 aircraft using multiple ADS-B ground systems over a 300x300 mile area at a data update period of 5 seconds. An aircraft performing conflict management in that airspace may only be interested in 10 aircraft within a 10 mile radius at a lower update period. Note that in these cases, the effective update period is not necessarily the same as the transmission period. In some operational environments, the possibility exists for a triggering mechanism to initiate a change in the update interval.

Most applications will not require the accuracy or update rate of the most demanding application. In fact, the requirements of almost all of the applications will be significantly less demanding than a few key applications. These key applications may also require higher integrity and certification levels than the great majority of applications. Users can then make an economic decision whether to implement for the more demanding, and presumably more expensive applications. An ADS-B design may reserve certain message types, with possibly higher accuracy and update rate requirements, for these more demanding applications. Applications need to be able to decode and utilize all relevant types of messages, and reject irrelevant types of messages. Applications also need to identify which users are eligible for what level of service depending on the message types they are broadcasting.

From an overall surveillance perspective, ADS-B should provide a seamless[1] continuous service for both aircraft-to-aircraft and aircraft-to-ground surveillance users. From an ATS ground control perspective, this service will be provided by an evolving radar and ADS-B surveillance network. A "chock-to-chock" continuous and common view of the surveillance situation from the perspective of all users will greatly enhance coordination, communication, and safety and is a major goal of ADS-B.

The ADS-B architecture should balance the need for spectrum efficiency with other ADS-B design objectives. Appendix F provides a description of factors that affect spectrum utilization. See RTCA DO-237 [13] for a more complete description of spectrum planning issues.

1.2.2.2 Safety Goals

ADS-B supports improved safety through a combination of enhancements to ATS surveillance coverage and by enabling cost effective techniques to improve flight crew situational awareness. It also provides a common situational awareness in the cockpit and at ATS facilities. ADS-B can extend surveillance coverage and provide ATS services in airspace currently not served by radar-based surveillance systems. ADS-B, as an enabling technology for CDTI and conflict detection systems, supports improved flight safety for all users. These capabilities support Free Flight concepts in all airspace while maintaining a high level of flight safety.

Significant safety advantages are realized through cockpit modernization based on ADS-B. In the terminal area, ADS-B provides safety enhancements both at controlled and uncontrolled airports. Conflict detection using ADS-B information provides runway occupancy and incursion alert functions in all visibility conditions.

1.2.2.3 Economic Goals

In order to be a viable alternative to surveillance radar technology, ADS-B needs to be cost-effective for all levels of airspace users and ground systems.

1.2.2.3.1 Economic Goals—Air Traffic Service Provider

ATS providers could realize cost savings from implementation of an ADS-B based surveillance system. Replacement, upgrade, and maintenance of the existing aging radar-based surveillance infrastructure will be an expensive undertaking. Many secondary surveillance radars (SSRs) could be decommissioned rather than replaced after there is a high percentage of equipage with ADS-B. Because ADS-B ground stations can use simple omni-directional or sectorized antennas and receivers, they should be substantially less expensive than SSRs to acquire and maintain.

[1] No user intervention is required to maintain a consistent surveillance picture across adjacent coverage or operational boundaries.

Economic benefit through the use of ADS-B may be realized in numerous terminal areas. The combination of ADS-B and GNSS technology will support improved all weather operations in the air and on the ground. Airport capacity may be increased under all visibility conditions through the use of improved situational awareness and conflict detection automation. This improved utilization of the airport maximizes the use of existing airport facilities, lowers operating costs, may reduce the need for airport expansion and potentially provides better on-time performance.

1.2.2.3.2 Economic Goals—Airspace Users

Most economic benefits derive from capacity improvements such as envisioned in Free Flight, and safety enhancements. The cost of equipping with ADS-B should be low enough that these benefits can be realized by all airspace users. System design should consider modular implementations permitting the user to tailor the implementation to that user's needs. With appropriate ADS-B equipage, no user should be denied airspace access.

Benefits should be evident so that users can make informed decisions regarding equipage. Airlines and other users should benefit from procedures applicable only to those equipped with ADS-B. Widespread general aviation equipage of ADS-B systems may be facilitated by low cost designs that integrate ADS-B with other avionics (e.g. ELTs, VHF data radios or SSR transponders).

In certain regions, e.g., the U.S., financial incentives could conceivably be provided to aircraft operators that equip with a basic ADS-B providing limited functionality. Users would then decide if they only wanted the basic subsystem, or a more complete subsystem with increased functionality . The user would absorb the cost of an installation above and beyond the minimum capability.

1.2.2.4 System Operational Limitations

Limitations on the ADS-B system may result from the use of a navigation source to support both airborne navigation functions and surveillance functions. This feature places new requirements on both integrity and availability of the service. In order to obtain the integrity required for certain applications, independent position verification methods may be needed to verify the navigation data provided in ADS-B. In some environments, a method or system may be needed to reduce the potential for loss of both navigation and surveillance simultaneously.

Existing ATS procedures have evolved to cover the loss of independent surveillance. These may need further extension to accommodate the common failure modes associated with ADS-B. In any event, the air-to-air performance of ADS-B should not be affected by an ATS ground system failure.

1.2.3 Assumptions

1.2.3.1 Aircraft/Vehicle Equipage

Voluntary equipage is assumed and will be predicated on perceived benefits. Certain benefits may also be predicated on the availability of supporting ground infrastructure. Modular equipage will support a variety of user needs. A low cost minimum ADS-B system will aid voluntary equipage. While ADS-B user equipage will be voluntary, for some applications in certain airspace, equipage may be required. This document also assumes that the majority of users are equipped with GNSS; lesser capable navigation systems will be used primarily as a back-up.

1.2.3.2 ATS Service Provider Equipage

Both primary radars and SSRs may continue to be used in certain operational environments for the foreseeable future (i.e., ADS-B may not totally displace radar-based surveillance systems in high density areas).

ADS-B equipped aircraft may also need to support surveillance by secondary radar systems in certain environments.

Ground ATS systems may need a means to accommodate surveillance reports from both surveillance radars and ADS-B, including concurrent operations.

Surveillance services will be provided continuously across all operational environments and across the boundaries between operational environments.

Primary means of surveillance is defined as a preferred means of obtaining surveillance data for aircraft separation and avoidance of obstacles. If an ADS-B system is intended as a component for primary surveillance, then the surveillance system should satisfy fail-safe operation of navigation and surveillance, i.e., a failure of the navigation system should not result in a failure of the surveillance function. Once there is universal or near-universal equipage with ADS-B in an airspace, primary radars and/or SSRs may no longer be required in some areas. However, in certain domains ATS is expected to need an independent position validation capability[6] and in some domains a navigation independent surveillance capability is expected to be needed.

1.2.3.3 Standardization

In accordance with the goal for seamless operation of ADS-B across international boundaries, it is assumed that global interoperability of ADS-B will be achieved through harmonization of requirements with other world regions and through ICAO standardization. This may necessitate timely revision of the requirements stated in this document as operational requirements for ADS-B are being developed worldwide.

1.2.4 Operational Environment

ADS-B will operate in an environment that includes diverse levels of traffic and multiple airspace domains as well as the airport surface. Implementation of new ATS services that capitalize on the use of ADS-B will require careful planning to ensure a successful transition from the current ground-based beacon surveillance and ATS services to one in which the airborne user will gradually share in the responsibility for flight plan execution and separation. The required functionality and performance of the aircraft ADS-B subsystems, and ground ADS-B subsystems where applicable, will vary depending on the application under consideration and on the operational context in which the application is to be used. ADS-B will operate within all operational domains. Within these domains, ADS-B will be used for both aircraft-to-aircraft applications (i.e., those applications that pass information directly from one aircraft or vehicle to others, both in the air and on the ground) and aircraft-to-ground applications (i.e., those applications that require information be broadcast from an aircraft or vehicle to fixed ground users).

The major applications that may use ADS-B data are cockpit display of traffic information, aircraft-based collision avoidance, conflict management, ATS surveillance, and ATS conformance monitoring. These and other applications are described in §1.3and Appendices D and E. Additional requirements and/or applications may be addressed in future versions of this MASPS as worldwide requirements are developed.

Note: *In association with ADS-B, an aircraft-to-aircraft addressed data link, or cross-link, may be required for optimization of some applications, for example, airborne collision avoidance*

1.2.4.1 Levels of Functional Capability

ADS-B equipment will have different levels of capabilities certified for their intended use. ADS-B equipment onboard an A/V will conform to one or more functional levels:

One functional level broadcasts automatically and allows the A/V to be seen by other aircraft, vehicles, or fixed ground systems, but provides no support for any on-board applications on the aircraft or vehicle. Other functional levels are associated with the ability to support one or more applications on the A/V, such as cockpit traffic display.

In addition, a fixed ground system may implement a receive only capability. For example, receive only capability may be used in ATS surveillance applications. A detailed specification of the levels of functional capability is provided in Section 3.

The functional levels of capabilities discussed above do not fully define the capabilities and performance of an A/V's ADS-B equipment. An ADS-B subsystem should satisfy the performance requirements, as specified in Section 3, and support the specific operational performance requirements, as specified in Section 2, associated with the operational usage for which it is certified.

1.2.4.2 Levels of Operational Service Supported by ADS-B

The performance of an ADS-B subsystem should be consistent with the operational environments in which an equipped aircraft or vehicle is expected to operate (§2.2). The accuracy and integrity of the state vector and other transmitting A/V capability information are contained within the ADS-B reports, and are used by each operational application to determine the acceptability of the data.

1.2.5 Benefits Enabled by ADS-B from other A/Vs

The benefits enabled by ADS-B are related to ATS applications that will use the ADS-B data set. One benefit is increased airspace access. Other benefits can be divided into three main categories:

<u>Pair-wise Benefits (Single Aircraft-to-Single Aircraft)</u>

"Pair-wise" means only the two involved aircraft need to be ADS-B equipped. To realize voluntary equipage with ADS-B, benefits should be available to users equipping before there is substantial aircraft/vehicle equipage or ground infrastructure. Benefits will result from the use of procedures based on pair-wise ADS-B equipage. . The benefits in this category may include capabilities such as:

- In-trail passing maneuvers, such as In-Trail Climb (ITC) or In-Trail Descent (ITD).
- Station-keeping, whereby an aircraft is instructed to maintain a position relative to another aircraft.
- Supporting technology for enhanced collision avoidance systems between equipped aircraft.
- Long range conflict management.

<u>User Benefits based on Ground Infrastructure Improvements</u>

Individual aircraft equipped with ADS-B may realize additional benefits once a ground infrastructure has been deployed. Capabilities that may be enabled by ground infrastructure include:

- Surveillance services in airspace with limited or no radar coverage: Expansion of surveillance services in non-radar airspace will potentially reduce operating delays. Examples include surveillance approach services, possible preferential treatment to equipped aircraft, and reduced clearance intervals to non-radar satellite airports.
- Improved airport surface operations: When all aircraft and vehicles in designated areas of the airport operating area (e.g., vehicles operating on runways and taxiways) are equipped, ADS-B equipage will enhance airport surface movement during low visibility conditions and will also enhance airport safety automation functions that predict potential conflicts.
- Reduced and more flexible separation requirements: In areas where all participants are equipped (e.g., above FL 290), the increased accuracy of ADS-B, its update rate, and the additional parameters it supports may enable the reduction of separation

standards and hence increase airspace capacity and throughput, and may reduce delays and aircraft operating costs.

- Improved ATS ground-based conflict detection operation: The improved capabilities of ADS-B are seen as necessary for ground-based ATS support of Free Flight operations. ADS-B will enhance conflict prediction and alert functions in all operational domains.
- When combined with appropriate automation and other data link applications, ADS-B will provide the capability to optimize the flow of traffic by advising the crew well in advance of optimum cruise speed to avoid holdings at destination and to optimize the use of available airport capacity.

Full Population Benefits

At some time, the aircraft population in high density terminal areas or aircraft operating in high altitude airspace will be fully equipped. For this airspace, there are a number of benefits that include:

- Enhanced situational awareness: Users with a cockpit traffic display will have enhanced situational awareness, with traffic displays enhancing the ability to visually acquire proximate aircraft. Users will also be able to have a more strategic understanding of traffic. A fully capable traffic display may also support an "electronic VFR" see and avoid capability (e.g., cooperative-separation) in IMC conditions in designated airspace where all participants have the capability to monitor the movement of proximate aircraft.
- Improved aircraft- and ground-based conflict management: For example, in support of Free Flight, aircraft wishing to self separate could perform conflict management functions.
- Potential for reduced infrastructure costs: Surveillance via ADS-B is anticipated to be less expensive than the equivalent provided by ground radar systems. Actual cost savings may depend on the additional features that may be required for validation and backup. These costs may be expected to be highest in high density terminals, which would have the most stringent requirements for independent validation and backup. Lower levels of independent surveillance capability would likely be adequate in lower traffic density areas. Thus for some full population domain areas (especially lower traffic density areas), it may be possible to decommission radar equipment, reducing overall operating costs.

1.2.6 Aircraft Equipment Overview

The aircraft equipment for ADS-B includes a message generation function, transmission function, a receiver with message receipt and report assembly processing function (these may be optional in some implementations), and a number of interfaces (see Figure 1-2). Based on the intended use for an A/V, the ADS-B subsystem may be interactive, broadcast only or receive only. §3.2.2defines equipage classifications for air and ground capabilities. Depending on the implementation of the ADS-B avionics, some of the information may be constant (e.g., aircraft/vehicle category). For fixed obstacles, a message may be generated with no variable information.

Aircraft equipment may include:

- Backup sources of navigation data and interfaces (e.g., redundant GNSS, LORAN, FMS/RNAV, or INS)
- Augmented GNSS processing (to increase the state vector accuracy and/or integrity)
- Barometric pressure altitude and interface as required
- Interface to applications that process ADS-B reports from other aircraft
- Pilot interface (e.g., to allow pilot entry of fields such as the Call Sign or emergency status)
- Application equipment, such as processors and displays (see aircraft applications in §1.3).

1.2.7 Ground Equipment Overview

Ground equipment will vary depending on the ground application. At a minimum, there will be equipment to receive ADS-B messages. Based on these messages, ADS-B reports will be provided to ground applications, and may be combined with other information (such as radar data). Ground applications are listed in §1.3; other applications may also be implemented to meet a specific user need.

1.2.8 Transition from the Current Surveillance Architecture

The introduction of ADS-B equipment into aircraft and ground stations will be into an existing system of surveillance, navigation, and communications. There will be a period of transition rather than an abrupt change. The transition period will serve several useful purposes. It will allow air and ground participants time to make the equipment changes, which is in keeping with the traditions for such changes. Also it will allow experience to be gathered with ADS-B and the associated GNSS and other sources of navigation information. After a period of transition, which could extend over several years, it is possible that some of the existing systems may be discontinued.

For ATS providers, ADS-B is seen as supplementing and potentially replacing the current radar-based surveillance architecture. As ADS-B is increasingly used, there will be mixed coverage of ADS-B and radar surveillance, see Figure 1-3. Airspace not currently having radar coverage (e.g., low altitude airspace or airport surface) may be the first locations to have ADS-B coverage. During the ADS-B transition period, as changes in ground based systems are introduced to make use of ADS-B information, a number of different changes will be required, involving antennas, receivers, and automation systems including displays. These changes may take several forms and may encompass several intermediate conditions. For example, during one period a ground system may receive ADS-B information and also conduct SSR surveillance on a given aircraft, using a fusion function to merge the two forms of surveillance into a single track for that one aircraft. During a subsequent period, the ground system may receive ADS-B information from an aircraft and not conduct SSR surveillance on that aircraft, while using SSR for surveillance of other aircraft not equipped with ADS-B. For airborne collision avoidance systems, a similar evolution may be expected. To avoid unnecessary constraints during these changes, and to facilitate the acceptance of ADS-B, the ADS-B information may need to be backward compatible with existing capabilities.

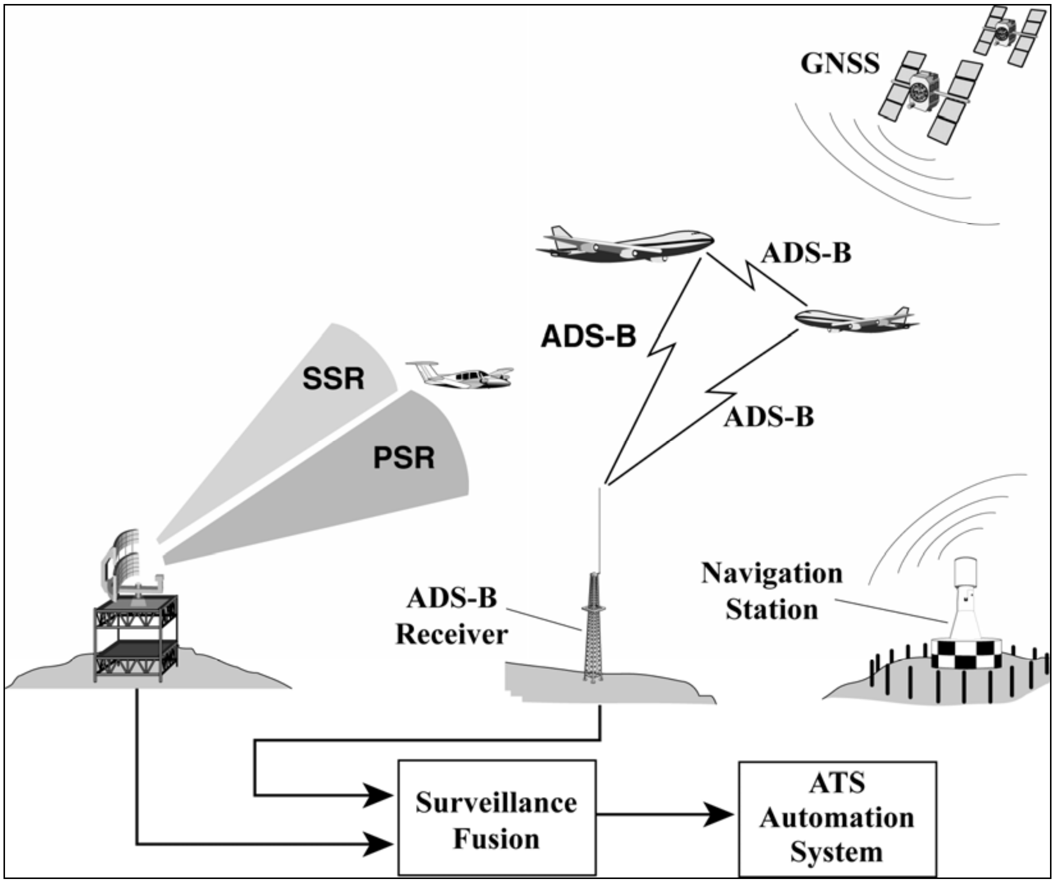

Figure 1-3: ATS Ground Surveillance Transition Configuration

Transitioning to coverage based on ADS-B will be done in incremental steps. In addition, ATS providers will need to update automation in order to take full advantage of ADS-B coverage, along with other improvements aimed at increasing the level of service provided to users. Finally, ATS providers will need to deal with mixed equipage of users in these airspaces for the transition period. For airspace users, transition concerns will be based on the level of service available to a given airspace. These levels of service will depend not only on the individual user's equipage, but may also depend on ground infrastructure improvements and whether other users in the airspace are equipped. A potential ATS ground surveillance configuration is depicted in Figure 1-4.

The transition surveillance architecture may use multi-sensor data fusion at the ATS centers to transform multiple radar and aircraft ADS-B reports into aircraft track files and aircraft path intent files. Controller needs for greater track accuracy and improved maneuver response may first translate into multi-sensor radar data fusion to achieve improved surveillance compared with today's legacy tracking systems. The data fusion codes will then be enhanced to blend ADS-B reports with radar and other remote sources to provide greatly enhanced surveillance capabilities for advanced applications such as surface surveillance and arrival fix metering. The need for more efficient and more weather-independent terminal operations will drive the transition to ADS-B equipage at busy hub airports. However, radar systems may remain to provide services for non-equipped users, and to provide backup capability in the event of ADS-B system failures.

1.2.8.1 Surveillance Architecture Transition

Many of the benefits related to ADS-B arise from the development of an ATS ground infrastructure to receive aircraft position reports. It is envisioned that much of the present beacon (i.e., secondary) radar-based system could eventually be replaced by an ADS-B surveillance system. The principal issues to be resolved concerning the feasibility of completely replacing beacon radar with ADS-B are the performance and cost of features needed to provide verifiable data to these future ADS-B ground stations. The ability of ADS-B ground stations to be the means for obtaining separation services at least equivalent to those received via SSR radar depends on ADS-B obtaining the required performance level.

Today's surveillance architecture is based on the use of beacon radar (Mode A/C/S) and primary radar. Transponder equipage is optional except for some airspaces (e.g., high altitude, high density, and some aircraft classes [e.g., those required to carry TCAS]). Existing navigation functions and existing surveillance functions are largely independent of each other and are generally based on ground equipment.

It is a design goal that the ADS-B surveillance architecture will achieve sufficient availability, integrity, and other performance measures to eventually achieve more cost effective ground surveillance than currently exists. For example, ADS-B may be the only airborne equipment necessary to support ground surveillance. At a minimum, the performance of the current system may be maintained using different means to achieve it; increased capabilities are also possible. This new architecture should be fully implemented for en route airspace. In some high-density terminal airspace, it is to be determined whether beacon radar will be required to economically and/or technically establish the needed surveillance system performance. Within the framework of an ADS-B based surveillance architecture, the long term role of the use of primary radar will also need to be considered.

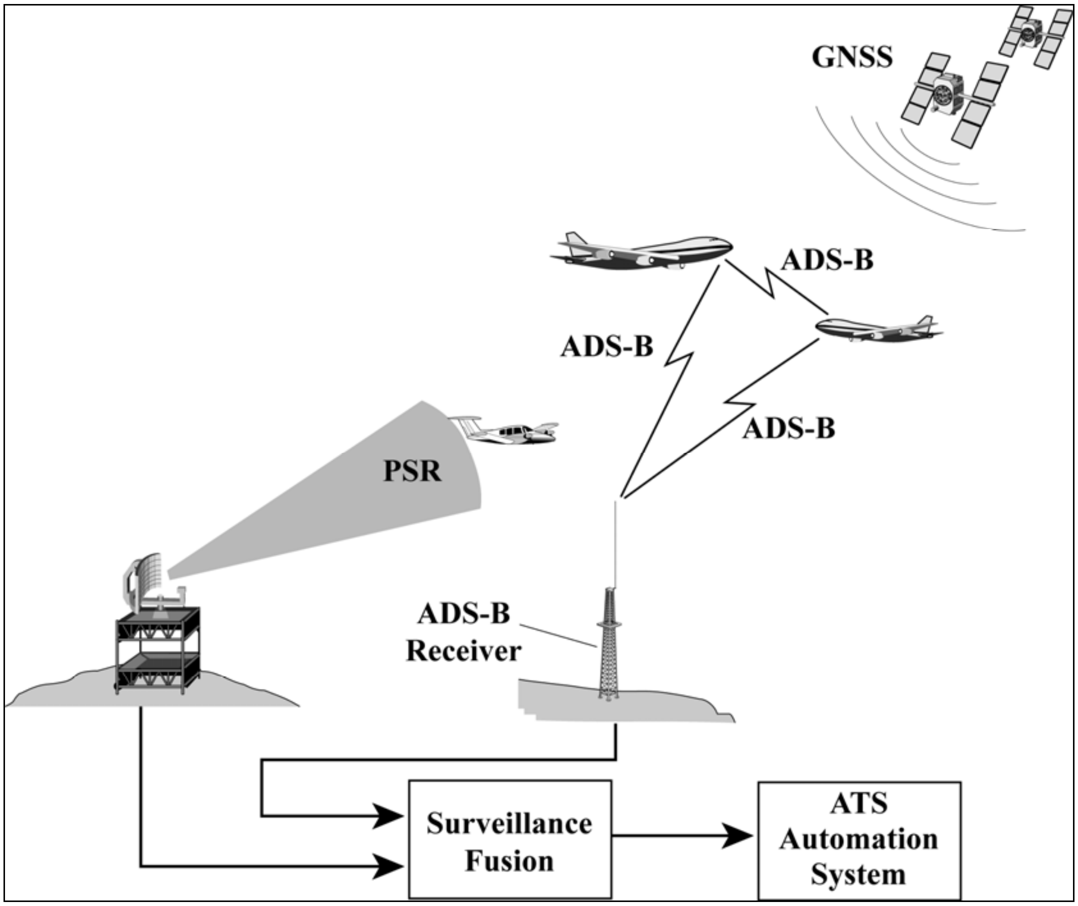

Figure 1-4: Potential ATS Ground Surveillance Configuration

During the ADS-B transition period, mixed SSR transponder and ADS-B equipage in the majority of airspaces will be accommodated (see Figure 1-4). That is, in a given airspace, there may be aircraft equipped with ADS-B, with transponders, with both, or with neither. Except for those cases where equipment requirements are specified, users will not be restricted from entering airspace based on aircraft equipment.

The strategy for integrating ADS-B into the current surveillance environment may require the development of an interface "surveillance data fusion system" to integrate data from the various ADS-B ground stations and existing ATS radars into the various ATS automation systems (see Figure 1-4). Initially, radar data and ADS-B data would be combined in such a way that the addition of ADS-B stations could be easily and effectively assimilated by the existent ATS system and radar data transmission system. Ground systems will display and use the best information about an aircraft if multiple sources are received.

The ATS surveillance data processing functions should be also upgraded in order to take maximum advantage of the additional surveillance information that ADS-B can offer. As ATS systems are upgraded to take full advantage of ADS-B data, the data transfer rate and content of ADS-B data delivered from the surveillance data fusion system could be tailored to meet the operational needs of individual flight domains.

One of the performance issues to be addressed is the effect of combining some navigation and surveillance functions resulting from common use of a navigation system as an information source for surveillance. The design of the surveillance system will need to ensure a means of maintaining safety when failure conditions occur in the ADS-B system.

The transition to a dependent surveillance architecture may be gradual, driven initially by user equipage in combination with associated benefits and increased confidence in the performance of a dependent surveillance system. Concurrent operation of beacon radar and ADS-B will provide a means for situations where increased confidence in the robustness of ADS-B equipment is needed. Equipage with ADS-B avionics is envisioned to be initially voluntary, and will be encouraged. Potential benefit may include increased capability in airspace not covered by radar and possible additional services to users that equip with ADS-B.

In the future, when either ATS procedures and operations become adapted to ADS-B capabilities or the cost to the ATS providers of replacing or modernizing radars becomes prohibitive relative to converting to full ADS-B surveillance, it is envisioned that universal aircraft equipage will be required in certain flight regions or domains, analogous to the airspace restrictions placed today on non Mode A/C transponder equipped aircraft. Some ATS service providers may wish to consider ATS service cost savings as the basis for offsetting the user cost burden of changing equipage. It is recognized that any additional forms of mandatory equipage and the associated cost of equipage is a highly sensitive issue that should be dealt with on a national/international basis, considering the differences in goals and needs of both the airspace users and the service providers.

Specific capabilities that will be introduced based on ground infrastructure improvements include the extension of services to airspace not covered by radar and implementation of ADS-B on the airport surface, improving surface operations. These have been identified by users as high-priority efforts [2].

1.2.8.2 Airspace User Transition

Most of the world's ATS surveillance services in high density airspace systems (including the air traffic control systems of Western Europe and the United States) are based on secondary surveillance beacon radar (SSR). Even with the widespread acceptance and implementation of ADS-B, SSR may still be required for the transition period to support specific surveillance capabilities within certain operational domains.

SSR transponder equipage will continue to be needed to support aircraft operations in airspace where ADS-B is not supported by ground ATS infrastructure. During the transition to a full ADS-B architecture, certain applications may need an independent validation of the ADS-B reported aircraft position in order for the ADS-B information to be used operationally (e.g., multilateration or SSR interrogations of transponders).

1.3 Operational Applications

Implementation of the following operational applications requires development of appropriate concepts, algorithms, procedures, standards and user training. This MASPS does not define these in detail.

1.3.1 Cockpit Display of Traffic Information

A Cockpit Display of Traffic Information (CDTI) is a generic display that provides the flight crew with surveillance information about other aircraft, including their position. Traffic information for a CDTI may be obtained from one or multiple sources (including ADS-B, TCAS, and TIS-B) and it may be used for a variety of purposes. Any means of communicating the information is acceptable (aural, graphical, head-up, etc.) as long as the information is conveyed effectively. Requirements for CDTI information will vary based on intended use of the data (i.e., application). A CDTI, supporting improved awareness of proximate aircraft, is an essential element to supporting a wide range of capabilities in the cockpit. Such a capability can be easily supported by direct air-to-air transmission of ADS-B messages from other aircraft in the same airspace.

With the ability to display the full population of proximate aircraft, the CDTI may be used as an overall situational awareness tool and as an aid to visual acquisition. As such, the display can support visual acquisition as part of the normal see and avoid operations. Visual acquisition is applicable under Visual Meteorological Conditions (VMC) which applies to all pilots, IFR and VFR. The CDTI is also seen as a key element to Free Flight operations. With mature Free Flight, and mutual controller/pilot agreement, separation responsibility may be delegated to the pilot. In this case, the ability to electronically "see and avoid" proximate aircraft becomes a necessary technology to enable the Free Flight concept. For example, the CDTI may be used for "Electronic VFR," with pilots applying "Rules of the Air" (as stated in the ICAO convention of international aviation) to maintain safe separation. The display may also support conflict management.

The CDTI function might display traffic based on ADS-B reports. Additional information may be integrated with this display, such as current weather conditions, selected portions of a pre-stored aviation data base of the terrain, airspace structure, obstructions, detailed airport maps, or other static information relevant to the efficiency and safety of flight.

The CDTI operates in a consistent manner while airborne and while on the airport surface. Depending on the intended use, the CDTI will modify what is displayed. For example, the range may be adjusted depending on the airspace (short range for terminal, long range for oceanic). Altitude may be used as another filter, and aircraft may be highlighted or not displayed depending on whether there is a potential conflict or threat. In addition, the CDTI system may integrate state vector information directly received from ADS-B equipped aircraft with supplementary information, such as could be received from a Traffic Information Service (TIS) [17] or a broadcast traffic information service (TIS-B).

Early benefits can be obtained before all proximate aircraft are visible via the CDTI. The display can be used to execute procedures associated with the identification of a specific aircraft such as passing maneuvers (e.g., ITC) or station-keeping (see pairwise benefits, §1.2.3). For the passing maneuvers procedure, a pilot may be authorized by the controller to increase altitude once the distance and relative speed of the lead aircraft is obtained via the CDTI. For station-keeping, the CDTI displays the lead aircraft along with relevant information (e.g., call sign, ground speed, etc.). Other information, such as a history of the lead aircraft's path, may also be included.

1.3.2 Airborne Collision Avoidance

ADS-B is seen as a valuable technology to enhance operation of airborne collision avoidance systems (ACAS) as defined by ICAO[4]. ADS-B data may be used to improve surveillance performance, for example, by further reducing the potential for airborne interference with ground radar interrogations. It may also be used within the collision avoidance logic to reduce the number of unnecessary alerts and improve the Resolution Advisory maneuver selection process, for example, by eliminating alerts for aircraft which will pass with large lateral separation and by enabling more accurate trajectory prediction.

1.3.2.1 Improvements to Existing Collision Avoidance Systems

Existing collision avoidance systems may benefit in a number of ways from ADS-B; the following list contains some examples:

1. Existing ACAS systems actively interrogate and track other aircraft within their surveillance volume. The surveillance range of ACAS is reduced when operating in high density terminal airspace in order to limit interference to other users of the spectrum (e.g., associated with air/ground ATS surveillance). Use of ADS-B messages may decrease the number of active interrogations required, and increase the effective range of the ACAS system.

2. The collision avoidance algorithms may be enhanced by using highly accurate ADS-B state vector, aircraft intent, and other information. These enhancements may substantially reduce the unnecessary alarm rate.

3. The traffic display which is normally provided with ACAS equipment may also serve as a CDTI supporting other applications. For example, by showing Call Sign on the display, there will be positive identification of other aircraft equipped with ADS-B. Passing maneuvers in oceanic airspace will benefit immediately from positive aircraft identification. See §1.3.1for a discussion of benefits based on the display capability.

4. Extend collision avoidance below 1000 ft. AGL and be able to detect runway incursions.

1.3.2.2 ACAS Based on ADS-B

It may be possible for future ACAS systems to be based solely on ADS-B (i.e., no active interrogations of other aircraft transponders). This would only occur after a significant proportion of aircraft in a given airspace have been equipped with ADS-B, backup mechanisms and procedures have been developed to handle possible system failures, and after the use of ADS-B has been validated through extensive experience. In addition, it would need to be established that common mode failures make a negligible contribution to the risk of collision when ADS-B is used as the basis of separation assurance and collision avoidance. Such an ADS-B based collision avoidance system would probably need the means to coordinate its Resolution Advisories with the TCAS/ACAS function on the other aircraft.

1.3.3 Conflict Management and Airspace Deconfliction

Conflict management and airspace deconfliction functions may be provided both by ground and aircraft automation systems. Aircraft conflict management functions will be used to support cooperative separation during the periods that separation responsibility has been delegated to the aircraft, such as in Free Flight. Ground conflict management functions will also be in place, both as a backup and as the primary tool to monitor aircraft for conflict detection. Airspace deconfliction based on the exchange of intent information will be used for strategic separation.

Since both the pilot and the ground-based ATS controller have the same view of the surveillance picture, including position of own and surrounding aircraft, resolution maneuvers are expected to be better coordinated.

1.3.3.1 On-board Conflict Management and Airspace Deconfliction

ADS-B supports conflict management needs for optimized separation and sequencing as well as on the airport surface (such as in the prediction of potential runway incursions). On the airport surface, the CDTI will aid pilot situational awareness, especially at night and during low visibility conditions.

ADS-B will also allow aircraft to exchange intent information and project their flight paths to detect potential conflicts. Intent may include information concerning changes of trajectory (e.g., top of descent or a turn point). Within airspace designated for Free Flight, users are free to change their altitude, heading and airspeed without a clearance from an air traffic controller as long as new intent information is immediately made available. Rules of the air (ICAO document PANS-RAC 4444) will need to be reviewed to ensure that conflict resolutions of opposing threat aircraft are executed in a coordinated manner.

1.3.3.2 ATS Surveillance and Conflict Management

The current surveillance environment consists of primary radars and SSRs providing continuous high altitude coverage and incomplete low altitude coverage. While air carrier operations do not frequently extend into non-radar ATS areas, commuter operators and general aviation users commonly conduct operations in the non-radar areas. Existing radar technology provides surveillance performance and capabilities that fully support the current ATS operational concepts, however the high cost of such systems excludes their use from many low altitude and remote areas.

ADS-B will support ATS surveillance needs in four main areas:

1. Airport surface surveillance and surface movement. The goal for ADS-B is to support surface movement in low/zero-visibility conditions.

2. Provision of improved surveillance services in non-radar airspace. This includes low-altitude airspace, remote airspace (e.g., mountainous areas), and coastal waters.

3. Enhanced surveillance services and reduced separation standards. The improved accuracy and timeliness of the ADS-B reports, in combination with other capabilities, may allow reduced separation standards to be applied to aircraft.

4. ADS-B is intended to be capable of supporting surveillance. As equipage levels increase, ADS-B may become the primary source of surveillance information for a majority of airspace.

In areas where there is both ADS-B and radar coverage of aircraft, controllers should be provided with a uniform display of surveillance information. The receiving ground surveillance system should have the capability to correlate a received ADS-B report with a radar return.

ADS-B will support ground system conflict management surveillance needs in all airspace domains including the airport surface. Ground automation systems will be able to take advantage of ADS-B information in analysis of potential conflicts. In areas also served by radar, the information reported by an ADS-B aircraft will improve the prediction of potential conflicts. In areas not served by radar, ADS-B may be the primary means for detection of conflicts.

The more accurate state vector information provided by ADS-B will support improved conflict detection with reduced false alarms as compared with radar-based predictions. The availability of intent information will further improve this capability.

1.3.4 ATS Conformance Monitoring

ADS-B will be used to support and enhance ATS conformance monitoring, which is the process of ensuring that an aircraft maintains conformance to its agreed-to trajectory. The degree of deviation from the trajectory, or the conformance bounds, is based on factors such as the aircraft's navigation capability and the separation standards in place. Conformance monitoring occurs for all controlled aircraft or airspace, and applies to all operational airspace domains. In the case of protected airspace or Special Use Airspace (SUA), conformance monitoring is performed to ensure that an aircraft does not enter or leave a specific airspace. Conformance monitoring includes monitoring of simultaneous approaches to multiple runways, and surface operations.

1.3.4.1 Simultaneous Approaches

A specific example of conformance monitoring is the monitoring of simultaneous instrument approaches, a task that enables closer separation between aircraft on adjacent approach courses due to monitoring of each approach path by an ATS controller.

Parallel approaches that are not individually monitored require a stagger between aircraft on adjacent approaches, thus reducing arrival rates. Conformance monitoring of simultaneous approaches using a dedicated ATS controller for each approach stream allows simultaneous approaches to be flown. No stagger is required and the potential arrival rate can be higher than for staggered approaches. Simultaneous approaches can be flown as close as 5,000 ft (three runways) and 4,300 ft (dual runways) with controllers using conventional sensors and displays, and as close as 3400 ft when controllers use PRM, which is a specialized sensor for simultaneous approaches. Simultaneous approaches may also be flown to converging runways, and in the future may be flown along curved or segmented courses that are tailored for local airport noise and arrival procedures. ADS-B may offer a viable alternative to the substantially more expensive PRM technology to support simultaneous approaches, and may allow simultaneous approaches at airports that cannot currently justify the cost of a PRM or conventional equipment for simultaneous approach monitoring.

1.3.4.2 Incursion Processing

ADS-B information may be used to support incursion processing for both airborne and surface operations. Specific zones may be defined including:

- special use airspace,
- restricted airspace,
- hazardous weather locations,
- runways and taxiways,
- lighting control areas (areas where lighting is under ATS control),
- weight limited or wingspan limited areas, and
- other operational control zones such as noise sensitive areas.

Projected position information based on ADS-B state vectors, when used in combination with zone incursion processing, can provide early warnings to ATS and the pilot.

1.3.5 Other Applications

Other applications for ADS-B may not be directly related to ground-based surveillance, CDTI, or a Traffic Situation Display (TSD), but still offer many users a direct economic or operational benefit. These should be developed and exploited as a means to encourage users to promptly and voluntarily equip with ADS-B systems. Some examples of these other applications are summarized below. These applications, and others, are described in greater detail in Appendix E. Although this section lists potential applications for ADS-B, these applications are not seen as services that drive requirements for ADS-B.

- Improved Search and Rescue
- Enhanced Flight Following
- Lighting Control and Operation
- Airport Ground Vehicle and Aircraft Rescue and Fire Fighting (ARFF) Vehicle Operational Needs
- Altitude/Height Keeping Performance Measurements
- General Aviation Operations Control

1.4 Verification Procedures

The verification procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirements. Although specific test procedures are cited (Section 4), it is recognized that other methods may be used. Alternate procedures may be used if it can be demonstrated that they provide at least equivalent information. System performance tests as they relate to operational capability are the most important tests. Subsystem tests are useful as subsystems are added during system buildup and to ensure continued subsystem performance as it relates to system performance.

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2 OPERATIONAL REQUIREMENTS

2.1 General Requirements

ADS-B is designed to support numerous applications. Many of these applications are described in this Section and in the Appendices. None of these applications are currently designed, implemented or certified to use ADS-B. An underlying premise of these MASPS is that if these applications were developed to the point that the ADS-B requirements for these applications were fully specified it would delay any work on ADS-B for a number of years. Rather, it was decided to develop reasonable requirements for ADS-B based on operational judgment and initial analysis for a number of stressful applications. These applications are described in this section. The requirements derived from these scenarios are thought to be reasonable for the initial implementation of these applications. Applications not described in this section and less demanding subsets of the applications herein are expected to have requirements less stringent than those developed in the section. The capability of the ADS-B system described in this MASPS is a compromise of capabilities of current ADS-B technology and the intermediate term requirements of the applications. The system requirements in this MASPS will generally require further validation in the context of specific ADS-B applications. More stringent requirements speculated for the long term are accounted for by the required expandability described in §2.1.1.3.

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

The following key terms are used within this section.

- **ADS-B Message**. An ADS-B Message is a block of formatted data that conveys the information elements used in the development of ADS-B reports. Message contents and formats are specific to the ADS-B data link; this MASPS does not address message definitions and structures.
- **ADS-B Report**. An ADS-B report contains the information elements assembled using messages received from a transmitting participant. These information elements are available for use by applications external to the ADS-B system.

2.1.1 General Performance

2.1.1.1 Consistent Quantization of Data

When the full resolution of available aircraft data cannot be accommodated within an ADS-B message, a common quantization algorithm **shall** (R2.1) be used to ensure consistent performance across different implementations. To minimize uncertainty, a standard algorithm for rounding/truncation is required for all parameters. For example, if one system rounds altitude to the nearest 100 ft and another truncates, the same measured altitude could be reported as different values.

2.1.1.2 ADS-B Reports Characteristics

The output of ADS-B **shall** (R2.2) be standardized so that it can be translated without compromising accuracy. The ADS-B reports should support surface and airborne applications anywhere around the globe and should support chock-to-chock operations without the need for pilot adjustments or calibrations.

2.1.1.3 Expandability

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

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

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

2.1.2 Information Transfer Requirements

The ADS-B system **shall** (R2.3) be capable of transmitting messages and issuing reports containing the information specified in the following subsections. This MASPS does not specify a particular message structure or encoding technique. The information specified in the following subparagraphs can be sent in one or more messages in order to meet the report update requirements specified in Section 3.

2.1.2.1 Time of Applicability (TOA)

The time of applicability (TOA) of ADS-B reports indicates the time at which the reported values were valid. Time of applicability **shall** (R2.4) be provided in all reports. Requirements on the accuracy of the time of applicability are addressed in Section 3.

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

2.1.2.2 Identification

The basic identification information to be conveyed by ADS-B **shall** (R2.5) include the following elements:

- Call Sign (§2.1.2.2.1)
- Participant Address (§2.1.2.2.2.1) and Address Qualifier (§2.1.2.2.2.2)
- ADS-B Emitter Category (§2.1.2.2.3)

2.1.2.2.1 Call Sign

ADS-B **shall** (R2.6) be able to convey an aircraft call sign of up to 8 alphanumeric characters in length [6]. For aircraft/vehicles not receiving ATS services and military aircraft the call sign is not required.

Note: The call sign is reported in the Mode-Status (MS) report (§3.4.4 and §3.4.4.4 below).

