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# Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)

## With Change 1 and Change 2

DO-260C with Change 1 and Change 2
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## FOREWORD

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# 1 PURPOSE AND SCOPE

## 1.1 Introduction

This document contains Minimum Operational Performance Standards (MOPS) for airborne equipment for Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service – Broadcast (TIS-B) utilizing 1090 MHz Mode S Extended Squitter (1090ES). The supporting hardware can be incorporated within other on-board equipment, or alternatively, the ADS-B equipment may be a separate avionics unit.

*Note: Definitions of acronyms (e.g., MOPS, ADS-B, 1090ES) and of many other terms (e.g., "Extended Squitter") can be found in Appendix B of these MOPS.*

Compliance with these standards by manufacturers, installers and users is recommended as one means of assuring that the equipment will satisfactorily perform its intended functions under conditions encountered in routine aeronautical operations. The regulatory application of these standards is the responsibility of appropriate government agencies. For example, in the United States, the Federal Aviation Administration (FAA) publishes and maintains a Technical Standard Order (TSO-C166) for 1090ES ADS-B equipment to reference the requirements and bench test procedures in Section 2 of this document. In the European Union, the European Aviation Safety Agency (EASA) publishes and maintains a European Technical Standard Order (ETSO-C166) for 1090ES ADS-B equipment to the same reference in this document.

Since the equipment implementation includes a computer software package, the most recent version of the *Software Considerations in Airborne Systems and Equipment Certification*, (RTCA DO-178C/EUROCAE ED-12C) is applicable. When determining the level of software requirements, as defined in RTCA DO-178C/EUROCAE ED-12C, or subsequent versions, the equipment manufacturer should consider the criticality level appropriate for the installation certification, equipment failure analysis, and the fault monitoring being accomplished.

In addition, since the measured values of equipment performance characteristics may be a function of the measurement method, standard test conditions and methods of test are recommended in this document.

1090ES is documented and standardized internationally at ICAO. Relevant ICAO documents include Annex 10 Volume IV Standards and Recommended Practices (SARPs) as well as ICAO Document 9871 (Technical Provisions for Mode S Services and Extended Squitter).

Throughout this document, the term CAS is used to mean a generic collision avoidance system, applicable to any of the existing airborne collision avoidance implementations. Rarely, the terms TCAS (RTCA DO-185A/B / EUROCAE ED-143), ACAS Xa (RTCA DO-385 / EUROCAE ED-256), ACAS Xu (RTCA DO-386 / EUROCAE ED-275), or ACAS II (ICAO SARPs) are used when the associated text applies to a specific implementation. The full descriptor ACAS Xa/Xo is shortened to ACAS Xa, and TCAS II is shortened to TCAS. In this document, the term ACAS X is used when text applies equally to ACAS Xa and ACAS Xu. Original RF message names, e.g., TCAS Resolution Message, are retained.

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Section 1 of this document provides information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals and forms the basis for the standards stated in Sections 2 and 3.

Section 2 contains the minimum operational performance standards for the equipment. These standards define required performance under standard operating conditions and stressed physical environmental conditions. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimum requirements.

Section 3 describes the performance required of the installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4 describes the operational characteristics of the installed equipment, self test features, and controls.

Appendices A, E, G, J, N, and S are *normative* (i.e., they include requirements or direct guidance on requirements), whereas all other Appendices are *informative* (i.e., they do not include requirements). The following is a short description of each of the Appendices contained in this document:

- Appendix A defines the formats and coding for 1090 MHz Extended Squitter ADS-B and TIS-B Messages, expanding upon the requirements of Section 2.2.

- Appendix B contains a list of acronyms and definition of terms used in this document.

- Appendix C contains validation test vectors for testing the Broadcast Message Format Algorithm

- Appendix D provides references of specifications for ground architecture that can support surveillance for ATC using Extended Squitter ADS-B reports.

