2 Operational Requirements

2.1 General Requirements

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

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

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

The following key terms are used within this section.

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

2.1.1 General Performance

2.1.1.1 Consistent Quantization of Data

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

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

Note: Users of the ADS-B message formats should perform a comparison between the quality metrics applied and the resolution of each message element that those metrics are applied against. There are some combinations of message data elements and quality metrics that are not compatible: for example, the Airborne Velocity Message (Register 09H) Subtypes 1 or 3 (subsonic) with a minimum resolution of 1 knot (~0.5 m/s) and NACv = 4 (Velocity accuracy < 0.3 m/s). Another example would be the Airborne Velocity messsage Subtypes 2 or 4 (Supersonic) with a minimum resolution of 4 knots (~2 m/s) and NACv = 3 (Velocity accuracy < 1 m/s) or NACv = 4.~~Note:~~

2.1.1.2 ADS-B Reports Characteristics

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

2.1.1.3 Expandability

Applications envisioned for using the information provided by ADS-B are not fully developed. In addition, the potential for future applications to need information from an ADS-B system is considered fairly high. Therefore the ADS-B system defined to meet the requirements in 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.

2.2 System Performance – Standard Operational Conditions

2.2.1 ADS-B System-Level Performance

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

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

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

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

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

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

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

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

Notes:

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

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

Information Element ↓	Aid to Visual Acqui-sition (AIRB)	Spacing	Delegated Separation Assurance & Sequenc-ing	Simulta-neous Ap-proaches	Airport Surface (A/V to A/V & A/V to ATS)	Flight Path Deconflic-tion Planning (Self Sep)	ATS Surveill ance ADS-B OUT	TSAA Traffic Situation Awareness W/Alerts	Notes
Identification									
Flight ID (Call Sign)		•	•	•	•	•	•		1
Address	•	•	•	•	•	•	•	•	
Category			•	•	•	•	•		
Mode A Code							•		
State Vector									
Horizontal Position	•	•	•	•	•	•	•	•	
Vertical Position	•	•	•	•		•	•	•	
Horizontal Velocity	•	•	•	•		•	•	•	
Vertical Velocity	•	•	•	•		•	•	•	
Surface Heading					•				
Ground Speed					•				
NIC		•	•	•	•	•	•	•	
Mode-Status									
Emergency/ Priority Status	•	•					•		
Capability Codes		•	•	•	•	•	•	•	
Operational Modes		•	•	•	•	•	•	•	
NACp	•	•	•	•	•	•	•	•	
NACv~~ARV~~		•	••	••	•	•	••	•	
SIL		•	•	•	•	•	•	•	
SDA	•	•	•	•	•	•	•	•	
~~TS reports~~			•				•		
ARV~~TC+0 reports~~			**TBD**•				•		
Intent Data~~TC+n reports~~			**TBD**			**TBD**	•	**TBD**	

<u>Notes for Table 2-6:</u>

• = Expected Application Requirement

1. *A/Vs not receiving ATS services are not required to transmit call sign.*
2. *Application requirements are ~~to be~~ <u>referenced in Section 4.</u>~~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 2-7 ADS-B Transmit Sources – Minimum Required Performance vs ADS-B In Application Requirements

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

Notes:

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

2. FAA TSO-C195 states applications' Hazard Level for ownship when airborne or on surface > 80 knots = Major (SDA=2), Hazard Level for ownship < 80 knots = Minor (SDA=1)

3. TIS-B Service does not broadcast an SDA value but SBS ICD defines TIS-B service SDA equivalent to 2.

4. SURF surface targets require NACp >=9, SURF airborne targets require NACp = 7 or 9 depending on parallel runway spacing

5. The airborne source's performance levels are from the FAA Final ADS-B Out Rule and Advisory Circular (Refs TBD). The TIS-B and ADS-R performance levels are from the latest version of the SBS ICD (Ref TBD)

6. This is an assumption in the FIM-S SPR. Will be revisited when FIM-S MOPS is developed.

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

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

Notes for Table 2-8:

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

2.2.1.1 ADS-B System-Level Performance—Aircraft Needs

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

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

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

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

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

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

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

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

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

~~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.~~ TCAS II systems requirements have been updated to incorporate a hybrid surveillance scheme (combining active TCAS interrogation and passive reception~~ipt~~ of ADS-B broadcast data) to further reduce interference with ground ATS in the Hybrid Surveillance application, DO-300 (Ref TBD). Future e~~E~~nhancements may use ADS-B data in h~~H~~orizontal m~~M~~iss-d~~D~~istance f~~F~~iltering to further reduce the number of unnecessary RAs. Other modifications may include the use of ADS-B information in aircraft trajectory modeling and prediction.

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

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

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

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

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

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

Environment

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

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

Operational Scenario

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

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

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

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

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

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

Environment

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

Operational Scenario

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

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

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

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

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

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

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

Environment

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

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

Operational Scenario

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

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

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

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

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

➔ ACTION DEAN: Need to fix this whole section

[ITP, ICSR, TBD]

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

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

Environment

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

Operational Scenarios

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

2.2.1.1.7 Aircraft Needs While Performing Delegated Separation Simultaneous Approaches

[PCSPA, ICSPA]

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

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

Environment

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

Operational Scenarios

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

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

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

On the airport surface, ADS-B may be used in conjunction with a CDTI to improve safety and efficiency. The pilot could use CDTI and a moving map display for basic surface situational awareness. Advanced surface applications could support traffic alerting, low visibility taxi guidance and surface spacing. ADS-B used in conjunction with a moving map display may be used to show cleared taxi travel paths. Other proximate vehicles within the surface movement area and aircraft may also be identified using ADS-B information. At night, or at times of poor visibility, the airport surface digital map may be used for separation and navigation purposes. To support spacing on the airport surface, the in-trail aircraft needs to monitor the position and speed of the lead aircraft and to detect changes of speed to ensure that safe separation is maintained (see §0).

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

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

Environment

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

Operational Scenarios

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.

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

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

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

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

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

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

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

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

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

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

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

<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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Environment

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

Operational Scenario

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

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

Requirements

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

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

2.2.2 ATS Conformance Monitoring Needs

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

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

2.2.2.1 Operational Scenario (Parallel Runway Monitoring)

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

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

2.2.2.2 Requirements

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