2.1.2.2.2 Participant Address and Address Qualifier

The ADS-B system design **shall** (R2.7) include a means (e.g., an address) to (a), correlate all ADS-B messages transmitted from the A/V and (b), differentiate it from other A/Vs in the operational domain.

Those aircraft requesting ATC services may be required in some jurisdictions to use the same 24 bit address for all CNS systems. Aircraft with Mode-S transponders using an ICAO 24 bit address **shall** (R2.8) use the same 24 bit address for ADS-B. All aircraft/vehicle addresses **shall** (R2.9) be unique within the applicable operational domain(s).

The ADS-B system design **shall** (R2.10) accommodate a means to ensure anonymity whenever pilots elect to operate under flight rules permitting an anonymous mode.

Notes

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

2. *Mode A transponder codes are not included in the ADS-B message set. Therefore, ground-based surveillance systems may need to correlate ADS-B messages with Mode A transponder codes to facilitate the integration of radar and ADS-B information on the same A/V.*

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

2.1.2.2.2.1 Participant Address

The Participant Address field **shall** (R2.11) be included in all ADS-B reports. This 24-bit field contains either the ICAO 24-bit address assigned to the particular aircraft about which the report is concerned, or another kind of address that is unique within the operational domain, as determined by the Address Qualifier field.

2.1.2.2.2.2 Address Qualifier

The Address Qualifier field **shall** (R2.12) be included in all ADS-B reports. This field consists of one or more bits and describes whether or not the Address field contains the 24-bit ICAO address of a particular aircraft, or another kind of address that is unique within the operational domain.

<u>*Notes:*</u>

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

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

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

2.1.2.2.3 ADS-B Emitter Category

An ADS-B participant's "emitter category" is conveyed in the Mode-Status report (§3.4.4 and §3.4.4.5). The emitter category describes the type of A/V or other ADS-B participant. The ADS-B system **shall** (R2.13) provide for at least the following emitter categories:

- Light (ICAO) - 7,000 kg (15,500 lbs) or less
- Small aircraft – 7,000 kg to 34,000 kg (15,500 lbs to 75,000 lbs)
- Large aircraft – 34,000 kg to 136,000 kg (75,000 lbs to 300,00 lbs)
- High vortex large (aircraft such as B-757)
- Heavy aircraft (ICAO) - 136,000 kg (300,000 lbs) or more
- Highly maneuverable (> 5g acceleration capability) and high speed (> 400 knots cruise)
- Rotorcraft
- Glider/Sailplane
- Lighter-than-air
- Unmanned Aerial vehicle

- Space/Trans-atmospheric vehicle
- Ultralight / Hang glider / Paraglider
- Parachutist/Skydiver
- Surface Vehicle - emergency vehicle
- Surface Vehicle - service vehicle
- Point obstacle (includes tethered balloons)
- Cluster obstacle
- Line obstacle

Notes:

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

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

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

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

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

2.1.2.3 A/V Length and Width Codes

The A/V length and width codes describe the amount of space that an aircraft or ground vehicle occupies and are components of the Mode-Status report (§3.4.4, §3.4.4.6). The aircraft length and width codes are not required to be transmitted by all ADS-B participants all of the time. However, they *are* required (§3.4.4.6) to be transmitted by aircraft above a certain size, at least while those aircraft are in the airport surface movement area.

2.1.2.4 Position

Position information **shall** (R2.14) be transmitted in a form that can be translated, without loss of accuracy and integrity, to latitude, longitude, geometric height, and barometric pressure altitude. The position report elements may be further categorized as geometric position and barometric altitude.

- The <u>geometric position</u> report elements are horizontal position (latitude and longitude), and geometric height. All geometric position elements **shall** (R2.15) be referenced to the WGS-84 ellipsoid.
- Barometric pressure altitude **shall** (R2.16) be reported referenced to standard temperature and pressure.

For any ADS-B participant that sets the "reporting reference point position" CC code (in MS report element #7g, §3.4.4.9.7) to ONE, the position that is broadcast in ADS-B messages as that participant's nominal position **shall** (R2.17) be the position of that participant's ADS-B position reference point (§2.1.2.5 below).

For any ADS-B participant that sets the "reporting reference point position" CC code (in MS report element #7g, §3.4.4.9.7) to ZERO, the position that is broadcast in ADS-B messages is not corrected from the position as given by the participant's navigation sensor to the position of that participant's ADS-B position reference point.

<u>Note:</u> *It is likely that future surface movement and runway incursion applications will require high NAC_P values. To obtain those high values, it may be necessary to correct the reported position to that of the ADS-B Position Reference Point (§2.1.2.5) if the antenna of the navigation sensor is not located in very close proximity to the ADS-B reference point.*

2.1.2.5 ADS-B Position Reference Point

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

<u>Note 1:</u> *The "reporting reference point position" CC code (in MS report element #7g) indicates whether a transmitting ADS-B participant has corrected the position given by its navigation sensor (e.g., the position of the antenna of a GPS receiver) to the location of its ADS-B position reference point. (The process of correcting the position to that of the position reference point need not be done in the transmitting ADS-B subsystem; it might be applied in the navigation sensor, or in another device external to the ADS-B transmitting subsystem.) (See the description of MS report element #7g, §3.4.4.9.7.)*

The *ADS-B position reference point* of an A/V **shall** (R2.18) be defined as the center of a rectangle (the "defining rectangle for position reference point") that has the following properties:

a. The defining rectangle for position reference point **shall** (R2.18-A) have length and width as defined in Table 2-1 below for the length and width codes that the participant is transmitting in messages to support the MS report.

b. The defining rectangle for position reference point **shall** (R2.18-B) be aligned parallel to the A/V's heading.

c. The ADS-B position reference point (the center of the defining rectangle for position reference point) **shall** (R2.18-C) lie along the axis of symmetry of the A/V. (For an asymmetrical A/V, the center of the rectangle should lie midway between the maximum port and starboard extremities of the A/V.)

d. The forward extremity of the A/V **shall** (R2.18-D) just touch the forward end of the defining rectangle for position reference point.

Table 2-1: Dimensions of Defining Rectangle for Position Reference Point.

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

Note 2: The lengths and widths given in Table 2-1 are least upper bounds for the possible lengths and widths of an aircraft that reports the given length and width code as specified in Table 3-10 (§3.4.4.6). An exception, however, is made for the largest length and width codes, since there is no upper bound for the size of an aircraft that broadcasts those largest length and width codes.

Figure 2-1 illustrates the location of the ADS-B reference point, for an example aircraft of length 31 m and width 29 m. Such an aircraft will have length code 2 (L < 35 m) and width code 0 (W < 33m). The ADS-B position reference point is then the center of a rectangle that is 35 m long and 33 m wide and positioned as given in the requirements just stated. As required in §2.1.2.4, this is the position that a transmitting ADS-B participant broadcasts when its "reporting reference point position" CC code is ONE.

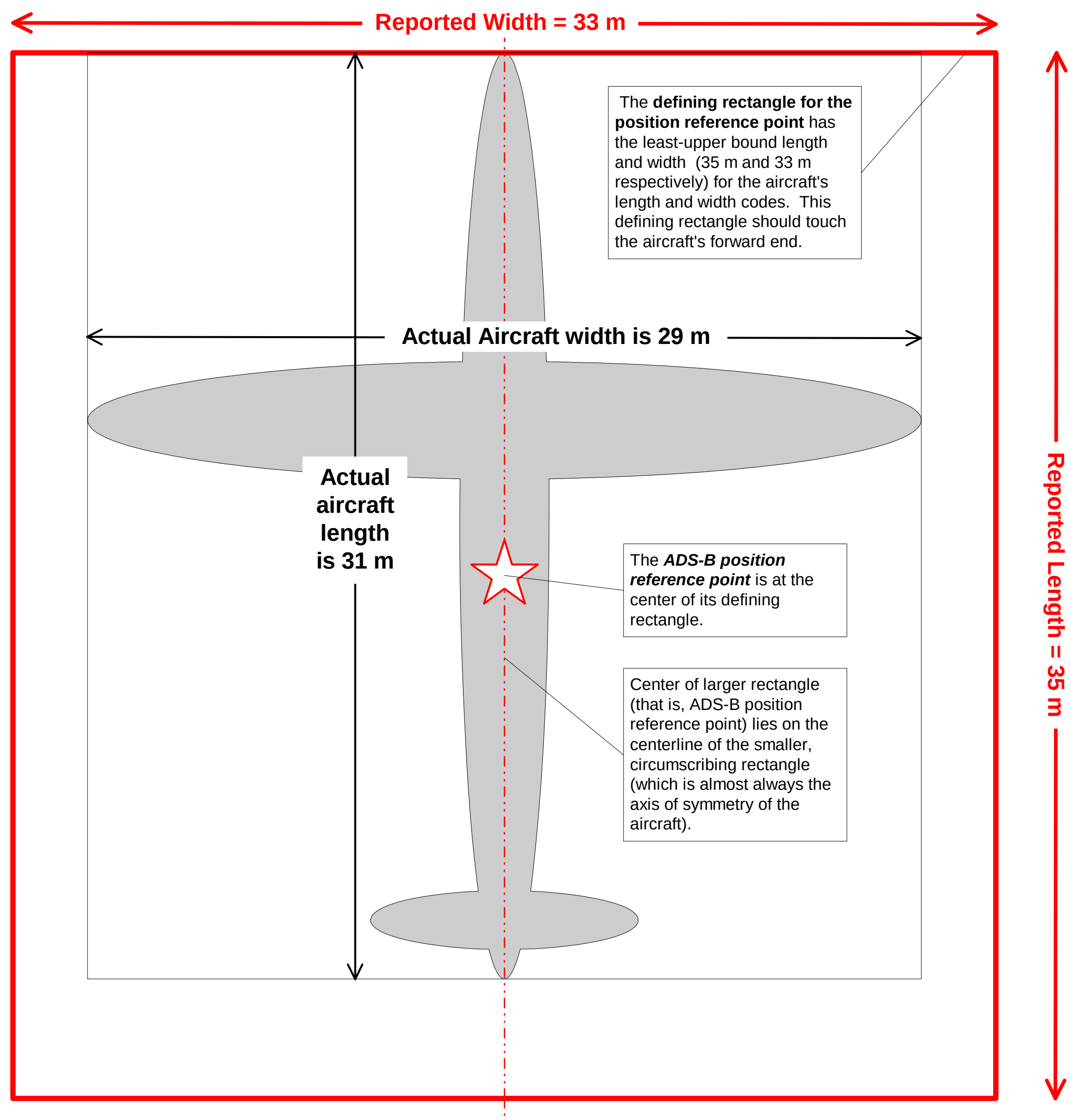

Figure 2-1: Position Reference Point Definition.

Note 3: *Any inaccuracies in the reported position due to the transmitting participant's not correcting the position from the navigation sensor to that of the ADS-B position reference point must be announced by setting the "reporting reference point position" CC code to ZERO (R3.109 in §3.4.4.9.7 below) and be accounted for in determining the* NAC_P *code that the transmitting participant position broadcasts (R2.32 in §2.1.2.13 below).*

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

2.1.2.6 Altitude

Both barometric pressure altitude and geometric altitude (height above the WGS-84 ellipsoid) **shall** (R2.19) be provided, if available, to the transmitting ADS-B subsystem. Some applications may have to compensate if only one source is available. However, when an A/V is operating on the airport surface, the altitude is not required to be reported, provided that the A/V indicates that it is on the surface.

Altitude **shall** (R2.20) be provided with a range from -1,000 ft up to +100,000 ft. For fixed or movable obstacles, the altitude of the highest point should be reported.

2.1.2.6.1 Pressure Altitude

ADS-B link equipment **shall** (R2.21) support a means for the pilot to indicate that the broadcast of altitude information from pressure altitude sources is invalid. This capability can be used at the request of ATC or when altitude is determined to be invalid by the pilot. Pressure Altitude

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

Pressure altitude, which is currently reported by aircraft in SSR Mode C and Mode S, will also be transmitted in ADS-B messages and reported to client applications in SV reports. The pressure altitude reported **shall** (R2.22) be derived from the same source as the pressure altitude reported in Mode C and Mode S for aircraft with both transponder and ADS-B.

2.1.2.6.2 Geometric Altitude

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

2.1.2.7 Horizontal Velocity

There are two kinds of velocity information:

- "Ground-referenced" or "geometric" velocity is the velocity of an A/V relative to the earth, or to a coordinate system (such as WGS-84) that is fixed with respect to the earth. Ground-referenced velocity is communicated in the SV report (§3.4.3, §3.4.3.8 and §3.4.3.16).
- Air-referenced velocity is the velocity of an aircraft relative to the air mass through which it is moving. Airspeed, the *magnitude* of the air-referenced velocity vector, is communicated in the ARV report, §3.4.6. The ARV report also includes heading (§2.1.2.9), which is used in that report as an estimate of the *direction* of the air-referenced velocity vector. Conditions for when the broadcast of ARV data is required are specified in §3.4.6.1.

ADS-B geometric velocity information **shall** (R2.23) be referenced to WGS-84 [7]. Transmitting A/Vs that are not fixed or movable obstacles **shall** (R2.24) provide ground-referenced geometric horizontal velocity.

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

2.1.2.8 Vertical Rate

Transmitting A/Vs that are not fixed or movable obstacles and that are not known to be on the airport surface **shall** (R2.25) provide vertical rate.

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

Vertical Rate **shall** (R2.26) be designated as climbing or descending and **shall** (R2.27) be reported up to 32,000 feet per minute (fpm). Barometric altitude rate is defined as the current rate of change of barometric altitude. Likewise, geometric altitude rate is the rate of change of geometric altitude. At least one of the two types of vertical rate (barometric and geometric) **shall** (R2.28) be reported.

If only one of these two types of vertical rate is reported, it **shall** (R2.29) be obtained from the best available source of vertical rate information. If differentially corrected GPS (WAAS, LAAS, or other) is available, geometric altitude rate as derived from the GPS source should be transmitted. If differentially corrected GPS is not available, but inertial augmented barometric altitude rate is available, inertial augmented barometric altitude rate will be the preferred source of altitude rate information.

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

Note 3: *Vertical rate is reported in the SV report (§3.4.3 below).*

2.1.2.9 Heading

Heading indicates the orientation of an A/V, that is, the direction in which the nose of the aircraft is pointing. Heading is described as an angle measured clockwise from true north or magnetic north. The heading reference direction (true north or magnetic north) is conveyed in the Mode-Status report (§3.4.4).

Heading occurs not only in the SV report (§3.4.3) for participants on the airport surface, but also in the ARV report (§3.4.6) for airborne participants.

2.1.2.10 Capability Class (CC) Codes

Capability class codes are used to indicate the capability of a participant to support engagement in various operations. Known specific capability class codes are listed below. However, this is not an exhaustive set and provision should be made for future expansion of available class codes, including appropriate combinations thereof.

- TCAS/ACAS ~~installed and~~ operational (§3.4.4.9.1)
- ~~CDTI based traffic display capability (§3.4.4.9.2)~~
- Service Level of the transmitting A/V (§3.4.4.9.3)
- ARV report capability (§3.4.4.9.4)
- TS report capability (§3.4.4.9.5)
- TC report capability level (§3.4.4.9.6)
- Reporting ADS-B reference position (§3.4.4.9.7)
- Reporting ADS-B Receive Capability
- Other capabilities, to be defined in later versions of this MASPS

Note: *Capability Class (CC) codes are conveyed in the MS report (§3.4.4 below).*

2.1.2.11 Operational Mode (OM) Codes

Operational Mode (OM) codes are used to indicate the current operational mode of transmitting ADS-B participants. Specific operational mode codes are listed below. However, this is not an exhaustive set and provision should be made for future expansion of available OM codes, including appropriate combinations thereof.

- TCAS/ACAS resolution advisory active (§3.4.4.10.1).
- IDENT switch active flag (§3.4.4.10.2)
- Reserved for Receiving ATC services (§3.4.4.10.3)
- Single Antenna Flag
- System Design Assurance
- GPS Antenna Offset
- Other operational modes, to be defined in later versions of this MASPS.

2.1.2.12 Navigation Integrity Category

The Navigation Integrity Category (NIC) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable level of integrity containment region for the intended use. The NIC parameter described in this subsection is intimately associated with the SIL (Surveillance Source Integrity Level) parameter described in §2.1.2.15 below. The NIC parameter specifies an integrity containment region radius, R_C. The SIL parameter specifies the probability of the true reported horizontal position lying outside that exceeding the containment radius defined by the NIC without alerting, including the effects of the airborne equipment condition, which airborne equipment is in use, and which external signals are usedassuming no avionics faults.

Note: "NIC" and "NAC_P" as used in the current version (DO-242A) of this MASPS replace the earlier term, "NUC_P", used in the first edition (DO-242) of this MASPS.

The Navigation Integrity Category is reported in the State Vector (SV) report (§3.4.3 below).

Table 2-2 defines the navigation integrity categories that transmitting ADS-B participants **shall** (R2.30) use to describe the integrity containment radius, R_C, associated with the horizontal position information in ADS-B messages from those participants.

Table 2-2: Navigation Integrity Categories (NIC).

NIC (Notes 1, 2)	Horizontal and Vertical Containment Bounds	Comment	Notes
0	R_C ≥ 37.04 km (20 NM) Unknown	Unknown Integrity	
1	R_C < 37.04 km (20 NM)	RNP-10 containment radius	6
2	R_C < 14.816 km (8 NM)	RNP-4 containment radius	3, 6
3	R_C < 7.408 km (4 NM)	RNP-2 containment radius	6
4	R_C < 3.704 km (2 NM)	RNP-1 containment radius	6
5	R_C < 1852 m (1 NM)	RNP-0.5 containment radius	6
6	R_C < 1111.2 m (0.6 NM)	RNP-0.3 containment radius	6
7	R_C < 370.4 m (0.2 NM)	RNP-0.1 containment radius	6
8	R_C < 185.2 m (0.1 NM)	RNP-0.05 containment radius	6
9	R_C < 75 m and VPL < 112 m	e.g., WAAS HPL, VPL	4, 5
10	R_C < 25 m and VPL < 37.5 m	e.g., WAAS HPL, VPL	4, 5
11	R_C < 7.5 m and VPL < 11 m	e.g., LAAS HPL, VPL	4, 5

➔ **Editor's Question:** Is it appropriate to revise the NIC Table above to represent the NIC Supplements as they were defined in either DO-260B or DO-282B? ➔

Notes for Table 2-2:

1. *NIC is reported by an aircraft because there will not be a uniform level of navigation equipage among all users. Although GNSS is intended to be the primary source of navigation data used to report ADS-B horizontal position, it is anticipated that during initial uses of ADS-B or during temporary GNSS outages an alternate source of navigation data may be used by the transmitting A/V for ADS-B position information. ~~The integration of alternate navigation sources is a function that must be performed by a navigation set that is certified to use multiple sources, which then is responsible for supplying the corresponding integrity containment radius (e.g.., HPL). It is important to point out that this is not a function that can be performed by the ADS-B equipment.~~*

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

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

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

5. *If geometric altitude is not being reported then the VPL tests are not assessed.*

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

7. *~~VPL values have not been specified for NIC of 8 or lower. Typical airborne systems, e.g. RNAV equipment, that provide horizontal position data for these NIC values do not also provide geometric vertical position or geometric vertical position integrity data. Also applications using these lower NIC values are likely to use barometric altitude data to be consistent with typical airspace operational practice for these applications. Provisions have been identified for Barometric Altitude Integrity (NIC_{baro}) in §2.1.2.17.~~*

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

a. Equipment that conforms to the current version of this MASPS ("version 1" equipment) will recognize the equivalent NUC_P codes from the first edition of this MASPS, and

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

2.1.2.13 Navigation Accuracy Category for Position (NAC_P)

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

Table 2-3 defines the navigation accuracy categories that **shall** (R2.31) be used to describe the accuracy of positional information in ADS-B messages from transmitting ADS-B participants. The NAC_P value broadcast from an ADS-B participant **shall** (R2.32) include any inaccuracies in the reported horizontal position due to the transmitting participant's not correcting the horizontal position from the navigation sensor to that of the ADS-B position reference point (see §2.1.2.5).

Notes:

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

2. *It is likely that future surface movement and runway incursion applications will require high NAC_P values. To obtain those high values, it may be necessary to correct the reported position to that of the ADS-B Position Reference Point (§2.1.2.5) if the antenna of the navigation sensor is not located in very close proximity to the ADS-B reference point.*

3. *The processing to determine the degraded position accuracy reported in NAC_P may be performed outside the ADS-B transmitting subsystem when the reported position of an A/V is not corrected to that of the ADS-B Position Reference Point (i.e. the "reporting reference point position" CC code is set to ZERO).*

4. *The Estimated Position Uncertainty (EPU) used in Table 2-3 is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position being outside the circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).*

5. *~~Likewise, Vertical Estimated Position Uncertainty (VEPU) is a 95% accuracy limit on the vertical position. VEPU is defined as a vertical position limit, such that the probability of the actual vertical position differing from the reported vertical position by more than that limit is 0.05. When reported by a GPS or GNSS system, VEPU is commonly called VFOM (Vertical Figure of Merit).~~*

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

Table 2-3: Navigation Accuracy Categories for Position (NAC_P).

NAC_P	95% Horizontal ~~and Vertical~~ Accuracy Bounds (EPU ~~and VEPU~~)	Comment	Notes
0	EPU ≥ 18.52 km (10 NM)	Unknown accuracy	
1	EPU < 18.52 km (10 NM)	RNP-10 accuracy	1
2	EPU < 7.408 km (4 NM)	RNP-4 accuracy	1
3	EPU < 3.704 km (2 NM)	RNP-2 accuracy	1
4	EPU < 1852 m (1NM)	RNP-1 accuracy	1
5	EPU < 926 m (0.5 NM)	RNP-0.5 accuracy	1
6	EPU < 555.6 m (0.3 NM)	RNP-0.3 accuracy	1
7	EPU < 185.2 m (0.1 NM)	RNP-0.1 accuracy	1
8	EPU < 92.6 m (0.05 NM)	e.g., GPS (with SA)	1
9	EPU < 30 m ~~and VEPU < 45 m~~	e.g., GPS (SA off)	2
10	EPU < 10 m ~~and VEPU < 15 m~~	e.g., WAAS	2
11	EPU < 3 m ~~and VEPU < 4 m~~	e.g., LAAS	2

Notes for Table 2-3:

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

~~*2.If geometric altitude is not being reported, then the VEPU tests are not assessed.*~~

~~*3.VEPU values have not been specified for NAC_P of 8 or lower. Typical airborne systems, e.g. RNAV equipment, that provide horizontal position data for these NAC_P values do not also provide geometric vertical position or geometric vertical position accuracy. Also applications using these lower NAC_P values are likely to use barometric altitude data to be consistent with typical airspace operational practice for these applications. Provisions have been identified for Barometric Altitude Quality (BAQ) in §2.1.2.16.*~~

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

2.1.2.14 Navigation Accuracy Category for Velocity (NAC_V)

The velocity accuracy category of the least accurate velocity component being supplied by the reporting A/V's source of velocity data **shall** (R2.33) be as indicated in Table 2-4.

Notes:

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

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

3. *NAC_V does not apply to barometric velocity accuracy.*

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

Table 2-4: Navigation Accuracy Categories for Velocity (NAC_V).

NAC_V	Horizontal Velocity Error (95%)	Vertical Geometric Velocity Error (95%)
0	Unknown or ≥ 10 m/s	Unknown or ≥ 50 feet (15.24 m) per second
1	< 10 m/s	< 50 feet (15.24 m) per second
2	< 3 m/s	< 15 feet (4.57 m) per second
3	< 1 m/s	< 5 feet (1.52 m) per second
4	< 0.3 m/s	< 1.5 feet (0.46 m) per second

Notes for Table 2-4:

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

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

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

2.1.2.15 ~~Surveillance~~ Source Integrity Level (SIL)

The ~~Surveillance~~ Source Integrity Level (SIL) defines the probability of the reported horizontal position exceeding the ~~integrity~~ containment radius ~~used in~~ defined by the NIC ~~parameter~~ (§2.1.2.12 above), ~~being exceeded, without detection, including the effects of the airborne equipment condition, which airborne equipment is in use, and which external signals are used by the navigation source~~ without alerting, assuming no avionics faults. Although the SIL assumes there are no unannunciated faults in the avionics system, the SIL must consider the effects of a faulted Signal-in-Space, if a Signal-in-Space is used by the position source. The probability of an avionics fault causing the reported horizontal position to exceed the radius of containment defined by the NIC, without alerting, is covered by the System Design Assurance (SDA) parameter. The ~~Surveillance~~ Source Integrity Limit encoding **shall** (R2.34) be as indicated in Table 2-5. The SIL probability can be defined as either "per sample" or "per hour."

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

Table 2-5: ~~Surveillance~~ Source Integrity Level (SIL) Encoding.

SIL	Probability of Exceeding the ~~R_C~~ ~~Integrity~~ NIC Containment Radius ~~Without Detection~~	~~Comment~~
0	Unknown or > 1 x 10^{-3} per flught hour or per sample	~~"No Hazard Level" Navigation Source~~
1	1×10^{-3} per flight hour or per ~~operation~~sample	~~"Minor Hazard Level" Navigation Source~~
2	1×10^{-5} per flight hour or per ~~operation~~sample	~~"Major Hazard Level" Navigation Source~~
3	1×10^{-7} per flight hour or per ~~operation~~sample	~~"Severe Major Hazard Level" Navigation Source~~

2.1.2.16 ~~Barometric Altitude Quality Code (BAQ)~~Reserved

~~The Barometric Altitude Quality Code, BAQ, is a 2-bit field which **shall** (R.35) be ZERO for equipment that conforms to this version (DO-242A) of the ADS-B MASPS.~~

~~*Notes:*~~

~~*1. Non-zero values of the barometric altitude accuracy code will be defined in future versions of this MASPS. One proposed encoding is given in Table 2-6; however, it is not certain that this encoding will be the one specified in future versions of this MASPS.*~~

~~**Table 2-6: Possible Future Encoding for Barometric Altitude Quality.**~~

~~*BAQ*~~	~~*Meaning*~~
~~*0*~~	~~*Barometric altitude not certified for IFR use*~~
~~*1*~~	~~*Barometric altitude with 100 feet resolution*~~
~~*2*~~	~~*Barometric altitude with 25 feet resolution*~~
~~*3*~~	~~*Barometric altitude meets RVSM requirements*~~

~~*2.1. BAQ, the barometric altitude accuracy code, is reported in the Mode-Status report (§3.4.4.14 below)*~~.

2.1.2.17 Barometric Altitude Integrity Code (NIC_{baro})

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

Note: NIC_{baro}, the barometric altitude integrity code, is reported in the Mode-Status report (§3.4.4).

2.1.2.18 Emergency/Priority Status

The ADS-B system **shall** (R2.36) be capable of supporting broadcast of emergency and priority status. Emergency/priority status is reported in the MS report (§3.4.4) and the encoding for this field is defined in §3.4.4.8.

2.1.2.19 Intent Information

➔ **Editor's Note:** This whole topic should be reviewed and potentially revised ➔

Note: *Persons familiar with the first (DO-242) edition of this MASPS are urged to study the definitions presented here. The terminology has been refined – and changed – from that used in the first edition of the MASPS.*

The reason for considering broadcast of intent information in ADS-B systems is to extend the domain of predictability of aircraft trajectories beyond short-term extrapolations using current aircraft position and velocity states. Many applications of ADS-B currently under consideration could require intent information to extend look-ahead time for trajectory predictions beyond the current flight segment, or as a means of enhancing integrity of extrapolated path predictions. Proposed air-air applications of intent information include airborne separation planning where more than a few minutes look-ahead time is desirable for conflict detection and conflict prevention, and conflict resolution, where broadcast of intended resolution maneuvers may be important for situation awareness of all nearby equipped aircraft. ADS-B intent information is also proposed to enable advanced air-ground applications such as sequencing and merging of terminal area flow streams, conformance monitoring, and use of precision trajectory separation concepts for aircraft arrival and departure flows in congested airspace.

Short-term intent provides information on the current horizontal and vertical targets for the active flight segment. These targets reflect the current path and automation states being used for aircraft guidance and control. Primary short-term intent elements include target altitude and target heading or track angle. Long-term intent provides strategic path information, consisting of trajectory change points and their connecting flight segments. While short-term intent is available in almost all operational flight modes, four-dimensional long-term intent is only available when equipped aircraft are using sophisticated FMS and area navigation (RNAV) systems. Appendix N provides a detailed discussion of intent availability related to aircraft control state and equipment. Intent information over ADS-B is supported by two on-condition reports: Target State (TS) report (§3.4.7) and Trajectory Change (TC) Report (§3.4.8). These reports correspond to short and long-term intent, respectively.

Intent information provided in TS and TC reports reflects aircraft states and targets programmed into the transmitting aircraft's automation system.

Note 1: *When broadcasting intent, the ADS-B transmitting subsystem should not infer a pilot's future actions. Some intent information communicated may not reflect the aircraft's actual intended trajectory until the pilot takes further actions.*

This MASPS incorporates intent information elements that are sufficiently understood and developed, with strong preference to information available from many current aircraft. Intent elements not currently available on avionics data buses are provided in DO-242A in cases where they can likely be derived from current avionics systems and when needed to support international intent applications.

Note 2: *Some data elements in the TS report (§3.4.7) and TC report (§3.4.8) formats are indicated in this MASPS as "reserved for" use in future versions of this MASPS. These "reserved for" data elements are expected to be of operational value for future applications, but presently lack sufficient development. Further development and validation of these concepts are planned for future MASPS revisions.*

This MASPS defines requirements for the Target State (TS) report and first Trajectory Change (TC+0) report. Requirements for additional TC reports beyond the TC+0 report are deferred for later MASPS revisions, pending the results of ongoing studies. Current work on management of multiple TC reports is documented in Appendix N.

Detailed intent element requirements and conditions for broadcasting TS and TC Report information, are described in §3.4.7 and §3.4.8, respectively. Required update rates and minimum acquisition ranges are specified in §3.3.3.1.4.

2.1.2.19.1 Short Term Intent

Short-term intent is reported in the Target State (TS) report (§3.4.7) and consists primarily of the target altitude (or appropriate substitutes for target altitude, see §3.4.7.13) and target heading or target track angle for the active flight segment.

- The *target altitude* is the aircraft's next intended level flight altitude if in a climb or descent or its current intended altitude if commanded to hold altitude.
- The *target heading* is the aircraft's intended heading after turn completion or its current intended heading if in straight flight.
- The *target track angle* is the aircraft's intended track angle over the ground after turn completion or its current intended track angle if in straight flight.

Target track angle is only provided if the aircraft is being controlled to a ground referenced track angle, whereas target heading is provided when being controlled to a heading.

These parameters represent the aircraft's tactical intent and are often selected directly by the pilot through an autopilot control panel. Examples include selected altitude for limiting a descent or climb transition and selected heading when following vectors issued by air traffic control. Target altitude and target heading or track angle can also refer to the current intended targets flown by an autopilot in more automated modes, such as those supported by RNAV and FMS. In this case, the target track angle may be the track to the next waypoint or the outbound track angle following a turn maneuver.

The TS report provides a way for aircraft equipped with less sophisticated automation systems or flying in tactical flight modes to exchange short-term intent information. This information can be used for separation assurance and clearance verification applications.

For equipage classes A2 and A3, the ADS-B system **shall** (R2.37) provide the capability to transmit and receive messages in support of the TS report.

Note: TS report capability is optional for equipage class A1.

Short term horizontal intent is conveyed in the Target State (TS) report (§3.4.7) and includes the following report elements:

- Target Heading or Track Angle (§3.4.7.5)
- Target Heading / Target Track Indicator (§3.4.7.6)
- Horizontal Target Source Indicator (§3.4.7.4)
- Horizontal Mode Indicator (§3.4.7.8)

Short term vertical intent is conveyed in the Target State (TS) report (§3.4.7) and includes the following report elements:

- Target Altitude (§3.4.7.11)
- Target Altitude Type (§3.4.7.12)
- Target Altitude Capability (§3.4.7.13)
- Vertical Target Source Indicator (§3.4.7.10)
- Vertical Mode Indicator (§3.4.7.14)

2.1.2.19.2 Long-Term Intent

The following material in this section for Long Term Intent represents best engineering judgment for intent at the time of publication of this MASPS. This material is therefore necessarily subject to further validation and refinement. It is not intended that ADS-B link MOPS implement requirements for the broadcast of Long Term Intent based on this version of the ADS-B MASPS. However, this material is intended to be used:

- in link design considerations,
- to assess system capacity and performance, and
- as a basis for application development efforts.

Long-term intent represents information on the current and subsequent trajectory change points and flight segments. It is likely to come from flight planning contained in FMS or RNAV systems. Long-term intent includes information on Trajectory Change Points (TCPs) and their connecting flight segments. Communicating intent information helps a receiving participant to facilitate path re-generation, data confidence assessment, and conformance monitoring for targets of interest. This strategic intent information is expected to be beneficial for applications such as flight path deconfliction and traffic flow management.

A *trajectory change point (TCP)* is a point where an anticipated change in the aircraft's velocity vector will cause an intended change in trajectory. The change in trajectory may be either a change in path or a change in speed. The location of a full three-dimensional TCP *may not always be known* to the transmitting ADS-B subsystem, and the information defining the locus of possible change points for a TCP may be conveyed in *more than just a single* report. For instance, information about a TCP may be conveyed in the most recent SV and TS reports, or in the most recent TS and TC+0 reports, or in a single TC+0 or TC+n report.

Note: *The first edition (DO-242) of this MASPS defined trajectory change points differently, as a particular kind of on-condition report that conveys information about where the aircraft trajectory is intended to change. In this current (DO-242A) MASPS, the terms SV, TS, and TC reports are reserved for the various types of reports that may be used to convey TCP information; but the term TCP is reserved for a 3-D location in space where the aircraft trajectory is intended to change.*

The *current TCP* is that TCP to which the aircraft is currently being controlled. This definition includes cases where flight segment changes do not occur at a known 3D point.

For example, Figure 2-2(a) shows an aircraft descending toward a target altitude. In this case, the current TCP – the point where the aircraft's trajectory is expected to change – is communicated using elements from the SV report (§3.4.3) and the Target State Report (§3.4.7). The actual latitude and longitude of the current TCP may not be known precisely, but an estimate can be derived from information that the transmitting ADS-B participant broadcasts.

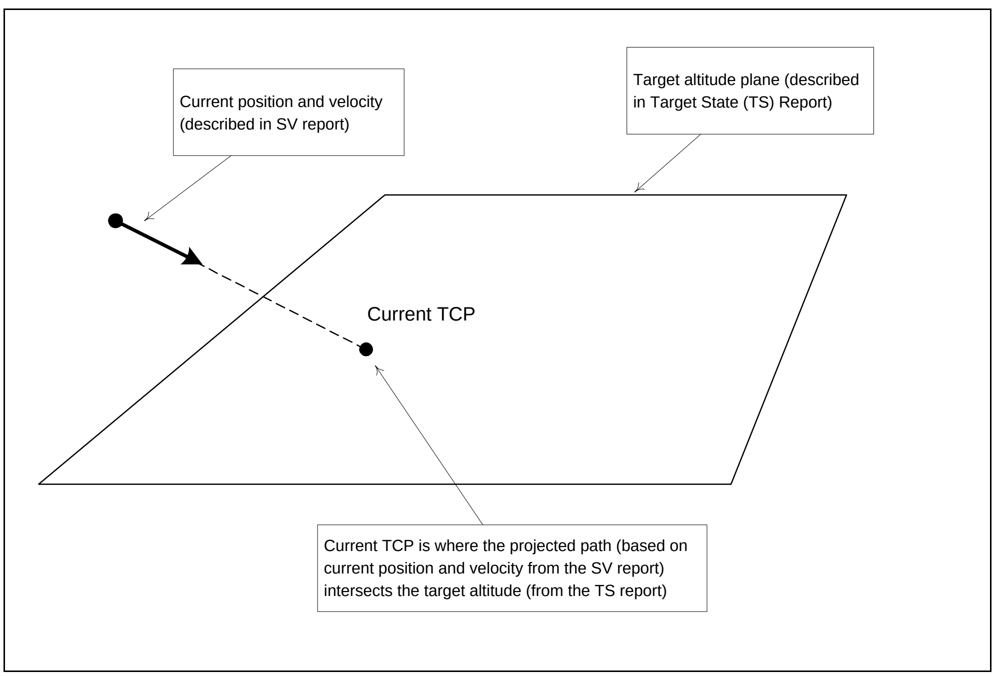

Figure 2-2(a): Current TCP Information, As Conveyed With SV and TS Reports.

As another example, consider the case of a flight plan defined by several FMS (Flight Management System) waypoints. Our transmitting ADS-B participant is not yet flying along that flight plan, but is in the process of joining the first leg of the flight plan. Figure 2-2(b): shows the situation. This example is for an aircraft in which the FMS does not provide the current TCP.

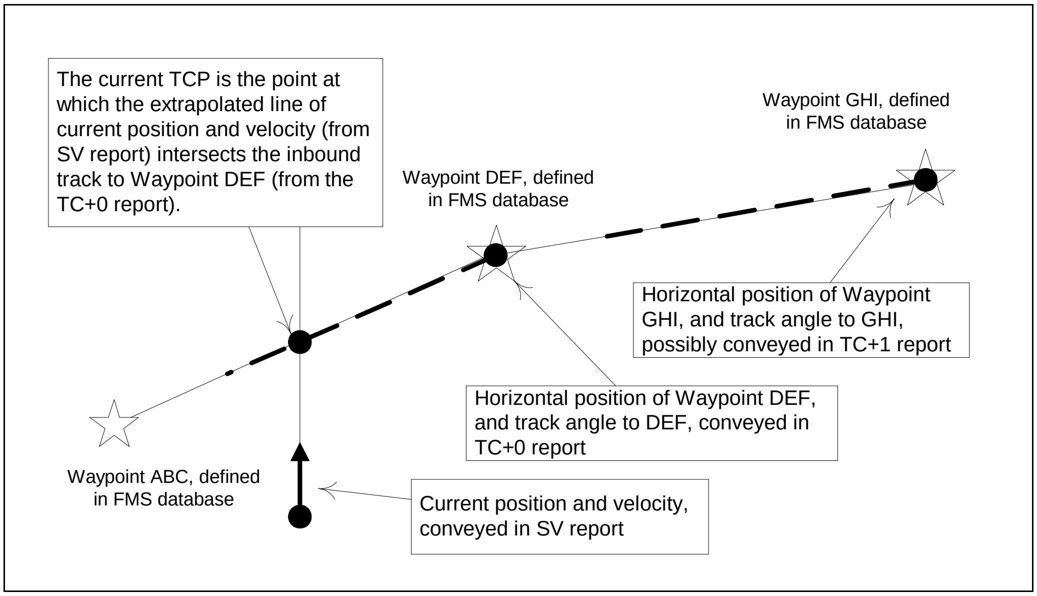

Figure 2-2(b): Current TCP,
As Conveyed With SV and TC+0 Reports.

Note: *The goal in defining the various report types (e.g., SV, TS, and TC reports) in this MASPS was to minimize the amount of information that must be broadcast to describe an ADS-B participant's intentions with suitable accuracy and integrity for intended applications.*

Thus, in the example of Figure 2-2(b), the position of waypoint ABC in the flight plan may be stored in the transmitting participant's FMS and communicated to the transmitting ADS-B subsystem, but that position is not transmitted over the air in ADS-B messages; nor is it delivered to client applications on board receiving aircraft in ADS-B reports. Instead, the message generation function at the transmitting ADS-B participant is expected to infer the track angle along which the aircraft intends to approach waypoint DEF. The track angle to DEF and the position of DEF are then conveyed in a TC+0 report for waypoint DEF. The current position and velocity of the transmitting aircraft are conveyed in a SV report. The client application at the receiving aircraft could infer the anticipated location of the next point at which the transmitting aircraft's trajectory is intended to change (that is, the current TCP) from the information it receives in the SV and TC+0 reports.

TC report elements are designed to reflect the capabilities of existing and future aircraft avionics. TC report fields are filled based on information available aboard the transmitting aircraft and the horizontal and vertical TC types. Example TC types include 2D routing changes, the start and end points of a specified turn transition, FMS predicted Top of Climb and Top of Descent points, and selected altitude from an autopilot control panel when currently in climb or descent transitions. All broadcast trajectory change information must correspond to one of the horizontal and/or vertical TC types defined in §3.4.8.8 and §3.4.8.16. Additional TC types, such as waypoint altitude constraints, may be incorporated into future MASPS revisions.

The TC report enables ADS-B user applications to assess the reliability of the transmitting aircraft's trajectory change data by distinguishing between *command* and *planned* trajectory changes. This information is provided through horizontal and vertical command/planned flags, discussed in §3.4.8.15 and §3.4.8.22, respectively. The aircraft's *command trajectory* reflects the path the aircraft will fly without pilot input. *Planned trajectory* changes are programmed into onboard navigation systems, but only occur if the pilot changes an automation setting. Trajectory changes are also labeled as "planned" if prior TCP's may exist without a corresponding TC report (refer to example shown in Figure 2-2(b)). Command Trajectory may have information with enough integrity to assist in conflict resolution alerting and recommended maneuvers. Planned Trajectory information may be of value to some applications that can use this information for situational awareness in anticipation of a change to commanded trajectory. It is expected that many modern aircraft will only be able to label trajectory changes as "planned". Appendix N provides additional discussion of command and planned trajectories.

For equipage class A2, the ADS-B system **shall** (R2.38) provide the capability to transmit and receive messages in support of one TC (TC+0) report. For equipage class A3, the ADS-B system **shall** (R2.39) provide the capability to transmit and receive messages in support of multiple TC reports.

Long-term intent is conveyed in the Trajectory Change Report (§3.4.8) and contains the following report elements:

- Participant Address (§2.1.2.2.2.1)
- Address Qualifier (§2.1.2.2.2.2)
- Time of Applicability (§3.4.8.3)
- TC Report Sequence Number (§3.4.8.4)
- TC Report Cycle Number (§3.4.8.5)
- Time to Go (§3.4.8.7)
- Horizontal Data Available and Horizontal TC Type (§3.4.8.8)
- TC Latitude (§3.4.8.9)
- TC Longitude (§3.4.8.10)
- Turn Radius (§3.4.8.11)
- Track to TCP (§3.4.8.12)
- Track from TCP (§3.4.8.13)
- Horizontal Command/Planned Flag (§3.4.8.15)
- Vertical Data Available and Vertical TCP Type (§3.4.8.16)
- TC Altitude (§3.4.8.17)
- TC Altitude Type (§3.4.8.18)
- Vertical Command/Planned Flag (§3.4.8.15)

2.1.2.20 Other Information

2.2 System Performance – Standard Operational Conditions

2.2.1 ADS-B System-Level Performance

The standard operating conditions for ADS-B are determined by the operational needs of the target applications listed in §1.3. System performance requirements and needs for ADS-B are provided in terms of the operational environments and the information needs of applications making use of ADS-B information in those environments.