- Appendix E provides guidance for establishing ADS-B Weather (ADS-B Wx) parameter values for ADS-B systems broadcasting Aircraft State, Weather State and Alternate Weather State Messages. Broadcast of these messages along with data contained in the Emergency/Priority Status Message comprises the ADS-B Weather Air Reports (ADS-B Wx AIREPs). ADS-B Wx AIREP parameters include aircraft and meteorological data primarily sourced through interfaces with external onboard systems. Certain ADS-B Wx AIREP parameters are specified for configuration during ADS-B system installation. Others are generally available onboard advanced aircraft from typical systems such as air data and/or flight management systems. A subset of the ADS-B Wx AIREP data must be sourced from dedicated sensing systems or derivation algorithms that are typically installed under supplemental type certificates. ADS-B Wx AIREPs support next generation ADS-B applications such as Flight-deck Interval Management (FIM), wake vortex separation and surfing applications, hazardous weather detection and avoidance, aviation weather forecasting, and air traffic management and control procedures.

- Appendix F contains guidance in determining the ADS-B Position Reference Point, the nominal location of a transmitting ADS-B participant.

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- Appendix G provides a concept of operations (ConOps) and recommendations for reporting meteorological information based on pilot observations via ADS-B. Broadcast of Flight Weather Messages, Temp, Wind & Turbulence Messages, and Hazardous Weather Messages, which comprises ADS-B Weather Pilot Reports (ADS-B Wx PIREPs). Pilot Report messages, when sent, include data sourced from pilots through an appropriate avionics interface device. ADS-B Wx PIREPs support hazardous weather detection and avoidance, aviation weather forecasting, and air traffic management and control procedures.

- Appendix H discusses ADS-B report assembly and provides additional guidance on the subject.

- Appendix I identifies and discusses examples of the enhanced reception techniques for Extended Squitter that have been shown to meet the enhanced reception performance requirements.

- Appendix J discusses determining the Navigation Accuracy Category for Velocity ($NAC_V$) and Geometric Vertical Rate Accuracy and describes the rationale for the values used in Table 2-18, "$NAC_V$ Data."

- Appendix K Commitment to License (CtL) Phase Overlay Technology.

- Appendix L discusses and provides a table showing, by equipage class, the impact of radio frequency interference on Extended Squitter report integrity.

- Appendix M provides a description of techniques for extending the effective air-to-air range of 1090 MHz ADS-B Subsystems, and discusses the transmission power for Class A3 airborne installations.

- Appendix N defines the formats and coding for 1090 MHz Extended Squitter ADS-B Messages that are broadcast by ADS-B Version Zero (0), RTCA DO-260/EUROCAE ED-102 compliant 1090 MHz ADS-B Subsystems, ADS-B Version One (1), RTCA DO-260A compliant 1090 MHz ADS-B Subsystems, and ADS-B Version Two (2), RTCA DO-260B/EUROCAE ED-102A compliant 1090 MHz ADS-B Subsystems, and defines how the ADS-B Report Generation Function of Version Three (3) 1090 MHz ADS-B Receiving Subsystems is to utilize messages received from targets that are broadcasting with Version Zero (0), Version One (1), and Version Two (2) Message formats.

- Appendix O provides a sample algorithm that meets the requirements for position message format determination in §2.2.3.2.2.1.3. This algorithm calculates the *derived format* of the system. The *reported format* is determined as per the requirements in §2.2.3.2.2.1.4.1.

- Appendix P presents the results of modeling and simulations to estimate the air-to-air performance of 1090 MHz Extended Squitter.

- Appendix Q reserved.

- Appendix R provides a calculation of 1090 MHz Extended Squitter broadcast rates for different operational scenarios to show that transmission rates achieved over a 60 second

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period meet the required average rate over 60 seconds, and that there is no need to implement a function to limit the total number of 1090 MHz Extended Squitters transmitted over a certain period of time.

- Appendix S specifies requirements for the Interrogation/Reply Monitor (IRM) application. IRM broadcasts two low-rate squitters. The IRM Interrogation Rate Monitor Message includes data concerning interrogation and suppression rates experienced by the transponder. The IRM Reply Rate Monitor Message includes data concerning current transponder reply rates. IRM is an optional capability and is not expected to be widely implemented.

- Appendix T provides a tutorial and gives explanations and derivations of the Compact Position Reporting (CPR) equations given in Appendix A. CPR encoding and decoding can be implemented without using any of the information in this Appendix but, if a CPR implementation has problems, the information in this Appendix may be helpful in resolving the issue.

