3.4.3 ADS-B Subsystem Requirements

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

3.4.3.1 ADS-B Surveillance Coverage

Air-to-air coverage requirements for illustrative operational scenarios were given in Table 2-8, and values associated with current ATS surveillance capabilities were summarized in Table 2-9(a). Transmitter and receiver requirements follow from these coverage requirements. Ideally, all airborne participants would have the same transmitter power and same receiver sensitivity. Recognizing, however, that lower equipage costs may be achieved with lower transmit power and receiver sensitivity, surveillance coverage requirements are based on minimum acceptable capability. Users interested in a certain level of operational capability can thus select an equipage class appropriate to their needs (see Table 3.2.1.3.3a~~3.4.3.1a~~).

ADS-B equipage classes summarized in Table 3.2.1.3.3a **shall** (242AR3.1) provide the air-to-air coverage specified in Table ~~3.2.1.4.1a~~3.4.3.1a. The stated ranges are the basis for the indicated relative effective radiated power (ERP) and the receiver sensitivity requirement for each transmit unit.

Since many users will share the same airspace, and all must be seen by ATS, all A, B, and C equipage classes must be interoperable. The ERP and minimum signal detection capabilities **shall** (242AR3.2) support the associated pair-wise minimum operational ranges listed in Table ~~3.2.1.4.1~~3.4.3.1b. Broadcast only aircraft (class B0 and B1) **shall** (242AR3.3) have ERP values equivalent to those of class A0 and A1, respectively, as determined by own aircraft maximum speed, operating altitude, and corresponding coverage requirements. Ground vehicles operating on the airport surface (class B2) **shall** (242AR3.4) provide a 5 NM coverage range for class A receivers. If required due to spectrum considerations, ADS-B transmissions from ground vehicles (class B2) **shall** (242AR3.5) be automatically prohibited when those vehicles are outside the surface movement area (i.e., runways and taxiways). ERP for these vehicles may thus be as low as -12 dB relative to class A1. Fixed obstacle (class B3) broadcast coverage **shall** (242AR3.6) be sufficient to provide a 10 NM coverage range from the location of the obstacle.

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

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

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

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

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

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

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

3.4.3.2 ADS-B Information Exchange Requirements by Equipage Class

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

The rationale for the requirements in Table 3.4.3.2a is as follows. Column 1 of Table 3.4.3.2a combines the equipage classes (which are based on user operational interests) from Table 3.2.1.3.3a with the required ranges given in Table 3.4.3.1a. Information exchange requirements by application were taken from Table 2-7 to determine the broadcast and receive data required for each equipage class (column 2 of Table 3.4.3.2a and Table 3.4.3.2b). A correlation between the equipage class and the ability of that class to support and perform that application was done next. (The determination of the information exchange ability of an equipage class to support a specific application is determined by the information transmitted by that equipage class, while the ability to perform a specific application is determined by the ability of that equipage class to receive and process the indicated information.)

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

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

Notes:

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

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

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

Notes:

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

3.4.3.3 ADS-B Data Exchange Requirements

3.4.3.3.1 Report Accuracy, Update Period and Acquisition Range

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

3.4.3.3.1.1 State Vector Report Acquisition, Update Interval and Acquisition Range

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

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

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

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

Table 3.4.3.3.1.1a shows accuracy values in two ways: one describing the ADS-B report information available to applications, and the other presenting the error budget component allocated to ADS-B degradation of this information. The ADS-B system **shall** (242AR3.12) satisfy the error budget requirements specified in the table in order to assure satisfaction of ADS-B report accuracies. Degradation is defined here to mean additional errors imposed by the ADS-B system on position and velocity measurements above the inherent navigation source errors. The errors referred to in this section are specifically due to ADS-B quantization of state vector information, and other effects such as tracker lag. ADS-B timing and latency errors are treated as a separate subject under heading §3.2.1.4.3.2. The maximum errors specified in Table 3.4.3.3.1.1a are limited to contributions from the following two error sources:

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

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

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

Definitions for Table 3.4.3.3.1.1a:

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

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

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

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

n/a: not applicable.

Notes for Table 3.4.3.3.1.1a:

1. *The lower number represents the desired accuracy for best operational performance and maximum advantage of ADS-B. The higher number, representative of GPS standard positioning service, represents an acceptable level of ADS-B performance, when combined with barometric altimeter.*
2. *The analysis in Appendix O indicates that a 3-second report received update period for the full state vector will yield improvements in both safety and alert rate relative to TCAS II, which does not measure velocity. Further improvement in these measures can be achieved by providing a one-second report received update rate. Further definition of ADS-B based separation and conflict avoidance system(s) may result in refinements to the values in the Table.*
3. *The 90 NM range requirement applies in the forward direction (that is, the direction of the own aircraft's heading). The required range aft is 40 NM. The required range 45 degrees to port and starboard of the own aircraft's heading is 64 NM (see Appendix E). The required range 90 degrees to port and starboard of the own aircraft's heading is 45 NM. [The 120 NM desired range applies in the forward direction. The desired range aft is 42 NM. The desired range 45 degrees to port and starboard of the own-aircraft's heading is 85 NM.]*
4. *Requirements apply to both aircraft and vehicles.*
5. *Supporting analyses for update period and update probability are provided in Appendices H and O.*
6. *The position error requirement for aircraft on the airport surface is stated with respect to the aircraft's ADS-B position reference point (§2.1.2.5).*
7. *This row represents the allowable contribution to total state vector error from ADS-B.*
8. *The requirements on horizontal velocity error (σ_{hv},) apply to aircraft speeds of up to 600 knots. Accuracies required for velocities above 600 knots are TBD.*
9. *Specific system parameter requirements in Table 3.4.3.3.1.1a can be waived provided that the system designer shows that the application design goals stated in Appendix O or equivalent system level performance can be achieved.*
10. *Air-to-air ranges extending to 90 NM were originally intended to support the application of Flight Path Deconfliction Planning, Cooperative Separation in Oceanic/Low Density En Route Airspace, as described in §2.2.2.6. It is noted in Section 2.2.2.6, in connection with Table 2-8, that the operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.*

11. *Requirements for applications at ranges less than 10 NM are under development. The 3-second update period is required for aircraft pairs with horizontal separation less than [1.1 NM] and vertical separation less than [1000 feet]. The 3 second update period is also required to support ACM for aircraft pairs within 3 NM lateral separation and 6000 feet vertical separation that are converging at a rate of greater than 500 feet per minute vertically or greater than 6000 feet per minute horizontally. The update rate can be reduced to once per 5 seconds (95%) for aircraft pairs that are not within these geometrical constraints and for applications other than ACM. Requirements for ACM are under development. Requirements for future applications may differ from those stated here.*
12. *These values are based on the scenario in §2.2.2.5.2 which assumes a reduced horizontal separation standard of 2 NM. Separation standards of more than 2 NM may require longer acquisition ranges to provide adequate alerting times.*

3.4.3.3.1.2 Mode-Status Acquisition, Update Interval and Acquisition Range

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

Note: As requirements mature for applications that require MS reports, the required probably of acquisition at specified ranges may change. It is possible that these requirements may be more stringent in later versions of 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 3.4.3.3.1.2a: MS Accuracy and Acquisition Range Requirements

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

Definitions for Table 3.4.3.3.1.2a:

n/a: not applicable.

Notes for Table 3.4.3.3.1.2a:

1. *Requirements apply to both aircraft and vehicles. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.*
2. *The 90 NM range requirement applies in the forward direction (that is, the direction of the own aircraft's heading). The required range aft is 40 NM. The required range 45 degrees to port and starboard of the own aircraft's heading is 64 NM (see Appendix E). The required range 90 degrees to port and starboard of the own aircraft's heading is 45 NM. [The 120 NM desired range applies in the forward direction. The desired range aft is 42 NM. The desired range 45 degrees to port and starboard of the own-aircraft's heading is 85 NM.]*
3. *Air-to-air ranges extending to 90 NM are intended to support the application of Cooperative Separation in Oceanic/Low Density En Route Airspace, as described in §2.2.2.6. It is noted in Section 2.2.2.6, in connection with Table 2-8, that the operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary.*
4. *These requirements are to be met for essential level applications. As these applications are developed, these requirements may be further refined in terms of more stringent ranges and acquisition probability.*
5. *It is assumed that the population for which these acquisition requirements is to be met are aircraft that have been operating and broadcasting MS reports within radio line of sight at ranges significantly greater than the acquisition range.*
6. *These values are based on the scenario in §2.2.2.5.2 which assumes a reduced horizontal separation standard of 2 NM. Separation standards of more than 2 NM may require longer acquisition ranges to provide adequate alerting times.*

3.4.3.3.1.3 Target State Report Acquisition, Update Interval and Acquisition Range

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

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

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

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

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

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

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

Notes:

1. *It is desired that requirement 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 3.4.3.3.1.3a shows the values for the required minimum update periods as calculated by the above formulae at the ranges indicated as required and desired for A2 and A3 aircraft.

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

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

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

Notes for Table 3.4.3.3.1.1a:

1. *Table 3.4.3.3.1.1a is based on an air-air en route scenario between two aircraft closing at 1200 knots, which is considered a worst-case scenario for deriving range requirements for ADS-B conflict alerting. See Appendix O for scenario details.*
2. *The ranges shown in Table 3.4.3.3.1.1a are meant to represent operational airspace with aircraft densities equivalent to those defined in Table 2-8.*
3. *The trigger conditions for the desired broadcasting of TS reports at the "state change" update rate are specified in §3.4.7.2.*

3.4.3.3.2 State Vector Report Latency and Report Time Error Requirements

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

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

Delays that occur prior to the information reaching ADS-B are not the subject of requirements in 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.

3.4.3.3.2.1 Latency Definitions

The following definitions are used in the requirements concerning latency.

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

3.4.3.3.2.2 State Vector Latency Requirements

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