The following subsections describe representative scenarios used to derive ADS-B system-wide functional and performance requirements. The list of scenarios is not exhaustive and is not presented in any order of priority. The ASA MASPS, currently under development, will provide detailed operational concepts and requirements for selected ADS-B applications. Appendices D and E identify additional near-term and other applications.

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

A summary of the broadcast information provided by ADS-B and its applicability to the target applications is provided in Table 2-7. Assumptions for A/V-to-A/V scenarios are summarized in Table 2-8. A summary of ATS provider surveillance and conflict management current capabilities for sample scenarios is provided in Table 2-9(a). Additional and refined capabilities appropriate for ADS-B are provided in Table 2-9(b). Table entries not containing references supporting the value specified are based on operational judgment and may need further validation.

Table 2-7: Expected Information Needed to Support Selected ADS-B Applications

Information Element ↓	Aid to Visual Acqui-sition	Conflict Avoid-ance and Collision Avoid-ance	Separation Assurance & Sequenc-ing	Flight Path Deconflic-tion Planning	Simulta-neous Ap-proaches	Airport Surface (A/V to A/V & A/V to ATS)	ATS Surveil-lance	Notes
Identification								
Call Sign			•	•	•	•	•	1
Address	•	•	•	•	•	•	•	
Category			•	•	•	•	•	
State Vector								
Horizontal Position	•	•	•	•	•	•	•	
Vertical Position	•	•	•	•	•		•	
Horizontal Velocity	•	•	•	•	•	•	•	
Vertical Velocity	•	•	•	•	•		•	
Heading						•		
NIC		•	•	•	•	•	•	
Mode-Status								
Emergency/ Priority Status							•	
Capability Codes		•	•	•	•	•	•	
Operational Modes		•	•	•	•	•	•	
SV Quality		•	•	•	•	•	•	
ARV		•	•	•	•		•	
Intent								
TS reports		•	•	•			•	
TC+0 reports			•	•			•	
TC+n reports				•			•	

Notes for Table 2-7:

• = Expected Application Requirement

1. *A/Vs not receiving ATS services are not required to transmit call sign.*

2. *Application requirements are to be defined in the ASA MASPS.*

3. *ADS-B is one potential means to provide intent information to support ATS. Other alternatives, not involving ADS-B, may become available.*

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

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

Notes for Table 2-8:

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

2. *References are provided where applicable. Alert time data is provided in Appendix J for simulated scenarios. Else, best engineering judgment was used to obtain performance data.*

3. *Best engineering judgment applied. Not intended to prescribe alert time for airspace.*

4. *System must support all traffic in line of sight that have operational significance for the associated applications (i.e. within operationally relevant ranges and altitudes for these applications). The numbers in the table indicate the number of aircraft expected to participate in or affect a given operation. (Refer to Table 3-2 for requirements which are based on operational traffic densities derived from the Los Angeles basin model)*

5. *Service availability includes any other systems providing additional sources of surveillance information.*

6. *See Appendix J for alert times in simulated scenarios.*

7. *Initial acquisition of intent information is also required at this range.*

8. *This includes inappropriate runway occupancy at non-towered airports.*

9. *The operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.*

2.2.2 ADS-B System-Level Performance—Aircraft Needs

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

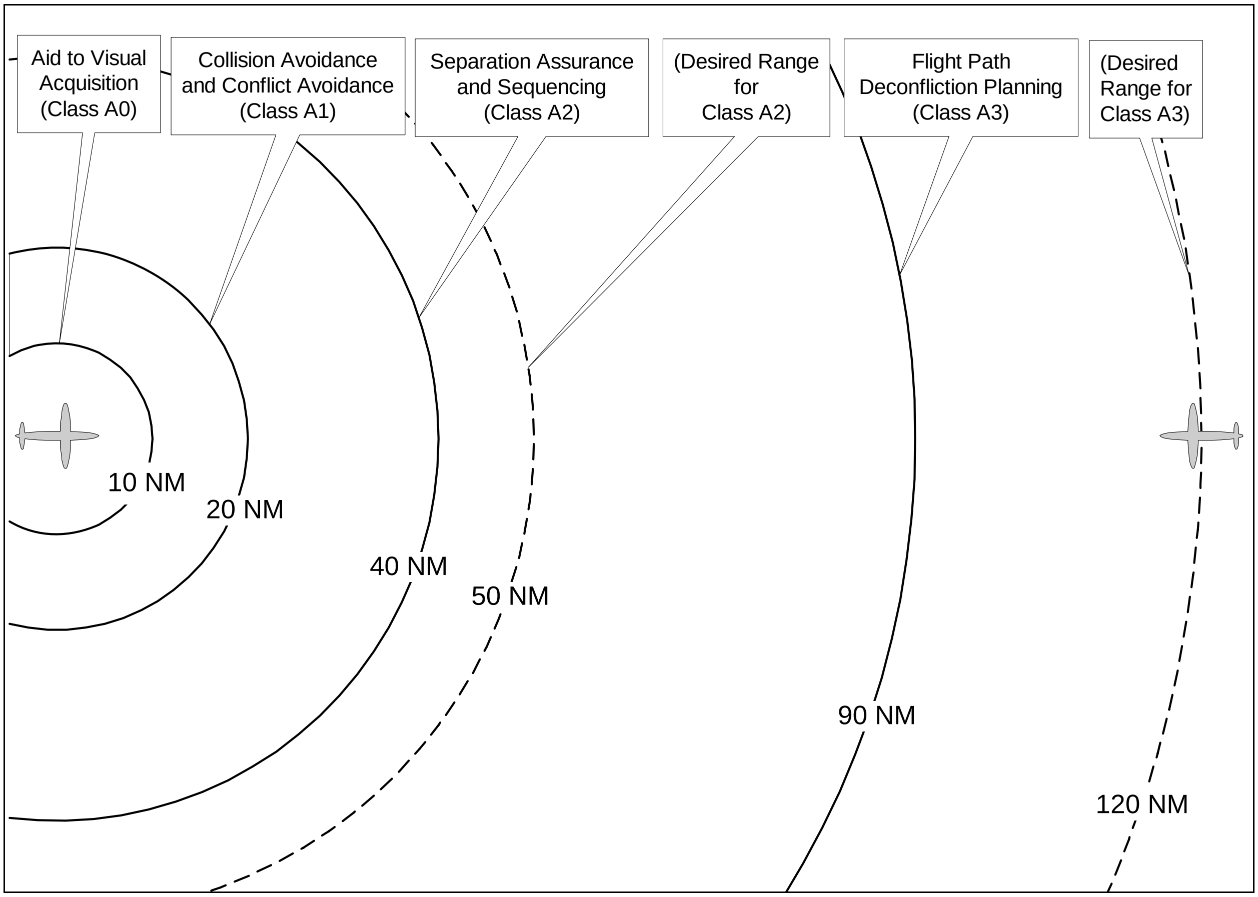

Figure 2-3: Air-To-Air Capabilities Enabled By ADS-B Equipage Classes

2.2.2.1 Aircraft Needs While Performing Aid to Visual Acquisition

Transmission, air-to-air reception, and cockpit display of ADS-B information enables an aid to visual acquisition. This scenario is applicable in all airspace domains. See Table 2-7 for the information exchange needs and Table 2-8 for operational performance requirements to support the aid to visual acquisition.

2.2.2.2 Aircraft Needs for Conflict Avoidance and Collision Avoidance

Requirements for conflict avoidance and collision avoidance were developed using scenarios for future collision avoidance and station keeping. Collision avoidance can be invoked when conflict avoidance fails.

2.2.2.3 Aircraft Needs for Future Collision Avoidance

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

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

The evolution of current TCAS II systems, which are now based on active interrogation of aircraft transponders, toward full use of broadcast ADS-B information will take place over several years. Early use of ADS-B information will support display modifications and procedural enhancements. Later, TCAS II systems will be updated to incorporate a hybrid surveillance scheme (combining active interrogation and receipt of broadcast data) to further reduce interference with ground ATS, as well as to use ADS-B data in Horizontal Miss-Distance Filtering to further reduce the number of unnecessary RAs. Other modifications will include the use of ADS-B information in aircraft trajectory modeling and prediction.

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

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

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

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

See Table 2-7 for the information exchange needs and Table 2-8 for operational performance requirements to support collision avoidance.

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

2.2.2.3.1 Environment

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

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

2.2.2.3.2 Operational Scenario

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

2.2.2.4 Aircraft Needs While Performing Station-Keeping

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

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

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

See Table 2-7 for the information exchange needs and Table 2-8 for operational performance requirements to support terminal station keeping. Information provided to the display should be continuously updated to provide adequate presentation quality by using ADS-B velocity information to extrapolate changing positions.

2.2.2.4.1 Environment

Station-keeping may occur in all operational domains. The subsequent scenario will focus on terminal station-keeping.

2.2.2.4.2 Operational Scenario

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

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

2.2.2.5 Aircraft Needs for Separation Assurance and Sequencing (Cooperative-Separation for Free Flight)

Free Flight is an operational concept in which the participating operators have the freedom to select their path and speed in real time. Research is in progress to fully develop operational concepts and requirements for cooperative-separation. Free Flight uses the concept of "alert" and "protected" airspace surrounding each aircraft. In this concept, both general aviation and air carriers would benefit. Aircraft operations can thus proceed with due regard to other aircraft, while the air traffic management system would monitor the flight's progress to ensure safe separation. By enabling the relaxing of restrictions and increasing flexibility, ADS-B (aircraft-to-aircraft) is a key component leading to both Free Flight and IFR cooperative-separation [2].

Free Flight includes a transfer of responsibility for separation assurance from ground based ATS to aircraft pairs involved in close proximity encounters. Participating aircraft will be specially equipped with high accuracy, high integrity navigation and high reliability ADS-B capability for critical flight operations. The airborne separation assurance function includes separation monitoring, conflict prediction, and providing guidance for resolution of predicted conflicts.

See Table 2-7 for the information exchange needs and Table 2-8 for operational performance requirements to support aircraft needs while performing Free Flight.

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

2.2.2.5.1 Environment

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

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

2.2.2.5.2 Operational Scenario

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

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

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

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

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

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

See Table 2-7 for the information exchange needs and Table 2-8 for operational performance requirements to support aircraft needs while performing cooperative separation in low density en route airspace (requirements are also listed as flight path deconfliction planning).

2.2.2.6.1 Environment

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

2.2.2.6.2 Operational Scenarios

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

2.2.2.7 Aircraft Needs While Performing Simultaneous Approaches

Operational improvements through the use of ADS-B for closely spaced runway operations are described in Section 1. ADS-B supported applications will enable increased capacity at airports currently without PRM support. ADS-B permits faster detection times for the blunder, resulting in the ability to operate with lower separations between runways for simultaneous approaches. By providing information in the cockpit, the pilot can detect and react to a blunder without incurring delays associated with the controller-to-pilot communication link. Currently, allowances are made for such communication problems as blocked transmissions and non-receipt of controller maneuver instructions. These allowances are needed to achieve desired levels of safety but they result in greater separation between runways than would be required if pilots received the critical information more quickly.

See Table 2-7 for the information exchange needs and Table 2-8 for operational performance requirements to support aircraft needs while performing simultaneous independent approaches.

2.2.2.7.1 Environment

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

2.2.2.7.2 Operational Scenarios

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

- Case 1: Runway centerline separation is 1000 feet.
- Case 2: Runway centerline separation is 2500 feet.
- Evader aircraft speed is 140 knots; intruder aircraft speed is 170 knots.
- The intruder aircraft turns 30 degrees, at 3 degrees per second, with a resulting near mid-air collision.
- A false alarm scenario consists of the two runway spacings with normal approaches and landings.
- Plant noise (normal aircraft dynamics in flight) is added to the aircraft trajectories to simulate total system error in the approach.

2.2.2.8 Aircraft Needs While Operating on the Airport Surface

On the airport surface, ADS-B may be used in conjunction with a CDTI to improve safety and efficiency. The pilot could use CDTI and a moving map display to perform taxi guidance and surface station-keeping. ADS-B used in conjunction with a moving map display may be used to show cleared taxi travel paths. Other proximate vehicles within the surface movement area and aircraft may also be identified using ADS-B information. At night, or at times of poor visibility, the airport surface digital map may be used for separation and navigation purposes. To support station-keeping on the airport surface, the in-trail aircraft needs to monitor the position and speed of the lead aircraft and to detect changes of speed to ensure that safe separation is maintained (see §2.2.2.1).

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

See Table 2-7 for the information exchange needs and Table 2-8 for operational performance requirements to support aircraft needs while operating on the airport surface.

2.2.2.8.1 Environment

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

2.2.2.8.2 Operational Scenarios

Blind Taxi:

The aircraft are taxiing in conditions of impaired visibility (down to 100 meters RVR). One aircraft is following another, with both maintaining 30 knots. The desired spacing between the aircraft while moving is 150 meters (nose to tail). The lead aircraft decelerates at 1.0 m/sec^2 until it stops. The pilot in the following aircraft is alerted to the lead aircraft's deceleration. Pilot reaction time is .75 seconds. The in-trail aircraft deceleration is 1.0 m/sec^2 to a stop. The required minimum separation is 50 meters under such conditions (nose to tail).

Runway Incursion:

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

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

The following discussion focuses on ground ATS surveillance and automation systems that use surveillance information pertaining to aircraft within the area of operational control. A summary of the current ATS surveillance system capabilities is provided in Table 2-9(a). While the individual parameter values in the table may not be directly applicable to the ADS-B system, the ADS-B System is expected to support equivalent or better overall system level performance for the cited applications. ADS-B requirements, developed for the air-to-air applications discussed above, are expected to satisfy the required surveillance performance to support ATS. For aircraft required to support ATS surveillance in en route and terminal airspace, a capability to independently validate the surveillance information is likely to be required [6]. Alternative validation means are under study.

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

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

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

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

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

<u>Notes for Table 2-9(a) and Table 2-9(b):</u>

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

1) *References are provided where applicable. Else, best judgment was used to obtain performance data.*

2) *Received update period is the period between received state vector updates. A/V Call Sign and A/V Category can be received at a lower rate.*

3) *One or multiple ground receivers may be used in the operational domain to ensure acceptable performance for the intended traffic load. The numbers in the table indicate the number of aircraft expected to participate in or affect a given operation. (Refer to Table 2-8 for requirements which are based on operational traffic densities derived from the Los Angeles basin model)*

4) *Service availability includes any other systems providing additional sources of surveillance information.*

5) *Altitude accuracy: Some aircraft currently have only 100 ft resolution capability.*

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

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

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

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

Current requirements in the En Route and Terminal airspace are deemed to be much less stressful than the other applications in Section 2. Characteristics of surveillance systems currently in use in the NAS for En Route and Terminal are listed in Table 2-9(a). These characteristics are provided for information and comparison only. ADS-B will support equal or better surveillance application performance (e.g., see Table 2-9(b)). Traffic densities and operational domain radius can be used for expected loading on the ADS-B data link broadcast medium. The existing degree of independence between navigation and surveillance will be needed in the future until combined system performance standards are developed [6].

2.2.3.2 ATS Provider Needs for Separation and Conflict Management on the Airport Surface

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

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

In the early stages of implementation, functions supported by ADS-B can be integrated with the controller's automation tools to provide several benefits including 1) reduction in taxi delays, based on improved controller situational awareness, 2) operation in zero-visibility conditions for equipped aircraft and airport surface vehicles, and 3) improved controller ability to predict and intervene in potential incursions, along with a reduction in false alarms.

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

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

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

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

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

2.2.3.2.1 Environment

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

2.2.3.2.2 Operational Scenario

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

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

2.2.3.2.3 Requirements

See Table 2-7 for information exchange needs and see Table 2-9(a) and Table 2-9(b) for operational performance needs to support ATS surveillance on the airport surface.

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

2.2.3.3 ATS Conformance Monitoring Needs

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

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

2.2.3.3.1 Operational Scenario (Parallel Runway Monitoring)

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

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

2.2.3.3.2 Requirements

See Table 2-7 for information exchange needs and see Table 2-9(a) and Table 2-9(b) for operational performance needs to support ATS parallel runway conformance monitoring.

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3 ADS-B System definition and Functional Requirements

This section defines, within the context of the operational applications discussed in Section 2, the ADS-B System and its functional and performance requirements. Section 3.1 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 3.3are 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

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.

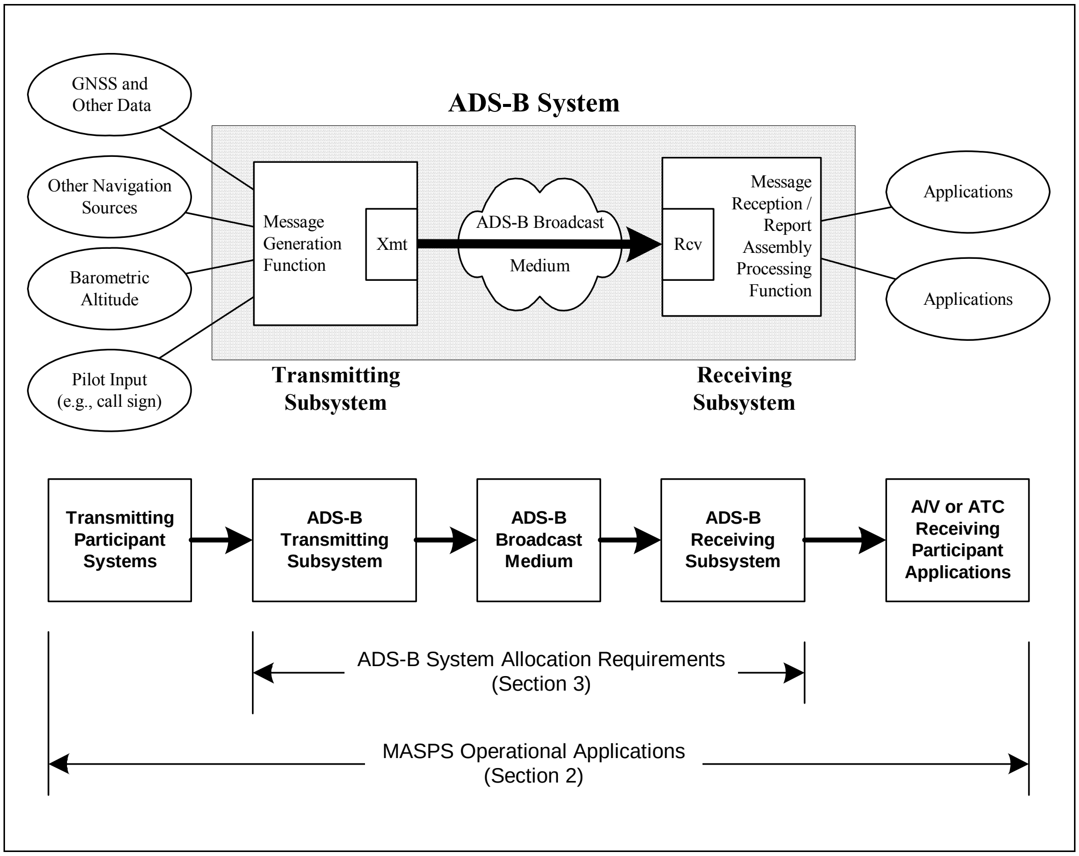


Figure 3-1: Relationship of MASPS Operational Requirements to ADS-B System Requirements

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 ADS-B System Description

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

3.2.1 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.

3.2.1.1 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 ~~Target State reports for short-term intent information,~~ 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.

3.2.1.2 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.

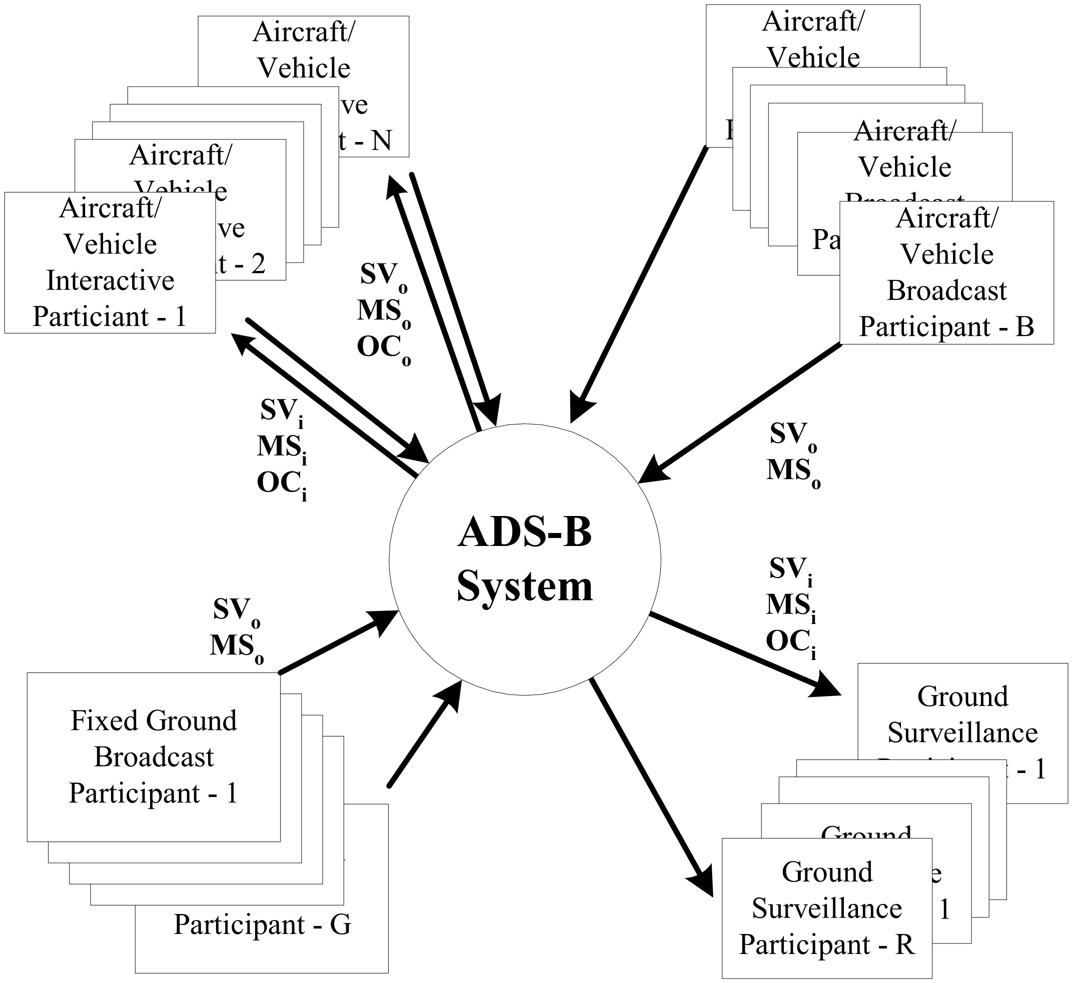
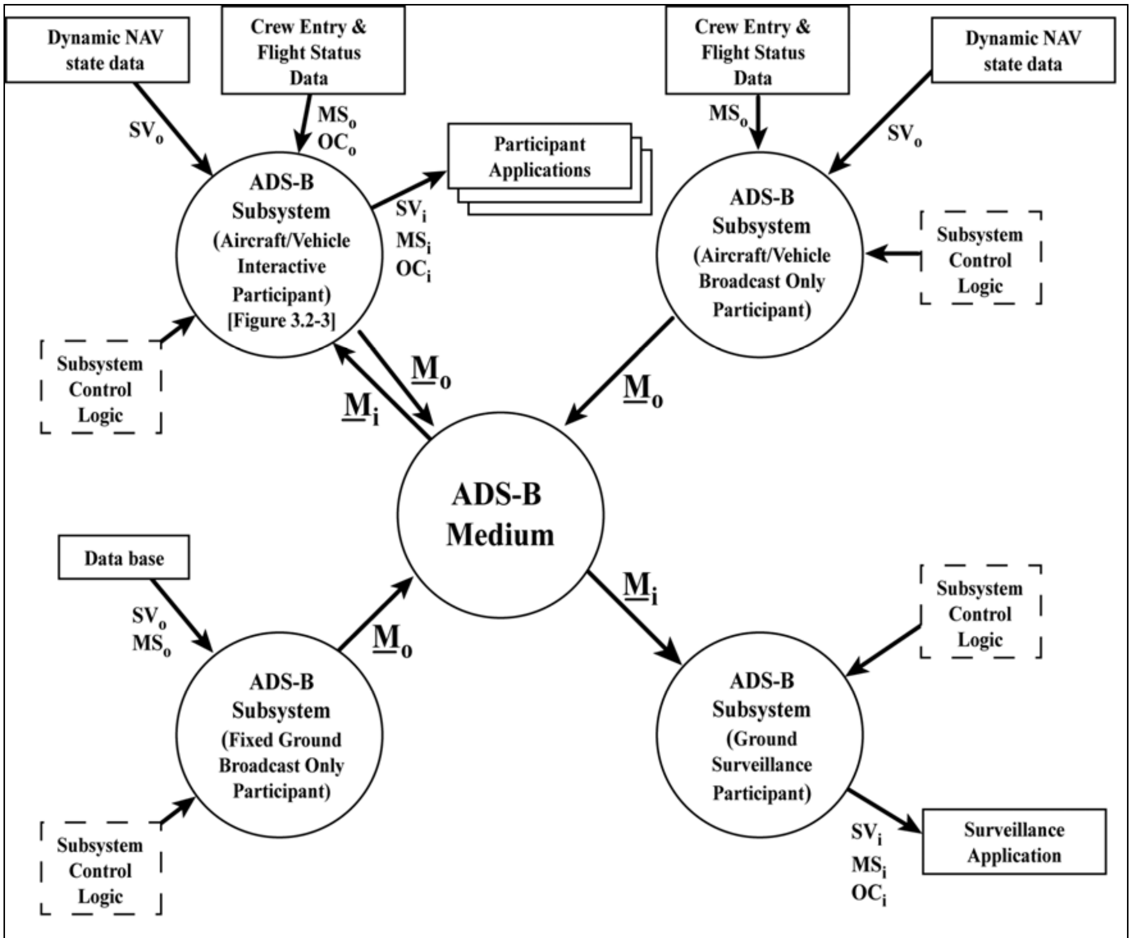


Figure 3-2: Illustrative ADS-B System Level Context Diagram

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



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

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

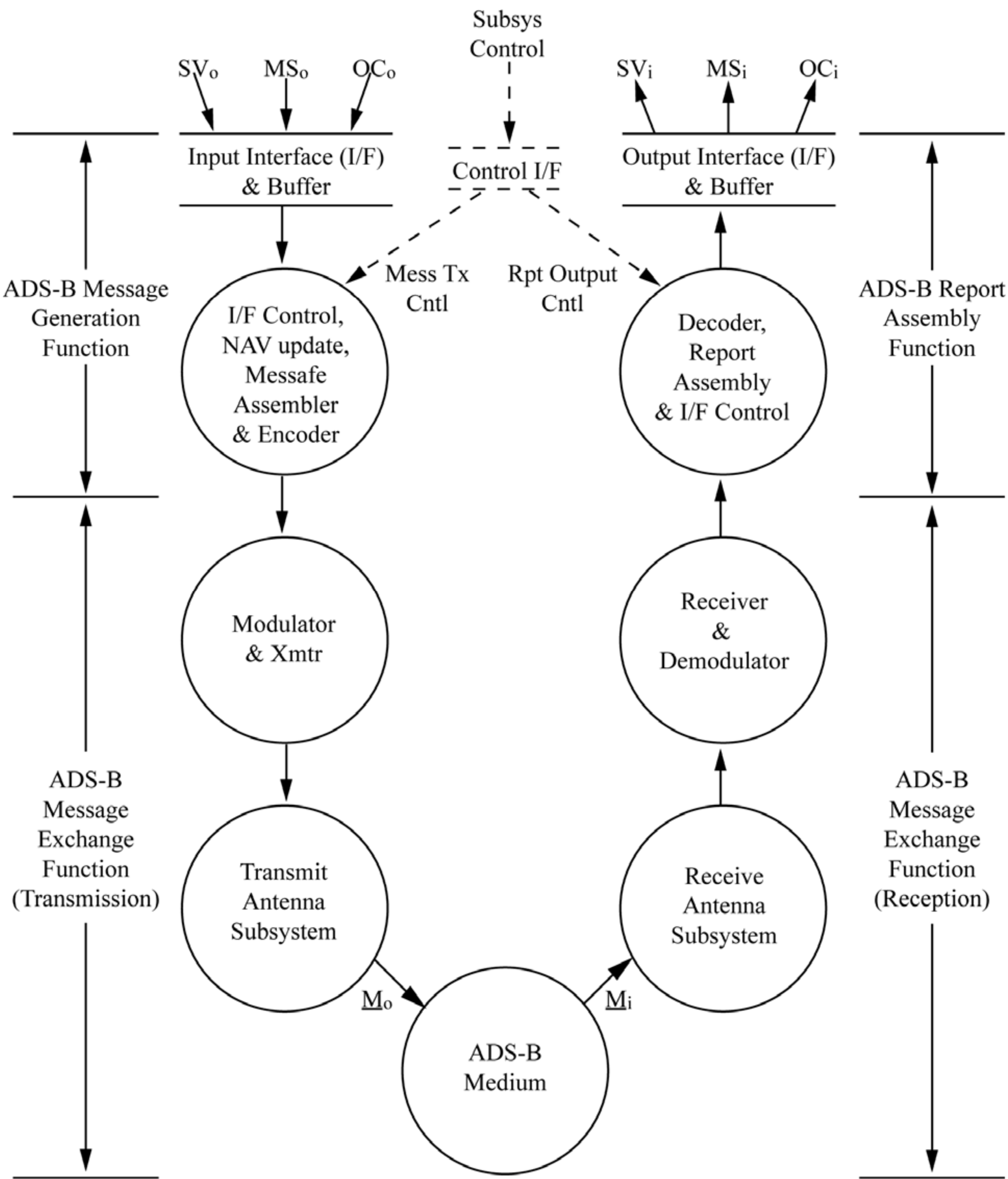


Figure 3-4: ADS-B Functional Level Context Diagram for Aircraft Interactive Subsystem

3.2.1.3 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.

3.2.2 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.

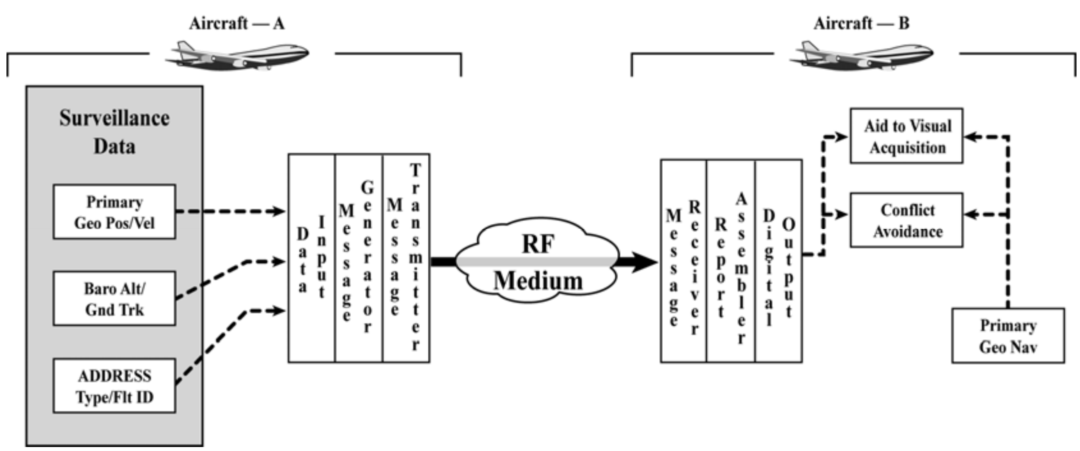


Figure 3-5: Example of A/C Pair Supporting Aid to Visual Acquisition and Conflict Avoidance Applications

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.

3.2.3 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 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 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)

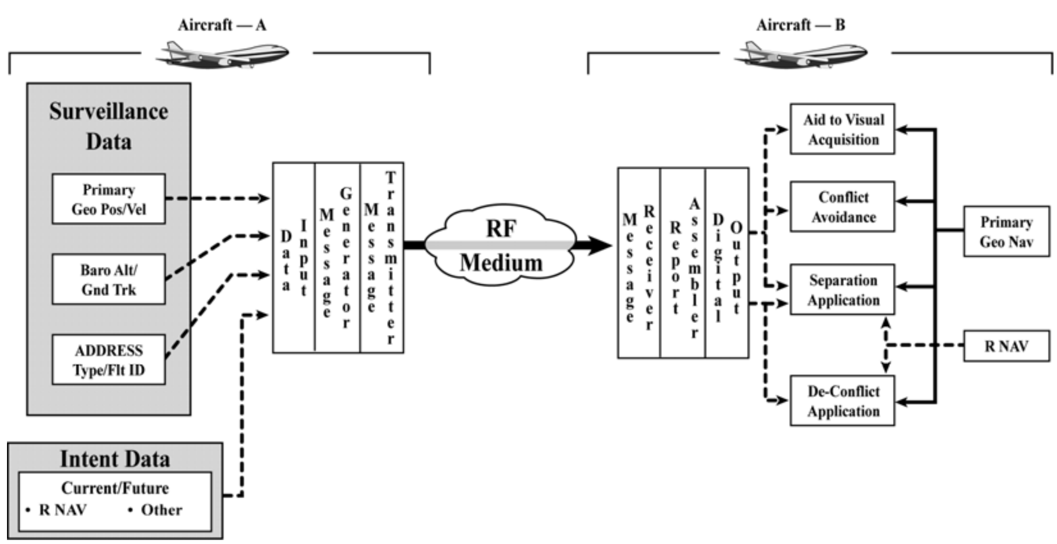


Figure 3-6: Example of A/C Pair Capable of Supporting Free Flight Applications

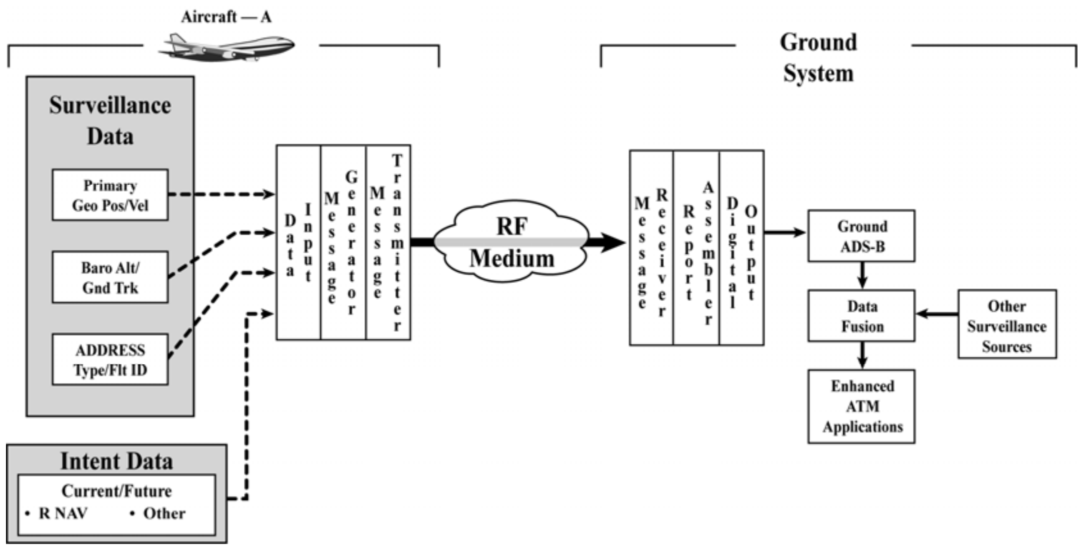


Figure 3-7: Example of ADS-B Support of Ground ATS Applications

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.

3.2.3.1 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 conflict management. Class A3 has the ability to broadcast and receive multiple TC reports.

3.2.3.2 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	Features	Comments
Interactive Aircraft/Vehicle Participant Subsystems (Class A)				
A0	Minimum Interactive Aircraft/Vehicle	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	Standard transmit and receive	Provides ADS-B based conflict avoidance and interface to current TCAS surveillance algorithms/ display
A2	Enhanced Interactive Aircraft	A1 plus merging, conflict management, in-trail climb	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.
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.
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.

3.2.3.3 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 System 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; 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.

3.3.1 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** (R3.1) provide the air-to-air coverage specified in Table 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** (R3.2) support the associated pair-wise minimum operational ranges listed in Table 3-2(b). Broadcast only aircraft (class B0 and B1) **shall** (R3.3) 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** (R3.4) 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** (R3.5) 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** (R3.6) 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) and Table 3-2(b). Given the air-to-air ranges from Table 2-8, and repeated in Table 3-2(a), 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) 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), 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) and Table 3-2(b) 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 3-2(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 3-2(b) Interoperability Ranges in NM for Aircraft Equipage Class Parameters Given in Table 3-2(a)

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

3.3.2 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** (R3.7) meet the required information broadcast and receiving capability at the indicated range to support the applications indicated in Table 3-3(a) and Table 3-3(b).

The rationale for the requirements in Table 3-3(a) is as follows. Column 1 of Table 3-3(a) 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). 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) and Table 3-3(b)). 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): 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 visual 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., 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.)*

Table 3-3(b): 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 visual 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., 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	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B1 Aircraft	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 ADS-B Data Exchange Requirements

3.3.3.1 Report Accuracy, Update Period, and Acquisition Range

The subparagraphs below specify the report accuracy, update period, and acquisition range requirements for state vector, modes status, and specific on-condition reports. For each of these subparagraphs, report acquisition **shall** (R3.8) 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.

3.3.3.1.1 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). The state vector report **shall** (R3.9) 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), the state vectors from at least 95% of the observable user population (radio line-of-sight) supporting that application **shall** (R3.10) 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** (R3.11) be as specified in Table 3-4(a): (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3).

Table 3-4(a) 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** (R3.12) 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. The maximum errors specified in Table 3-4(a) 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** (R3.13) be sufficient to provide equivalent track accuracy implied in Table 3-4(a) 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).

Table 3-4(a): SV Accuracy, Update Interval, and Acquisition Range Requirements

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

<u>*Definitions for Table 3-4(a):*</u>

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.

<u>*Notes for Table 3-4(a):*</u>

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) 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.*

3.3.3.1.2 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). For each of the equipage classes included in Table 3-4(b), the mode status reports from at least 95% of the observable (radio line of sight) population **shall** (R3.14-A) be acquired at the range specified in the "Required 95th Percentile Acquisition Range" row of Table 3-4(b). (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), the mode status reports from at least 99% of the observable (radio line of sight) population **shall** (R3.14-B) be acquired at the reduced range specified in the "Required 99th Percentile Acquisition Range" row of Table 3-4(b).

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): 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)		Merging, Conflict Management, In-Trail Climb	Long Range Conflict Management	AILS, Paired Approach	Surface Situational Awareness
	Enhanced Visual Acquisition	Station Keeping				
Required 95^{th} 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 99^{th} 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):

n/a: not applicable.

<u>Notes for Table 3-4(b):</u>

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 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.*

3.3.3.1.3 Air Referenced Velocity Acquisition, Update Interval, and Acquisition Range

Air referenced velocity (ARV) update periods and acquisition range requirements are summarized in <u>Table 3-4(c)</u>. 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.

<u>Note:</u> *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) 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): *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** (R3.15) 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** (R3.16) 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** (R3.17) 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** (R3.18) 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** (R3.19) 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** (R3.20) be consistent with those stated in Note 3 of Table 3-4(a).

3.3.3.1.4 Target State and Trajectory Change Report Acquisition, Update Interval, and Acquisition Range

Target State and Trajectory Change report update periods and acquisition range requirements are summarized in Table 3-4(d). 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 Target 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 TS 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** (R3.21) 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) 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** (R3.22) have a 20 NM acquisition range for TS Report. For equipage class A2, the acquisition range for TS reports and TC reports **shall** (R3.23) be 40 NM, with 50 NM desired. For equipage class A3, the acquisition range for TC reports in the forward direction **shall** (R3.24) be 90 NM, with 120 NM desired. The range requirements in all other directions for A3 equipment **shall** (R3.25) be consistent with those stated in Note 3 of Table 3-4(a).

Table 3-4(d): 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):

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(d) 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 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 State Vector Report Latency and Report Time Error Requirements

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 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.

3.3.3.2.2 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** (R3.26) be less than 1.2 s with 95 percent confidence. If either $NAC_P \geq 10$ or NIC ≥ 9, then ADS-B latency **shall** (R3.27) be less than 0.4 s with 95% confidence. The standard deviation of the report time error **shall** (R3.28) be less than 0.5 s (1 sigma). The mean report time error for position **shall** (R3.29) not exceed 0.5 s. The mean report time error for velocity **shall** (R3.30) not exceed 1.5 s. Differential delay errors should be considered and, if necessary, compensated for by the using application. ADS-B is not required to compensate for differential delays; however, all necessary information to perform such compensation is included in the ADS-B state vector report. Appendices G, J, and K provide a more detailed discussion of the different sources of latency, and provide the rationale for these numerical requirements.

3.3.4 ADS-B Network Capacity

The ADS-B network must be designed to accommodate expected future peak airborne traffic levels, as well as any airport surface units within range. The expected airborne and surface count in the United States is based on the LA Basin 1999 maximum estimate. [9, 16] It is assumed that air traffic in this area would increase by a few percent each year until 2020, when it would be 50% higher than the maximum level measured in 1999. The distribution of aircraft in the scenario is based on approximations of measured altitude and range density distributions. The distribution for LA Basin 2020 scenario is given by the labeled curves in Figure 3-8.

Note: *The LA2020 scenario in Figure 3-8 is taken from the summary published by the Technical Link Assessment Team (TLAT) in Appendix H of the Technical Link Assessment Report, March 2001. The March 2001 TLAT Report summarizes the technical assessment of candidate ADS-B/situational awareness links commissioned by both (1) the Safe Flight 21 (SF21) Steering Committee consistent with the recommendations of the RTCA Free Flight Select Committee and (2) the Eurocontrol ADS Programme Steering Group (PSG). The March 2001 TLAT Report builds upon the November 1999, Phase One Report developed by a precursor to the TLAT, the SF21 Technical ADS-B Link Evaluation Team.*

The ADS-B system **shall** (R3.31) be capable of meeting the requirements of this document, unless otherwise explicitly noted for a given requirement, in the traffic density shown by the LA 2020 curves in Figure 3-8, and as further detailed in Table 3-5. Requirements specified for en route, Low Density air space **shall** (R3.32) be met in the traffic density shown by the Low Density curve in Figure 3-8.