- Appendix U provides detailed analysis of total and uncompensated latency in the broadcast horizontal position information. It provides unambiguous context for the timing requirements on the ADS-B Transmitting Subsystem, as well as recommendations for timing at the aircraft level.

## 1.2 System Overview

### 1.2.1 Definitions

ADS-B (Automatic Dependent Surveillance – Broadcast) is a function for airborne or surface aircraft, or surface vehicles operating within the airport surface movement area, that periodically transmits their state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B is *automatic* because no external stimulus is required; it is *dependent* because it relies on on-board position sources and on-board broadcast Transmitting Subsystems to provide *surveillance* information to other users. The aircraft or vehicle *broadcasts* the data which is available to any user capable of receiving its broadcast; any user, either aircraft or ground-based, within range of this broadcast, may choose to receive and process the ADS-B surveillance information. ADS-B supports improved use of airspace, reduced ceiling/visibility restrictions, improved surface surveillance, and enhanced safety.

The ADS-B Rebroadcast Service (ADS-R) provides the Rebroadcast on 1090 MHz of an ADS-B Message from an alternate data link. The ADS-R information is transmitted from ground-based ADS-B Ground Stations. ADS-R information is received by the Ground Station from ADS-B-equipped aircraft/vehicle on a particular ADS-B radio data link and transmitted on an alternate ADS-B data link. ADS-B Same Link Rebroadcast (ADS-SLR) is a variant of ADS-R that rebroadcasts on the same ADS-B data link and is used in areas such as surface coverage on airports where direct ADS-B reception is potentially limited by blockage and multipath conditions.

TIS-B (Traffic Information Service – Broadcast) is a function in which transmitters on the ground provide aircraft with information about nearby aircraft. The TIS-B information is likely to come from ground-based surveillance sensors such as air traffic control radars or multilateration systems. However, TIS-B information broadcast on a particular radio data

link might also be derived from the reception on the ground of ADS-B Messages that were transmitted on a different data link. For example, 1090 MHz TIS-B transmitters might broadcast information about nearby aircraft based on ground reception of ADS-B Messages on other data links.

For the purposes 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.

Figure 1-1 shows the extent of the 1090 MHz ADS-B system and its major components.

As indicated in the figure, the ADS-B system includes the following components: message generation/transmission by the source A/V, propagation medium, and message reception/report assembling by the user. The ADS-B transmit system does *not* include the sources of the data to be sent by the transmitting subsystem on board the transmitting aircraft. Neither does it include the client applications, which use the information received by the ADS-B user subsystem on board the receiving aircraft. 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 to transmit.