The following assumptions are made for the airborne and ground aircraft, and ground vehicles for the LA Basin 2020 scenario:

- The density of airborne aircraft is taken to be:
    a. Constant in range from the center of the area out to 225 nautical miles (5.25 aircraft/NM), (i.e., the inner circle of radius one NM would contain approximately five aircraft, as would the ring from 224 to 225 NM) and
    b. Constant in area from 225 NM to 400 NM (0.00375 aircraft/NM2)

- There are assumed to be a fixed number of aircraft on the ground (within a circle of radius 5 NM at each airport), divided among LAX, San Diego, Long Beach, and five other small airports. Half of the aircraft at each airport were assumed to be moving at 15 knots, while the other half were stationary. In addition, a total of 300 ground vehicles are distributed at these airports as well.
- The altitude distribution of the airborne aircraft is assumed to be exponential, with a mean altitude of 5500 feet. This distribution is assumed to apply over the entire area.

  Note: *The TLAT LA2020 traffic scenario did not account for local terrain as it assumed a smooth earth model. For improved fidelity, adjustment off the aircraft altitudes in the traffic scenarios appropriate when used in conjunction with a link performance model that includes terrain.*

- The airborne aircraft are assumed to have the following average velocities, determined by their altitude. The aircraft velocities for aircraft below 25000 feet are uniformly distributed over a band of average velocity +/- 30 percent.
  a. 0-3000 feet altitude 130 knots
  b. 3000-10000 ft 200 knots
  c. 10000-25000 ft 300 knots
  d. 25000-up 450 knots
- The aircraft are all assumed to be moving in random directions in the horizontal direction defined by their respective velocities.
- ADS-B MASPS equipage class A0 aircraft are restricted to fly below 18,000 feet. All other aircraft are assumed to be capable of flying at any altitude. The aircraft in the LA 2020 scenario are assumed to be in the following proportions:
  a. A3 30%
  b. A2 10%
  c. A1 40%
  d. A0 20%

3.3.4.1 High Density

The scenario for the 2020 high density LA Basin case contains a total of 2694 aircraft: 1180 within the core area of 225 NM, 1289 between 225-400 NM, and 225 on the ground. This represents a scaling of the estimated maximum 1999 LA Basin levels upward by 50 percent. Of these aircraft, approximately 500 lie within 60 NM of the center (this includes aircraft on the ground). Approximately ten percent of the total number of aircraft are above 10,000 feet in altitude, and more than half of the aircraft are located in the outer (non-core) area of the scenario.

An attempt was made to at least partially account for the expected lower aircraft density over the ocean. In the third quadrant (between 180 degrees and 270 degrees), for distances greater than 100 NM from the center of the scenario, the density of aircraft is reduced to 25 % of the nominal value used. The other 75 % of aircraft, which would have been placed in this area, are distributed uniformly among the other three quadrants at the same range from the center. This results in relative densities of 1:5 between the third quadrant and the others.

3.3.4.2 Low Density

For simplicity, the number of aircraft for the low-density scenario is set by scaling the current maximum LA Basin levels downward by a factor of five, amounting to 360 total aircraft. These aircraft are uniformly distributed in the horizontal plane within a circle of 400 nautical miles. In the vertical direction, they are distributed uniformly between 25,000 feet and 37,000 feet. The velocities are all set to 450 knots and are randomly distributed in azimuth. All of the aircraft are assumed to be A3 equipped.

Table 3-5: Number of A/V and Range Distribution

Range (NM)	LA Basin 2020			Low Density
	On-the-Ground	Airborne Only	Total Units	Total Units
50	143	260	403	4
100	190	520	710	20
150	225	781	1006	48
200	225	1045	1270	88
250	225	1321	1546	138
300	225	1648	1873	203
350	225	2021	2246	274
400	225	2469	2694	360

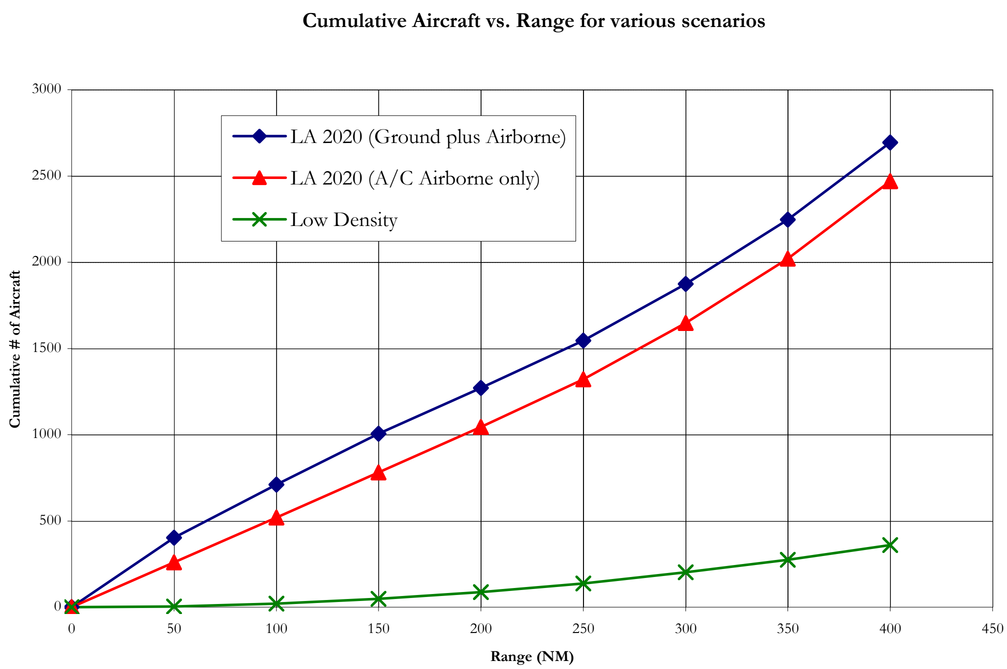


Figure 3-8: Peak Traffic Based on Los Angeles Basin 2020 Scenario And Assumed Surface Traffic

3.3.5 ADS-B Medium

The ADS-B RF medium **shall** (R3.33) be suitable for all-weather operation, and ADS-B system performance will be specified relative to a defined interference environment for the medium. Radio frequencies used for ADS-B Message transmission **shall** (R3.34) operate in an internationally allocated aeronautical radionavigation band(s). Appendix G summarizes certain antenna and multipath considerations that relate to the selection of a frequency band and message format.

Note: *The interference environment for a particular ADS-B medium will be specified in the relevant MOPS.*

3.3.6 ADS-B System Quality of Service

3.3.6.1 Required Monitoring Performance

A key concept in the definition of future ATS systems is that of Required Monitoring Performance (RMP). The term "Monitoring Performance" refers to capabilities of an airspace user to monitor other users and be monitored by other users and ATS at a level sufficient for participation of the user in both strategic and tactical operations. RMP is intended to characterize aircraft path prediction capability and received accuracy, integrity, continuity of service, and availability of a monitoring system for a given volume of airspace and/or phase of operation. Important monitoring system parameters such as state vector report received update rate can be derived from the primary RMP parameters.

Aircraft path prediction capability is defined by a 95 percent position uncertainty volume as a function of prediction time over a specified look ahead interval. Monitoring integrity (assurance of accurate, reliable information), where there is availability of service, must be defined consistent with the desired airspace application. Monitoring continuity of service and availability also must be defined consistent with the desired airspace application.

Development of the RMP concept is in progress by RTCA. Companion concepts of Required Navigation Performance (RNP) and Required Communications Performance (RCP) have also been developed in order to provide the necessary characterization of Required System Performance (RSP) of aviation Communications, Navigation, and Surveillance (CNS) systems. RMP, RNP, and RCP are central to the future FANS/ATM system and the realization of Free Flight. ADS-B delivery technologies, data definition, and applications must conform to appropriate RMP specifications on an end-to-end basis.

3.3.6.2 Failure Mode and Availability Considerations

Navigation and radar surveillance in the horizontal dimensions are independent; this independence is beneficial under certain failure modes. Today, an aircraft with failed navigation capability may get failure mode recovery vectors from ATS based on SSR/PSR tracks. Today, an aircraft with a failed transponder may still report navigation based position information to ATS for safe separation from other traffic even if no PSR is available. On the other hand, a navigation capability failure in an ADS-B only surveillance environment results in both the aircraft and ATS experiencing uncertainty about the aircraft's location. The operational impact of such a failure depends upon the nature of the failure: i.e., a single unit failure, or an area wide outage. Additional factors include the duration of the failure, the traffic density at the time of the failure, and the overall navigation and surveillance architecture. Detailed treatment of these issues should consider the failure mode recovery process in the context of the service outage duration and the total CNS environment. Figure 3-9 suggests how such a failure mode recovery process depends upon the total ATS architecture. Different states may implement different ATS architectures.

It is anticipated that ADS-B will be used as a supplemental means of surveillance for some ATS-based airspace operations during a transition period leading to full ADS-B equipage. When used as a supplemental means of surveillance, ADS-B adds availability within a larger surveillance system. Primary means of surveillance is defined as a preferred means (when other means are available) of obtaining surveillance data for aircraft separation and avoidance of obstacles. Use of ADS-B as a sole means of surveillance presumes that aircraft can engage in operations with no other means of surveillance. If ADS-B were to be used as a sole means of surveillance, availability would be calculated using only ADS-B, aircraft sources, and applications. ADS-B is not expected to be used as a sole means of ATS surveillance for the near future in US domestic airspace.

Where the ADS-B System is used as a supplemental means of surveillance, the ADS-B system is expected to be available with a probability of at least 0.95 for all operations, independent of the availability of appropriate inputs to the ADS-B system. Where the ADS-B System is used as a primary means of surveillance, the system is expected to be available with a probability of at least 0.999 for all air-air operations.

If an ADS-B system is used as a primary means of surveillance, then a supplemental surveillance system, independent of the navigation system, is expected to be available. The overall surveillance system will need to satisfy fail-safe operation of navigation and surveillance, i.e., a failure of the navigation system will not result in a failure of the surveillance function. This will enable ATS to provide an independent means of guidance to aircraft losing all navigation capability. The overall requirement for the surveillance system is adequate availability of the surveillance function, independent of navigation system availability. Where this requirement cannot be satisfied in a system intended for primary means of surveillance, the avionics and support infrastructure should be designed such that the simultaneous loss of both navigation and surveillance is extremely improbable. The expected availability of the total surveillance system is at least 0.99999, independent of navigation system availability.

3.3.6.3 ADS-B Availability Requirements

Availability is calculated as the ADS-B System Mean-Time-Between-Failures (MTBF) divided by the sum of the MTBF and Mean-Time-To-Restore (MTTR). ADS-B equipage is defined to be available for an operation if the following conditions are met: (1) ADS-B equipage outputs are provided at the rates defined in Tables 3-4(a) through 3-4(e) and (2) the ADS-B reports have the integrity required by §3.3.6.5. For the purposes of calculating availability, an ADS-B transmission subsystem is considered to be one participant's message generation function and message exchange (transmission) function. An ADS-B receiver subsystem is considered to be one participant's message exchange (receiver) and one report generation function.

ADS-B availability **shall** (R3.35) be 0.9995 for class A0 through class A3 and class B0 through class B3 transmission subsystems. ADS-B availability **shall** (R3.36) be 0.95 for class A0 receiver subsystems. Class A1, A2, and A3 receiver subsystems **shall** (R3.37) have an availability of 0.9995. Specification of Class C receiver subsystem availability requirements are beyond the scope of this MASPS.

High transmission availability (0.9995) is required of all classes in order to support the use of ADS-B as a primary means of surveillance for ATS. The combination of 0.9995 availability of transmission and 0.9995 availability of receive for classes A1 through A3 results in availability of 0.999, allowing the use of ADS-B as a primary means of surveillance for some air-to-air operations. A lower availability is permissible for Class A0 receiver subsystems as ADS-B is expected to be used as a supplemental, rather than as a primary tool of separation, for this class.

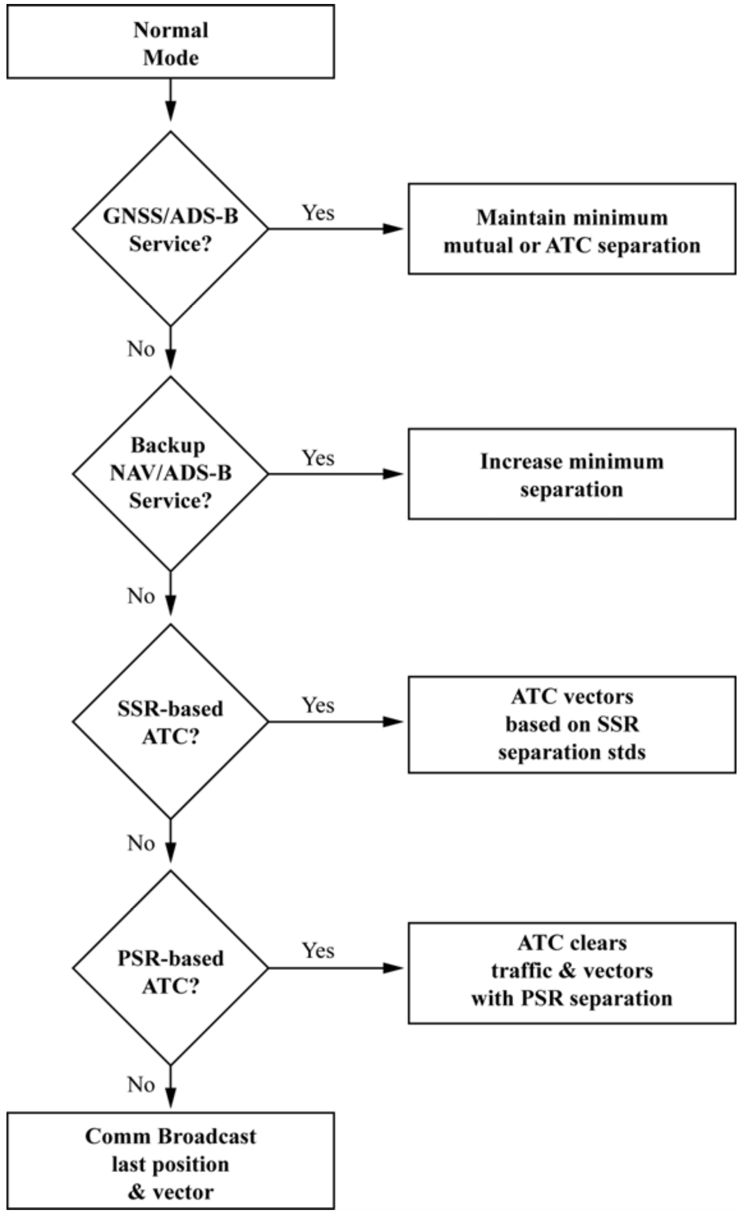


Figure 3-9 GNSS/ADS-B Surveillance/Navigation Failure Recovery Modes

3.3.6.4 ADS-B Continuity of Service

The probability that the ADS-B System, for a given ADS-B Message Generation Function and in-range ADS-B Report Generation Processing Function, is unavailable during an operation, presuming that the System was available at the start of that operation, **shall** (R3.38) be no more than 2 x 10^{-4} per hour of flight. The allocation of this requirement to ADS-B System Functions should take into account the use of redundant/diverse implementations and known or potential failure conditions such as equipment outages and prolonged interference in the ADS-B broadcast channel.

3.3.6.5 ADS-B Integrity

ADS-B integrity is defined in terms of the probability of an undetected error in a report received by an application, given that the ADS-B system is supplied with correct source data. The integrity of the ADS-B System **shall** (R3.39) be 10^{-6} or better on a per report basis. Appendix I contains information relevant to the development of high integrity end-to-end surveillance, conflict detection and management, and separation assurance applications using ADS-B.

Demonstration of compliance with ADS-B System integrity requirements will require a safety assessment to evaluate the System's implementation against known or potential failure conditions such as encoding, decoding and processing errors and interference in the ADS-B channel.

3.4 ADS-B Messages And Reports

This section provides requirements and definition of ADS-B reports and the relationship between these reports and the received messages. The ADS-B output report definitions establish the standard contents and conditions for outputting data qualified for user applications. Exchange of broadcast messages and report assembly considerations are discussed in §3.4.2. Report data elements are specified in §3.4.3 to §3.4.8 and standardized according to content, nomenclature, parameter type, applicable coordinate system, logical content, and operational conditions. Reports required for each Equipment Class and supporting message contents are defined in §3.3.2. Report contents and message requirements are based on the information requirements summarized in Table 2-7. These definitions provide the basis for:

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

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

3.4.1 Report Assembly Design Considerations

Three report types are defined as ADS-B outputs to applications. They provide flexibility in meeting delivery and performance requirements for the information needed to support the operations identified in Section 2. Report types, also shown in Figure 3-8, are:

- Surveillance State Vector Report (SV, §3.4.3);
- Mode-Status Report (MS, §3.4.4);

- Various On-Condition Reports (OC, §3.4.5) – a category that includes the following report types:
  - Air Referenced Velocity Report (ARV, §3.4.6),
  - Target State Report (TS, §3.4.7),
  - Trajectory Change Report (TC+0 or TC+n, §3.4.8), and
  - Other On-Condition Reports, which may possibly be defined in future versions of this MASPS.

All interactive participants must receive messages and assemble reports specified for the respective equipage class (Table 3-3(a). All transmitting participants must output at least the minimum data for the SV and MS reports. The minimum requirements for exchanged information and report contents applicable for equipage classes are provided in §3.3.2.

3.4.2 ADS-B Message Exchange Technology Considerations in Report Assembly

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

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

The messages **shall** (R3.40) be correlated, collated, uncompressed, re-partitioned, or otherwise manipulated as necessary to form the output reports specifically defined in §3.4.3 to §3.4.8 below. The message and report assembly processing capability of the receiving subsystem **shall** (R3.41) support the total population of the participants within detection range provided by the specific data link technology.

Receiving subsystem designs must provide reports based on all decodable messages received, i.e., for each participant the report **shall** (R3.42) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is received from that participant with the exception that no type of report is required to be issued at a rate of greater than once per second. The Report Assembler function converts the received messages into the reports appropriate to the information conveyed from the transmitting participant. The applicable reports **shall** (R3.43) be made available to the applications on a continual basis in accordance with the local system interface requirements.

Each ADS-B report contains an address, for the purpose of enabling the receiver to associate the receptions into a single track. If the ADS-B design uses the ICAO 24-bit address, then there **shall** (R3.44) be agreement between the address currently being used by the Mode S transponder and the reported ADS-B address, for aircraft with both transponder and ADS-B.

3.4.3 State Vector Report

Table 3-6 lists the report elements that comprise the state vector (SV) report. The SV report contains information about an aircraft or vehicle's current kinematic state. Measures of the state vector quality are contained in the NIC element of the SV report and in the NAC_P, NAC_V, NIC_{baro} and SIL elements of the Mode Status Report (§3.4.4 below).

Table 3-6: State Vector Report Definition.

	SV Elem. #	Contents	[Resolution or # of bits]	Required from airborne participants	Required from surface participants	Reference Section	Notes
ID	1	Participant Address	[24 bits]	•	•	2.1.2.2.2.1	
	2	Address Qualifier	[1 bit]	•	•	2.1.2.2.2.2	1
TOA	3	Time Of Applicability	[0.2 s]	•	•	3.4.3.3	
Geometric Position	4a	Latitude (WGS-84)		•	•	3.4.3.4	2, 3
	4b	Longitude (WGS-84)		•	•		
	4c	Horizontal Position Valid	[1 bit]	•	•	3.4.3.5	
	5a	Geometric Altitude		•		3.4.3.6	3, 4
	5b	Geometric Altitude Valid	[1 bit]	•		3.4.3.7	
Horizontal Velocity	6a	North Velocity while airborne		•		3.4.3.8	3
	6b	East Velocity while airborne		•			3
	6c	Airborne Horizontal Velocity Valid	[1 bit]	•		3.4.3.9	
	7a	Ground Speed while on the surface	[1 knot]		•	3.4.3.10	
	7b	Surface Ground Speed Valid	[1 bit]		•	3.4.3.11	
Heading	8a	Heading while on the Surface	[6° or better (6 bits)]		•	3.4.3.12	
	8b	Heading Valid	[1 bit]		•	3.4.3.13	
Baro Altitude	9a	Pressure Altitude		•		3.4.3.14	3, 4
	9b	Pressure Altitude Valid	[1 bit]	•		3.4.3.15	
Vertical Rate	10a	Vertical Rate (Baro/Geo)		•		3.4.3.16	3
	10b	Vertical Rate Valid	[1 bit]	•		3.4.3.17	
NIC	11	Navigation Integrity Category	[4 bits]	•	•	3.4.3.18	
Report Mode	12	SV Report Mode	[2 bits]			3.4.3.19	

Notes for Table 3-6:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links..*

2. *A horizontal position resolution finer than 20 m will be required if the NAC_P element of the MS report (§3.4.4.11) is 9 or greater (§2.1.2.13).*

3. *Resolution requirements of these elements must be sufficient to meet the error requirements specified in Table 3-4(a).*

4. *Future revisions of this MASPS may not require that both geometric and pressure altitudes – if available – to be broadcast at the SV rate. Conditions will need to be specified as to when each altitude must be the "primary" altitude being sent at the SV rate.*

3.4.3.1 Air/Ground State

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

Notes:

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

2. *A transmitting ADS-B participant's air/ground state also affects whether the aircraft size (length and width) codes in the MS report are to be broadcast. (See §3.4.4.6 below.)*

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

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

3.4.3.1.1 Determination of Air/Ground State

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

1. If a transmitting ADS-B participant is *not* equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is one of the following, then it **shall** (R3.45) set its air/ground state to "known to be airborne" :

   a. Light Aircraft
   b. Glider or Sailplane
   c. Lighter Than Air
   d. Unmanned Aerial Vehicle
   e. Ultralight, Hang Glider, or Paraglider
   f. Parachutist or Skydiver
   g. Point Obstacle
   h. Cluster Obstacle
   i. Line Obstacle

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

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

participant's emitter category is one of the following, then that participant **shall** (R3.46) set its air/ground state to "known to be on the surface" :

a. Surface Vehicle – Emergency
b. Surface Vehicle – Service

3. If a transmitting ADS-B participant is *not* equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is "rotorcraft," then that participant **shall** (R3.47) set its air/ground state to "uncertain whether airborne or on the surface."

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

4. If a transmitting ADS-B participant is *not* equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and its ADS-B emitter category is not one of those listed under tests 1, 2, and 3 above, then that participant's ground speed (GS), airspeed (AS) and radio height (RH) **shall** (R3.48-A) be examined, provided that some or all of those three parameters are available to the transmitting ADS-B subsystem. If GS < 100 knots, or AS < 100 knots, or RH < ~~100~~ 50 feet, then the transmitting ADS-B participant **shall** (R3.48-B) set its Air/Ground state to "known to be on the surface."

5. If a transmitting ADS-B participant *is* equipped with a means, such as a weight-on-wheels switch, to determine automatically whether it is airborne or on the surface, and that automatic means indicates that the participant is airborne, then that participant **shall** (R3.49) set its air/ground state to "known to be airborne."

6. If a transmitting ADS-B participant _is_ equipped with a means, such as a weight-on-wheels switch, to determine automatically whether it is airborne or on the surface, and that automatic means indicates that the participant is on the surface, then the following additional tests **shall** (R3.50) be performed to validate the "on-the-surface" condition:

   a. If the participant's ADS-B emitter category is any of the following:
      "Small Aircraft" or
      "Medium Aircraft" or
      "High-Wake-Vortex Large Aircraft" or
      "Heavy Aircraft" or
      "Highly Maneuverable Aircraft" or
      "Space or Trans-atmospheric Vehicle"

      and one or more of the following parameters is available to the transmitting ADS-B system:
      Ground Speed (GS) or
      Airspeed (AS) or
      Radio height from radio altimeter (RH)

      and any of the following conditions is true:
      GS > 100 knots or
      AS > 100 knots or
      RH > ~~100~~ 50 ft,

      then the participant **shall** (R3.51-A) set its Air/Ground state to "known to be airborne."

   b. Otherwise, the participant **shall** (R3.51-B) set its Air/Ground state to "known to be on the surface."

3.4.3.1.2 Effect of Air/Ground State

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

a. ADS-B participants that are known to be on the surface **shall** (R3.52) transmit those State Vector report elements that are indicated with bullets ("•") in the "required from surface participants" column of Table 3-6.

b. ADS-B participants that are known to be airborne **shall** (R3.53) transmit those SV report elements that are indicated by bullets ("•") in the "required from airborne participants" column of Table 3-6.

c. ADS-B participants for which the air/ground state is uncertain **shall** (R3.54) transmit those SV report elements that are indicated by bullets in the "required from airborne participants" column. It is recommended that such participants should also transmit those SV elements that are indicated with bullets in the "required from surface participants" column.

3.4.3.2 SV Report Update Requirements

Required SV report update rates, described by operating range, are given in Table 3-4(a) in §3.3.3.1 above.

a. A receiving ADS-B subsystem **shall** (R3.55) update the SV report that it provides to user applications about a transmitting ADS-B participant whenever it receives messages from that participant providing updated information about any of the SV report elements with the exception that SV reports are not required to be issued at a rate of greater than once per second.

b. For ADS-B systems that use segmented messages for SV data, *time-critical SV report elements* that are not updated in the current received message **shall** (R3.56) be estimated whenever the SV report is updated. The *time-critical SV elements* are defined as the following:

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

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

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

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

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

   vi. NIC (element 11).

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

c. For time-critical elements of the SV report, a receiving ADS-B subsystem's report assembly function **shall** (R3.57) indicate "no data available" if no data are received in the preceding coast interval specified in Table 3-4(a) (§3.3.3.1.1 above).

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

3.4.3.3 Time of Applicability (TOA) Field for SV Report

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

Note: *As mentioned in the definition of latency in §3.3.3.2.1 above, the times of applicability of position and velocity may differ. The TOA field in the SV report contains the time of applicability of position.*

The time of applicability (TOA) relative to local system time **shall** (R3.58) be updated with each State Vector report update.

Requirements on the accuracy of the TOA field in the SV report are given in §3.3.3.2.2 above, and may be paraphrased as follows:

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

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

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

Note: *The recommended TOA resolution of 0.2 s specified in Table 3-6 will meet the specifications in items a, b, and c above.*

3.4.3.4 Horizontal Position

Horizontal position (§2.1.2.4) **shall** (R3.59) be reported as WGS-84 latitude and longitude. Horizontal position **shall** (R3.60) be reported with the full range of possible latitudes (-90° to +90°) and longitudes (-180° to +180°).

Horizontal position **shall** (R3.61) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_P field of the Mode-Status report (§2.1.2.13 and §3.4.4). Moreover, horizontal position **shall** (R3.62) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to horizontal position error, σ_{hp}, listed in Table 3-4(a): 20 m for airborne participants, or σ_{hp} = 2.5 m for surface participants.

3.4.3.5 Horizontal Position Valid Field

The Horizontal Position Valid field in the SV report **shall** (R3.63-A) be set to ONE if a valid horizontal position is being provided in geometric position (latitude and longitude) fields of that report; otherwise, the Horizontal Position Valid field **shall** (R3.63-B) be ZERO.

3.4.3.6 Geometric Altitude Field

Geometric altitude **shall** (R3.64) be reported with a range from -1,000 feet up to +100,000 feet. If the NAC_P code reported in the MS report (§2.1.2.13) is 9 or greater, geometric altitude **shall** (R3.65) be communicated and reported with a resolution sufficiently fine that it does not compromise the vertical accuracy reported in the NAC_P field. Moreover, geometric altitude **shall** (R3.66) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to vertical position error, σ_{vp}, listed in Table 3-4(a): σ_{vp} = 30 feet for airborne participants.

Note: *A resolution of 100 feet or finer is sufficient not to compromise the one-sigma (one standard deviation) ADS-B contribution to vertical position error listed in Table 3-4(a). This is because the error introduced by rounding altitude to the nearest multiple of 100 feet has a uniform probability distribution, for which the standard deviation is 100 feet divided by the square root of 12, that is, about 28.9 feet.*

3.4.3.7 Geometric Altitude Valid Field

The Geometric Altitude Valid field in the SV report is a one-bit field which **shall** (R2.67) be ONE if valid data is being provided in the Geometric Altitude field (§3.4.3.6), or ZERO otherwise.

3.4.3.8 Geometric Horizontal Velocity

Geometric horizontal velocity is the horizontal component of the velocity of an A/V with respect to the earth (or with respect to an earth-fixed reference system, such as the WGS-84 ellipsoid). The range of reported horizontal velocity **shall** (R2.68) accommodate speeds of up to 250 knots for surface participants and up to 4000 knots for airborne participants. Horizontal velocity **shall** (R3.69) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode-Status report. Moreover, horizontal velocity **shall** (R3.70) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to horizontal velocity error, σ_{hv}, listed in Table 3-4(a): that is, 0.5 m/s (about 1 knot) for airborne participants with speeds of 600 knots or less, or 0.25 m/s (about 0.5 knot) for surface participants.

Note: *The rounding of velocity to the nearest encoded representation may be modeled with a uniform probability distribution. As such, the standard deviation (one-sigma velocity error, σ_{hv}) due to rounding to the nearest possible encoded representation is the weight of the LSB divided by the square root of 12. Thus, σ_{hv} = 0.5 m/s (about 1 knot) for airborne participants implies a resolution of $res_{hv} = \sigma_{hv} \cdot \sqrt{12}$ = 1.73 m/s (about 3.4 knots), so even a horizontal velocity resolution of 2 knots is sufficiently fine to meet the constraint imposed by Table 3-4(a) on airborne participants with speeds up to 600 knots. Likewise, a horizontal velocity resolution of 1 knot is sufficiently fine to satisfy the constraint imposed by Table 3-4(a) for surface participants.*

3.4.3.9 Airborne Horizontal Velocity Valid Field

The Airborne Horizontal Velocity Valid field in the SV report is a one-bit field which **shall** (R3.71-A) be set to ONE if a valid horizontal geometric velocity is being provided in the “North Velocity while airborne” and “East velocity while airborne” fields of the SV report; otherwise, the “Airborne Horizontal Velocity Valid” field **shall** (R3.71-B) be ZERO.

3.4.3.10 Ground Speed While On the Surface Field

The ground speed (the magnitude of the geometric horizontal velocity) of an A/V that is known to be on the surface **shall** (R3.72) be reported in the “ground speed while on the surface” field of the SV report. For A/Vs moving at ground speeds less than 70 knots, the ground speed **shall** (R3.73) be communicated and reported with a resolution of 1 knot or finer. Moreover, the resolution with which the “ground speed while on the surface” field is communicated and reported **shall** (R3.74) be sufficiently fine so as not to compromise the accuracy of that speed as communicated in the NAC_V field of the MS report (§2.1.2.14 below).

3.4.3.11 Surface Ground Speed Valid Field

The Surface Ground Speed Valid field in the SV report is a one-bit field which **shall** (R3.75) be ONE if valid data is available in the Ground Speed While on the Surface field (§3.4.3.10), or ZERO otherwise.

3.4.3.12 Heading While On the Surface Field

Heading (§2.1.2.9) indicates the orientation of an A/V, that is, the direction in which the nose of an aircraft is pointing. ADS-B Participants are not required to broadcast heading if their length code (part of the aircraft size code, §2.1.2.3 above) is 0. However, each ADS-B participant that reports a length code of 2 or greater **shall** (R3.76) transmit messages to support the heading element of the SV report when that participant is on the surface and has a source of heading available to its ADS-B transmitting subsystem.

Heading **shall** (R3.77-A) be reported for the full range of possible headings (the full circle, from 0° to nearly 360°). The heading of surface participants **shall** (R3.77-B) be communicated and reported with a resolution of 6 degrees of arc or finer.

<u>Notes:</u>

1. *If heading is encoded as a binary fraction of a circle, a resolution of 6° of arc or finer would require at least 6 binary bits.*

2. *The reference direction for heading (true north or magnetic north) is communicated in the True/Magnetic Heading Flag of the Mode-Status report (§3.4.4.16).*

3. *For operations at some airports, heading may be required to enable proper orientation and depiction of an A/V by applications supporting those surface operations.*

3.4.3.13 Heading Valid Field

The "heading valid" field in the SV report **shall** (R3.78-A) be ONE if a valid heading is provided in the "heading while on the surface" field of the SV report; otherwise, it **shall** (R3.78-B) be ZERO.

3.4.3.14 Pressure Altitude Field

Barometric pressure altitude **shall** (R3.79) be reported referenced to standard temperature and pressure (1013.25 hPa or mB, or 29.92 in Hg). Barometric pressure altitude **shall** (R3.80) be reported over the range of -1,000 feet to +100,000 feet.

If a pressure altitude source with 25-foot or better resolution is available to the ADS-B transmitting subsystem, then pressure altitude from that source **shall** (R3.81-A) be communicated and reported with 25-foot or finer resolution. Otherwise, if a pressure altitude source with 100-foot or better resolution is available, pressure altitude from that source **shall** (R3.81-B) be communicated and reported with 100-foot or finer resolution.

<u>Note:</u> *A field is reserved in the MS report ("BAQ" field, §3.4.4.14) for future use in reporting the accuracy and resolution of the pressure altitude provided in the SV report.*

3.4.3.15 Pressure Altitude Valid Field

The "pressure altitude valid" field in the SV report is a one-bit field which **shall** (R3.82-A) be ONE if valid information is provided in the "pressure altitude" field; otherwise, the "pressure altitude valid" field **shall** (R3.82-B) be ZERO.

3.4.3.16 Vertical Rate Field

The "vertical rate" field in the SV report contains the altitude rate (§2.1.2.8) of an airborne ADS-B participant. This **shall** (R3.83) be either the rate of change of pressure altitude or of geometric altitude, as specified by the "vertical rate type" element in the MS report. The range of reported vertical rate **shall** (R3.84) accommodate up to ±32000 ft/min for airborne participants. Geometric vertical rate **shall** (R3.85) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode-Status report. Moreover, vertical rate **shall** (R3.86) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to vertical rate error, σ_{vv}, listed in Table 3-4(a), that is, 1.0 ft/s for airborne participants.

Note: *Future versions of this MASPS will require that the resolution of barometric altitude rate be sufficiently fine that it does not compromise the Barometric Altitude Quality (BAQ) field (§3.4.4.14) reported in the MS report, which is not defined in this version of the MASPS.*

3.4.3.17 Vertical Rate Valid Field

The "vertical rate valid" field in the SV report is a one-bit field which **shall** (R3.87-A) be ONE if valid information is provided in the "vertical rate" field; otherwise, the "vertical rate valid" field **shall** (R3.87-B) be ZERO.

3.4.3.18 Navigation Integrity Category (NIC) Field

The NIC field in the SV report is a 4-bit field that **shall** (R3.88) report the Navigation Integrity Category described in Table 2-2 in §2.1.2.12 above.

3.4.3.19 Report Mode Field

The "Report Mode" provides a positive indication when SV and MS acquisition is complete and all applicable data sets and modal capabilities have been determined for the participant or that a default condition is determined by the Report Assembly function. The information for this SV element is not transmitted over the ADS-B data link, but is provided by the report assembly function at the receiving ADS-B participant. Table 3-7 lists the possible values for the SV Report Mode.

Table 3-7: SV Report Mode Values.

Value	Meaning
0	Acquisition
1	Track
2	Default

3.4.4 Mode Status Report

The mode-status (MS) report contains current operational information about the transmitting participant. This information includes participant type, mode specific parameters, status data needed for certain pair-wise operations, and assessments of the integrity and accuracy of position and velocity elements of the SV report. Specific requirements for a participant to supply data for and/or generate this report subgroup will vary according to the equipage class of each participant. §3.3.2 defines the required capabilities for each Equipage Class defined in §3.2.3. Equipage classes define the level of MS information to be exchanged from the source participant to support correct classification onboard the user system.

The Mode-Status report for each acquired participant contains the unique participant address for correlation purposes, static and operational mode information and Time of Applicability. Contents of the Mode-Status report are summarized in Table3-8.

The static and operational mode data includes the following information:

- Capability Class (CC) Codes – used to indicate the capabilities of a transmitting ADS-B participant.
- Operational Mode (OM) Codes – used to indicate the current operating mode of a transmitting ADS-B participant.

For each participant the Mode-status report **shall** (R3.89) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is accepted from that participant.

Table 3-8: Mode-Status (MS) Report Definition.

	MS Elem. #	Contents [Resolution or # of bits]	Elements That Require Rapid Update	Reference Section	Notes
ID	1	Participant Address [24 bits]		2.1.2.2.2.1	
	2	Address Qualifier [1 bit]		2.1.2.2.2.2	1
TOA	3	Time of Applicability [1 s resolution]		3.4.4.2	
Version	4	ADS-B Version Number [3 bits]		3.4.4.3	
ID, Continued	5a	Call sign [up to 8 alpha-numeric characters]		3.4.4.4	
	5b	Emitter Category [5 bits]		3.4.4.5	
	5c	A/V Length and Width Codes [4 bits]		3.4.4.6	2
Status	6a	Mode-Status Data Available [1 bit]		3.4.4.7	
	6b	Emergency/Priority Status [3 bits]		3.4.4.8	3
CC, Capability Codes	7	Capability Class Codes [16 bits]		3.4.4.9	
		7a: TCAS/ACAS ~~installed and~~ operational [1 bit]	•	3.4.4.9.1	4
		~~7b: CDTI display capability [1 bit]~~		3.4.4.9.2	
		7b: 1090 MHz ES Receive Capability [1 bit]			
		7c: (Reserved for Service Level) [4 bits]		3.4.4.9.3	
		7d: ARV report Capability Flag [1 bit]		3.4.4.9.4	
		7e: TS report Capability Flag [1 bit]		3.4.4.9.5	
		7f: TC report Capability Level [2 bits]		3.4.4.9.6	
		~~7g: Reporting ADS-B Reference Position [1 bit]~~		3.4.4.9.7	
		7g: UAT Receive Capability [1 bit]			
		(CC Codes reserved for future growth) [~~6~~ 3 bits]		3.4.4.9.8	
OM, Operational Mode	8	Operational Mode Parameters [16 bits]		3.4.4.10	
		8a: TCAS/ACAS resolution advisory active [1 bit]	•	3.4.4.10.1	4
		8b: IDENT Switch Active [1 bit]		3.4.4.10.2	3
		8c: Reserved for Receiving ATC services [1 bit]		3.4.4.10.3	
		8d: Single Antenna Flag [1 bit]		3.4.4.10.4	
		8e: System Design Assurance [2 bits]		3.4.4.10.5	
		8f: GPS Antenna Offset [8 bits]		3.4.4.10.6	
		(Reserved for future growth) [~~13~~ 2 bits]		~~3.4.4.10.4~~	
SV Quality	9a	Nav. Acc. Category for Position (NAC_P) [4 bits]	•	3.4.4.11	4
	9b	Nav Acc. Category for Velocity (NAC_V) [3 bits]	•	3.4.4.12	4
	9c	~~Surveillance~~ Source Integrity Level (SIL) [2 bits]	•	3.4.4.13	4
	9d	~~(Res. For BAQ, Barometric Altitude Quality) [2 bits]~~		3.4.4.14	
	9e	NIC_{baro} - Altitude Cross Checking Flag [1 bit]		3.4.4.15	
Data Reference	10a	True/Magnetic Heading [1 bit]		3.4.4.16	
	10b	Vertical Rate Type (Baro./Geo.) [1 bit]		3.4.4.17	
Other	11	Reserved for Flight Mode Specific Data [3 bits]		3.4.4.18	

Notes for Table 3-8:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. For example, address qualifier bits might be needed to distinguish reports about TIS-B targets from reports about ADS-B targets. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links.*

2. *The aircraft size code only has to be transmitted by aircraft above a certain size, and only while those aircraft are on the ground. (See §3.4.4.6 for details.)*

3. *These elements are primarily for air-to-ground use. Update rate requirements for ground applications are not defined in this MASPS. If higher rates are later deemed to be required, they will be addressed in a future revision of this MASPS.*

4. *Changes to the values of these elements may trigger the transmission of messages conveying the changed values at higher than nominal update rates. (Only those elements whose values have changed need be updated, not the entire MS report.) These update rates, the duration for which those rates must be maintained, and the operational scenario to be used to evaluate these requirements are to be defined in a future revision of this MASPS.*

3.4.4.1 MS Report Update Requirements

The report assembly function **shall** (R3.90-A) provide update when received. For those elements indicated in Table 3-8 as "elements that require rapid update", the report assembly function **shall** (R3.90-B) indicate the data has not been refreshed with the "Mode Status Data Available" bit (§3.4.4.7) if no update is received in the preceding 24 second period.

Note: *The 24-second period before which the "Mode-Status Data Available" bit is cleared was chosen as being the longest coast interval for SV reports, as indicated in Table 3-4(a) above.*

3.4.4.2 Time of Applicability (TOA) Field for MS Report

The time of applicability relative to local system time **shall** (R3.91) be updated with every Mode-Status report update.

3.4.4.3 ADS-B Version Number

The ADS-B Version Number is a 3-bit field that specifies the ADS-B version of the transmitting ADS-B system. The ADS-B Version Number **shall** (R3.92) be defined as specified in Table 3-9 below.

Table 3-9: ADS-B Version Number

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

Note: *Messages transmitted to support this report element might signify lower level document (i.e. MOPS) version. However, ADS-B reports need to – at a minimum – signify MASPS version so that applications can appropriately interpret received ADS-B data.*

3.4.4.4 Call Sign Field

An ADS-B participant's call sign (§2.1.2.2.1) is conveyed in the Call Sign field of the MS report. The call sign **shall** (R3.93) consist of up to 8 alphanumeric characters. The characters of the call sign **shall** (R3.94) consist only of the capital letters A-Z, the decimal digits 0-9, and – as trailing pad characters only – the "space" character.

3.4.4.5 Emitter Category Field

An ADS-B participant's category code (§2.1.2.2.3) is conveyed in the Emitter Category field of the MS report. The particular encoding of the emitter category is not specified in this MASPS, being left for lower level specification documents, such as the MOPS for a particular ADS-B data link. Provision in the encoding **shall** (R3.95) be made for at least 24 distinct emitter categories, including the particular categories listed in §2.1.2.2.3 above.

3.4.4.6 A/V Length and Width Codes

The "A/V Length and Width Codes" field in the MS field is a 4-bit field that describes the amount of space that an aircraft or ground vehicle occupies. The aircraft length and width codes **shall** (R3.96) be as described in Table 3-10 below. The aircraft size code is a four-bit code, in which the 3 most significant bits (the length code) classify the aircraft into one of eight length categories, and the least significant bit (the width code) classifies the aircraft into a "narrow" or "wide" subcategory.

Each aircraft **shall** (R3.97) be assigned the smallest length and width codes for which its overall length and wingspan qualify it.

Note: *For example, consider a powered glider with overall length of 24 m and wingspan of 50 m. Normally, an aircraft of that length would be in length category 1. But since the wingspan exceeds 34 m, it will not fit within even the "wide" subcategory of length category 1. Such an aircraft would be assigned length category 4 and width category 1, meaning "length less than 55 m and wingspan less than 52 m."*

Each aircraft ADS-B participant for which the length code is 2 or more (length greater than or equal to 25 m or wingspan greater than 34 m) **shall** (R3.98) transmit its aircraft size code while it is known to be on the surface. For this purpose, the determination of when an aircraft is on the surface **shall** (R3.99) be as described in §3.4.3.1.1 above.

Table 3-10: Aircraft Size (Length and Width) Codes

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

A/V - L/W Code (decimal)	Length Code			Width Code	Length Category (meters)	Width Category (meters)
	Bit 2	Bit 3	Bit 4	Bit 5		
0	0	0	0	0	0 < L < 15	0 < W < 11.5
1				1		11.5 ≤ W < 23
2	0	0	1	0	15 ≤ L < 25	23 ≤ W < 28.5
3				1		28.5 ≤ W < 34
4	0	1	0	0	25 ≤ L < 35	28 ≤ W < 33
5				1		33 ≤ W < 38
6	0	1	1	0	35 ≤ L < 45	34 ≤ W < 39.5
7				1		39.5 ≤ W < 45
8	1	0	0	0	45 ≤ L < 55	38 ≤ W < 45
9				1		45 ≤ W < 52
10	1	0	1	0	55 ≤ L < 65	52 ≤ W < 59.5
11				1		59.5 ≤ W < 67
12	1	1	0	0	65 ≤ L < 75	65 ≤ W < 72.5
13				1		72.5 ≤ W < 80
14	1	1	1	0	L ≥ 75	W < 80
15				1		W ≥ 80

3.4.4.7 Mode-Status Data Available Field

The Mode-Status Data Available field is a one-bit field in the MS report. The report assembly function **shall** (R3.100-A) set this field to ZERO if no data has be received within 24 seconds under the conditions specified in 3.4.4.1; otherwise the report assembly function **shall** (R3.100-B) set this bit to ONE.

3.4.4.8 Emergency/Priority Status Field

The emergency/priority status field in the MS report is a 3-bit field which **shall** (R3.101) be encoded as indicated in Table 3-11.

Table 3-11: Emergency/Priority Status Encoding

Value	Meaning
0	No emergency / not reported
1	General emergency
2	Lifeguard / medical emergency
3	Minimum fuel emergency
4	No communications
5	Unlawful interference
6	Downed Aircraft
7	(Reserved for future definition)

3.4.4.9 Capability Class (CC) Codes Field

A transmitting ADS-B participant broadcasts Capability Class (CC) codes (§2.1.2.10) so as to indicate capabilities that may be of interest to other ADS-B participants. The subfields of the CC codes field are described in the following subparagraphs.

3.4.4.9.1 TCAS/ACAS ~~Installed and~~ Operational

The CC code for "TCAS/ACAS ~~installed and~~ operational" **shall** (R3.102-A) be set to ONE if the transmitting ~~aircraft is fitted with a TCAS II or ACAS computer and that computer is turned on and operating in a mode that can generate Resolution Advisory (RA) alerts~~ subsystem receives information from an appropriate interface that indicates that the TCAS/ACAS system is operational. ~~Likewise, this CC code **shall** (R3.102-B) be set to ONE if the transmitting ADS-B equipment cannot ascertain whether or not a TCAS II or ACAS computer is installed, or cannot ascertain whether that computer, if installed, is operating in a mode that can generate RA alerts.~~ Otherwise, this CC code **shall** (R3.102-C) be ZERO.

Notes:

1. ~~*A value of ONE is intended to signal a receiving application that if it is necessary to avoid the transmitting aircraft, this should be done by horizontal rather than vertical maneuvers, because a Resolution Advisory from TCAS II or ACAS will advise the pilot to maneuver vertically. If it is unknown whether or not the transmitting aircraft has TCAS, it should set this CC code to ONE so that receiving aircraft will be more likely to use horizontal than vertical maneuvers if necessary to avoid the transmitting aircraft*~~ *ADS-B does not consider TCAS Operational equal to ONE (1) unless the TCAS is in a state which can issue an RA (e.g., RI=3 or 4). RTCA DO-181D (EUROCAE ED-73C) Mode-S Transponders consider that the TCAS System is operational when "MB" bit 16 of Register 10_{16} is set to "ONE" (1). This occurs when the transponder / TCAS interface is operational and the transponder is receiving TCAS RI=2, 3 or 4. (Refer to RTCA DO-181D (EUROCAE ED-73C), Appendix B, Table B-3-16.) RI=0 is STANDBY, RI=2 is TA ONLY and RI=3 is TA/RA.*

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

3.4.4.9.2 ~~CDTI Traffic Display~~ 1090 MHz ES Receive Capability

~~The CC code for "CDTI based traffic display capability" **shall** (R3.103-A) be set to ONE if the transmitting aircraft has a Cockpit Display of Traffic Information (CDTI) installed and is currently operating in a mode capable of displaying nearby ADS-B traffic. Otherwise, this CC code **shall** (R3.103-B) be ZERO.~~ The CC Code for "1090ES IN" in **shall** be set to ONE (1) if the transmitting aircraft has the capability to receive ADS-B 1090ES Messages. Otherwise, this CC code subfield **shall** be set to ZERO (0).

3.4.4.9.3 Service Level of Transmitting A/V

At least four bits (sixteen possible encodings) **shall** (R3.104) be reserved in the capability class codes for the "service level" of the transmitting ADS-B participant. ADS-B equipment conforming to the current version of this MASPS (DO-242A) **shall** (R3.105) set the Service Level code to ZERO.

Note: *When Service Levels are defined in the ASA MASPS, future versions of this MASPS will define Service Levels other than ZERO.*

3.4.4.9.4 ARV Report Capability Flag

The ARV Report Capability Flag is a one-bit field that **shall** (R3.106) be encoded as in Table 3-12.

Table 3-12: ARV Report Capability Flag

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

3.4.4.9.5 TS Report Capability Flag

The TS Report Capability Flag is a one-bit field that **shall** (R3.107) be encoded as in Table 3-13.

Table 3-13: TS Report Capability Flag

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

3.4.4.9.6 TC Report Capability Level

The TC Report Capability Level is a two-bit field that **shall** (R3.108) be encoded as in Table 3-14.

Table 3-14: TC Report Capability Levels

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

3.4.4.9.7 Reporting ADS-B Reference Position Flag UAT Receive Capability

The Reporting ADS-B Reference Position Flag is a one-bit subfield within the CC subfield that a transmitting ADS-B participant **shall** (R3.109-A) set to ONE if the A/V position that it transmits (in messages to support the SV report) is that of the participant's ADS-B position reference point (defined in §2.1.2.5 above). Otherwise, the transmitting ADS-B participant **shall** (R3.109-B) set this flag to ZERO. (See Figure 2-1 in §2.1.2.5 for an illustration of the ADS-B position reference point.) The "UAT IN" CC Code **shall** be set to ZERO (0) if the aircraft is NOT fitted with the capability to receive ADS-B UAT Messages. The "UAT IN" CC Code **shall** be set to ONE (1) if the aircraft has the capability to receive ADS-B UAT Messages.

3.4.4.9.8 Other Capability Codes

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

3.4.4.10 Operational Mode (OM) Parameters

Operational Mode (OM) codes are used to indicate the current operational modes of transmitting ADS-B participants. Specific operational mode codes are described in §3.4.4.10.1 to §3.4.4.10.73.4.4.10.4 below.

3.4.4.10.1 TCAS/ACAS Resolution Advisory Active Flag

The CC code for "TCAS/ACAS Resolution Advisory Active" **shall** (R3.110-A) be set to ONE if the transmitting aircraft has a TCAS II or ACAS computer that is currently issuing a Resolution Advisory (RA). Likewise, this CC code **shall** (R3.110-B) be set to ONE if the transmitting ADS-B equipment cannot ascertain whether the TCAS II or ACAS computer is currently issuing an RA. This CC code **shall** (R3.110-C) be ZERO only if it is explicitly known that a TCAS II or ACAS computer is not currently issuing a Resolution Advisory (RA).

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

3.4.4.10.2 IDENT Switch Active Flag

The "IDENT Switch Active" Flag is a one-bit OM code that is activated by an IDENT switch. Initially, the "IDENT switch active" OM code **shall** (R3.111-A) be ZERO. Upon activation of the IDENT switch, this flag **shall** (R3.111-B) be set to ONE for a period of 20 ± 3 seconds; thereafter, it **shall** (R3.111-C) be reset to ZERO.

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

3.4.4.10.3 Reserved for Receiving ATC Services Flag

The "Reserved for Receiving ATC Services" flag is a one-bit OM code. If implemented into future versions of this MASPS, ~~When~~ when set to ONE, this code **shall** (R3.112) indicate that the transmitting ADS-B participant is receiving ATC services; otherwise this flag should be set to ZERO.

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

3.4.4.10.4 Single Antenna Flag

The "Single Antenna Flag" is a 1-bit field that **shall** (R3.xxx) be used to indicate that the ADS-B Transmitting Subsystem is operating with a single antenna. The following conventions **shall** (R3.xxx) apply both to Transponder-Based and Stand Alone ADS-B Transmitting Subsystems:

a. Non-Diversity, i.e., those transmitting functions that use only one antenna, **shall** (R3.xxx) set the Single Antenna subfield to "ONE" at all times.

b. Diversity, i.e., those transmitting functions designed to use two antennas, **shall** (R3.xxx) set the Single Antenna subfield to "ZERO" at all times that both antenna channels are functional.

At any time that the diversity configuration cannot guarantee that both antenna channels are functional, then the Single Antenna Flag **shall** (R3.xxx) be set to "ONE."

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

3.4.4.10.5 System Design Assurance

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

The "System Design Assurance" (SDA) field is a 2-bit field that **shall** (R3.xxx) define the failure condition that the position transmission chain is designed to support as defined in Table 3-3.4.4.10.5.

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

Table 3-3.4.4.10.5: "System Design Assurance" OM Subfield in Aircraft Operational Status Messages

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

Notes:

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

3.4.4.10.6 GPS Antenna Offset

The "GPS Antenna Offset" field is an 8-bit field in the OM Code Subfield of surface format Aircraft Operational Status Messages that **shall** (R3.xxx) define the position of the GPS antenna in accordance with the following.

a. Lateral Axis GPS Antenna Offset:

The Lateral Axis GPS Antenna Offset **shall** (R3.xxx) be used to encode the lateral distance of the GPS Antenna from the longitudinal axis (Roll) axis of the aircraft. Encoding **shall** (R3.xxx) be established in accordance with Table 3-3.4.4.10.6A.

Table 3-3.4.4.10.6A: Lateral Axis GPS Antenna Offset Values

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

Notes:

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

b. Longitudinal Axis GPS Antenna Offset:

The Longitudinal Axis GPS Antenna Offset **shall** (R3.xxx) be used to encode the longitudinal distance of the GPS Antenna from the NOSE of the aircraft. Encoding **shall** (R3.xxx) be established in accordance with Table 3-3.4.4.10.6B. If the Antenna Offset is compensated by the Sensor to be the position of the ADS-B participant's ADS-B Position Reference Point (See §3.4.4.9.7), then the encoding is set to binary "00001" in Table 3-3.4.4.10.6B.

Table 3-3.4.4.10.6B: Longitudinal Axis GPS Antenna Offset Encoding

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

Notes:

1. *Maximum distance aft from aircraft nose is 60 meters or 196.85 feet. If the distance is greater than 60 meters, then the encoding should be set to 60 meters.*

2. *The accuracy requirement is assumed to be better than 2 meters, consistent with the data resolution.*

~~3.4.4.10.4~~3.4.4.10.7 Other Operational Mode Codes

Other operational mode (OM) codes are expected to be defined in later versions of this MASPS.

3.4.4.11 Navigation Accuracy Category for Position (NAC_P) Field

The Navigation Accuracy Category for Position (NAC_P, §2.1.2.13) is reported so that surveillance applications may determine whether the reported position has an acceptable level of accuracy for the intended use. The NAC_P field in the MS report is a 4-bit field which **shall** (R3.113) be encoded as described in Table 2-3 in §2.1.2.13 above.

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

3.4.4.12 Navigation Accuracy Category for Velocity (NAC_V) Field

The Navigation Accuracy Category for Velocity (NAC_V, §2.1.2.14) is reported so that surveillance applications may determine whether the reported velocity has an acceptable level of accuracy for the intended use. The NAC_V field in the MS report is a 3-bit field which **shall** (R3.114) be encoded as described in Table 2-4 in §2.1.2.14 above.

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

3.4.4.13 ~~Surveillance~~ Source Integrity Level (SIL) Field

The SIL field in the MS report is a 2-bit field which **shall** (R3.115) be coded as described in Table 2-5 in §2.1.2.15 above.

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

3.4.4.14 (Reserved for) ~~BAQ Field~~

A 2-bit field in the MS Report is reserved for future use ~~as a "Barometric Altitude Quality" field. In the current version (DO-242A) of this MASPS, the "Reserved for Barometric Altitude Quality" field **shall** (R3.116) be ZERO.~~

~~*Note: A possible future encoding of the BAQ field is described in §2.1.2.16.*~~

3.4.4.15 NIC_{baro} Field

The NIC_{baro} field in the MS report is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude. A transmitting ADS-B participant **shall** (R3.117-A) set NIC_{baro} to ONE in the messages that it sends to support the MS report only if there is more than one source of barometric pressure altitude data and cross-checking of one altitude source against the other is performed so as to clear the "barometric altitude valid" flag in the SV report if the two altitude sources do not agree. Otherwise, it **shall** (R3.117-B) set this flag to ZERO.

3.4.4.16 True/Magnetic Heading Flag

The True/Magnetic Heading Flag in the Mode-Status report is a one-bit field which **shall** (R3.118) be ZERO to indicate that heading is reported referenced to true north, or ONE to indicate that heading is reported referenced to magnetic north.

Note: The True/Magnetic Heading Flag applies to heading being reported in the SV report while on the surface (§3.4.3.12), heading reported in the ARV report while airborne (§3.4.6.6), and the target heading or track angle reported in the TS report (§3.4.7.5).

3.4.4.17 Vertical Rate Type Field

The Primary Vertical Rate Type field in the MS report is a one-bit flag which **shall** (R3.119) be ZERO to indicate that the vertical rate field in the SV report 3.4.3.16 holds the rate of change of barometric pressure altitude, or ONE to indicate that the vertical rate field holds the rate of change of geometric altitude.

3.4.4.18 (Reserved for) Flight Mode Specific Data Field

A 3-bit field in the MS Report is reserved for future use as a “Flight Mode Specific Data” field. In the current version (DO-242A) of this MASPS, the “Reserved for Flight Mode Specific Data” field **shall** (R3.120) be ZERO.

3.4.5 On-Condition Reports

The following paragraphs (§3.4.6 to §3.4.8) describe various On Condition (OC) reports. The OC reports are those for which messages are not transmitted all the time, but only when certain conditions are satisfied. Those OC report types currently defined are as follows:

ARV: Air Referenced Velocity (ARV) Report (§3.4.6).

TS: Target State (TS) Report (§3.4.7).

TC+0, TC+n: Trajectory Change (TC) Reports (§3.4.8).

Other On-Condition reports may be defined in future versions of this MASPS. Examples of such reports are to be found in Appendix M.

3.4.6 Air Referenced Velocity (ARV) Report

The Air Referenced Velocity (ARV) report contains velocity information that is not required from all airborne ADS-B transmitting participants, and that may not be required at the same update rate as the position and velocity elements in the SV report. Table 3-15 lists the elements of the ARV Report.

Table 3-15: Air Referenced Velocity (ARV) Report Definition.

	ARV Elem. #	Contents [Resolution or # of bits]	Reference Section	Notes
ID	1	Participant Address [24 bits]	2.1.2.2.2.1	
	2	Address Qualifier [1 bit]	2.1.2.2.2.2	1
TOA	3	Time of Applicability [1 s resolution]	3.4.6.3	
Airspeed	4a	Airspeed [1 knot or 4 knots]	3.4.6.4	
	4b	Airspeed Type and Validity [2 bits]	3.4.6.5	
Heading	5a	Heading while airborne [1 degree]	3.4.6.6	2
	5b	Heading Valid [1 bit]	3.4.6.7	

<u>*Notes for Table 3-15:*</u>

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links.*

2. *The heading reference direction (true north or magnetic north) is given in the MS report (§3.4.4).*

3.4.6.1 Conditions for Transmitting ARV Report Elements

There are no conditions specified in this MASPS for which it is required to transmit messages supporting ARV reports. Possible future conditions being considered for requiring ARV reports are discussed in Appendix Q.

Notes:

1. *Uses of the ARV report are anticipated for future applications such as in-trail spacing, separation assurance when the transmitting aircraft is being controlled to an air-referenced heading, and for precision turns. For example, ARV report information allows wind conditions encountered by the transmitting aircraft to be derived. Current heading also provides a consistent reference when the aircraft is being controlled to a target heading. Such anticipated uses for ARV information are described in Appendix Q.*

2. *Such uses will be associated with conditions for transmitting messages to support the ARV report. It is anticipated that when the requirements for such future applications are better understood, that additional conditions for transmitting the ARV report information may be included in a future revision of this MASPS.*

3.4.6.2 ARV Report Update Requirements

This section is reserved for update rate requirements when future versions of this MASPS define conditions under which the support of ARV reports is required.

Note: *It is expected that required ARV report update rates will not exceed those for State Vector (SV) reports.*

3.4.6.3 Time of Applicability (TOA) Field for ARV Report

The time of applicability relative to local system time **shall** (R3.121) be updated with every Air-Referenced Velocity report update.

3.4.6.4 Airspeed Field

Reported airspeed ranges **shall** (R3.122) be 0-4000 knots airborne. Airspeeds of 600 knots or less **shall** (R3.123) be reported with a resolution of 1 knot or finer. Airspeeds between 600 and 4000 knots **shall** (R3.124) be reported with a resolution of 4 knots or finer.

3.4.6.5 Airspeed Type and Validity

The Airspeed Type and Validity field in the ARV report is a 2-bit field that **shall** (R3.125) be encoded as specified in Table 3-16.

Table 3-16: Airspeed Type Encoding

Airspeed Type	Meaning
0	Airspeed Field Not Valid
1	True Airspeed (TAS)
2	Indicated Airspeed (IAS)
3	Reserved for Mach

3.4.6.6 Heading While Airborne Field

An aircraft's heading (§2.1.2.9) is reported as the angle measured clockwise from the reference direction (magnetic north or true north) to the direction in which the aircraft's nose is pointing. If an ADS-B participant broadcasts messages to support ARV reports, and heading is available to the transmitting ADS-B subsystem, then it **shall** (R3.126) provide heading in those messages. Reported heading range **shall** (R3.127) cover a full circle, from 0 degrees to (almost) 360 degrees. The heading field in ARV reports **shall** (R3.128) be communicated and reported with a resolution at least as fine as 1 degree of arc.

Note: *The reference direction for heading (true north or magnetic north) is reported in the True/Magnetic Heading Flag of the Mode-Status report §3.4.4.16 above).*

3.4.6.7 Heading Valid Field

The "Heading Valid" field in the ARV report **shall** (R3.129) be ONE if the "Heading While Airborne" field contains valid heading information, or ZERO if that field does not contain valid heading information.

3.4.7 Target State (TS) Report

The Target State (TS) Report provides information on the horizontal and vertical targets for the active flight segment. Table 3-17 lists the elements of this report.

➔ The Target State Report Definition in Tab;e 3-17 and the subparagraphs below will be totally revised based on the definition of the elements of the Target State and Status Messages in DO-260B and DO-282B. ➔

Table 3-17: Target State (TS) Report Definition.

	TS Report Elem. #	Contents [Resolution or # of bits]	Reference Section
ID	1	Participant Address [24 bits]	2.1.2.2.2.1
	2	Address Qualifier [1 bit]	2.1.2.2.2.2
TOA	3	Time of Applicability [1 s resolution]	3.4.7.3
~~**Horizontal Short Term Intent**~~	4a	~~Horizontal Data Available and Horizontal Target Source Indicator [2 bits]~~	~~3.4.7.4~~
	4b	~~Target Heading or Track Angle [1 degree]~~	~~3.4.7.5~~
	4c	~~Target Heading/Track Indicator [1 bit]~~	~~3.4.7.6~~
	4d	~~(Reserved for Heading/Track Capability) [1 bit]~~	~~3.4.7.7~~
	4e	~~Horizontal Mode Indicator [2 bits]~~	~~3.4.7.8~~
	4f	~~(Reserved for Horizontal Conformance) [1 bit]~~	~~3.4.7.9~~
~~**Vertical Short Term Intent**~~	5a	~~Vertical Data Available and Vertical Target Source Indicator [2 bits]~~	~~3.4.7.10~~
	5b	~~Target Altitude [100 ft]~~	~~3.4.7.11~~
	5c	~~Target Altitude Type [1 bit]~~	~~3.4.7.12~~
	5d	~~Target Altitude Capability [2 bits]~~	~~3.4.7.13~~
	5e	~~Vertical Mode Indicator [2 bits]~~	~~3.4.7.14~~
	5f	~~(Reserved for Vertical Conformance) [1 bit]~~	~~3.4.7.15~~
Reserved		~~(Reserved for future growth) [4 bits]~~	

3.4.7.1 Conditions for Transmitting TS Report Information

An airborne ADS-B participant of equipage class A2 or A3 **shall** (R3.130) transmit messages to support the TS report when either of the following conditions are met:

a. The flight director or autopilot is engaged in a vertical mode and a target altitude or an acceptable substitute for target altitude (§3.4.7.11) is available from the automation system; or

b. The flight director or autopilot is engaged in a horizontal mode and a target heading or target track (§3.4.7.6) is available from the automation system.

Note: *TS Reports are also optional for A1 equipment. If A1 equipment chooses to support TS reports those reports must meet the requirements specified in §3.4.7 and all of its subsections.*

3.4.7.2 TS Report Update Requirements

The nominal update interval for TS Report information is specified in §3.3.3.1.4 and Table 3-4(d).

The higher "state change" update interval requirements specified for TS report information in §3.3.3.1.4 and Table 3-4(d) **shall** (R3.131) be met whenever there is a change in the value of any of the following TS report fields:

- ~~Horizontal Data Available and Horizontal Source Indicator (§3.4.7.4);~~
- ~~Target Heading or Track Angle (§3.4.7.5);~~
- ~~Target Heading/Track Indicator (§3.4.7.6);~~
- ~~Vertical Data Available and Vertical Source Indicator (§3.4.7.10);~~
- ~~Target Altitude (§3.4.7.11)~~.

3.4.7.3 Time of Applicability (TOA) field for TS Report

The time of applicability relative to local system time **shall** (R3.132) be updated with every Target State report update.

3.4.7.4 ~~Horizontal Data Available and Horizontal Target Source Indicator Field~~ Selected Altitude Type

a. The "Selected Altitude Type" subfield is a 1-bit field that is used to indicate the source of Selected Altitude data. Encoding of the "Selected Altitude Type" **shall** (R3.xxx) be in accordance with Table 3-18.

b. Whenever there is no valid MCP / FCU or FMS Selected Altitude data available, then the "Selected Altitude Type" subfield **shall** (R3.xxx) be set to ZERO (0).

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

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

~~The Horizontal Data Available and Horizontal Target Source Indicator field is a 2-bit field in the TS report and will have a value of ZERO to indicate that no valid horizontal Target State data is available. Non-ZERO values will be used to provide the source of target heading or track angle information. An aircraft system is considered to be the target source when a change to that system's settings (for the current operational mode) would cause the aircraft trajectory to change.~~

~~The Horizontal Data Available and Horizontal Target Source Indicator field **shall** (R3.133) be encoded as specified in Table 3-18below.~~

Table 3-18: ~~Horizontal Data Available and Horizontal Target Source Indicator~~Selected Altitude Type Field Values

Value	Meaning
0	Data being used to encode the Selected Altitude data field is derived from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment.~~No valid horizontal Target State data is available.~~
1	Data being used to encode the Selected Altitude data field is derived from the Flight Management System (FMS).~~Autopilot control panel selected value, such as Mode Control Panel (MCP) or Flight Control Unit (FCU)~~
~~2~~	~~Maintaining current heading or track angle (e.g., autopilot mode select)~~
~~3~~	~~FMS/RNAV system (indicates track angle specified by leg type)~~

~~In cases where the aircraft is operated in a horizontal FMS/RNAV mode and the FMS/RNAV target track angle is the same as the autopilot control panel selected track angle, the Horizontal Data Available and Horizontal Target Source Indicator **shall** (R3.134) be set to "FMS/RNAV system."~~

3.4.7.5 ~~Target Heading Or Track Angle~~MCP/FCU Selected Altitude or FMS Selected Altitude Field

a. The "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield is an 11-bit field that **shall** (R3.xxx) contain either the MCP / FCU Selected Altitude or the FMS Selected Altitude data in accordance with the following subparagraphs.

b. Whenever valid Selected Altitude data is available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, such data **shall** (R3.xxx) be used to encode the Selected Altitude data field in accordance with Table 3-3.4.7.5. Use of MCP / FCU Selected Altitude **shall** (R3.xxx) then be declared in the "Selected Altitude Type" subfield as specified in Table 3-18.

c. Whenever valid Selected Altitude data is NOT available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, but valid Selected Altitude data is available from the Flight Management System (FMS), then the FMS Selected Altitude data **shall** (R3.xxx) be used to encode the Selected Altitude data field in accordance with Table 3-3.4.7.5 provided in paragraph "d." Use of FMS Selected Altitude **shall** (R3.xxx) then be declared in the "Selected Altitude Type" subfield as specified in Table 3-18.

d. Encoding of the Selected Altitude data field **shall** (R3.xxx) be in accordance with Table 3-3.4.7.5. Encoding of the data **shall** (R3.xxx) be rounded so as to preserve accuracy of the source data within ±½ LSB.

e. Whenever there is NO valid MCP / FCU or FMS Selected Altitude data available, then the "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield **shall** (R3.xxx) be set to ZERO (0) as indicated in Table 3-3.4.7.5.

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

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

Table 3-3.4.7.5: "MCP/FCU Selected Altitude or FMS Selected Altitude" Field Values

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

The "Target Heading or Track Angle" field in the TS Report contains either the transmitting aircraft's *target heading* or its *target track angle*, depending on the value reported in the "Target Heading/Track Indicator" field (§3.4.7.6).

- The target heading is the aircraft's intended heading after turn completion or its current intended heading if in straight flight. Target heading is only provided if the aircraft is being controlled to a heading reference.

- The target track angle is the aircraft's intended track angle over the ground after turn completion or its current intended track angle if in straight flight. Target track angle is only provided if the aircraft is being controlled to a ground referenced track angle.

Target heading or track angle **shall** (R3.135) be reported over the full range of all possible directions, 0° to almost 360°, expressed as an angle measured clockwise from a reference direction. Target heading or track angle **shall** (R3.136) be communicated and reported with a resolution at least as fine as one degree of arc.

~~*Note: The reference direction for heading (true north or magnetic north) is communicated in the True/Magnetic Heading Flag of the Mode-Status report (§3.4.4.16).*~~

3.4.7.6 ~~Target Heading/Track Indicator~~Barometric Pressure Setting (Minus 800 millibars) Field

a. The "Barometric Pressure Setting (Minus 800 millibars)" subfield is a 9-bit field that **shall** (R3.xxx) contain Barometric Pressure Setting data that has been adjusted by subtracting 800 millibars from the data received from the Barometric Pressure Setting source.

b. After adjustment by subtracting 800 millibars, the Barometric Pressure Setting **shall** (R3.xxx) be encoded in accordance with Table 3-3.4.7.6.

c. Encoding of Barometric Pressure Setting data **shall** (R3.xxx) be rounded so as to preserve a reporting accuracy within ±½ LSB.

d. Whenever there is NO valid Barometric Pressure Setting data available, then the "Barometric Pressure Setting (Minus 800 millibars) subfield **shall** (R3.xxx) be set to ZERO (0) as indicated in Table 3-3.4.7.6.

e. Whenever the Barometric Pressure Setting data is greater than 1208.4 or less than 800 millibars, then the "Barometric Pressure Setting (Minus 800 millibars)" subfield **shall** (R3.xxx) be set to ZERO (0).

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

Table 3-3.4.7.6: Barometric Pressure Setting (Minus 800 millibars) Field Values

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

~~The orientation type (heading or track angle) is conveyed in the Target Heading/Track Indicator field of the TS Report. This field **shall** (R3.137) be ZERO to indicate that the "Target Heading or Track Angle" field conveys target heading, or ONE to indicate that it conveys target track angle. The reference direction (true north or magnetic north) is conveyed in the MS report.~~

3.4.7.7 ~~(Reserved for) Heading/Track Capability~~Selected Field

The "Selected Heading Status" is a 1-bit field that **shall** (R3.xxx) be used to indicate the status of Selected Heading data that is being used to encode the Selected Heading data in accordance with Table 3-3.4.7.7.

Table 3-3.4.7.7: Selected Heading Status Field Values

Value	Meaning
0	Data being used to encode the Selected Heading data is either **NOT** Available or is **INVALID**. See Table 3-3.4.7.9.
1	Data being used to encode the Selected Heading data is Available and is **VALID**. See Table 3-3.4.7.9.

~~A one-bit field is reserved in the TS Report for future use as a "Heading/Track Capability" field. This field will indicate whether or not the transmitting aircraft has the capability to provide the horizontal guidance target. In the current version (DO-242A) of the MASPS, the "Reserved for Heading/Track Capability" field **shall** (R3.138) be ZERO.~~

3.4.7.8 ~~Horizontal Mode Indicator~~Selected Heading Sign Field

The "Selected Heading Sign" is a 1-bit field that **shall** (R3.xxx) be used to indicate the arithmetic sign of Selected Heading data that is being used to encode the Selected Heading data in accordance with Table 3-3.4.7.8.

Table 3-3.4.7.8: Selected Heading Sign Field Values

Value	Meaning
0	Data being used to encode the Selected Heading data is Positive in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is positive or Zero for all values that are less than 180 degrees). See Table 3-3.4.7.9.
1	Data being used to encode the Delected Heading data is Negative in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is ONE for all values that are greater than 180 degrees). See Table 3-3.4.7.9.

~~The Horizontal Mode Indicator element of the TS Report is a two-bit field that reflects the aircraft's state relative to the target heading or track angle.~~

~~The Horizontal Mode Indicator **shall** (R3.139) be encoded as specified in Table 3-19 below.~~

~~**Table 3-19: Horizontal Mode Indicator Values**~~

~~Value~~	~~Meaning~~
~~0~~	~~Unknown Mode or Information Unavailable~~
~~1~~	~~"Acquiring" Mode~~
~~2~~	~~"Capturing" or "Maintaining" Mode~~
~~3~~	~~Reserved~~

3.4.7.9 ~~(Reserved for) Horizontal Conformance~~Selected Heading Field

a. The "Selected Heading" is an 8-bit field that **shall** (R3.xxx) contain Selected Heading data encoded in accordance with Table 3-3.4.7.9.

b. Encoding of Selected Heading data **shall** (R3.xxx) be rounded so as to preserve accuracy of the source data within ±½ LSB.

c. Whenever there is NO valid Selected Heading data available, then the Selected Heading Status, Sign, and Data subfields **shall** (R3.xxx) be set to ZERO (0) as indicated in Table 3-3.4.7.9.

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

Table 3-3.4.7.9: Selected Heading Status, Sign and Data Field Values

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

~~A one-bit field in the TS Report is reserved for future use as a "Horizontal Conformance" flag. In the current version (DO-242A) of this MASPS, the "Reserved for Horizontal Conformance" field **shall** (R3.140) be ZERO.~~

3.4.7.10 Vertical Data Available and Vertical Target Source Indicator FieldStatus of MCP/FCU Mode Bits

The "Status of MCP / FCU Mode Bits" is a 1-bit field that **shall** (R3.xxx) be used to indicate whether the mode indicator bits are actively being populated (e.g., set) in accordance with Table 3-3.4.7.10.

If information is provided to the ADS-B Transmitting Subsystem to set the Mode Indicator bits to either "0" or "1," then the "Status of MCP/FCU Mode Bits" **shall** (R3.xxx) be set to ONE (1). Otherwise, the "Status of MCP/FCU Mode Bits" **shall** (R3.xxx) be set to ZERO (0).

Table 3-3.4.7.10: Status of MCP/FCU Mode Bits Field Values

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

Vertical Data Available and Vertical Target Source Indicator field is a 2-bit field in the TS Report and will have a value of ZERO to indicate that no valid vertical Target State data is available. Non-ZERO values will be used to provide the source of target altitude information. An aircraft system is considered to be the target source when a change to that system's settings (for the current operational mode) would cause the aircraft trajectory to change.

The Vertical Data Available and Vertical Target Source Indicator field **shall** (R3.141) be encoded as specified in Table 3-20 below.

Table 3-20: Vertical Data Available and Vertical Target Source Indicator Field Values

Value	**Meaning**
0	No valid vertical Target State data is available.
1	Autopilot control panel selected value, such as Mode Control Panel (MCP) or Flight Control Unit (FCU)
2	Holding Altitude
3	FMS/RNAV system

In cases where the aircraft is operated in a vertical FMS/RNAV mode and the FMS/RNAV target altitude is the same as the autopilot control panel selected altitude, the Vertical Data Available and Vertical Target Source Indicator **shall** (R3.142) be set to "FMS/RNAV system."

3.4.7.11 Target AltitudeMode Indicator: Autopilot Engaged Field

The "Mode Indicator: Autopilot Engaged" subfield is a 1-bit field that **shall** (R3.xxx) be used to indicate whether the autopilot system is engaged or not.

a. The ADS-B Transmitting Subsystem **shall** (R3.xxx) accept information from an appropriate interface that indicates whether or not the Autopilot is engaged.

b. The ADS-B Transmitting Subsystem **shall** (R3.xxx) set the Mode Indicator: Autopilot Engaged field in accordance with Table 3-3.4.7.11.

Table 3-3.4.7.11: Mode Indicator: Autopilot Engaged Field Values

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

Target altitude is the aircraft's next intended level flight altitude if in a climb or descent or its current intended altitude if commanded to hold altitude. Target altitude **shall** (R3.143) be represented as the operational altitude recognized by the transmitting aircraft's guidance system.

For aircraft unable to determine target altitude as defined above, the Target Altitude field may contain a substitute value. If a substitute value is provided, that value **shall** (R3.144) be consistent with the aircraft's target altitude capability as listed in Table 3-22.

In order to ensure a consistent reference for target altitude, all aircraft must follow standard conventions by using barometric corrected altitude (altimeter set to local setting) below the transition level and pressure altitude (altimeter set to 29.92 in Hg, or 1013.25 hPa) above the transition level. Target altitude **shall** (R3.145) be provided with a range from -1000 ft to +100,000 feet and **shall** (R3.146) have a resolution of 100 feet. be communicated and reported with a resolution of 100 feet or finer.

Note: *The 100-foot resolution for target altitude was chosen because that is the resolution supported by the Mode Control Panel (MCP) or Flight Control Unit (FCU) equipment in use on commercial aircraft. Since target altitude can only be input in multiples of 100 feet, there is no need for a finer resolution for the encoding of target altitude. This MASPS requirement does not, of course, dictate how target altitude will be encoded on a particular ADS-B data link.*

3.4.7.12 Target Altitude TypeMode Indicator: VNAV Mode Engaged Field

The "Mode Indicator: VNAV Mode Engaged" is a 1-bit field that **shall** (R3.xxx) be used to indicate whether the Vertical Navigation Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** (R3.xxx) accept information from an appropriate interface that indicates whether or not the Vertical Navigation Mode is active.

b. The ADS-B Transmitting Subsystem **shall** (R3.xxx) set the Mode Indicator: VNAV Mode Engaged field in accordance with Table 3-3.4.7.12.

Table 3-3.4.7.12: "Mode Indicator: VNAV Engaged" Field Values

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

The target altitude type field in the Target State Report is a one-bit field that indicates whether the target altitude is a barometric pressure altitude or flight level (used for target altitudes above the transition level between altitude types), or a locally corrected altitude (used for target altitudes below the transition level). The Target Altitude Type **shall** (R3.147) be encoded as specified in Table 3-21 below.

Table 3-21: Target Altitude Type Values.

Value	Meaning
0	Pressure Altitude ("Flight Level") — target altitude is above transition level
1	Baro-Corrected Altitude ("MSL") — target altitude is below transition level

3.4.7.13 Target Altitude CapabilityMode Indicator: Altitude Hold Mode Field

The "Mode Indicator: Altitude Hold Mode" is a 1-bit field that **shall** (R3.xxx) be used to indicate whether the Altitude Hold Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** (R3.xxx) accept information from an appropriate interface that indicates whether or not the Altitude Hold Mode is active.

b. The ADS-B Transmitting Subsystem **shall** set the Mode Indicator: Altitude Hold Mode field in accordance with Table 3-3.4.7.13.

Table 3-3.4.7.13: "Mode Indicator: Altitude Hold Mode" Field Values

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

Alternate values of target altitude may be provided by aircraft unable to support the general definition of target altitude. The target altitude capability is a two-bit field that describes the potential values occupying the target altitude field. The target altitude capability field **shall** (R3.148) be encoded as shown in Table 3-22 below.

Table 3-22: Target Altitude Capability Field Values

Value	Meaning
0	Capability for holding altitude only
1	Capability for either holding altitude or for autopilot control panel selected altitude
2	Capability for either holding altitude, for autopilot control panel selected altitude, or for any FMS/RNAV level-off altitude
3	Reserved

3.4.7.14 Vertical Mode IndicatorMode Indicator: Approach Mode Field

The "Mode Indicator: Approach Mode" is a 1-bit field that **shall** (R3.xxx) be used to indicate whether the Approach Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** (R3.xxx) accept information from an appropriate interface that indicates whether or not the Approach Mode is active.

b. The ADS-B Transmitting Subsystem **shall** (R3.xxx) set the Mode Indicator: Approach Mode field in accordance with Table 3-3.4.7.14.

Table 3-3.4.7.14: "Mode Indicator: Approach Mode" Field Values

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

The Vertical Mode Indicator is a two-bit field that reflects the aircraft's position relative to the target altitude.

The Vertical Mode Indicator **shall** (R3.149) be encoded as shown in Table 3-23 below.

Table 3-23: Vertical Mode Indicator Values

Value	Meaning
0	Unknown Mode or Information Unavailable
1	"Acquiring" Mode
2	"Capturing" or "Maintaining" Mode
3	Reserved

3.4.7.15 (Reserved for) Vertical ConformanceMode Indicator: LNAV Mode Engaged Field

The "Mode Indicator: LNAV Mode Engaged" is a 1-bit field that **shall** (R3.xxx) be used to indicate whether the Lateral Navigation Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall** (R3.xxx) accept information from an appropriate interface that indicates whether or not the Lateral Navigation Mode is active.

b. The ADS-B Transmitting Subsystem **shall** (R3.xxx) set the Mode Indicator: LNAV Mode Engaged field in accordance with Table 3-3.4.7.15.

Table 3-3.4.7.15: "Mode Indicator: LNAV Mode Engaged" Field Values

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

A one-bit field is reserved in the TS Report for future use as a "Vertical Conformance" flag. In ADS-B systems that conform to this version of this MASPS (DO-242A), the "Reserved for Vertical Conformance" field **shall** (R3.150) be ZERO.

3.4.8 Trajectory Change (TC+0, TC+n) Reports

➔ What do we do about the Trajectory Change ?? ➔

The following requirements in this section for Trajectory Change (TC) reports represent best engineering judgment at the time of publication of this MASPS. These requirements are therefore necessarily subject to further validation and refinement. It is not intended that ADS-B link MOPS implement requirements for the broadcast of Trajectory Change (TC) reports based on this version of the ADS-B MASPS. However, these requirements are intended to be used:

- in link design considerations,
- to assess system capacity and performance, and
- as a basis for application development efforts.

Note: *This MASPS provides a structure that is intended to accommodate multiple TC reports. The "reserved for" fields in this structure will be defined in future versions of this MASPS for the management of those multiple reports.*

Trajectory Change (TC) Reports contain long-term intent information providing strategic path information for path prediction and other functions, such as conformance monitoring. This information can include waypoint constraints, TCPs, and their connecting flight segments. Table 3-24 shows the overall structure for TC Reports.

Table 3-24: Trajectory Change (TC) Report Definition.

	TC Report Elem. #	Contents [Notes]	[Resolution or # of Bits]	Needed Only For TC+0 Reports	Reference Section	Notes
ID	1	Participant Address	[24 bits]		2.1.2.2.2.1	
	2	Address Qualifier	[1 bit]		2.1.2.2.2.2	
TOA	3	Time of Applicability	[1 s resolution]		3.4.8.3	
TC Report #	4	TC Report Sequence Number	[2 bits]		3.4.8.4	1
TC Report Version	5a	TC Report Cycle Number	[2 bits]		3.4.8.5	1,2
	5b	(Reserved for TC Management Indicator)	[3 bit]	•	3.4.8.6	2
TTG	6	Time To Go	[4 s resolution]		3.4.8.7	
Horizontal TC Report Information	7a	Horizontal Data Available and Horizontal TC Type	[4 bits]		3.4.8.8	
	7b	TC Latitude	[700 m or better]		3.4.8.9	3,4
	7c	TC Longitude	[700 m or better]		3.4.8.10	3,4
	7d	Turn Radius	[700 m or better]		3.4.8.11	3,4
	7e	Track to TCP	[1 degree]		3.4.8.12	3
	7f	Track from TCP	[1 degree]		3.4.8.13	3
	7g	(Reserved for Horizontal Conformance)	[1 bit]	•	3.4.8.14	3
	7h	Horizontal Command/Planned Flag	[1 bit]		3.4.8.15	
Vertical TC Report Information	8a	Vertical Data Available and Vertical TC Type	[4 bits]		3.4.8.16	
	8b	TC Altitude	[100 ft resolution]		3.4.8.17	
	8c	TC Altitude Type	[1bit]		3.4.8.18	
	8d	(Reserved for Altitude Constraint Type)	[2 bits]		3.4.8.19	
	8e	(Res. for Able/Unable Altitude Constraint)	[1 bit]	•	3.4.8.20	
	8f	(Reserved For Vertical Conformance)	[1 bit]	•	3.4.8.21	
	8g	Vertical Command/Planned Flag	[1 bit]		3.4.8.22	

Notes for Table 3-24:

1. *This MASPS (DO-242A) provides for up to four TC Reports.*

2. *Changes to the values of these elements may trigger the transmission of messages conveying the changed values at higher than nominal update rates. (Only those elements whose values have changed need be updated, not the entire TC report.) These update rates, the duration for which those rates must be maintained, and the operational scenario to be used to evaluate these requirements are to be defined in a future revision of this MASPS.*

3. *The value of the Horizontal Data Available and Horizontal TC Type element, determines (a) whether this element is required in the TC report and (b) the element's required resolution (weight of the LSB in reporting this TC report element). See §3.4.8.8 below.*

4. *Finer resolution than 0.38 NM (700 m) may be required for non-precision approach and precision approach/departure applications. It is expected that new TC report types will be defined for applications with finer resolution requirements.*

3.4.8.1 Conditions for Transmitting Trajectory Change Report Information

The following conditions are necessary requirements to initiate generation of TC reports:

1. The transmitting aircraft has an autopilot or flight director engaged and have access to active FMS/RNAV planning data or next target altitude. If the aircraft only supports a single axis autopilot or flight director, then the complementary axis data fields for TC reports are marked "not available".