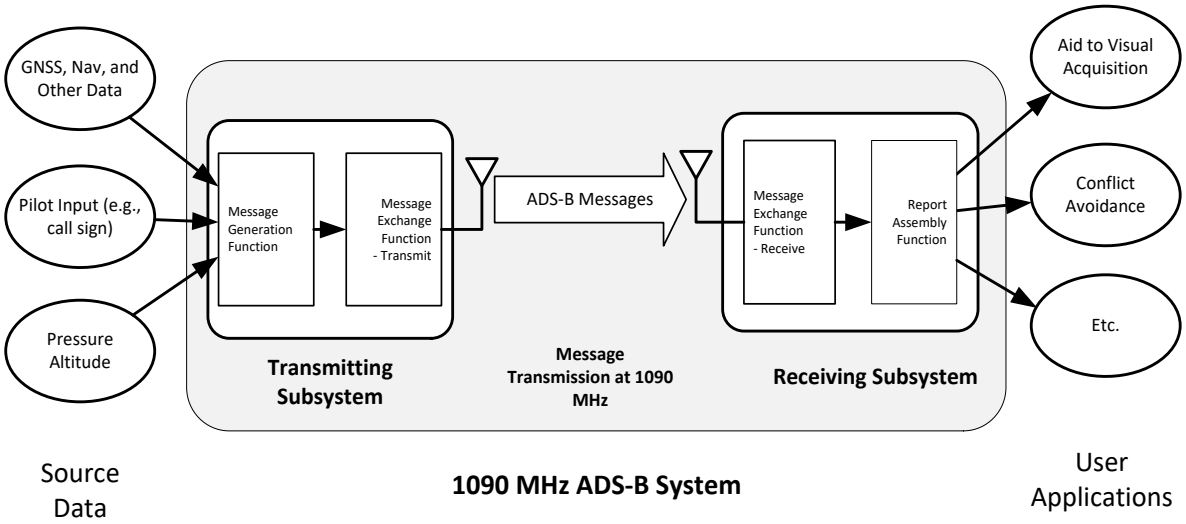



**Figure 1-1: Scope of the 1090 MHz ADS-B System**

Figure 1-2 shows the extent of the 1090 MHz TIS-B system and its major components. As indicated in Figure 1-2, only the 1090 MHz TIS-B Messages and airborne TIS-B Receiving Subsystem are described in these MOPS.

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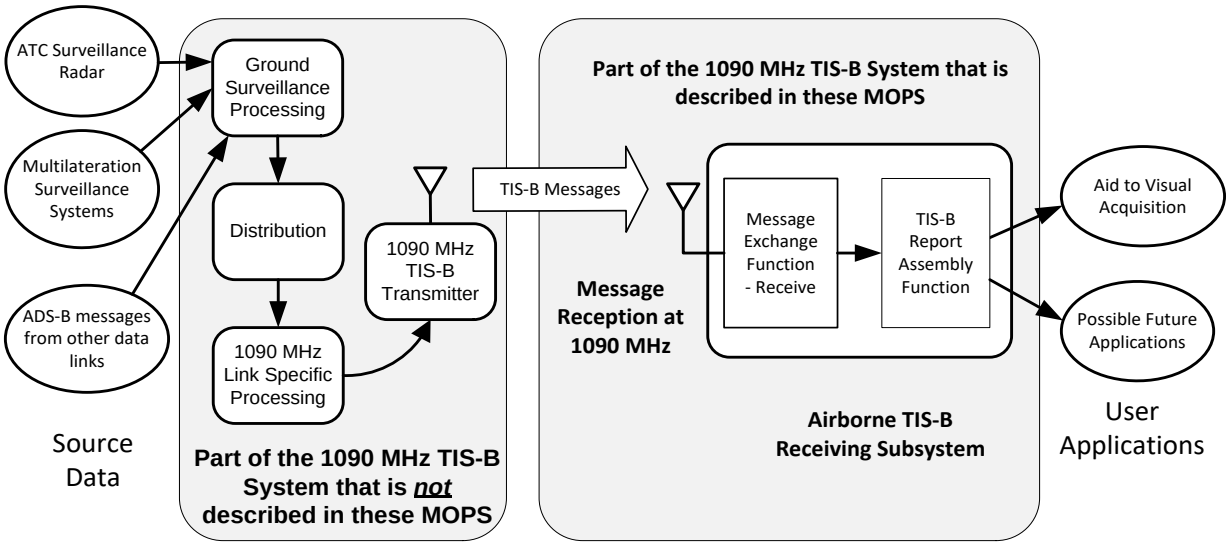



**Figure 1-2: Scope of the 1090 MHz TIS-B System**

### 1.2.2 1090 MHz ADS-B System

The "ADS-B Messages" transmitted on 1090 MHz are the Mode S Extended Squitters (Airborne Position squitter, Airborne Velocity squitter, Surface Position squitter, etc.) described in Appendix A of this document.

The source 1090 MHz Transmitting Subsystem may or may not be implemented in conjunction with a Mode S transponder, although certain equipage classes are required to be based on a Mode S transponder as detailed in §2.1.

The user 1090 MHz Receiving Subsystem may or may not be implemented in conjunction with a CAS (Collision Avoidance System).

### 1.2.3 ADS-B Avionics Integrity

The integrity requirements for the total system to support ADS-B related applications are determined for a particular airborne architecture by conducting a functional hazard assessment and system safety assessment. For each application, the classification (typically expressed in terms of a category such as hazardous, major, minor etc.) of unannunciated and unmitigated failure conditions of ADS-B avionics that cause out-of-tolerance error conditions will be derived from these assessments.

Guidance on the above assessments can be found in:

- SAE ARP4761 – Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment;
- SAE ARP4754A/ED-79A – Guidelines for Development of Civil Aircraft and Systems;
- EASA AMC 25.1309 – System Design and Analysis

- FAA AC 23.1309-1E – System Safety Analysis and Assessment for Part 23 Airplanes;
- FAA AC 25.1309-1A – System Design and Analysis.