2. Each TC report has an associated stable TTG value generated by the FMS/RNAV system or by extrapolation from current state vector and intent information available at the transmitting ADS-B subsystem. A TTG value is considered "stable" if the estimated TTG value based on previous information is consistent with the current TTG value, i.e. the difference between the previous TTG estimate updated for delta elapsed time and the current TTG estimate is less than some threshold value. Threshold values for determining stability of TTG will be determined in lower level documentation.

Given that the above conditions are satisfied, and any TC+0 report previously generated is not currently valid, an A2 level system **shall** (R3.151) initiate broadcast of a TC+0 report when the aircraft is within 4 minutes TTG to the trajectory change described in that TC+0 report, or as otherwise needed to meet the acquisition range requirements for A2 equipage as specified in Table 3-4(e). Similarly, an A3 level system **shall** (R3.152) initiate broadcast of a TC+0 report when the aircraft is within 8 minutes TTG to the trajectory change described in that report, or as otherwise needed to meet the acquisition range requirements for A3 equipage as specified in Table 3-4(e).

Note: As specified in §3.4.8.5, the TC cycle number will be incremented in all subsequent TC+0 broadcast reports.

For most TC types, the active flight segment is sequenced when the aircraft passes the transition point whose latitude and longitude are given in the TC report or captures the current target altitude. However, for Fly-By turns, the TC latitude and longitude are for a point in the middle of the turn segment, and the active flight segment (turn maneuver) is not completed until the target track in the TC report, i.e. track-from value has been captured. Normally, this condition is signaled by the Horizontal Mode Indicator. If the TS report target track is not available, then a test should be performed on current state vector components to verify capture of the track-from value as a condition for sequencing the turn maneuver. In either event, the Fly-By turn **shall** (R3.153) be sequenced if more than 2 minutes has elapsed since the time of Fly-By transition sequencing.

Note: *Figure 3-10(b) in §3.4.8.8 illustrates the geometry of a Fly-By turn including the end of turn TCP.*

In the event that the active flight segment is sequenced, or a major change in intent is detected such that TC+0 report data is no longer valid, the aircraft broadcasting TC+0 reports **shall** (R3.154) increment the TC report cycle number (modulo 4) for subsequent TC report broadcasts. The transmitting ADS-B participant will then begin broadcasting TC+0 report elements provided conditions (1) and (2) above are satisfied. The aircraft must broadcast the TC+0 report data at a rate sufficient to achieve range reception requirements shown in Table 3-4(e). If no intent data is available for subsequent TC+0 broadcast, the broadcast of an incremented TC report cycle number in a new TC report is sufficient for receiving aircraft to mark all previous TC report intent data from that aircraft as invalid or not available.

Notes:

1. *In the future, the TC Management Indicator (§3.4.8.6) will probably be used to signal A3 systems when it is possible to 'roll over' previous TC +1 report data into the TC+0 report slot, and when it is necessary to delete or mark invalid previously broadcast TC+n report data.*

2. *Simple changes in estimated values such as estimated altitude at a waypoint are not considered major changes in intent. Major changes of intent typically would result in TC report resequencing or would involve changes in TCP type associated with a pilot input, e.g. a "direct to" clearance that bypasses one or more current TCP points.*

3. *For level A3 systems, it is important to achieve continuity of intent as the aircraft approaches the end of the current flight segment. An A3 system should initiate broadcast of a TC+1 report when suitable intent is available and the aircraft is within 8 minutes TTG to TC+1, or whenever TTG to TC+0 is less than 2 minutes if TTG to TC+1 exceeds the 8 minute threshold. Other conditions for broadcasting TC+1 reports and more remote TCPs are under development, and are summarized in Appendix N.*

4. *A TC report for any trajectory change other than TC+0 will not be required if the TTG to that trajectory change exceeds 20 minutes. For example, if the TTG to the next trajectory change waypoint is 26 minutes, then no TC reports beyond the next waypoint (TC+0) are required. This limitation would prevent indiscriminate broadcast of TC reports that are not operationally relevant.*

3.4.8.2 TC Report Update Requirements

The nominal update interval for TC+0 information is specified in §3.3.3.1.4 and Table 3-4(e).

The higher "state change" update interval specified for TC Report information in §3.3.3.1.4 and Table 3-4(e) is desired whenever there is a change in the TC Report Cycle Number of the TC report (§3.4.8.5).

Notes:

1. *Update requirements for TC+0 reporting for nominal conditions and those following a major change in long term intent are not specified in this version of the MASPS. Proposed values are summarized in Section N.11 of Appendix N.*

2. *Update intervals for subsequent TC reports (TC+1,…,TC+n) are under development, but are expected to be a function of TTG and may have less stringent requirements on reception probability.*

3.4.8.3 Time of Applicability (TOA) Field for TC Report

The time of applicability relative to local system time **shall** (R3.155) be updated with every TC report update.

3.4.8.4 TC Report Sequence Number

The TC Report Sequence Number is a sequence number for the set of Trajectory Change Reports that describe a target's current intent; it is "n" in the expression "TC+n". The current TC ("TC+0") is the trajectory change report that describes the next point (Trajectory Change Point, TCP) at which the aircraft's trajectory will change. "TC+1" is a Trajectory Change report that describes the next trajectory change after the one described in the TC+0 report.

The "TC Report Sequence Number field in the TC report **shall** (R3.156) contain a value of ZERO for this version of the MASPS.

3.4.8.5 TC Report Cycle Number

The TC Report Cycle Number is a 2 bit field in the TC report. This field indicates a current "version number" for the numbering of the TC reports. The TC Report Cycle Number is a means for indicating when the trajectory change intent information previously broadcast is current and relevant, and when TC report elements previously broadcast need to be deleted or resequenced.

The TC Report Cycle Number **shall** (R3.157) increment when any of the following conditions are met:

- A change in TC estimated time of arrival (i.e., TOA+TTG) of greater than 30 seconds;
- A change in the Horizontal Data Available and Horizontal TC Type (§3.4.8.8) field;
- A change in horizontal position greater than 2 NM from the position defined by TC Latitude and TC Longitude (§3.4.8.9 and §3.4.8.10, respectively);
- A change in the Horizontal Command/Planned flag (§3.4.8.15);
- A change in the Vertical Data Available and Vertical TC Type (§3.4.8.16) field;
- A change in TC Altitude (§3.4.8.17) – if the Vertical TC Type (§3.4.8.16) is not Estimated Altitude - of more than 100 feet;
- A change in the Vertical Command/Planned flag (§3.4.8.22);

Note 1: *TC report resequencing will be a future condition on which TC Report Cycle Number will be incremented.*

The TC Report Cycle Number **shall** (R3.158) be a number in the range from 0 to 3 that is incremented (modulo 4) each time the numbering of TC reports changes. That is, the TC report cycle number is incremented from 0 to 1, then from 1 to 2, then from 2 to 3, and then from 3 back to 0.

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

3.4.8.6 (Reserved for) Trajectory Change Management Indicator (TCMI)

A 3-bit field is reserved for the Trajectory Change Management Indicator (TCMI) in the TC report. This field will be used in future versions of the MASPS to assist in the proper management of multiple TC reports. However, since this version of the MASPS (DO-242A) only specifies handling of TC+0 reports, this field is reserved.

For this version of the MASPS (DO-242A), the "Reserved for TC Report Management Indicator field **shall** (R3.159) be given a value of ZERO.

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

3.4.8.7 Time To Go (TTG) Field in TC Reports

The Time to Go (TTG) field in a TC report contains the estimated remaining flight time to the trajectory change described in that report. The TTG field **shall** (R3.160) have a resolution of 4 seconds or better, and **shall** (R3.161-A) have a range from –120 sec to +1200 sec (20 min), and **shall** (R3.161-B) have a means to indicate a TTG value of greater than 20 minutes.

TTG is originally computed from ETA or estimated time of arrival at a waypoint as the time difference between the ETA point and the estimated time of applicability for ADS-B broadcasting. When TCP message data with TTG is received, coast time is set to zero, and TTG is referenced relative to the report Time of Applicability. If no further messages for that TCP are received at the next report time, then coast time is incremented and TTG is decremented by delta time of applicability, i.e. the report time, coast time and TTG are all updated relative to the current time of applicability. This process of TC report data 'refreshment' continues until an updated TCP message with TTG is received, or the coast time exceeds a threshold limit for data renewal and the TC report data is marked "not available", or the current flight segment is sequenced.

3.4.8.8 Horizontal Data Available and Horizontal TC Type

The horizontal trajectory change information given in TC reports varies according to the Horizontal TC Type, of the TC report, as indicated in Table 3-25 below.

The Horizontal Data Available and Horizontal TC Type will have a value of ZERO if valid horizontal TCP information is ***not*** available in the TC Report and have Non-ZERO values to indicate the horizontal TC Type. The Horizontal TC Type **shall** (R3.162) be encoded as specified in the first column of Table 3-25. For each Horizontal TC Type listed in the first column of the table, consult the corresponding Figure, also referenced in that column of the table, for an illustration of the meaning of the data being reported for that TC type. For each Horizontal TC Type listed, the resolution of the TC report elements listed in the following columns **shall** (R3.163) be at least as fine as indicated in the table, *except* that elements marked as "n/r" are not required to be reported in TC reports for that horizontal TC type.

Note: *The bearing angle from the previous TC report or from the current state to the endpoint TCP may be reported in the Track-To-Trajectory-Change field for "Direct to Fix" and "Direct to Fly-By" TC report types.*

Table 3-25: Horizontal TC Type Encoding and Horizontal TC Report Elements Required For Each Horizontal TC Type

Horizontal TC Type	Required Resolution (Weight of LSB in Report Element)			
	TC Latitude, TC Longitude	Turn Radius	Track Angle	
			To TCP	From TCP
(§3.4.8.8)	(§3.4.8.10)	(§3.4.8.11)	(§3.4.8.12)	(§3.4.8.13)
0: Data Not Available (note 1)	Horizontal TC Report Information Not Available			
1: Direct to Fix (DF) [Figure 3-10(a)]	700 m (0.38 NM)	n/r	1 degree	n/r
2: Geodesic Path to Fix, Course to Fix (CF) or Track to Fix (TF) [Figure 3-10(a)]	700 m (0.38 NM)	n/r	1 degree	n/r
3: CF or TF to Fly-By Turn [Figure 3-10(b)]	700 m (0.38 NM)	700 m (0.38 NM)	1 degree	1 degree
4: DF to Fly-By Turn [Figure 3-10(b)]	700 m (0.38 NM)	700 m (0.38 NM)	1 degree	1 degree
5. Radius to Fix (RF) Turn Transition [Figure 3-10(c)]	700 m (0.38 NM)	700 m (0.38 NM)	n/r	1 degree
6-15: Reserved (note 2)	Reserved for Definition in Future Versions of This MASPS			

Notes for Table 3-25:

1. *The value of ZERO for the Horizontal TC Type code is reserved to mean "Horizontal TC Data Not Available" so that a separate one-bit field is not needed.*

2. *Future versions of this MASPS may specify addition Horizontal TC types, with different requirements on the resolution of the horizontal TC report elements.*

Figure 3-10(a) illustrates the meanings of the TC report fields that are reported for Horizontal TC types 1 and 2, which correspond to the TF, DF, and CF leg types (from DO-236A, §3.2.3.2, §3.2.3.9, and §3.2.3.8 respectively).

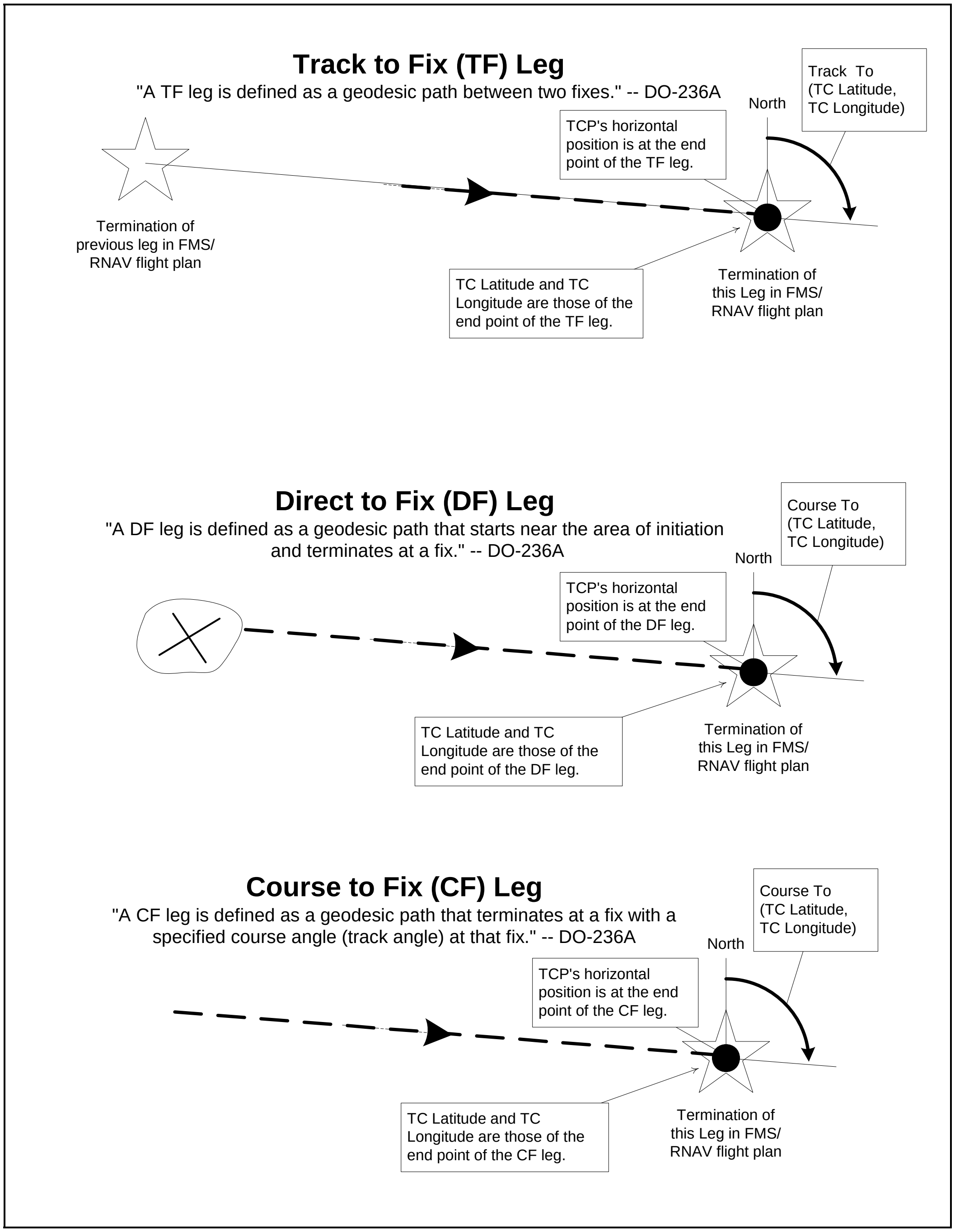


Figure 3-10(a): Meaning of Fields for Horizontal TC Types 1 and 2.

Figure 3-10(b) illustrates the meanings of the TC report fields that are reported for Horizontal TC types 3 and 4, which correspond to the TF, CF, and DF legs to Fly-By Transitions as described in DO-236A, §3.2.5.4.1.

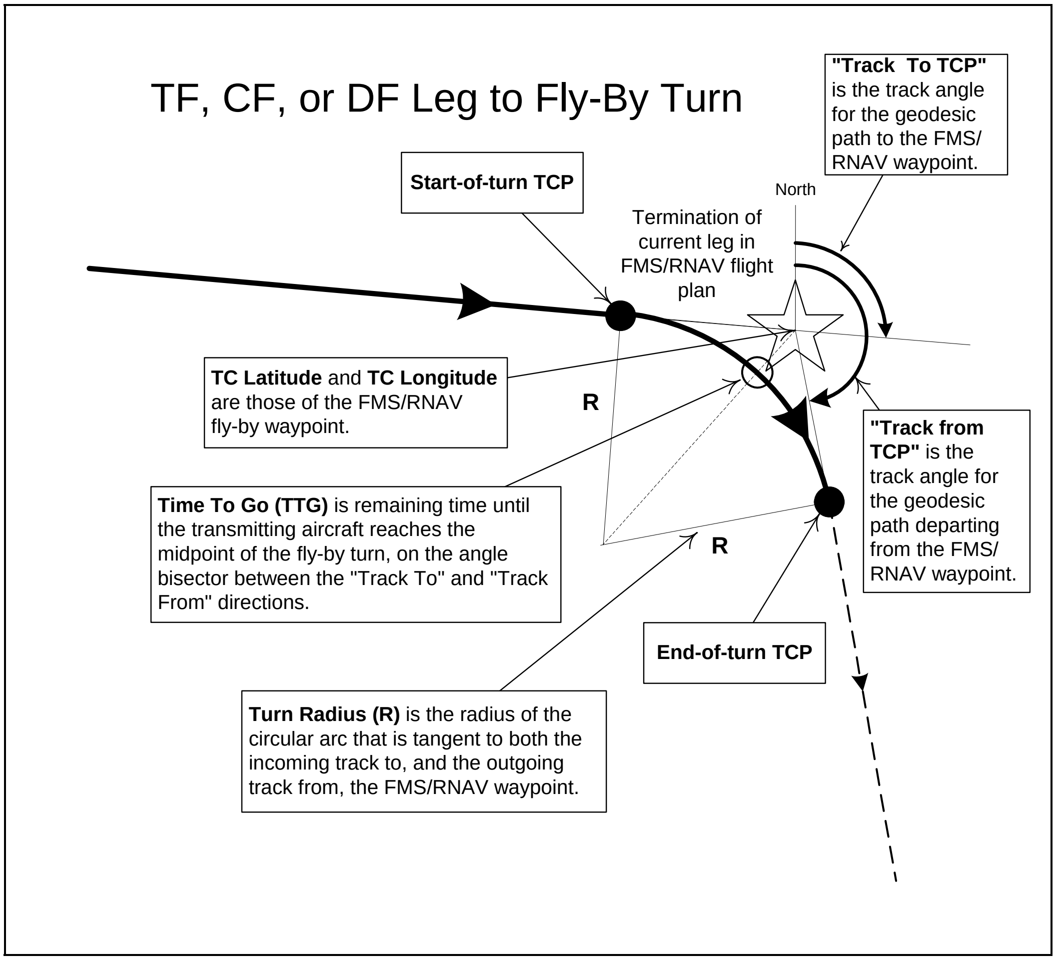


Figure 3-10(b): Meaning of Fields for Horizontal TC Types 3 and 4.

Figure 3-10(c) illustrates the meanings of the TC report fields that are reported for Horizontal TC type 5, which corresponds to the Radius to Fix (RF) leg type as described in DO-236A, §3.2.3.3.

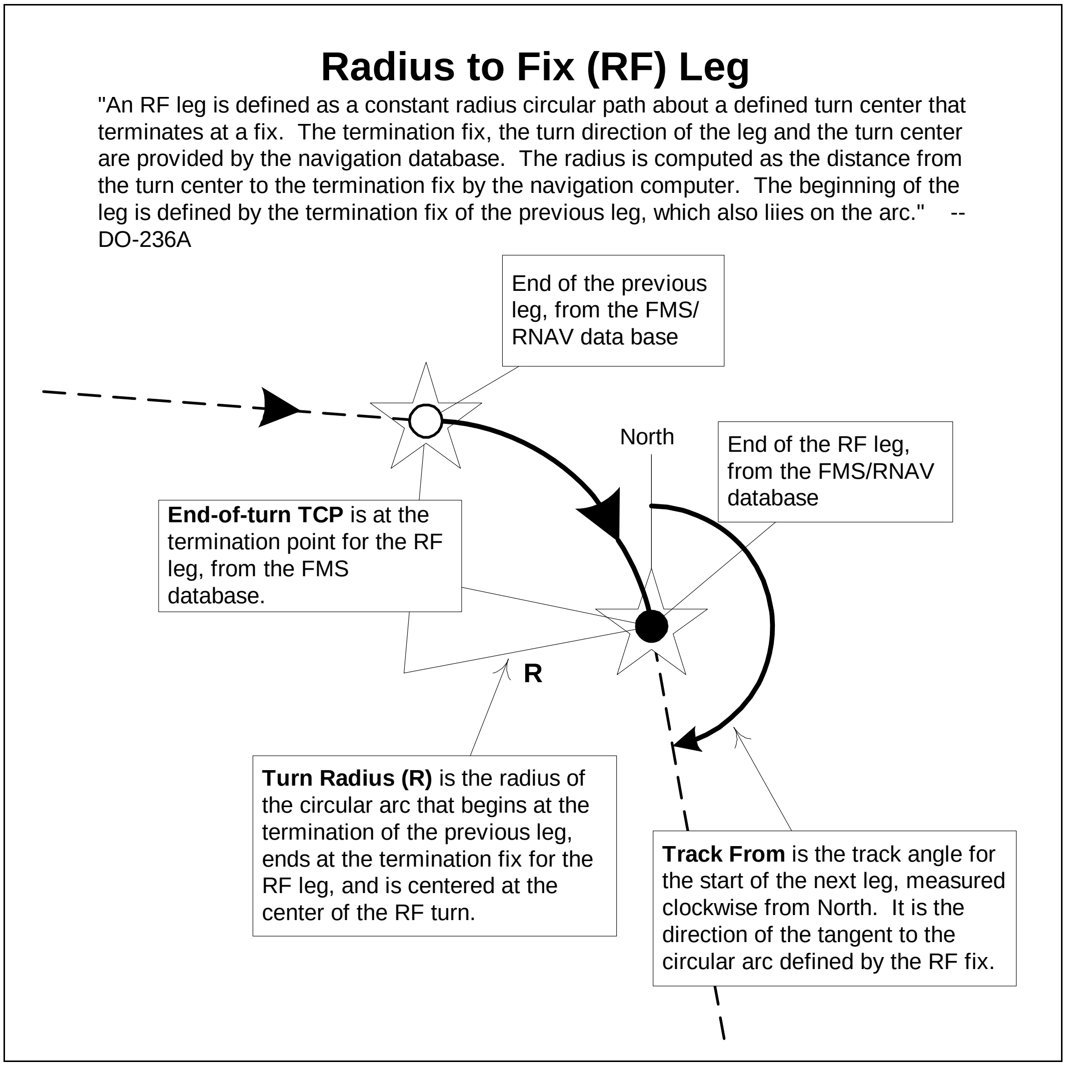


Figure 3-10(c): Meaning of Fields for Horizontal TC Type 5.

3.4.8.9 TC Latitude

TC Latitude **shall** (R3.164) be reported as WGS-84 latitude. TC horizontal position **shall** (R3.165) be reported with the full range of possible latitudes (-90° to +90°). Resolution of TC latitude **shall** (R3.166) be 700 m or finer for the horizontal TC types shown in Table 3-25.

3.4.8.10 TC Longitude

TC Longitude **shall** (R3.167) be reported as WGS-84 longitude. TC horizontal position **shall** (R3.168) be reported with the full range of possible longitudes (-180° to +180°). Resolution of TC longitude **shall** (R3.169) be 700 m or finer for the horizontal TC types shown in Table 3-25.

3.4.8.11 Turn Radius

Turn radius in NM **shall** (R3.170-A) be reported if available as an input to the ADS-B transmitting subsystem for horizontal TC types 3 and 4, i.e. when the TC report describes a Fly-By turn. For horizontal TC type 5 (radius to fix turns), turn radius in nautical miles **shall** (R3.170-B) be reported as a mandatory TC report element, i.e. if turn radius is unavailable, then the horizontal TC report data fields should be marked not valid. Resolution of turn radius **shall** (R3.170-C) be 700 m or finer when reported. The range of possible turn radius values is (0.0 to 28.6 NM).

Note: *The maximum turn radius above is based on a maximum turn anticipation distance of 20 NM, a maximum track angle change of 70 degrees (for high altitude transitions), and an analytic relationship between turn radius, turn anticipation and track angle change (RNP RNAV MASPS, DO-236A, §3.2.5.4.1), i.e. R = 20 / tan(70/2) ~ 28.6 NM. Turn radius values input to the ADS-B system larger than the maximum value will be truncated, and intent quality may be downgraded, e.g. reported as planned rather than command data.*

3.4.8.12 Track to TCP

Track to TCP is the intended track angle for horizontal TC types 1 to 4 that specifies the inbound transition from the current position or from the endpoint of one flight segment to the next TC Report. Track-to may not be output on an avionics bus unless the horizontal leg type is a Course to Fix (CF) type, and should then be derived from information that is available on avionics buses, e.g. ARINC 702A trajectory bus. The track-to element is typically computed using the previous “From” (start point) waypoint and “To” (end point) waypoint as the track angle between the two waypoints. If the leg type is a Direct to Fix (DF) type, then the bearing from the current position to the endpoint TCP **shall** (R3.171) be used to represent track-to for the active flight segment, e.g. TC+0.

3.4.8.13 Track from TCP

Track from TCP is the intended track angle on completion of a horizontal turn segment (horizontal TC types 3 to 5) that specifies the outbound transition from the turn TC point, i.e. Fly-By point or Radius to Fix turn endpoint. Track from TCP is typically not available on an avionics bus and should be derived from the endpoint TCP and succeeding horizontal waypoint data. Track-from is computed as the track angle from the turn TCP point to the next waypoint.

Note: *If both TC+0 and TC+1 report information are broadcast and TC+0 is a Fly-By or RF turn point, then track-from TC+0 is the same as track-to TC+1.*

3.4.8.14 (Reserved for) Horizontal Conformance

A one-bit field is reserved in the Trajectory Change Report for future use as a “Horizontal Conformance” flag. In ADS-B systems that conform to this version (DO-242A) of this MASPS, the “Reserved for Horizontal Conformance” field **shall** (R3.172) be ZERO.

3.4.8.15 Horizontal Command/Planned Flag

The Horizontal Command/Planned flag is a one-bit field that conveys information about the reliability of horizontal trajectory change data. It distinguishes between *command* and *planned* horizontal trajectory changes and indicates the ability of the transmitting aircraft to ensure that all intended horizontal trajectory changes are made available for broadcast. For further discussion on *comman*d and *planned* trajectories, see Appendix N.

- The *horizontal command trajectory* refers to the horizontal path the aircraft will fly if the pilot does not engage a new flight mode nor change the targets for the active or upcoming flight modes. The command trajectory may include multiple flight mode transitions.
- The *horizontal planned trajectory* includes horizontal intent information that is conditional upon the pilot changing an automation setting. Engaging a new horizontal flight mode is an example of a change in automation setting. Without pilot input, the aircraft will only fly toward the command trajectory targets.

The horizontal command/planned flag **shall** (R3.173) be set to "Planned" unless both of the following conditions are met:

- It has been determined on the transmitting aircraft that the horizontal trajectory change is part of the command trajectory, as defined above.
- It has been determined on the transmitting aircraft that it is broadcasting trajectory change information for each intended horizontal trajectory change between the current aircraft position and the corresponding TCP.

Note: *This determination must consider flight mode logic and targets resident in all autoflight systems that support aircraft guidance. This MASPS does not specify which system(s) on the transmitting aircraft make this determination.*

3.4.8.16 Vertical Data Available and Vertical TC Type

The Vertical Data Available and Vertical TC Type will have a value of ZERO if valid vertical TCP information is *not* available in the TC Report and have NON-ZERO values to indicate the vertical TC Type. The vertical trajectory change information given in TC Reports varies according to the vertical TC Type, as indicated in Table 3-26 below. The Vertical TC Type **shall** (R3.174) be encoded as specified in the first column of Table 3-26.

Table 3-26: Vertical TC Report Elements For Each Vertical TC Type.

Value	Vertical TCP Type
0	Data Not Available
1	Unknown Vertical TC Type
2	Target Altitude
3	Reserved for Constraint Altitude
4	Estimated Altitude
5	Top of Climb (TOC)
6	Top of Descent (TOD)
7-15	Reserved

3.4.8.17 TC Altitude

The Trajectory Change Altitude in the TC report provides the altitude of the trajectory change point. The ADS-B system **shall** (R3.175) support TC altitudes in the range from -1,000 feet to +100,000 feet. The resolution with which TC altitude is reported **shall** (R3.176) be 100 feet.

3.4.8.18 TC Altitude Type

The TC Altitude Type in the TC report, is a one-bit field that indicates whether the TC altitude is a barometric pressure altitude or flight level (used for TCPs with altitudes above the local transition level between altitude types), or a locally corrected altitude (used for TCPs with altitudes below the local transition level). The TC Altitude Type **shall** (R3.177) be encoded as specified in Table 3-27 below.

Notes:

1. *If the TC altitude type is unknown, then the vertical elements of the TC report should not be communicated or reported.*

2. *The default value of TC Altitude Type is ZERO for TCPs located in U.S. NAS airspace above 18,000 feet.*

Table 3-27: TCP Altitude Type Encoding.

Value	Meaning
0	Pressure Altitude ("Flight Level") – TCP above local transition level
1	Baro-Corrected Altitude ("MSL") – TCP below local transition level

3.4.8.19 (Reserved for) Altitude Constraint Type

A two-bit field is reserved in the TC Report for future use as a "Altitude Constraint Type" field. In ADS-B systems that conform to this version of this MASPS (DO-242A), the "Reserved for Altitude Constraint Type" field **shall** (R3.178) be ZERO.

Note: *See Appendix N for description and intended specifications for a future "Altitude Constraint Type" TC report element.*

3.4.8.20 (Reserved for) Able/Unable Altitude Constraint

A one-bit field is reserved in the TC Report for future use as a "Able/Unable Altitude Constraint" flag. In ADS-B systems that conform to this version of this MASPS (DO-242A), the "Reserved for Able/Unable Altitude Constraint" field **shall** (R3.179) be ZERO.

Note: *See Appendix N for a description of intended function and specifications for a future "Able/Unable Altitude Constraint" TC report element.*

3.4.8.21 (Reserved for) Vertical Conformance

A one-bit field is reserved in the TC Report for future use as a "Vertical Conformance" flag. In ADS-B systems that conform to this version (DO-242A) of this MASPS, the "Reserved for Vertical Conformance" field **shall** (R3.180) be ZERO.

Note: *See Appendix N for a description and intended specifications for a future "Vertical Conformance" TC report element.*

3.4.8.22 Vertical Command/Planned Flag

The Vertical Command/Planned flag is a one-bit field that conveys information about the reliability of vertical trajectory change data. It distinguishes between *command* and *planned* vertical trajectory changes and indicates the ability of the transmitting aircraft to ensure that all intended vertical trajectory changes are made available for broadcast. For further discussion on *comman*d and *planned* trajectories, see Appendix N.

- The *vertical command trajectory* refers to the vertical path the aircraft will fly if the pilot does not engage a new flight mode nor change the targets for the active or upcoming flight modes. The command trajectory may include multiple flight mode transitions.
- The *vertical planned trajectory* includes vertical intent information that is conditional upon the pilot changing an automation setting. Example changes in automation setting include engaging a new vertical flight mode or removing autopilot control panel restrictions to a current FMS/RNAV vertical mode. Without pilot input, the aircraft will only fly toward the command trajectory targets.

The vertical command/planned flag **shall** (R3.181) be set to "Planned" unless both of the following conditions are met:

- It has been determined on the transmitting aircraft that the vertical trajectory change is part of the command trajectory, as defined above.
- It has been determined on the transmitting aircraft that it is broadcasting trajectory change information for each intended vertical trajectory change between the current aircraft position and the corresponding TCP.

Note: *This determination must consider flight mode logic and targets resident in all autoflight systems that support aircraft guidance. This MASPS does not specify which system(s) on the transmitting aircraft make this determination.*

3.4.8.23 TC Report Management

TC reports will need to be managed on both transmit and receive subfunctions of ADS-B and the applications that use intent information. In this version of the MASPS (DO-242A), only TC+0 reports are specified, so only single TC reports need to be managed. The management actions to be taken are solely dependant on the value of the TC Report Cycle Number (§3.4.8.5). However, in future versions of this MASPS, multiple TC reports will be supported and the management of those reports will be much more complicated. The TC Sequence Number (§3.4.8.4) and the Trajectory Change Management Indicator (TCMI, §3.4.8.6) will assist in this future management. Appendix N discusses some of the factors that will need to be considered when handling multiple TC reports.

3.4.8.23.1 Transmit Subsystem TC Report Management

If the current TC+0 report is being updated or refreshed, the message generation function in the ADS-B transmitting subsystem **shall** (R3.182) do the following:

a. keep the value of the TC Report Cycle Number the same as in the messages previously sent to support TC+0 reports;

b. refresh the TOA and TTG fields in the messages being generated to support the TC+0 report; and

c. update all pertinent TC+0 report elements in those messages.

If a new TC+0 report is to be generated, then the message generation function in the ADS-B transmitting subsystem **shall** (R3.183) do the following:

a. increment (modulo 4) the TC Report Cycle Number from the messages previously generated to support the previous TC+0 report;

b. reinitialize all TC+0 report elements; and

c. generate messages to support the new TC+0 report.

If the current TC+0 report is no longer valid and no subsequent TC+0 reports are to be generated, the message generation function in the ADS-B transmitting subsystem **shall** (R3.184) do the following:

a. increment (modulo 4) the TC Report Cycle Number from the messages previously generated to support the previous TC+0 report;

b. set the "Horizontal Data Available and Horizontal TC Type" and "Vertical Data Available and Vertical TC Type" fields in the newly generated messages to 0.

If the previous TC+0 report is considered invalid and no subsequent TC+0 reports are to be immediately issued, the message generation function in the ADS-B transmitting subsystem **shall** (R3.185) transmit messages supporting the current TC+0 report for a time period of at least twice the required update interval for TC reports as specified in §3.3.3.1.4 that has the incremented TC Cycle Number and indicates "no horizontal or vertical data available".

3.4.8.23.2 Receive Subsystem TC Report Management

If a message is received supporting TC+0 reports from a participant with the TC Report Cycle Number matching that of previously received reports, the message will be considered an update for the current TC+0 report. In this case the report assembly function in the ADS-B receiving subsystem **shall** (R3.186) refresh the TOA and TTG fields and update the report fields with the received data.

If a message is received supporting TC+0 reports from a participant with the TC Report Cycle Number incremented (modulo 4) from that of previously received TC+0 reports, the message will be considered as an indication that current TC+0 report is no longer valid. In this case the report assembly function in the ADS-B receiving subsystem **shall** (R3.187) clear the current TC+0 report by setting the "Horizontal Data Available and Horizontal TC Type" and "Vertical Data Available and Vertical TC Type" fields to 0.

3.5 ADS-B Subsystem Requirements

Note: *This section (§3.5) and all of its subsections will be updated in the next revision of this MASPS. The update will harmonize these system requirements with those allocated to the ADS-B link system by the ASA MASPS. The changes made in this revision of the document were limited to those changes needed for consistency with other sections of this document.*

Subsystem requirements are defined with respect to the equipage classifications in §3.2.3. The ADS-B system requires each subsystem to be capable of interfacing directly with all other subsystem types implemented with the same broadcast link technology. This requirement applies to all subsystems whether interactive, broadcast only or receive only participants.

Note: *Specification of testable requirements is completed in §3.4; therefore no new requirement reference numbers are assigned beyond this point*

3.5.1 Aircraft/Vehicle Interactive Subsystem Requirements

Figure 3-3 shows ADS-B subsystems in the local environments applicable to each ADS-B participant type. For each ADS-B equipage class, ADS-B subsystems must interface with local data sources, local applications and all other ADS-B subsystems within the range required for the operational capabilities provided by the respective class. Such interface requirements are described in further detail in the following subparagraphs.

3.5.1.1 Onboard Required Data Sources

The ADS-B transmit subsystem will interface with data sources necessary to obtain the data for State Vector, Mode Status and On-condition reports appropriate to the ADS-B equipage class.

Source input data to the transmit subsystem are outside ADS-B system definitions; however, end to end certification of ADS-B delivered data will require each source to be proven compatible with the selected broadcast medium link protocol and the intended operational use. Validation of compatibility should be provided along with any critical assumptions upon which the implementation depends.

Input data exhibiting performance attributes (e.g., integrity, dynamic range, resolution, update rate, availability etc.) compatible with achieving the received report output performance requirements in Table 2-4(a) and Table 2-9(b) should be made available to the ADS-B transmit subsystem. The interface transferring information between the sources and the transmit subsystem should have the necessary features and be validated to support the required transfer of data into and out of the ADS-B subsystems.

3.5.1.1.1 Air Data Source

The transmit subsystem must interface with the onboard barometric altitude source, if available. The input will include an indication of data validity and an indication of 100 or 25 ft resolution provided by the source. If available, altitude rate and airspeed will be input to the ADS-B transmit subsystem. The airspeed may be either IAS/CAS or TAS with a discrete to indicate data type.

3.5.1.1.2 Geometric Navigation System

The ADS-B transmit subsystem will interface with the onboard source of geometric position and velocity navigation with position and velocity data suitable for all intended operational regimes. The source will be certified for use of its data by other airborne and/or ground participants in ADS-B supported separation applications.

The navigation data will be accompanied with accuracy and integrity metrics for determination of the Navigation Integrity Category (NIC) and Navigation Accuracy Category (NAC_P for position and NAC_V for velocity) of the data. If available, backup sources should be substituted in the event of loss of the normal primary source. When operating with a backup, the NIC, NAC, and SIL values should be adjusted to represent the backup source navigation performance. The geometric navigation data should include the following and must support the requirements of Table 3-4(a).

- Own vehicle Position in Latitude and Longitude,
- Own vehicle Velocity (North & East). (Ground Speed/Ground Track may be used if $Velocity_{North/East}$ is not available. Ground Track requires a discrete to indicate True/Mag reference.)
- Own vehicle NIC,
- Own vehicle NAC,
- Own Time Reference if needed for latency compensation before message transmission
- Own GNSS height above ellipsoid surface if available. (This requirement provides the capability to report GPS/GNSS based Altitude as envisioned for the future)
- Own vehicle Position Validity
- Own intent may be provided when equipped with RNAV capability
    - For classes A2 and A3 equipage, data needed to support TS and TC+0 reports will be provided from the RNAV equipment.
    - For class A3 equipage data needed for TC+n reports will be provided from the RNAV equipment.

3.5.1.1.3 Flight Mode Status Data Input Devices

The transmit subsystem **shall** (R3.188) interface with the onboard data entry mechanisms such as flight deck keyboards/selectors, encoded data sources, and logical discrete inputs to provide the subsystem with the following data:

- participant address
- emitter category
- call sign
- emergency/priority status
- capability class codes

3.5.1.1.4 Subsystem Control Logic

In many physical implementations, the ADS-B aircraft subsystem will require interfacing with other avionics equipment or functions to control/manage data flow through the ADS-B subsystem and between the user applications. Interactive participant subsystems will typically support multiple onboard applications. Not all applications require the same report data, therefore, the output reports may employ participant file management to simplify each application and minimize application complexity and interdependency. System control logic may also facilitate efficient interface operation. In such configurations, own ship navigation position and velocity can be included with the control logic. With this capability, the control logic interface permits qualified external sources to adjust rates of transmitted information under special operation conditions if required. Control logic interfaces, if any, will be completely specified in all implementations with defined verification requirements to ensure safe consistent interoperability between all ADS-B subsystems.

The ADS-B functions may be embedded in equipment performing other functions; (e.g., surveillance, TCAS, navigation or display electronics) for efficiency and reuse of existing equipment. Timing, priority and integrity management provisions must be given careful attention in all such designs. Certification of shared-resource designs will be supported with design specifications and a defined means to verify acceptable implementation. As such the design must provide ADS-B reports to the supported application as specified in §3.4.

3.5.1.2 Required Data Sources

The receive subsystem will provide an appropriate receiver and antenna system to interface with the designated ADS-B broadcast link for the purpose of recovering received information to enable assembly of the ADS-B reports. Each interactive equipment class will be capable of receiving and decoding message set(s) from all detected system participants. Only message contents appropriate to the receiving equipment class and the applications to be supported are required to be processed into output reports.

The system design requires determination of the need for diversity or other means to meet the coverage requirements on a pair-wise basis between all participant classes. MOPS or other documents governing design and certification requirements will provide requirements for compliance of the receiver and antenna system to comply with §3.3.1 while meeting all report delivery requirements of Tables 3-4(a), through 3-4(e).

3.5.1.3 Onboard Data Sinks

User applications form the sinks for the subsystem outputs. Applications will vary according to user equipage classes defined for A0 through A3. Some avionics systems will also require onboard transmitting and/or receiving functions status monitoring outputs.

3.5.1.3.1 ADS-B Operational Applications

The subsystem interfaces with the applications processing SV, MS and OC reports as required by the approved operational capabilities of the respective class and the applications installed. The reports made available for each class must comply with Section 3.4.4.1.

3.5.1.3.2 TCAS Enhancements

ADS-B information might be used to enhance TCAS traffic displays and to reduce interrogations rates under conditions to be defined in those systems. The ADS-B subsystem may interface with TCAS for support of enhanced applications. This interface must not cause any degradation in the overall level of safety provided by the collision avoidance function. Only SV reports are required for this application. (Some TCAS directed screening of received ADS-B participants may be required to implement this application.) Independence will be maintained between this and other subsystem functions.

3.5.1.4 External Data Sinks

The subsystem provides an appropriate interface with the designated ADS-B broadcast link protocol and waveform for the purpose of transmitting messages containing required information. This interface must be capable of encoding and transmitting the message set(s) defined for each equipage class in Section 3.4.1. The output power, receiver sensitivity, and antenna system will meet the coverage requirements defined in Section 3.3.1. Transmission rates will be specified and validated to provide the report update rates of Tables 3-4(a) through 3-4(e).

3.5.1.5 Levels of Service

The subsystem need only be capable of those functions consistent with the intended level of service. For instance, if an installation is not capable of providing a full suite of navigation or flight management data, it is not required to provide more than SV and MS data to other users. Subsystems for each equipage class implementation must comply with the respective information requirements for transmitted message content and output reports of Table 3-3(a) and Table 3-3(b).

3.5.1.6 Co-Site Interference Considerations

The transmit and receive subsystems must be certified capable of operation in its intended environment while complying with mutual interference standards with respect to other operating systems within that environment. The transmit and receive subsystems, as well as all installation wiring and hardware, must be designed to be compatible with other operating electrical systems within the installation environment. Likewise, the transmit and receive subsystems and installation should not be susceptible to interference generated by other operating electrical or magnetic systems in near proximity. The transmit and receive subsystems should comply with mutual interference limits applicable to the operational environment.

3.5.1.7 Environmental Considerations

Appropriate equipment environmental categories for the aircraft or vehicle must be met. The subsystem, as well as all installation wiring and mounting hardware, must be capable of sustaining the environmental conditions anticipated for the installation. As a minimum, all consideration should be given to providing an ADS-B Subsystem capable of surviving the thermal, vibration, electrical, magnetic, fluid, fungus, High Intensity Radiated Fields (HIRF), explosion, etc., conditions anticipated for the ADS-B Aircraft Subsystem installation. The subsystem should comply with DO-160D, or equivalent, as appropriate to the aircraft or vehicle.

3.5.1.8 Subsystem Reliability

Each subsystem design should be capable of supporting ADS-B system Quality of Service (QOS) described in §3.3.6. Specifications of each subsystem implementation will define requirements necessary to support the QOS. The subsystem should provide reliability required for the intended service environment commensurate with the criticality levels supported. Requirements for single thread or redundant configurations will depend on the FAR category of the operator, the aircraft system approval requirements, and the airspace operations supported by the subsystems.

MOPS or other subsystem specifications should provide definitive allocation of reliability factors considering failure probabilities, detected and undetected failure effects and probabilities specifically applicable to acquiring/transmitting and to receiving/reporting ADS-B exchanged information. Reliability includes maintenance of integrity in the applicable broadcast exchange technology. Attributes of the subsystem and the specific exchange technology must be shown to meet the operational and system requirements of Sections 2 and 3 respectively. These requirements apply between all subsystems on a pair-wise basis. Assumptions pertaining to reliable exchange of data intended for use in separation support will be required to support certification and operational approval. All MOPS or other specifications governing implementations should define major design assumptions, system/subsystem allocations and means to validate the subsystem results.

3.5.2 Broadcast-Only Subsystem Requirements

Figure 3-3 depicts participant types which only broadcast ADS-B information. Subsystem requirements for each are given below. These subsystems apply to equipage classes B0 through B3.

- Airborne Subsystems: Broadcast-Only ADS-B subsystems are intended for installation in aircraft or other vehicles that do not have display or other crew interface capabilities that would allow use of received data from other ADS-B installations. Examples of Broadcast-Only ADS-B installations may be smaller General Aviation aircraft, gliders, parachutists, tethered obstacles, or balloons, etc.
- Surface Subsystems: Surface Broadcast-Only ADS-B equipment may be comprised of airport surface vehicles, various emergency vehicles, obstacles or other hazards.

For each ADS-B equipage class, ADS-B subsystems should be defined to interface with approved data sources required for the operational capabilities provided by the respective class. Required sources are described in further detail in the following subparagraphs.

3.5.2.1 Onboard Required Data Sources

Sources should include the State Vector and Mode/Status data given below to the extent required in §3.4.4.2 for the respective equipage classes. The interface transferring information between the sources and the transmit subsystem should have the necessary features certified to support transfer of data into the ADS-B message generation connection. Airborne data characteristics are given by the appropriate subset of §3.5.1.1.

Fixed obstacle transmit subsystems, B3, require an interface for only partial SV information sufficient to define surface position, height, and identification.

3.5.2.1.1 Air Frame Reference Data Source

The transmit subsystem, if required, must interface with the onboard altitude source in order to obtain barometric altitude data which dynamically represents the altitude of the installation within the required accuracy for altitude reporting of the air vehicle. The input should include an indication of validity and an indication of 100 or 25 ft resolution provided by the source. If available, altitude rate and airspeed will be input to the transmit subsystem. Airspeed may be either IAS/CAS or TAS with a discrete to indicate data type. Ground track requires a discrete to indicate a reference frame. Therefore, magnetic or true heading reference will also be provided.

No air data is required for ground vehicles or fixed obstacles. Fixed obstacle transmit subsystems, B3, should interface with a data source to input the obstacle's maximum height above terrain or the designated safe operational clearance.

3.5.2.1.2 Geometric Navigation System

The transmit subsystem will interface with an approved source of geometric position and velocity navigation data to parameters which dynamically represent the position and velocity of the vehicle in all operational regimes. The source data will be certified for use by other airborne and/or ground participants in ADS-B supported separation applications. For a fixed object subsystem the input source may be supplied from a qualified data base accompanied by a means to validate the transmitted information. Only static data is required.

The navigation data will be accompanied with the accuracy and integrity metrics for determination of Navigation Integrity Category (NIC) and Navigation Accuracy Category (NAC_P for position and NAC_V for velocity) of the data. If available, backup sources should be substituted in the event of loss of the normal primary source. When operating with a backup, the NIC, NAC, and SIL values should be adjusted to represent the backup source navigation performance capability.

The geometric navigation data should include the following and must support the requirements of Table 3-4(a) to the extent applicable to the equipment class of the participant vehicle's intended operation:

- Own vehicle Position in Latitude and Longitude,
- Own vehicle Velocity (North & East) (Ground Speed/Ground Track may be used if Velocity $_{North/East}$ is not available)
- Own vehicle NIC,
- Own vehicle NAC,
- Own Time Reference if needed for latency compensation before message transmission
- Own GNSS height above ellipsoid surface if available: this requirement provides the capability to report GPS/GNSS based Altitude as envisioned for the future.
- Own vehicle Position Validity

3.5.2.1.3 Mode Status Data Input Devices

The transmit subsystem **shall** (R3.189) interface with the onboard data base or approved data entry mechanisms such as flight deck keyboards/selectors, encoded data sources, and logical discrete inputs to provide the subsystem with the following data:

- participant address
- emitter category
- emergency/priority status
- capability class codes

Fixed obstacle transmit subsystems, B3, require interface only for data to provide receiving participants with a M/S report sufficient to define obstacle identity, type and operational status information.

3.5.2.1.4 Subsystem Control Logic

System control logic may be required to interface with qualified external sources to adjust rates of transmitted information or indicate current status information. Control logic interfaces, if any, will be completely specified in all implementations with defined verification requirements to ensure safe consistent interoperability between all ADS-B subsystems. The subsystem may be embedded in equipment performing other functions (e.g., surveillance, navigation or communication electronics) for efficiency and reuse of existing equipment. Timing, priority and integrity management provisions must be given careful attention in all such designs. Certification of shared-resource designs will be supported with design specifications and a defined means to verify acceptable implementation.

3.5.2.2 Aircraft Onboard Data Sinks

User applications form the sinks for the subsystem outputs. Applications will vary according to user equipage classes defined for B0 through B3. Some avionics, ground vehicle or fixed object subsystems will require outputs to monitoring applications of the ADS-B subsystem. Each subsystem implementation will include appropriate specifications for these capabilities.

3.5.2.3 Levels of Service

Broadcast-only subsystems need only be capable of those functions consistent with the intended level of service required by receiving subsystems. Each implementation should specify the level of service consistent with the intended usage within the ADS-B system.

3.5.2.4 Co-Site Interference Considerations

The transmit and receive subsystems must be certified capable of operation in its intended environment while complying with mutual interference standards with respect to other operating systems within that environment. The transmit and receive subsystems, as well as all installation wiring and hardware, must be designed to be compatible with other operating electrical systems within the installation environment. Likewise, the transmit and receive subsystems and installation should not be susceptible to interference generated by other operating electrical or magnetic systems in near proximity. The transmit and receive subsystem should comply with mutual interference limits applicable to the operational environment.

3.5.2.5 Environmental Considerations

Appropriate equipment environmental categories for the aircraft, vehicle of fixed object must be met. The subsystem, as well as all installation wiring and mounting hardware, must be capable of sustaining the environmental conditions anticipated for the installation. As a minimum, all consideration should be given to providing a subsystem capable of surviving the thermal, vibration, electrical, magnetic, fluid, fungus, High Intensity Radiated Fields (HIRF), explosion, etc., conditions anticipated for the subsystem installation. The subsystem should comply with DO-160D, or equivalent, as appropriate to the environment.

3.5.2.6 Subsystem Reliability

Each subsystem design should be capable of supporting ADS-B system Quality of Service (QOS) described in §3.3.6. Specifications of each subsystem implementation will define requirements necessary to support the QOS. The subsystem should provide reliability required for the intended service environment commensurate with the levels of separation supported. Requirements for single thread or redundant configurations will depend on the FAR category of the aircraft operator, the ground vehicle or fixed object system approval requirements, and the airspace operations supported by the subsystems.

MOPS or other subsystem specifications should provide definitive allocation of reliability factors considering failure probabilities, detected and undetected failure effects and probabilities specifically applicable to acquiring/and transmitting ADS-B exchanged information. Reliability includes maintenance of integrity in the applicable broadcast exchange technology. Attributes of the subsystem and the specific exchange technology must be shown to meet ADS-B operational and system requirements of Sections 2and 3 respectively. These requirements apply between all subsystems on a pair-wise basis. Assumptions pertaining to reliable exchange of data intended for use in separation support will be required to support certification and operational approval. All MOPS or other specifications governing implementations should define major design assumptions, system/subsystem allocations and means to validate the subsystem results

3.5.3 Ground Receive-Only Subsystem Requirements

Figure 3-1 illustrates participant types which only receive ADS-B information from aircraft/vehicle types that may be engaged in either air or ground operations. These subsystems apply to equipage classes C1 through C3. Specific subsystem requirements for equipage classes C1 through C3 are to be specified in the future.

3.6 ADS-B Functional Level Requirements

Note: *This section (§3.6) and all of its subsections will be updated in the next revision of this MASPS. The update will harmonize these system requirements with those allocated to the ADS-B link system by the ASA MASPS. The changes made in this revision of the document were limited to those changes needed for consistency with other sections of this document.*

Each ADS-B subsystem requires certain minimum functional level capabilities as illustrated in Figure 3-4. The functions may be implemented using dedicated and/or shared resources of hardware and software appropriate to the actual system solutions. Certification of ADS-B subsystems will require traceability of these functional allocations in designs implemented by multiple suppliers and integrated in a wide range of architectures.

Figure 3-4 addresses all functions since it depicts an interactive subsystem. Other subsystems require only those functions appropriate to its role in the overall ADS-B system. Classes B0 through B3 and C1 through C3 require functions for broadcast only and receive only, respectively. A specific design approach may rearrange sub-functions; however, the implementation should define and address equivalency with MASPS subsystem interface requirements to support certification and operational approval processes. Each subsystem component MOPS or other specifications used to support ADS-B certification is required to show the mapping of equivalent functional and sub-functional capabilities and specific allocations of responsibilities and performance into requirements which govern implementations. Pair-wise operations between different subsystem implementations using the same broadcast medium must be ensured.

3.6.1 Required Message Generation Function

Message generation includes all capabilities necessary to accept source data inputs, process the data into messages appropriate to the selected ADS-B medium, and provide the inputs to the message exchange function.

3.6.1.1 Input Interface Sub-function

Internal input mechanisms for all onboard source and/or control data used in ADS-B message development and exchange control is covered by this sub-function. The ADS-B system does not include the onboard sources and distribution systems which provide the information conveyed in the messages. The following assumptions concern the data appearing as inputs to the ADS-B sub-system.

- Information will be provided to the input function via approved digital transfer buses interfaces. Appropriate discrete inputs may be used to provide the ADS-B subsystem with configuration or control information. All digital communication buses will implement appropriate error control techniques (i.e., parity as a minimum) to ensure that data is properly delivered to the input function. Data delivery mechanisms will ensure that each data parameter is provided to the input function at a sufficient update rate to support the transmission rate required for the medium.
- Latency of the critical input parameters supporting SV delivery will be allocated and managed in the onboard sensor and distribution system to be consistent with the latency requirements of §3.3.3.2.2.
- The accuracy and integrity of all source data is established within the installed certified and approved sources. ADS-B system responsibilities begin at the input port of the connected ADS-B subsystem.

The input sub-function should be capable of efficiently processing all data input interfaces in a manner that ensures all required data parameters are made available to the message generation function at rates necessary for the transmission update rates required for the message exchange medium. The function should ensure that the most recent source data is internally available to the message generation function.

3.6.1.2 Input Interface Control/Processing Sub-function

This sub-function implements all algorithms or other arithmetic methods to ensure that each data parameter content can be maintained at the allocated integrity level for the information through the exchange process. Capabilities provided must ensure that all data is properly updated for processing to scale, convert, compress, extrapolate, format, structure and deliver messages to the message exchange function. The application of prescribed encoding and error detection/correction mechanisms required by the media is included in this sub-function. The output includes message and protocol contents, and priority data to control scheduling of the modulator/transmitter sub-function

3.6.2 Required Message Exchange Function

Message exchange includes all capabilities necessary to deliver and recover all messages conveyed within a defined ADS-B RF medium in accordance the specific signaling standards and the predicted performance.

3.6.2.1 Modulator/Transmitter Sub-function

This sub-function implements all algorithms or logical operations to apply the encoded inputs and produce modulated waveform outputs conforming to the signal and spectrum requirements of the medium. Integrity and/or output monitoring is included in this sub-function to the levels appropriate to the subsystem design requirements. Internal logic to manage transmitter recovery between outputs, implement diversity control logic, participate in coordination with other on-board systems (e.g., mutual suppression signals for other on-board transmitters/receivers operating at or near ADS-B message transmission frequencies) is included. Signal modulation requirements are governed by the RF carrier frequency and the type of carrier modulation approved for the particular ADS-B service. The transmitted power level must support the coverage requirements discussed in §3.3.1 and include the impact of installation losses and antenna system performance. The sub-function should be capable of transmitting messages at the rates and power required for the selected medium to meet the coverage and required update performance applicable to each equipment class. Any diversity operation impact on transmitter operation should be accommodated in this sub function.

3.6.2.2 Transmit/Receive Antenna Sub-functions

The antenna system must be designed appropriate for the RF carrier frequency selected for the ADS-B environment, the class of equipage, and the intended installation. The antenna system pattern must be optimized for coverage appropriate to the system platform. Aircraft antenna systems must provide coverage during operational maneuvering and between aircraft pairs as well as support ground ATS subsystems in any relative angular positions. Polarization, installed location and aerodynamic characteristics must be considered as appropriate to the ADS-B platform. Diversity coverage may be required. Detailed sub-system design requirements should be provided to establish an acceptable transmitting and/or receiving antenna system and installation approach for each equipage class.

3.6.2.3 Receiver/Demodulator Sub-function

This sub-function implements the specific subsystem receiving capabilities. Receiving capabilities require a receiver/demodulator sub-function appropriate to the exchange medium. The effective sensitivity must support the coverage requirements discussed in §3.3.1 and include the impact of installation losses and antenna system performance. The resultant performance must provide an adequate Signal-to-Noise Ratio (SNR) to ensure proper detection and extraction of the messages from the carrier to support the requirements of Table 3-4(a) through 3-4(e). Receiver features must be included to accommodate collocated and external sources of interference. If diversity reception is required, the sub-function should utilize independent receivers or equivalent techniques to attain the required report update rates for the user applications requiring ADS-B supplied data. Demodulated signals are provided to the report assembly function for message decoding and development of output reports.

3.6.3 Required Report Assembler Function

The report assembler includes all subsystem capabilities necessary to recover messages conveyed within the ADS-B system and output reports to user applications.

3.6.3.1 Decoder/Message Processor Sub-function

This sub-function provides all capabilities to accomplish the following required tasks: decode the demodulated inputs into data; remove artifacts from the medium protocol; recover, decompress message data and correct some errors; maintain incoming data integrity levels; manage throughput latency, and output the processed messages. Integrity data for all messages must be preserved and supplied with message data to the report assembler. Demodulated signal conflicts from diversity receivers should be resolved prior to report assembler processing.

3.6.3.2 Report Assembly Sub-function

This sub-function provides all capabilities to interpret and process input messages, develop, maintain and manage correlated files on each participant received, process SV, MS and OC reports into the formats required for all onboard applications and transfer reports to the output interface control sub-function for buffering and delivery to external systems.

Participant file management techniques must be designed with respect to the medium selected for the message exchange function and the throughput of the report structure appropriate to the receiving onboard system. Essential characteristics in probability of reception and transmission rates, message segmentation and range performance of broadcast technologies will determine the techniques required to meet required report update rates. Proposed implementations should provide detailed functional specifications which provide the following capabilities:

- Generate unambiguous valid files on each participant received. Each file should be correlated with the source participant and contain all information received. Each participant is to be managed with equal priority.
- Update all files with most recent information meeting validity requirements of the broadcast link protocol. Each file should include file status and the time of applicability referenced to the onboard system.

- Convert parameters to the specified local report format(s). All conversions should meet accuracy, latency, and integrity requirements of the MASPS. If necessary to meet dynamic accuracy and update rate of SV geometric data, perform position projections based on last received data until the estimation fails to meet the requirements for onboard applications. Adjust the NIC, NAC, and SIL values to represent the current condition. Each file should be maintained for a period to cover the longest update period required for S/V, MS and OC as appropriate to the onboard applications. Upon expiration of the period, the file should be removed.

3.6.3.3 Output Interface Sub-function

This sub-function provides all control capabilities (i.e., output data load, timing, buffer control, etc.) required to ensure that the output data can be delivered to onboard users. Interface controls from the applications may be used to select participant files based on criteria defined by the interface design detail. Reports should always contain the latest data received and or estimated by the report assembler. Output rates should meet the requirements of the supported applications. This function also provides encoding in accordance with labeling, protocol and timing required by the physical data transfer links. Appropriate discrete outputs may be used to provide other users with appropriate configuration and/or control information. Multiple interfaces may be required by the onboard system. This function should be capable of supporting each individual interface requirement without degradation of other outputs.

The following assumptions are applicable to output interfaces with onboard systems. First, outputs will be interfaced via approved digital transfer buses interfaces. Appropriate discretes may be used to provide ADS-B subsystem outputs of configuration or control information. Second, all digital communication buses will implement appropriate error control techniques (i.e., parity as a minimum) to ensure that data is properly delivered to the user function. Third, data delivery mechanisms will ensure that each data parameter is provided to the user functions at the required update rate with the accuracy and integrity of the reports retained.

3.6.4 Required Report Output Control Function

This function provides an interface with all necessary local control sources required to manage the report assembly function. Such output control modes may include report selection and screening.

4 Procedures for Requirement Verification

This Section indicates the minimum test procedures to verify that ADS-B System performance meets the requirements of Section 3 (which were derived from the operational requirements of Section 2). Particularly since this document specifies ADS-B system requirements in an ADS-B-medium-independent manner, the method of test for each requirement is specified, as opposed to the details of the tests themselves.

Testing of the ADS-B system and its subsystems must take into account factors including intended use/subsystem classes, integration with external avionics/equipment supplying inputs to the ADS-B system, and supporting ground subsystem infrastructure (for air-ground applications). Given the interdependencies between ADS-B subsystem performance and the end-to-end system within which that subsystem is embedded, particular emphasis must be placed on the verification of the assumptions in this document, installation requirements, and flight testing.

The following tables indicate the test procedures for each requirement of this MASPS. Lab Tests are intended to include bench tests, antenna range, anechoic chamber tests, environmental tests, etc.. Flight Tests are expected to be conducted in actual operational conditions, as well as instrumented range conditions. Flight tests are expected to be used to validate analytical and simulation models, which will then be used to extrapolate to future operational conditions.

Notes:

1. *Subsystems:*

   A = Interactive Aircraft/Vehicle ADS-B Subsystem
   - *A0 = Minimum Interactive*
   - *A1 = Basic Interactive*
   - *A2 = Enhanced Interactive*
   - *A3 = Extended Interactive*

   B = Broadcast-Only ADS-B Subsystem
   - *B0 = Aircraft Broadcast-Only*
   - *B1 = Aircraft Broadcast-Only*
   - *B2 = Ground Vehicle Broadcast-Only*
   - *B3 = Fixed Obstacle*

   C = Ground Receive-Only ADS-B Subsystem

2. *Functions:*

   MG = Message Generation
   ME = Message Exchange
   ME(T) = Message Exchange (transmit)
   ME(R) = Message Exchange (receive)
   RA = Report Assembly

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
R2.1	R2.1 (§2.1.1.1)	When the full resolution of available aircraft data cannot be accommodated within an ADS-B message, a common quantization algorithm shall (R2.1) be used to ensure consistent performance across different implementations.	A, B, C	MG, RA	X	X		
R.2.2	R.2.2 (§2.1.1.2)	The output of ADS-B shall (R2.2) be standardized so that it can be translated without compromising accuracy.	A, B, C	MG, RA	X	X		
R2.4	R2.3 (§2.1.2)	The ADS-B system shall (R2.3) be capable of transmitting messages containing the information specified in the following subsections [of §2.1.2].	A, B	MG		X		X
R2.3	R2.4 (§2.1.2.1)	Time of applicability shall (R2.4) be provided in all reports.	A, B, C	MG, RA	X	X		
R2.5	R2.5 (§2.1.2.2)	The basic identification information to be conveyed by ADS-B shall (R2.5) include the following elements: • Call Sign (§2.1.2.2.1) • Participant Address (§2.1.2.2.2.1) and Address Qualifier (§2.1.2.2.2.2) • ADS-B Emitter Category (§2.1.2.2.3)	A, B, C	MG, ME, RA		X		X
R2.7	R2.6 (§2.1.2.2.1)	ADS-B shall (R2.6) be able to convey an aircraft call sign of up to 8 alphanumeric characters in length. [Change from DO-242, which required only 7 characters.]	A, B, C	MG, ME, RA		X		X
R2.8	R2.7 (§2.1.2.2.2)	The ADS-B system design shall (R2.7) include a means (e.g., an address) to (a), correlate all ADS-B messages transmitted from the A/V and (b), differentiate it from other A/Vs in the operational domain.	A, B, C	MG, RA		X		X
R2.9	R2.8 (§2.1.2.2.2)	Aircraft with Mode-S transponders using an ICAO 24 bit address shall (R2.8) use the same 24 bit address for ADS-B.	A, B, C	MG, RA		X		X
R2.10	R2.9 (§2.1.2.2.2)	All aircraft/vehicle addresses shall (R2.9) be unique within the applicable operational domain(s).	A, B, C	MG, RA	X			
R2.6	R2.10 (§2.1.2.2.2)	The ADS-B system design shall (R2.10) accommodate a means to ensure anonymity whenever pilots elect to operate under flight rules permitting an anonymous mode.	A, B, C	MG, ME, RA	X			X
	R2.11 (§2.1.2.2.2.1)	The Participant Address field shall (R2.11) be included in all ADS-B reports. This 24-bit field contains either the ICAO 24-bit address assigned to the particular aircraft about which the report is concerned, or another kind of address that is unique within the operational domain, as determined by the Address Qualifier field.	A, B, C	MG, RA		X		X
	R2.12 (§2.1.2.2.2.2)	The Address Qualifier field shall (R2.12) be included in all ADS-B reports. This field consists of one or more bits and describes whether or not the Address field contains the 24-bit ICAO address of a particular aircraft, or another kind of address that is unique within the operational domain.	A, B, C	MG, RA		X		X

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
R2.11	R2.13 (§2.1.2.2.3)	The ADS-B system shall (R2.13) provide for at least the following emitter categories: • Light (ICAO) - 7,000 kg (15,500 lbs) or less • Small aircraft – 7,000 kg to 34,000 kg (15,500 lbs to 75,000 lbs) • Large aircraft – 34,000 kg to 136,000 kg (75,000 lbs to 300,00 lbs) • High vortex large (aircraft such as B-757) • Heavy aircraft (ICAO) - 136,000 kg (300,000 lbs) or more • Highly maneuverable (> 5g acceleration capability) and high speed (> 400 knots cruise) • Rotorcraft • Glider/Sailplane • Lighter-than-air • Unmanned Aerial vehicle • Space/Trans-atmospheric vehicle • Ultralight / Hang glider / Paraglider • Parachutist/Skydiver • Surface Vehicle - emergency vehicle • Surface Vehicle - service vehicle • Point obstacle (includes tethered balloons) • Cluster obstacle • Line obstacle	A, B, C	MG, RA		X		X
R2.14	R2.14 (§2.1.2.4)	Position information shall (R2.14) be transmitted in a form that can be translated, without loss of accuracy and integrity, to latitude, longitude, geometric height, and barometric pressure altitude.	A, B	MG	X			
R2.15	R2.15 (§2.1.2.4)	All geometric position elements shall (R2.15) be referenced to the WGS-84 ellipsoid.	A, B, C	RA	X	X		X
R2.18	R2.16 (§2.1.2.4)	Barometric pressure altitude shall (R2.16) be reported referenced to standard temperature and pressure.	A, B, C	RA				X

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R2.17 (§2.1.2.4)	For any ADS-B participant that sets the "reporting reference point position" CC code (in MS report element #7g, §3.4.4.9.7) to ONE, the position that is broadcast in ADS-B messages as that participant's nominal position **shall** (R2.17) be the position of that participant's ADS-B position reference point (§2.1.2.5 below)..	A, B	MG	X	X		X
	R2.18 (§2.1.2.5)	The *ADS-B position reference point* of an A/V **shall** (R2.18) be defined as the center of a rectangle (the "defining rectangle for position reference point") that has the following properties: a. The defining rectangle for position reference point **shall** (R2.18-A) have length and width as defined in Table 2-1 below for the length and width codes that the participant is transmitting in messages to support the MS report. b. The defining rectangle for position reference point **shall** (R2.18-B) be aligned parallel to the A/V's heading. c. The ADS-B position reference point (the center of the defining rectangle for position reference point) **shall** (R2.18-C) lie along the axis of symmetry of the A/V. (For an asymmetrical A/V, the center of the rectangle should lie midway between the maximum port and starboard extremities of the A/V.) d. The forward extremity of the A/V **shall** (R2.18-D) just touch the forward end of the defining rectangle for position reference point.	A, B	MG	X	X		X
	R2.19 (§2.1.2.6)	Both barometric pressure altitude and geometric altitude (height above the WGS-84 ellipsoid) shall (R2.19) be provided, if available, to the transmitting ADS-B subsystem.	A, B, C	MG, RA		X		X
R2.19	R2.20 (§2.1.2.6)	Altitude [barometric pressure altitude and geometric altitude] shall (R2.20) be provided with a range from -1,000 ft up to +100,000 ft.	A, B, C	MG, RA		X		
	R.2.21 (§2.1.2.6)	ADS-B link equipment **shall** (R2.21) support a means for the pilot to indicate that the broadcast of altitude information from pressure altitude sources is invalid. This capability can be used at the request of ATC or when altitude is determined to be invalid by the pilot.	A,B1	MG, RA		X		
R3.34	R2.22 (§2.1.2.6.1)	The pressure altitude reported shall (R2.22) be derived from the same source as the pressure altitude reported in Mode C and Mode S for aircraft with both transponder and ADS-B.	A	MG	X	X	X	X
R2.21	R2.23 (§2.1.2.7)	ADS-B geometric velocity information shall (R2.23) be referenced to WGS-84.	A, B, C	RA	X	X		X
R2.20	R2.24 (§2.1.2.7)	Transmitting A/Vs that are not fixed or movable obstacles shall (R2.24) provide ground-referenced geometric horizontal velocity.	A, B, C	MG, ME, RA		X		X

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R2.25 (§2.1.2.8)	Transmitting A/Vs that are not fixed or movable obstacles and that are not known to be on the airport surface shall (R2.25) provide vertical rate.	A, B, C	MG, ME, RA		X		X
R2.23	R2.26 (§2.1.2.8)	Vertical Rate shall (R2.26) be designated as climbing or descending.	A, B, C	MG, RA		X		
	R2.27 (§2.1.2.8)	Vertical Rate shall (R2.27) be reported up to 32,000 feet per minute (fpm).	A, B, C	MG, RA		X		
	R2.28 (§2.1.2.8)	At least one of the two types of vertical rate (barometric and geometric) shall (R2.28) be reported.	A, B, C	MG, RA		X		X
	R2.29 (§2.1.2.8)	If only one of these two types of vertical rate [barometric vertical rate and geometric vertical rate] is reported, it shall (R2.29) be obtained from the best available source of vertical rate information.	A, B	MG	X	X		
	R2.30 (§2.1.2.12)	Table 2-2 defines the navigation integrity categories [NIC] that transmitting ADS-B participants shall (R2.30) use to describe the integrity containment radius, R_C, associated with the horizontal position information in ADS-B messages from those participants.	A, B, C	MG, RA		X		
	R2.31 (§2.1.2.13)	Table 2-3 defines the navigation accuracy categories [NAC_P] that shall (R2.31) be used to describe the accuracy of positional information in ADS-B messages from transmitting ADS-B participants.	A, B, C	MG, RA		X		
	R2.32 (§2.1.2.13)	The NAC_P value broadcast from an ADS-B participant **shall** (R2.32) include any inaccuracies in the reported position due to the transmitting participant's not correcting the position from the navigation sensor to that of the ADS-B position reference point (see §2.1.2.5).	A, B, C	MG, RA		X		
R2.27	R2.33 (§2.1.2.14)	[In determining NAC_V , the] velocity accuracy category of the least accurate velocity component being supplied by the reporting A/V's source of velocity data shall (R2.33) be as indicated in Table 2-4.	A, B	MG	X	X		
	R2.34 (§2.1.2.15)	The Surveillance Integrity Limit [SIL] encoding shall (R2.34) be as indicated in Table 2-5.	A, B, C	MG, RA		X		
	R2.35 (§2.1.2.16)	The Barometric Altitude Quality Code, BAQ, is a 2-bit field which shall (R2.35) be ZERO for equipment that conforms to this version (DO-242A) of the ADS-B MASPS.	A, B, C	MG, RA		X		
R2.28	R2.36 (§2.2.1.8)	The ADS-B system shall (R2.36) be capable of supporting broadcast of emergency and priority status.	A, B, C	MG, RA		X		
	R2.37 (§2.1.2.19.1)	For equipage classes A2 and A3, the ADS-B system shall (R2.37) provide the capability to transmit and receive messages in support of the TS report.	A	MG, ME, RA	X	X		
	R2.38 (§2.1.2.19.2)	For equipage class A2, the ADS-B system shall (R2.38) provide the capability to transmit and receive messages in support of one TC (TC+0) report.	A	MG, ME, RA	X	X		
	R2.39 (§2.1.2.19.2)	For equipage class A3, the ADS-B system shall (R2.39) provide the capability to transmit and receive messages in support of multiple TC reports.	A	MG, ME, RA	X	X		

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
R3.1	R3.1 (§3.3.1)	ADS-B equipage classes summarized in Table 3-1 shall (R3.1) provide the air-to-air coverage specified in Table 3-2(a).	A, B	ME	X	X	X	
R3.2	R3.2 (§3.3.1)	The ERP and minimum signal detection capabilities shall (R3.2) support the associated pair-wise minimum operational ranges listed in Table 3-2(b).	A, B	ME	X	X	X	
R3.3	R3.3 (§3.3.1)	Broadcast only aircraft (class B0 and B1) shall (R3.3) 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.	B1	ME(T)	X	X	X	
R3.4	R3.4 (§3.3.1)	Ground vehicles operating on the airport surface (class B2) **shall** (R3.4) provide a 5 NM coverage range for class A receivers.	B2	ME	X	X	X	
R3.6	R3.5 (§3.3.1)	If required due to spectrum considerations, ADS-B transmissions from ground vehicles (class B2) **shall** (R3.5) be automatically prohibited when those vehicles are outside the surface movement area (i.e., runways and taxiways).	B2	MG		X	X	X
R3.7	R3.6 (§3.3.1)	Fixed obstacle (class B3) broadcast coverage shall (R3.6) be sufficient to provide a 10 NM coverage range from the location of the obstacle.	B3	ME	X	X	X	
R3.8	R3.7 (§3.3.2)	Each equipage class **shall** (R3.7) meet the required information broadcast and receiving capability at the indicated range to support the applications indicated in Table 3-3(a) and Table 3-3(b).	A, B, C	MG, ME, RA	X	X	X	
R3.12	R3.8 (§3.3.3.1)	For each of these subparagraphs, report acquisition **shall** (R3.8) be considered accomplished when all report elements required for an operational scenario have been received by an ADS-B participant.	A, B, C	MG, ME, RA	X	X	X	
	R3.9 (§3.3.3.1.1)	The state vector report **shall** (R3.9) meet the update period and 99 percentile update period requirements for each operational range listed [in Table 3-4(a)].	A, B	MG, ME, RA	X	X	X	
	R3.10 (§3.3.3.1.1)	For each of the scenarios included in Table 3-4(a), the state vectors from at least 95% of the observable user population (radio line-of-sight) supporting that application **shall** (R3.10) be acquired and achieve the time and probability update requirements specified for the operational ranges.	A, B	MG, ME, RA	X	X	X	
R3.13	R3.11 (§3.3.3.1.1)	Required ranges for acquisition **shall** (R3.11) be as specified in Table 3-4(a): (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3).	A, B	MG, ME, RA	X	X	X	
R3.14	R3.12 (§3.3.3.1.1)	The ADS-B system **shall** (R3.12) satisfy the error budget requirements specified in [Table 3-4(a)] in order to assure satisfaction of ADS-B report accuracies.	A, B, C	MG, RA	X	X	X	
R3.15	R3.13 (§3.3.3.1.1)	If a smoothing filter or tracker is used in the ADS-B design, the quality of the reports **shall** (R3.13) be sufficient to provide equivalent track accuracy implied in Table 3-4(a) 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).	A, B	MG, ME, RA	X	X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
R3.11	R3.14 (§3.3.3.1.2)	For each of the equipage classes included in Table 3-4 (a), the mode status reports from at least 95% of the observable (radio line of sight) population **shall** (R3.14-A) be acquired at the range specified in the "Required 95th Percentile Acquisition Range" row of Table 3-4(b). (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), the mode status reports from at least 99% of the observable (radio line of sight) population **shall** (R3.14-B) be acquired at the reduced range specified in the "Required 99th Percentile Acquisition Range" row of Table 3-4(b).	A, B	MG, ME, RA	X	X	X	
	R3.15 (§3.3.3.1.3)	When the ARV report is required as defined in §3.4.6.1, [its] nominal update interval **shall** (R3.15) be 5 seconds for A1, A2, and A3 equipment at ranges of 10 NM and closer.	A	MG, ME, RA	X	X	X	
	R3.16 (§3.3.3.1.3)	When the ARV report is required as defined in §3.4.6.1, [its] nominal update interval **shall** (R3.16) be 7 seconds for A1, A2, and A3 equipment at ranges greater than 10 NM and less than or equal to 20 NM.	A	MG, ME, RA	X	X	X	
	R3.17 (§3.3.3.1.3)	When the ARV report is required as defined in §3.4.6.1, [its] nominal update interval **shall** (R3.17) be 12 seconds for A2 equipment at ranges greater than 20 NM and less than or equal to 40 NM.	A2	MG, ME, RA	X	X	X	
	R3.18 (§3.3.3.1.3)	When the ARV report is required as defined in §3.4.6.1, [its] nominal update interval **shall** (R3.18) be 12 seconds for A3 equipment at ranges greater than 40 NM and less than or equal to 90 NM.	A3	MG, ME, RA	X	X	X	
	R3.19 (§3.3.3.1.3)	When the ARV report is required as defined in section §3.4.6.1, its acquisition range in the forward direction shall (R3.19) be: a. 20 NM for equipage class A1, b. 40 NM for equipage class A2, and c. 90 NM for equipage class A3.	A	MG, ME, RA	X	X	X	
	R3.20 (§3.3.3.1.3)	The acquisition range requirements [for ARV reports] in directions other than forward **shall** (R3.20) be consistent with those stated in Note 3 of Table 3-4(a).	A	MG, ME, RA	X	X	X	
	R3.21 (§3.3.3.1.4)	When there has been no change in intent information, the nominal [TS report and TC 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** (R3.21) be T_U, such that $$T_U = \max\left(12s,\quad 0.45\frac{s}{NM}\cdot R\right)$$ 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.	A2, A3	MG, ME, RA	X	X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.22 (§3.3.3.1.4)	If the TS report is implemented in ADS-B systems of equipage class A1, such systems **shall** (R3.22) have a 20 NM acquisition range for TS Report.	A1	MG, ME, RA	X	X	X	
	R3.23 (§3.3.3.164)	For equipage class A2, the acquisition range for TS reports and TC reports **shall** (R3.23) be 40 NM, with 50 NM desired.	A2	MG, ME, RA	X	X	X	
	R3.24 (§3.3.3.1.4)	For equipage class A3, the acquisition range for TC reports in the forward direction **shall** (R3.24) be 90 NM, with 120 NM desired.	A3	MG, ME, RA	X	X	X	
	R3.25 (§3.3.3.1.4)	The range requirements in all other directions [than the forward direction] for A3 equipment **shall** (R3.25) be consistent with those stated in Note 3 of Table 3-4(a).	A3	MG, ME, RA	X	X	X	
R3.16	R3.26 (§3.3.3.2.2)	If NAC_P is less than 10 and NIC is less than 9, then ADS-B latency of the reported information **shall** (R3.26) be less than 1.2 s with 95 percent confidence.	A, B, C	MG, ME, RA	X	X	X	
R3.17	R3.27 (§3.3.3.2.2)	If either $NAC_P \geq 10$ or NIC ≥ 9, then ADS-B latency **shall** (R3.27) be less than 0.4 s with 95% confidence.	A, B, C	MG, ME, RA	X	X	X	
R3.18	R3.28 (§3.3.3.2.2)	The standard deviation of the [SV] report time error **shall** (R3.28) be less than 0.5 s (1 sigma).	A, B, C	MG, ME, RA	X	X	X	
R3.19	R3.29 (§3.3.3.2.2)	The mean report time error for position [in the SV report] **shall** (R3.29) not exceed 0.5 s.	A, B, C	MG, ME, RA	X	X	X	
R3.20	R3.30 (§3.3.3.2.2)	The mean report time error for velocity [in the SV report] **shall** (R3.30) not exceed 1.5 s.	A, B, C	MG, ME, RA	X	X	X	
R3.21	R3.31 (§3.3.4)	The ADS-B system shall (R3.31) be capable of meeting the requirements of this document, unless otherwise explicitly noted for a given requirement, in the traffic density shown by the LA 2020 curves in Figure 3-8, and as further detailed in Table 3-5.	A, B, C	MG, ME, RA	X			
R3.21	R3.32 (§3.3.4)	Requirements specified for en route, Low Density air space **shall** (R3.32) be met in the traffic density shown by the Low Density curve in Figure 3-8.	A, B, C	MG, ME, RA	X		X	
R3.22	R3.33 (§3.3.5)	The ADS-B RF medium **shall** (R3.33) be suitable for all-weather operation, and ADS-B system performance will be specified relative to a defined interference environment for the medium.	A, B, C	ME	X		X	X
R3.23	R3.34 (§3.3.5)	Radio frequencies used for ADS-B Message transmission **shall** (R3.34) operate in an internationally allocated aeronautical radionavigation band(s).	A, B, C	ME				X
R3.24	R3.35 (§3.3.6.3)	ADS-B availability **shall** (R3.35) be 0.9995 for class A0 through class A3 and class B0 through class B3 transmission subsystems	A, B	MG, ME	X	X		
R3.25	R3.36 (§3.3.6.3)	ADS-B availability **shall** (R3.36) be 0.95 for class A0 receiver subsystems.	A0	ME(R), RA	X	X		
R3.26	R3.37 (§3.3.6.3)	Class A1, A2, and A3 receiver subsystems **shall** (R3.37) have an availability of 0.9995.	A1, A2, A3	ME(R), RA	X	X		

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
R3.27	R3.38 (§3.3.6.4)	The probability that the ADS-B System, for a given ADS-B Message Generation Function and in-range ADS-B Report Generation Processing Function, is unavailable during an operation, presuming that the System was available at the start of that operation, **shall** (R3.38) be no more than 2 x 10-4 per hour of flight. The allocation of this requirement to ADS-B System Functions should take into account the use of redundant/diverse implementations and known or potential failure conditions such as equipment outages and prolonged interference in the ADS-B broadcast channel.	A, B, C	MG, ME, RA	X	X	X	
R3.28	R3.39 (§3.3.6.5)	The integrity of the ADS-B System **shall** (R3.39) be 10^{-6} or better on a per report basis.	A, B, C	MG, ME, RA	X			
R3.29	R3.40 (§3.4.2)	The [ADS-B] messages **shall** (R3.40) be correlated, collated, uncompressed, re-partitioned, or otherwise manipulated as necessary to form the output reports specifically defined in §3.4.3 to §3.4.8 below.	A, C	RA	X	X	X	X
R3.30	R3.41 (§3.4.2)	The message and report assembly processing capability of the receiving subsystem **shall** (R3.41) support the total population of the participants within detection range provided by the specific data link technology.	A, C	ME(R), RA	X	X	X	
R3.31	R3.42 (§3.4.2)	Receiving subsystem designs must provide reports based on all decodable messages received, i.e., for each participant the report **shall** (R3.42) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is received from that participant with the exception that no type of report is required to be issued at a rate of greater than once per second..	A, C	ME(R), RA	X	X	X	
R3.32	R3.43 (§3.4.2)	The applicable reports **shall** (R3.43) be made available to the applications on a continual basis in accordance with the local system interface requirements.	A, C	RA		X	X	
R3.33	R3.44 (§3.4.2)	If the ADS-B design uses the ICAO 24-bit address, then there **shall** (R3.44) be agreement between the address currently being used by the Mode S transponder and the reported ADS-B address, for aircraft with both transponder and ADS-B.	A, B, C	MG, ME, RA		X	X	X