Presuming that all 24 parity check bits (§2.2.3.2.1.7) are employed for error detection, the 1090 MHz ADS-B Message formats have been designed to support an undetected error rate of less than 1 undetected error per $10^7$ ADS-B Messages.

### 1.2.4 1090 MHz ADS-B Subsystem Implementations

Figure 1-3 shows the 1090 MHz ADS-B Subsystems in more detail.

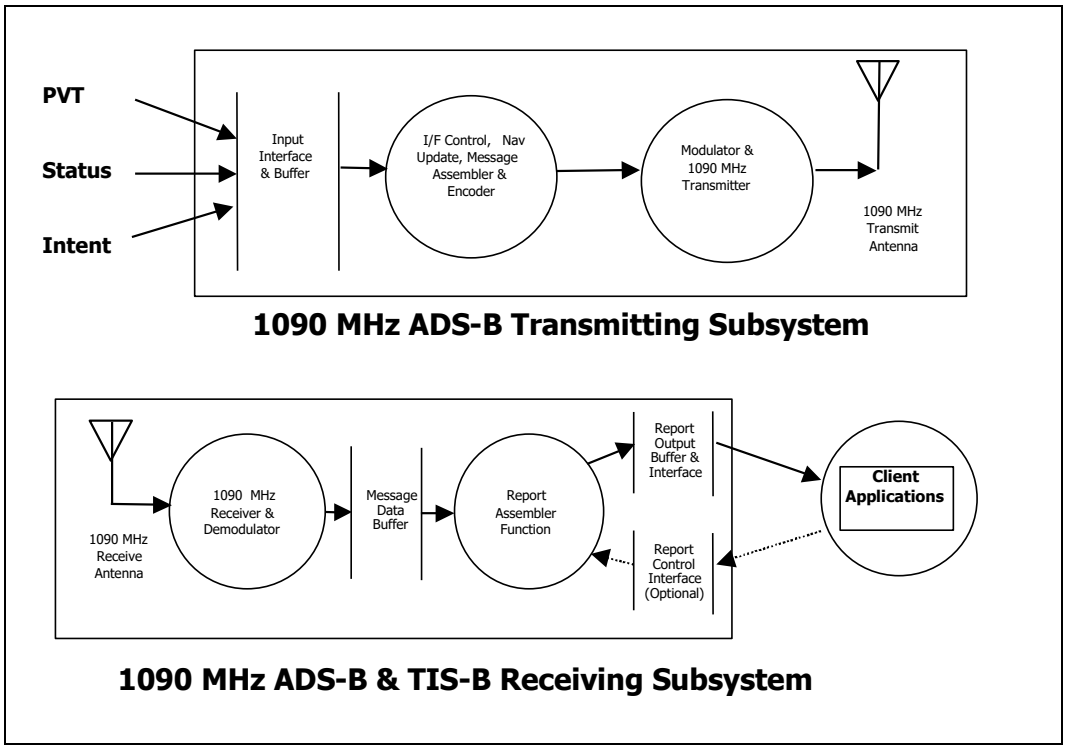



**Figure 1-3: 1090 MHz ADS-B Subsystems**

#### 1.2.4.1 Source 1090 MHz ADS-B Transmitting Subsystem

The transmitting subsystem consists of a message generation function and a transmitting message exchange function. The 1090 MHz ADS-B Transmitting Subsystem takes position, velocity, status, and intent inputs from other systems onboard the aircraft and transmits this information on the 1090 MHz frequency as Mode S Extended Squitter messages. The message generation function includes the input interface, message assembly, and encoding subfunctions. The message exchange function includes the radio equipment (modulator/transmitter) and 1090 MHz transmitting antenna subfunctions.

The ADS-B Transmitting Subsystem may be implemented either: (a) using a Mode S secondary surveillance radar transponder, or (b) using Non-Transponder-Based 1090 MHz transmitting equipment.

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#### 1.2.4.1.1 Transponder-Based Subsystems

In a Mode S Transponder-Based Subsystem, the ADS-B Message generation function and the modulator and 1090 MHz transmitter are present in the Mode S transponder itself. The transmit antenna subfunction consists of the Mode S antenna(s) connected to that transponder.