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.45 (§3.4.3.1.1)	If a transmitting ADS-B participant is *not* equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is one of the following, then it **shall** (R3.45) set its air/ground state to "known to be airborne" : Light Aircraft Glider or Sailplane Lighter Than Air Unmanned Aerial Vehicle Ultralight, Hang Glider, or Paraglider Parachutist or Skydiver Point Obstacle Cluster Obstacle Line Obstacle	A, B1, B3	MG		X		
	R3.46 (§3.4.3.1.1)	If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is one of the following, then that participant shall (R3.46) set its air/ground state to "known to be on the surface" : Surface Vehicle – Emergency Surface Vehicle – Service	B2	MG		X		
	R3.47 (§3.4.3.1.1)	If a transmitting ADS-B participant is *not* equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is "rotorcraft," then that participant **shall** (R3.47) set its air/ground state to "uncertain whether airborne or on the surface."	A, B1	MG		X		
	R3.48 (§3.4.3.1.1)	If a transmitting ADS-B participant is *not* equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and its ADS-B emitter category is not one of those listed under [R3.47, R3.48, and R3.49] above, then that participant's ground speed (GS), airspeed (AS) and radio height (RH) **shall** (R3.48-A) be examined, provided that some or all of those three parameters are available to the transmitting ADS-B subsystem. If GS < 100 knots, or AS < 100 knots, or RH < 100 feet, then the transmitting ADS-B participant **shall** (R3.48-B) set its Air/Ground state to "known to be on the surface."	A, B	MG		X		
	R3.49 (§3.4.3.1.1)	If a transmitting ADS-B participant *is* equipped with a means, such as a weight-on- wheels switch, to determine automatically whether it is airborne or on the surface, and that automatic means indicates that the participant is airborne, then that participant **shall** (R3.49) set its air/ground state to "known to be airborne."	A, B1	MG		X		

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.50 & R3.51 (§3.4.3.1.1)	If a transmitting ADS-B participant *is* equipped with a means, such as a weight-on- wheels switch, to determine automatically whether it is airborne or on the surface, and that automatic means indicates that the participant is on the surface, then the following additional tests **shall** (R3.50) be performed to validate the “on-the-surface” condition: a. If the participant’s ADS-B emitter category is any of the following: “Small Aircraft” or “Medium Aircraft” or “High-Wake-Vortex Large Aircraft” or “Heavy Aircraft” or “Highly Maneuverable Aircraft” or “Space or Trans-atmospheric Vehicle” and one or more of the following parameters is available to the transmitting ADS-B system: Ground Speed (GS) or Airspeed (AS) or Radio height from radio altimeter (RH) and any of the following conditions is true: GS > 100 knots or AS > 100 knots or RH > 100 ft, then the participant **shall** (R3.51-A) set its Air/Ground state to “known to be airborne.” b. Otherwise, the participant **shall** (R3.51-B) set its Air/Ground state to “known to be on the surface.”	A, B1	MG		X		
	R3.52 (§3.4.3.1.2)	ADS-B participants [for which the air/ground state is] “known to be on the surface” **shall** (R3.52) transmit those State Vector report elements that are indicated with bullets (“•”) in the “required from surface participants” column of Table 3-6.	A, B	MG		X		
	R3.53 (§3.4.3.1.2)	ADS-B participants [for which the air/ground state is] “known to be airborne” **shall** (R3.53) transmit those State Vector report elements that are indicated with bullets (“•”) in the “required from airborne participants” column of Table 3-6	A, B	MG		X		
	R3.54 (§3.4.3.1.2)	ADS-B participants for which the air/ground state is uncertain shall (R3.54) transmit those SV report elements that are indicated by bullets in the “required from airborne participants” column [of Table 3-6].	A, B	MG		X		

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
R3.36	R3.55 (§3.4.3.2)	A receiving ADS-B subsystem shall (R3.55) update the SV report that it provides to user applications about a transmitting ADS-B participant whenever it receives messages from that participant providing updated information about any of the SV report elements with the exception that SV reports are not required to be issued at a rate of greater than once per second.	A, B, C	RA	X	X	X	
R3.35	R3.56 (§3.4.3.2)	For ADS-B systems that use segmented messages for SV data, *time-critical SV report elements* that are not updated in the current received message **shall** (R3.56) be estimated whenever the SV report is updated. The *time-critical SV elements* are defined as the following: i) Geometric position (latitude, longitude, geometric height, and their validity flags – elements 4a, 4b, 4c, 5a, 5b); ii) Horizontal velocity and horizontal velocity validity (elements 6a, 6b, 6c, 7a, 7b); iii) Heading while on the surface (elements 8a, 8b); iv) Pressure altitude (elements 9a, 9b); v) Vertical rate (elements 10a, 10b); and vi) NIC (element 11).	A, B, C	RA	X	X	X	
R3.38	R3.57 (§3.4.3.2)	For time-critical elements of the SV report [as defined in R3.56 above], a receiving ADS-B subsystem's report assembly function **shall** (R3.57) indicate "no data available" if no data are received in the preceding coast interval specified in Table 3-4(a) (§3.3.3.1.1 above).	A, C	RA		X	X	
R3.37	R3.58 (§3.4.3.3)	The time of applicability (TOA) relative to local system time **shall** (R3.58) be updated with each State Vector report update.	A, C	RA		X	X	
	R3.59 (§3.4.3.4)	Horizontal position (§2.1.2.4) **shall** (R3.59) be reported as WGS-84 latitude and longitude.	A, B, C	RA	X	X		X
	R3.60 (§3.4.3.4)	Horizontal position **shall** (R3.60) be reported with the full range of possible latitudes (-90° to +90°) and longitudes (-180° to +180°).	A, B, C	RA		X		
	R3.61 (§3.4.3.4)	Horizontal position **shall** (R3.61) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_P field of the Mode-Status report (§2.1.2.13 and §3.4.4).	A, B, C	MG, RA	X	X	X	
	R3.62 (§3.4.3.4)	[H]orizontal position **shall** (R3.62) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to horizontal position error, σ_{hp}, listed in Table 3-4(a): 20 m for airborne participants, or σ_{hp} = 2.5 m for surface participants.	A, B, C	MG, RA	X	X	X	
	R3.63 (§3.4.3.5)	The Horizontal Position Valid field in the SV report **shall** (R3.63-A) be set to ONE if a valid horizontal position is being provided in geometric position (latitude and longitude) fields of that report; otherwise, the Horizontal Position Valid field **shall** (R3.63-B) be ZERO.	A, B, C	MG, RA		X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.64 (§3.4.3.6)	Geometric altitude **shall** (R3.64) be reported with a range from -1,000 feet up to +100,000 feet.	A, B, C	MG, RA		X		
	R3.65 (§3.4.3.6)	If the NAC_P code reported in the MS report (§2.1.2.13) is 9 or greater, geometric altitude **shall** (R3.65) be communicated and reported with a resolution sufficiently fine that it does not compromise the vertical accuracy reported in the NAC_P field.	A, B, C	MG, RA	X	X	X	
	R3.66 (§3.4.3.6)	[G]eometric altitude **shall** (R3.66) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to vertical position error, σ_{vp}, listed in Table 3-4(a): σ_{vp} = 30 feet for airborne participants.	A, B, C	MG, RA	X	X	X	
	R3.67 (§3.4.3.7)	The Geometric Altitude Valid field in the SV report is a one-bit field which **shall** (R2.67) be ONE if valid data is being provided in the Geometric Altitude field (§3.4.3.6), or ZERO otherwise.	A, B, C	MG, RA		X	X	
	R3.68 (§3.4.3.8)	The range of reported horizontal velocity **shall** (R3.68) accommodate speeds of up to 250 knots for surface participants and up to 4000 knots for airborne participants.	A, B, C	MG, RA		X		
	R3.69 (§3.4.3.8)	Horizontal velocity **shall** (R3.69) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode-Status report.	A, B, C	MG, RA	X	X	X	
	R3.70 (§3.4.3.8)	[H]orizontal velocity **shall** (R3.70) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to horizontal velocity error, σ_{hv}, listed in Table 3-4(a): that is, 0.5 m/s (about 1 knot) for airborne participants with speeds of 600 knots or less, or 0.25 m/s (about 0.5 knot) for surface participants.	A, B, C	MG, RA	X	X	X	
	R3.71 (§3.4.3.9)	The Airborne Horizontal Velocity Valid field in the SV report is a one-bit field which **shall** (R3.71-A) be set to ONE if a valid horizontal geometric velocity is being provided in the “North Velocity while airborne” and “East velocity while airborne” fields of the SV report; otherwise, the “Airborne Horizontal Velocity Valid” field **shall** (R3.71-B) be ZERO.	A, B, C	MG, RA		X	X	
	R3.72 (§3.4.3.10)	The ground speed (the magnitude of the geometric horizontal velocity) of an A/V that is known to be on the surface **shall** (R3.72) be reported in the “ground speed while on the surface” field of the SV report.	A, B, C	MG, RA		X	X	
	R3.73 (§3.4.3.10)	For A/Vs moving at ground speeds less than 70 knots, the ground speed **shall** (R3.73) be communicated and reported with a resolution of 1 knot or finer.	A, B, C	MG, RA		X	X	
	R3.74 (§3.4.3.10)	[T]he resolution with which the :ground speed while on the surface” field is communicated and reported **shall** (R3.74) be sufficiently fine so as not to compromise the accuracy of that speed as communicated in the NAC_V field of the MS report (§2.1.2.14 below).	A, B, C	MG, RA	X	X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.75 (§3.4.3.11)	The Surface Ground Speed Valid field in the SV report is a one-bit field which **shall** (R3.75) be ONE if valid data is available in the Ground Speed While on the Surface field (§3.4.3.10), or ZERO otherwise.	A, B, C	MG, RA		X	X	
	R3.76 (§3.4.3.12)	[E]ach ADS-B participant that reports a length code [part of the aircraft size code] of 2 or greater **shall** (R3.76) transmit messages to support the heading element of the SV report when that participant is on the surface and has a source of heading available to its ADS-B transmitting subsystem.	A, B1	MG		X	X	
	R3.77 (§3.4.3.12)	Heading **shall** (R3.77-A) be reported for the full range of possible headings (the full circle, from 0° to nearly 360°). The heading of surface participants **shall** (R3.77-B) be communicated and reported with a resolution of 6 degrees of arc or finer.	A, B, C	MG, RA		X	X	
	R3.78 (§3.4.3.13)	The "heading valid" field in the SV report **shall** (R3.78-A) be ONE if a valid heading is provided in the "heading while on the surface" field of the SV report; otherwise, it **shall** (R3.78-B) be ZERO.	A, B, C	MG, RA		X	X	
	R3.79 (§3.4.3.14)	Barometric pressure altitude **shall** (R3.79) be reported referenced to standard temperature and pressure (1013.25 hPa or mB, or 29.92 in Hg).	A, B, C	MG, RA		X	X	
	R3.80 (§3.4.3.14)	Barometric pressure altitude **shall** (R3.80) be reported over the range of -1,000 feet to +100,000 feet.	A, B, C	MG, RA		X	X	
	R3.81 (§3.4.3.14)	If a pressure altitude source with 25-foot or better resolution is available to the ADS-B transmitting subsystem, then pressure altitude from that source **shall** (R3.81-A) be communicated and reported with 25-foot or finer resolution. Otherwise, if a pressure altitude source with 100-foot or better resolution is available, pressure altitude from that source **shall** (R3.81-B) be communicated and reported with 100-foot or finer resolution.	A, B	MG		X	X	X
	R3.82 (§3.4.3.15)	The "pressure altitude valid" field in the SV report is a one-bit field which **shall** (R3.82-A) be ONE if valid information is provided in the "pressure altitude" field; otherwise, the "pressure altitude valid" field **shall** (R3.82-B) be ZERO.	A, B, C	MG, RA		X	X	
	R3.83 (§3.4.3.16)	The "vertical rate" field in the SV report contains the altitude rate (§2.1.2.8) of an airborne ADS-B participant. This **shall** (R3.83) be either the rate of change of pressure altitude or of geometric altitude, as specified by the "vertical rate type" element in the MS report.	A, B, C	MG, RA		X	X	
	R3.84 (§3.4.3.16)	The range of reported vertical rate **shall** (R3.84) accommodate up to ±32000 ft/min for airborne participants.	A, B, C	MG, RA		X		
	R3.85 (§3.4.3.16)	Geometric vertical rate **shall** (R3.85) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode-Status report.	A, B, C	MG, RA	X	X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.86 (§3.4.3.16)	[V]ertical rate **shall** (R3.86) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to vertical rate error, σ_{vv}, listed in Table 3-4(a): that is, 1.0 ft/s for airborne participants.	A, B, C	MG, RA	X	X	X	
	R3.87 (§3.4.3.17)	The "vertical rate valid" field in the SV report is a one-bit field which **shall** (R3.87-A) be ONE if valid information is provided in the "vertical rate" field; otherwise, the "vertical rate valid" field **shall** (R3.87-B) be ZERO.	A, B, C	MG, RA		X	X	
	R3.88 (§3.4.3.18)	The NIC field in the SV report is a 4-bit field that **shall** (R3.88) report the Navigation Integrity Category described in Table 2-2 in §2.1.2.12 above.	A, B, C	MG, RA		X	X	
R3.41	R3.89 (R3.4.4)	For each participant the Mode-status report shall (R3.89) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is accepted from that participant.	A, C	RA		X	X	
R3.43	R3.90 (§3.4.4.1)	The report assembly [of a receiving ADS-B subsystem] function **shall** (R3.90-A) provide update [of the MS report] when [any message containing MS information is] received. For those elements indicated in Table 3-8 as "elements that require rapid update", the report assembly function **shall** (R3.90-B) indicate the data has not been refreshed with the "Mode Status Data Available" bit (§3.4.4.7) if no update is received in the preceding 24 second period.	A, C	RA		X	X	
R3.42	R3.91 (§3.4.4.2)	The time of applicability relative to local system time **shall** (R3.91) be updated with every Mode-Status report update.	A, C	RA		X		
	R3.92 (§3.4.4.3)	The ADS-B Version Number[field in the MS report] **shall** (R3.92) be defined as specified in Table 3-9.	A, B, C	MG, RA		X		
	R3.93 (§3.4.4.4)	The call sign [field of the MS report] shall (R3.93) consist of up to 8 alphanumeric characters.	A, B, C	MG, RA		X		X
	R3.94 (§3.4.4.4)	The characters of the call sign **shall** (R3.94) consist only of the capital letters A-Z, the decimal digits 0-9, and – as trailing pad characters only – the "space" character.	A, B, C	MG, RA		X		
	R3.95 (§3.4.4.5)	Provision in the encoding [of the emitter category field in the MS report] **shall** (R3.95) be made for at least 24 distinct emitter categories, including the particular categories listed in §2.1.2.2.3 above.	A, B, C	MG, RA		X		X
	R3.96 (§3.4.4.6)	The aircraft length and width codes [field of the MS report] **shall** (R3.96) be as described in Table 3-10.	A, B, C	MG, RA		X		
	R3.97 (§3.4.4.6)	Each aircraft **shall** (R3.97) be assigned the smallest length and width codes for which its overall length and wingspan qualify it.	A, B1	MG	X			X
	R3.98 (§3.4.4.6)	Each aircraft ADS-B participant for which the length code is 2 or more (length greater than or equal to 25 m or wingspan greater than 34 m) **shall** (R3.98) transmit its aircraft size code while it is known to be on the surface.	A, B1	MG		X		X

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.99 (§3.4.4.6)	For [the purpose of requirement R3.98], the determination of when an aircraft is on the surface **shall** (R3.99) be as described in §3.4.3.1.1 above	A, B1	MG		X		
	R3.100 (§3.4.4.7)	The report assembly function **shall** (R3.100-A) set this field [the Mode Status available field in the MS report] to ZERO if no data has be received within 24 seconds under the conditions specified in 3.4.4.1; otherwise the report assembly function **shall** (R3.100-B) set this bit to ONE.	A, C	RA		X		
	R3.101 (§3.4.4.8)	The emergency/priority status field in the MS report is a 3-bit field which **shall** (R3.101) be encoded as indicated in Table 3-11.	A, B1	MG, RA		X		
	R3.102 (§3.4.4.9.1)	The CC code for "TCAS/ACAS installed and operational" **shall** (R3.102-A) be set to ONE if the transmitting aircraft is fitted with a TCAS II or ACAS computer and that computer is turned on and operating in a mode that can generate Resolution Advisory (RA) alerts. Likewise, this CC code **shall** (R3.102-B) be set to ONE if the transmitting ADS-B equipment cannot ascertain whether or not a TCAS II or ACAS computer is installed, or cannot ascertain whether that computer, if installed, is operating in a mode that can generate RA alerts. Otherwise, this CC code **shall** (R3.102-C) be ZERO	A, B1	MG, RA		X	X	
	R3.103 (§3.4.4.9.2)	The CC code for "CDTI based traffic display capability" **shall** (R3.103-A) be set to ONE if the transmitting aircraft has the capability of displaying nearby traffic on a Cockpit Display of Traffic Information (CDTI). Otherwise, this CC code **shall** (R3.103-B) be ZERO.	A, B1	MG, RA		X	X	
	R3.104 (§3.4.4.9.3)	At least four bits (sixteen possible encodings) **shall** (R3.104) be reserved in the capability class codes [field of the MS report] for the "service level" of the transmitting ADS-B participant.	A, B, C	MG, RA				X
	R3.105 (§3.4.4.9.3)	ADS-B equipment conforming to the current version of this MASPS (DO-242A) **shall** (R3.105) set the Service Level code to ZERO.	A, B, C	MG, RA		X		
	R.106 (§3.4.4.9.4)	The ARV Report Capability Flag is a one-bit field that **shall** (R3.106) be encoded as in Table 3-12.	A, B	MG, RA		X		
	R3.107 (§3.4.4.9.5)	The TS Report Capability Flag is a one-bit field that **shall** (R3.107) be encoded as in Table 3-13.	A1, A2, A3	MG, RA		X		
	R3.108 (§3.4.4.9.6)	The TC Report Capability Level is a two-bit field that shall (R3.108) be encoded as in Table 3-14.	A2, A3	MG, RA		X		
	R3.109 (§3.4.4.9.7)	The Reporting ADS-B Position Reference Point Flag is a one-bit subfield within the CC subfield that a transmitting ADS-B participant **shall** (R3.109-A) set to ONE if the A/V position that it transmits (in messages to support the SV report) is that of the participant's ADS-B position reference point (defined in §2.1.2.5 above). Otherwise, the transmitting ADS-B participant **shall** (R3.109-B) set this flag to ZERO. (See §2.1.2.5 for an illustration of the ADS-B position reference point.)	A, B1	MG, RA		X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.110 (§3.4.4.10.1)	The CC code for "TCAS/ACAS Resolution Advisory Active" **shall** (R3.110-A) be set to ONE if the transmitting aircraft has a TCAS II or ACAS computer that is currently issuing a Resolution Advisory (RA). Likewise, this CC code **shall** (R3.110-B) be set to ONE if the transmitting ADS-B equipment cannot ascertain whether the TCAS II or ACAS computer is currently issuing an RA. This CC code **shall** (R3.110-C) be ZERO only if it is explicitly known that a TCAS II or ACAS computer is not currently issuing a Resolution Advisory (RA).	A, B1	MG, RA		X	X	
	R3.111 (§3.4.4.10.2)	Initially, the "IDENT switch active" OM code **shall** (R3.111-A) be ZERO. Upon activation of the IDENT switch, this flag **shall** (R3.111-B) be set to ONE for a period of 20 ± 3 seconds; thereafter, it **shall** (R3.111-C) be reset to ZERO.	A, B1	MG, RA		X	X	
	R3.112 (§3.4.4.10.3)	The "Receiving ATC Services" flag is a one-bit OM code. When set to ONE, this code **shall** (R3.112) indicate that the transmitting ADS-B participant is receiving ATC services; otherwise this flag should be set to ZERO,	A, B1	MG, RA		X	X	
	R3.113 (§3.4.4.11)	The NAC_P field in the MS report is a 4-bit field which **shall** (R3.113) be encoded as described in Table 2-3 in §2.1.2.13 above.	A, B, C	MG, RA		X	X	
	R3.114 (§3.4.4.12)	The NAC_V field in the MS report is a 3-bit field which **shall** (R3.114) be encoded as described in Table 2-4 in §2.1.2.14 above.	A, B, C	MG, RA		X	X	
	R3.115 (§3.4.4.13)	The SIL field in the MS report is a 2-bit field which **shall** (R3.115) be coded as described in Table 2-5 in §2.1.2.15 above.	A, B, C	MG, RA		X	X	
	R3.116 (§3.4.4.14)	In the current version (DO-242A) of this MASPS, the "Reserved for Barometric Altitude Quality" field shall (R3.116) be ZERO.	A, B, C	MG, RA		X		
	R3.117 (§3.4.4.15)	A transmitting ADS-B participant **shall** (R3.117-A) set NIC_{baro} to ONE in the messages that it sends to support the MS report only if there is more than one source of barometric pressure altitude data and cross-checking of one altitude source against the other is performed so as to clear the "barometric altitude valid" flag in the SV report if the two altitude sources do not agree. Otherwise, it **shall** (R3.117-B) set this flag to ZERO.	A, B, C	MG, RA		X	X	
	R3.118 (§3.4.4.16)	The True/Magnetic Heading Flag in the Mode-Status report is a one-bit field which **shall** (R3.118) be ZERO to indicate that heading is reported referenced to true north, or ONE to indicate that heading is reported referenced to magnetic north.	A, B, C	MG, RA		X	X	
	R3.119 (§3.4.4.17)	The Primary Vertical Rate Type field in the MS report is a one-bit flag which **shall** (R3.119) be ZERO to indicate that the vertical rate field in the SV report 3.4.3.16 holds the rate of change of barometric pressure altitude, or ONE to indicate that the vertical rate field holds the rate of change of geometric altitude.	A, B, C	MG, RA		X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.120 (§3.4.4.18)	In the current version (DO-242A) of this MASPS, the "Reserved for Flight Mode Specific Data" field **shall** (R3.120) be ZERO.	A, B, C	MG, RA		X		X
	R3.121 (§3.4.6.3)	The time of applicability relative to local system time **shall** (R3.121) be updated with every Air-Referenced Velocity report update.	A, C	RA		X		
	R3.122 (§3.4.6.4)	Reported airspeed ranges [in the ARV report] **shall** (R3.122) be 0-4000 knots.	A, B, C	MG, RA		X		
	R3.123 (§3.4.6.4)	Airspeeds of 600 knots or less **shall** (R3.123) be reported with a resolution of 1 knot or finer.	A, B, C	MG, RA		X		
	R3.124 (§3.4.6.4)	Airspeeds between 600 and 4000 knots **shall** (R3.124) be reported with a resolution of 4 knots or finer.	A, B, C	MG, RA		X		
	R3.125 (§3.4.6.5)	The Airspeed Type and Validity field in the ARV report is a 2-bit field that **shall** (R3.125) be encoded as specified in Table 3-16	A, B, C	MG, RA		X		
	R3.126 (§3.4.6.6)	If an ADS-B participant broadcasts messages to support ARV reports, and heading is available to the transmitting ADS-B subsystem, then it **shall** (R3.126) provide heading in those messages.	A, B1	MG		X		X
	R3.127 (§3.4.6.6)	Reported heading range [in the heading field of the ARV report] **shall** (R3.127) cover a full circle, from 0 degrees to (almost) 360 degrees.	A, B, C	MG, RA		X		
	R3.128 (§3.4.6.6)	The heading field in ARV reports **shall** (R3.128) be communicated and reported with a resolution at least as fine as 1 degree of arc.	A, B, C	MG, RA		X		
	R3.129 (§3.4.6.7)	The "Heading Valid" field in the ARV report **shall** (R3.129) be ONE if the "Heading While Airborne" field contains valid heading information, or ZERO if that field does not contain valid heading information.	A, B, C	MG, RA		X		
	R3.130 (§3.4.7.1)	An airborne ADS-B participant of equipage class A2 or A3 **shall** (R3.130) transmit messages to support the TS report when either of the following conditions are met: a. The flight director or autopilot is engaged in a vertical mode and a target altitude or an acceptable substitute for target altitude (§3.4.7.11) is available from the automation system; or b. The flight director or autopilot is engaged in a horizontal mode and a target heading or target track (§3.4.7.6) is available from the automation system.	A2, A3	MG, RA		X	X	
	R3.131 (§3.4.7.2)	The higher "state change" update interval requirements specified for TS report information in §3.3.3.1.4 and Table 3-4(d) shall (R3.131) be met whenever there is a change in the value of any of the following TS report fields: • Horizontal Data Available and Horizontal Source Indicator (§3.4.7.4); • Target Heading or Track Angle (§3.4.7.5); • Target Heading/Track Indicator (§3.4.7.6); • Vertical Data Available and Vertical Source Indicator (§3.4.7.10); • Target Altitude (§3.4.7.11).	A1, A2, A3	MG, ME, RA	X	X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.132 (§3.4.7.3)	The time of applicability relative to local system time shall (R3.132) be updated with every Target State report update.	A, C	RA		X		
	R3.133 (§3.4.7.4)	The Horizontal Data Available and Horizontal Target Source Indicator field [in the TSR report] **shall** (R3.133) be encoded as specified in Table 3-18 below.	A1, A2, A3	MG, RA		X		
	R3.134 (§3.4.7.4)	In cases where the aircraft is operated in a horizontal FMS/RNAV mode and the FMS/RNAV target track angle is the same as the autopilot control panel selected track angle, the Horizontal Data Available and Horizontal Target Source Indicator [filed in the TSR report] **shall** (R3.134) be set to "FMS/RNAV system."	A1, A2, A3	MG, RA		X	X	
	R3.135 (§3.4.7.5)	Target heading or track angle [a filed in the TS report] **shall** (R3.135) be reported over the full range of all possible directions, 0° to almost 360°, expressed as an angle measured clockwise from a reference direction.	A1, A2, A3	MG, RA		X		
	R3.136 (§3.4.7.5)	Target heading or track angle [field in the TS report] shall (R3.136) be communicated and reported with a resolution at least as fine as one degree of arc.	A1, A2, A3	MG, RA		X		
	R3.137 (§3.4.7.6)	The orientation type (heading or track angle) is conveyed in the Target Heading/Track Indicator field of the TS Report. This field **shall** (R3.137) be ZERO to indicate that the "Target Heading or Track Angle" field conveys target heading, or ONE to indicate that it conveys target track angle.	A1, A2, A3	MG, RA		X		
	R3.138 (§3.4.7.7)	In the current version (DO-242A) of the MASPS, the "Reserved for Heading/Track Capability" field [in the TS report] **shall** (R3.138) be ZERO.	A1, A2, A3	MG, RA		X		
	R3.139 (§3.4.7.8)	The Horizontal Mode Indicator **shall** (R3.139) be encoded as specified in Table 3-19.	A1, A2, A3	MG, RA		X		
	R3.140 (§3.4.7.9)	In the current version (DO-242A) of this MASPS, the "Reserved for Horizontal Conformance" field [in the TS report] **shall** (R3.140) be ZERO.	A1, A2, A3	MG, RA		X		
	R3.141 (§3.4.7.10).	The Vertical Data Available and Vertical Target Source Indicator field [in the TS report] **shall** (R3.141) be encoded as specified in Table 3-20.	A1, A2, A3	MG, RA		X		
	R3.142 (§3.4.7.10).	In cases where the aircraft is operated in a vertical FMS/RNAV mode and the FMS/RNAV target altitude is the same as the autopilot control panel selected altitude, the Vertical Data Available and Vertical Target Source Indicator **shall** (R3.142) be set to "FMS/RNAV system."	A1, A2, A3	MG, RA		X	X	
	R3.143 (§3.4.7.11)	Target altitude is the aircraft's next intended level flight altitude if in a climb or descent or its current intended altitude if commanded to hold altitude. Target altitude **shall** (R3.143) be represented as the operational altitude recognized by the transmitting aircraft's guidance system.	A1, A2, A3	MG, RA		X	X	
	R3.144 (§3.4.7.11)	For aircraft unable to determine target altitude as defined above, the Target Altitude field may contain a substitute value. If a substitute value is provided, that value **shall** (R3.144) be consistent with the aircraft's target altitude capability as listed in Table 3-22.	A1, A2, A3	MG, RA		X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.145 (§3.4.7.11)	Target altitude [field in the TS report] **shall** (R3.145) be provided with a range from –1000 ft to +100,000 feet.	A1, A2, A3	MG, RA		X		
	R3.146 (§3.4.7.11)	[The target altitude field in the TS report] **shall** (R3.146) be communicated and reported with a resolution of 100 feet or finer.	A1, A2, A3	MG, RA		X		
	R3.147 (§3.4.7.12)	The Target Altitude Type **shall** (R3.147) be encoded as specified in Table 3-21.	A1, A2, A3	MG, RA		X		
	R3.148 (§3.4.7.13)	The target altitude capability field [in the TS report] **shall** (R3.148) be encoded as shown in Table 3-22.	A1, A2, A3	MG, RA		X		
	R3.149 (§3.4.7.14)	The Vertical Mode Indicator [field in the TS report] **shall** (R3.149) be encoded as specified in Table 3-23.	A1, A2, A3	MG, RA		X		
	R3.150 (§3.4.7.15)	In ADS-B systems that conform to this version of this MASPS (DO-242A), the "Reserved for Vertical Conformance" field **shall** (R3.150) be ZERO	A1, A2, A3	MG, RA		X		
	R3.151 (§3.4.8.1)	The following conditions are necessary requirements to initiate generation of TC reports: 1. The transmitting aircraft has an autopilot or flight director engaged and have access to active FMS/RNAV planning data or next target altitude. If the aircraft only supports a single axis autopilot or flight director, then the complementary axis data fields for TC reports are marked "not available". 2. Each TC report has an associated stable TTG value generated by the FMS/RNAV system or by extrapolation from current state vector and intent information available at the transmitting ADS-B subsystem. A TTG value is considered "stable" if the estimated TTG value based on previous information is consistent with the current TTG value, i.e. the difference between the previous TTG estimate updated for delta elapsed time and the current TTG estimate is less than some threshold value. Threshold values for determining stability of TTG will be determined in lower level documentation. Given that the above conditions are satisfied, and any TC+0 report previously generated is not currently valid, an A2 level system **shall** (R3.151) initiate broadcast of a TC+0 report when the aircraft is within 4 minutes TTG to the trajectory change described in that TC+0 report, or as otherwise needed to meet the acquisition range requirements for A2 equipage as specified in Table 3-4(e).	A2, A3	MG, RA		X	X	
	R3.152 (§3.4.8.1)	Similarly, [i.e., given that the prerequisite conditions listed in R3.151 are met] an A3 level system **shall** (R3.152) initiate broadcast of a TC+0 report when the aircraft is within 8 minutes TTG to the trajectory change described in that report, or as otherwise needed to meet the acquisition range requirements for A3 equipage as specified in Table 3-4(e).	A2, A3	MG, RA		X	X	

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method: Analysis/ Simulation	Verification Method: Lab Tests	Verification Method: Flight Tests	Verification Method: Insp.
	R3.153 (§3.4.8.1)	[F]or Fly-By turns, the TC latitude and longitude are for a point in the middle of the turn segment, and the active flight segment (turn maneuver) is not completed until the target track in the TC report, i.e. track-from value has been captured. Normally, this condition is signaled by the Horizontal Mode Indicator. If the TS report target track is not available, then a test should be performed on current state vector components to verify capture of the track-from value as a condition for sequencing the turn maneuver. In either event, the Fly-By turn **shall** (R3.153) be sequenced if more than 2 minutes has elapsed since the time of Fly-By transition sequencing.	A2, A3	MG, RA		X		
	R3.154 (§3.4.8.1)	In the event that the active flight segment is sequenced, or a major change in intent is detected such that TC+0 report data is no longer valid, the aircraft broadcasting TC+0 reports **shall** (R3.154) increment the TC report cycle number (modulo 4) for subsequent TC report broadcasts.	A2, A3	MG, RA		X		
	R3.155 (§3.4.8.3)	The time of applicability relative to local system time **shall** (R3.155) be updated with every TC report update.	A2, A3	RA		X		
	R3.156 (§3.4.8.4)	The “TC Report Sequence Number field in the TC report **shall** (R3.156) contain a value of ZERO for this version of the MASPS.	A2, A3	MG, RA		X		
	R3.157 (§3.4.8.5)	The TC Report Cycle Number shall (R3.157) increment when any of the following conditions are met: • A change in TC estimated time of arrival (i.e., TOA+TTG) of greater than 30 seconds; • A change in the Horizontal Data Available and Horizontal TC Type (§3.4.8.8) field; • A change in horizontal position greater than 2 NM from the position defined by TC Latitude and TC Longitude (§3.4.8.9 and §3.4.8.10, respectively); • A change in the Horizontal Command/Planned flag (§3.4.8.15); • A change in the Vertical Data Available and Vertical TC Type (§3.4.8.16) field; • A change in TC Altitude (§3.4.8.17) – if the Vertical TC Type (§3.4.8.16) is not Estimated Altitude - of more than 100 feet; • A change in the Vertical Command/Planned flag (§3.4.8.22).	A2, A3	MG, RA		X		
	R3.158 (§3.4.8.5)	The TC Report Cycle Number **shall** (R3.158) be a number in the range from 0 to 3 that is incremented (modulo 4) each time the numbering of TC reports changes.	A2, A3	MG, RA		X		
	R3.159 (§3.4.8.6)	For this version of the MASPS (DO-242A), the “Reserved for TC Report Management Indicator: field **shall** (R3.159) be given a value of ZERO.	A2, A3	MG, RA		X		
	R3.160 (§3.4.8.7)	The TTG field[in the TC report] **shall** (R3.160) have a resolution of 4 seconds or better.	A2, A3	MG, RA		X		

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.161 (§3.4.8.7)	The TTG field [in the TC report] **shall** (R3.161-A) have a range from –120 sec to +1200 sec (20 min), and **shall** (R3.161-B) have a means to indicate a TTG value of greater than 20 minutes.	A2, A3	MG, RA		X		
	R3.162 (§3.4.8.8)	The Horizontal TC Type **shall** (R3.162) be encoded as specified in the first column of Table 3-25.	A2, A3	MG, RA		X		
	R3.163 (§3.4.8.8)	For each Horizontal TC Type listed [in Table 3-25], the resolution of the TC report elements listed in the following columns **shall** (R3.163) be at least as fine as indicated in the table, *except* that elements marked as "n/r" are not required to be reported in TC reports for that horizontal TC type	A2, A3	MG, RA		X		
	R3.164 (§3.4.8.9)	TC Latitude **shall** (R3.164) be reported as WGS-84 latitude.	A2, A3	MG, RA		X		
	R3.165 (§3.4.8.9)	TC horizontal position **shall** (R3.165) be reported with the full range of possible latitudes (-90° to +90°).	A2, A3	MG, RA		X		
	R3.166 (§3.4.8.9)	Resolution of TC longitude **shall** (R3.166) be 700 m or finer for the horizontal TC types shown in Table 3-25 [in §3.4.8.8].	A2, A3	MG, RA		X		
	R3.167 (§3.4.8.10)	TC Longitude **shall** (R3.167) be reported as WGS-84 longitude.	A2, A3	MG, RA		X		
	R3.168 (§3.4.8.10)	TC horizontal position **shall** (R3.168) be reported with the full range of possible longitudes (-180° to +180°).	A2, A3	MG, RA		X		
	R3.169 (§3.4.8.10)	Resolution of TC longitude **shall** (R3.169) be 700 m or finer for the horizontal TC types shown in Table 3-25.	A2, A3	MG, RA		X		
	R3.170 (§3.4.8.11)	Turn radius in NM **shall** (R3.170-A) be reported if available as an input to the ADS-B transmitting subsystem for horizontal TC types 3 and 4, i.e. when the TC report describes a Fly-By turn. For horizontal TC type 5 (radius to fix turns), turn radius in nautical miles **shall** (R3.170-B) be reported as a mandatory TC report element, i.e. if turn radius is unavailable, then the horizontal TC report data fields should be marked not valid. Resolution of turn radius **shall** (R3.170-C) be 700 m or finer when reported. The range of possible turn radius values is (0.0 to 28.6 NM).	A2, A3	MG, RA		X		
	R3.171 (§3.4.8.12)	If the leg type is a Direct to Fix (DF) type, then the bearing from the current position to the endpoint TCP **shall** (R3.171) be used to represent track-to for the active flight segment, e.g. TC+0.	A2, A3	MG, RA		X		
	R3.172 (§3.4.8.14)	In ADS-B systems that conform to this version (DO-242A) of this MASPS, the "Reserved for Horizontal Conformance" field **shall** (R3.172) be ZERO.	A2, A3	MG, RA		X		

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.173 (§3.4.8.15)	The horizontal command/planned flag [in the TC report] shall (R3.173) be set to “Planned” unless both of the following conditions are met: • It has been determined on the transmitting aircraft that the horizontal trajectory change is part of the command trajectory, as defined above. • It has been determined on the transmitting aircraft that it is broadcasting trajectory change information for each intended horizontal trajectory change between the current aircraft position and the corresponding TCP.	A2, A3	MG, RA		X	X	
	R3.174 (§3.4.8.16)	The Vertical TC Type [field in the TC report] **shall** (R3.174) be encoded as specified in the first column of Table 3-26.	A2, A3	MG, RA		X		
	R3.175 (§3.4.8.17)	The ADS-B system **shall** (R3.175) support TC altitudes in the range from -1,000 feet to +100,000 feet.	A2, A3	MG, RA		X		
	R3.176 (§3.4.8.17)	The resolution with which TC altitude is reported **shall** (R3.176) be 100 feet.	A2, A3	MG, RA		X		
	R3.177 (§3.4.8.18)	The TC Altitude Type **shall** (R3.177) be encoded as specified in Table 3-27.	A2, A3	MG, RA		X		
	R3.178 (§3.4.8.19)	In ADS-B systems that conform to this version of this MASPS (DO-242A), the “Reserved for Altitude Constraint Type” field **shall** (R3.178) be ZERO.	A2, A3	MG, RA		X		
	R3.179 (§3.4.8.20)	In ADS-B systems that conform to this version of this MASPS (DO-242A), the “Reserved for Able/Unable Altitude Constraint” field **shall** (R3.179) be ZERO.	A2, A3	MG, RA		X		
	R3.180 (§3.4.8.21)	In ADS-B systems that conform to this version (DO-242A) of this MASPS, the “Reserved for Vertical Conformance” field **shall** (R3.180) be ZERO.	A2, A3	MG, RA		X		
	R3.181 (§3.4.8.22)	The vertical command/planned flag [filed in the TC report] shall (R3.181) be set to “Planned” unless both of the following conditions are met: • It has been determined on the transmitting aircraft that the vertical trajectory change is part of the command trajectory, as defined above. • It has been determined on the transmitting aircraft that it is broadcasting trajectory change information for each intended vertical trajectory change between the current aircraft position and the corresponding TCP.	A2, A3	MG, RA		X	X	
	R3.182 (§3.4.8.23.1)	If the current TC+0 report is being updated or refreshed, the message generation function in the ADS-B transmitting subsystem **shall** (R3.182) do the following: a. keep the value of the TC Report Cycle Number the same as in the messages previously sent to support TC+0 reports; b. refresh the TOA and TTG fields in the messages being generated to support the TC+0 report; and c. update all pertinent TC+0 report elements in those messages.	A2, A3	MG, RA		X		

Old 242 Ref. #	New 242A Ref. #	Requirement	Subsystem	Function	Verification Method			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.183 (§3.4.8.23.1)	If a new TC+0 report is to be generated, then the message generation function in the ADS-B transmitting subsystem **shall** (R3.183) do the following: a. increment (modulo 4) the TC Report Cycle Number from the messages previously generated to support the previous TC+0 report; b. reinitialize all TC+0 report elements; and c. generate messages to support the new TC+0 report.	A2, A3	MG, RA		X		
	R3.184 (§3.4.8.23.1)	If the current TC+0 report is no longer valid and no subsequent TC+0 reports are to be generated, the message generation function in the ADS-B transmitting subsystem **shall** (R3.184) do the following: a. increment (modulo 4) the TC Report Cycle Number from the messages previously generated to support the previous TC+0 report; b. set the "Horizontal Data Available and Horizontal TC Type" and "Vertical Data Available and Vertical TC Type" fields in the newly generated messages to 0.	A2, A3	MG, RA		X		
	R3.185 (§3.4.8.23.1)	If the previous TC+0 report is considered invalid and no subsequent TC+0 reports are to be immediately issued, the message generation function in the ADS-B transmitting subsystem **shall** (R3.185) transmit messages supporting the current TC+0 report for a time period of at least twice the required update interval for TC reports as specified in §3.3.3.1.4 that has the incremented TC Cycle Number and indicates "no horizontal or vertical data available".	A2, A3	MG, RA		X		
	R3.186 (§3.4.8.23.2)	If a message is received supporting TC+0 reports from a participant with the TC Report Cycle Number matching that of previously received reports, the message will be considered an update for the current TC+0 report. In this case the report assembly function in the ADS-B receiving subsystem **shall** (R3.186) refresh the TOA and TTG fields and update the report fields with the received data.	A2, A3	MG, RA		X		
	R3.187 (§3.4.8.23.2)	If a message is received supporting either TC+0 or SC reports from a participant with the TC Report Cycle Number incremented (modulo 4) from that of previously received TC+0 reports, the message will be considered as an indication that current TC+0 report is no longer valid. In this case the report assembly function in the ADS-B receiving subsystem **shall** (R3.187) clear the current TC+0 report by setting the "Horizontal Data Available and Horizontal TC Type" and "Vertical Data Available and Vertical TC Type" fields to 0.	A2, A3	MG, RA		X		

Old 242 Ref. #	**New 242A Ref. #**	**Requirement**	**Subsystem**	**Function**	**Verification Method**			
					Analysis/ Simulation	Lab Tests	Flight Tests	Insp.
	R3.188 (§3.5.1.1.3)	The transmit subsystem shall (R3.188) interface with the onboard data entry mechanisms such as flight deck keyboards/selectors, encoded data sources, and logical discrete inputs to provide the subsystem with the following data: • participant address • emitter category • call sign • emergency/priority status • capability class codes	A	MG			X	X
	R3.189 (§3.5.2.1.3)	The transmit subsystem shall (R3.189) interface with the onboard data base or approved data entry mechanisms such as flight deck keyboards/selectors, encoded data sources, and logical discrete inputs to provide the subsystem with the following data: • participant address • emitter category • emergency/priority status • capability class codes	B	MG			X	X

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Robert Torn	Air Line Pilot Association/Delta Airlines
Vincent Trapani	BAE Systems
Tin Truong	Federal Aviation Administration
Michael Ylrey	The Boeing Company
Dwight Unruh	Rockwell Collins, Inc.
Kaelberger Urlich	Thales ATM, Inc.
Ed Valovage	Sensis Corporation
Garth Van Sickle	DCS Corporation
Stephen VanTrees	Federal Aviation Administration
Marvin Waller	National Aeronautics & Space Administration
James Walton	United Parcel Service
Ganghaui Wang	The MITRE Corporation
Jerry Watson	Honeywell International, Inc.
Richard Weather	Department of Defense
Michael Webb	ARINC, Inc.
Mike White	Federal Aviation Administration
George Wilson	Delta Air Lines, Inc.
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Alice Wong	Federal Aviation Administration
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Gene Wong	Federal Aviation Administration
Kathryn Ybarra	L-3 Communications, Inc.
Steve Young	National Aeronautics & Space Administration
Karim Zeghal	Eurocontrol
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