#### 1.2.4.1.2 Non-Transponder-Based Subsystems

Non-Transponder-Based ADS-B Subsystems might be installed in general aviation aircraft that have Mode A/C ATCRBS transponders rather than Mode S transponders. In such Non-Transponder-Based ADS-B Subsystems, the message generation function and the modulator and 1090 MHz transmitter will be housed together in the transmitting unit. The transmitting antenna subfunction may be separate from the transmitter unit or may also be incorporated in the unit.

*Note:*

1. *The term "Non-Transponder-Based" within the context of these MOPS is not intended to preclude an avionics configuration with a 1090 MHz ADS-B capability integrated with a Mode A/C ATCRBS Transponder.*

2. *Installation of Non-Transponder-Based 1090 MHz ADS-B equipment in airplanes equipped with Mode S transponders is prohibited. The transmission of squitters in addition to CAS interrogation responses contributes unnecessary RF energy to the spectral environment. CAS (in other airplanes) cannot take advantage of hybrid surveillance on the ADS-B data, since the non-transponder-based data cannot be validated by CAS interrogation.*

### 1.2.4.2 1090 MHz ADS-B & TIS-B Receiving Subsystem

The 1090 MHz ADS-B and TIS-B Receiving Subsystem consists of a Receiver and Demodulator function and a Report Assembly function. The 1090 MHz Receiving Subsystem takes ADS-B and TIS-B Mode S Extended Squitter messages and outputs information to other systems onboard the aircraft. The message exchange function includes the 1090 MHz receiving antenna and radio equipment (receiver/demodulator) subfunctions. The Report Assembly function includes the message decoding, report assembly, and output interface subfunctions. Several configurations of ADS-B Receiving Subsystems, which include the reception portion of the ADS-B Message Exchange Function and the ADS-B Report Assembly Function, are defined:

- Type 1 ADS-B and TIS-B Receiving Subsystems receive ADS-B and TIS-B Messages and produce application-specific subsets of ADS-B reports. Type 1 Receiving Subsystems are customized to the particular applications using ADS-B reports. Type 1 ADS-B Receiving Subsystems may additionally be controlled by an external entity to further limit its output to produce installation-defined subsets of the reports that those subsystems are capable of producing.

- Type 2 ADS-B and TIS-B Receiving Subsystems receive ADS-B and TIS-B Messages and must be capable of producing complete ADS-B and TIS-B reports in accordance with the ADS-B equipment class. Type 2 Receiving Subsystems may be controlled by an

external entity to produce installation-defined subsets of the reports that those subsystems are capable of producing.

- The ADS-B/TIS-B Message reception function may be physically partitioned into separate avionics from those that implement the ADS-B/TIS-B report assembly function.

#### 1.2.4.2.1 Type 1 Report Assembly Function

In *Type 1* the Report Assembly Function may be closely coupled to the client application using the information provided by the ADS-B system. In this case, the ADS-B Report Assembly Function might reside together with the associated client application in one piece of equipment.

An advantage of a closely coupled assembler and application is that the Report Assembly function can be customized for the needs of the particular client application with which it is associated. If the client application does not require all of the ADS-B data elements, then its associated Report Assembly function can customize the report by only providing the needed data. Again, if the client application is only concerned with certain targets, then its Report Assembly function can optimize performance by filtering out targets that have no relevance to that application.

In a *Type 1* configuration, any further control of output reports (beyond the customization) would require a control interface by which the client application(s) can specify which and how reports are to be assembled or output.

The *Type 1* configuration has the advantage that it places only minimal processing requirements on the ADS-B Receiving Subsystem.

#### 1.2.4.2.2 Type 2 Report Assembly Function

In *Type 2* the Report Assembly Function is of a general nature and is capable of supporting the needs of a variety of applications.

An advantage of *Type 2* is that it can support the needs of a variety of client applications, as it includes a generalized Report Assembly Function that can output reports that contain *all* the elements of the ADS-B Reports as described in §1.2.7.

In a *Type 2* configuration, any control of output reports would require a control interface by which the client application(s) can specify which and how reports are to be assembled or output.

### 1.2.4.3 Major Operating Characteristics

The 1090 MHz ADS-B/TIS-B System uses the Mode S Extended Squitter defined in RTCA DO-181F / EUROCAE ED-73F, to broadcast the Aircraft/Vehicle position, velocity and other relevant information over the RF medium.

For ADS-B Messages, Appendix A to this document provides the Mode S Transponder Register definitions and specifies the 56-bit data formats required for the ADS-B Messages. The transmission rate for each of the defined broadcast messages is defined in the subparagraphs of §2.2.3.3 and in Appendix A.

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TIS-B Messages are defined in §2.2.17 and §A.2 of this document.

The ADS-B Extended Squitters sent from a Mode S transponder use Downlink Format 17 (DF=17). Each squitter contains 112 bits, of which 56 bits contain the various data items comprising the ADS-B information. The other 56 bits include the 5-bit DF (Downlink Format) field, the 3-bit CA (Capability) field, the 24-bit AA (Announced Address) field, and the 24-bit PI (Parity/Interrogator ID) field.

Non-Transponder-Based ADS-B Transmitting Subsystems and TIS-B Transmitting equipment use DF=18. By using this format instead of DF=17, an ADS-B/TIS-B Receiving Subsystem will know that the message comes from equipment that cannot be interrogated.

The transmitter power is based on the classification of the ADS-B equipment. For example, ADS-B class A0 equipment may transmit at a lower power than class A3 equipment.

The operating range of the 1090 MHz Extended Squitter receiver is tailored to the classification of the equipment as well. Class A0 equipment may have a less sensitive receiver and thus support a comparatively short operating range. Class A3 equipment requires a more sensitive receiver, in order to receive ADS-B Messages from aircraft that are farther away.

The operation of the 1090 MHz ADS-B System must not have an adverse effect on other on-board systems.

### *1.2.5* Typical System Operation

A departing aircraft on the ground begins broadcasting its position, velocity, identification and status data via the 1090 MHz ADS-B System. This broadcast is received by other aircraft and the ground based receivers. The broadcasting aircraft also receives broadcasts from other aircraft. The aircraft processes this information for use by applications that may involve Cockpit Display of Traffic Information (CDTI). As the aircraft taxis to its holding area, it monitors the movement of other aircraft on the surface as well as those in final approach. The aircraft on approach can also monitor the ground traffic and watch for a potential runway incursion and/or a blunder on a parallel approach area.

An airborne aircraft broadcasts its position, velocity, identification, and status data. Additional data may be broadcast based on the equipment class and implemented optional capabilities. The aircraft may perform various applications with the received broadcasts from other aircraft within range.

### 1.2.6 ADS-B Message Content

The ADS-B Message refers to the transfer of data via 1090 MHz. An ADS-B Message is formatted data that conveys information used in the assembly of ADS-B reports. State Vector source data is provided by the platform dynamic navigation systems and sensors.

The information for the State Vector is contained in various registers. When broadcast, the contents of a register are inserted in the 56-bit message field of a 112-bit squitter transmission. The remaining 56 bits contain the aircraft address as well as required forward error correcting

parity information. Appendix A to this document defines the contents of the various transponder registers.

### 1.2.7 ADS-B Report Content

The ADS-B Report refers to the restructuring of ADS-B Message data received from a 1090 MHz broadcast into various reports that can be used directly by other on-board applications. Six report types are defined for ADS-B outputs to applications. These report types are State Vector (SV), Mode Status (MS), Target State (TS), Air Referenced Velocity (ARV), ADS-B Wx Air Report (AIREP), and Aircraft State (AS) Reports.

#### 1.2.7.1 State Vector Report

The State Vector report contains information about an aircraft or vehicle's current kinematic state as well as a measure of the accuracy of the State Vector. Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant. The State Vector data is the most dynamic of the six ADS-B reports; hence, the applications require frequent updates of the State Vector to meet the required accuracy for the operational dynamics of the typical flying aircraft or ground operations of aircraft and surface vehicles.

#### 1.2.7.2 Mode Status Report

The Mode Status report contains current operational information about the transmitting participant. This information may include current call sign, address, and other information that may be needed at a lower update rate than the information in the State Vector.

#### 1.2.7.3 Target State Report

The Target State Report contains information that will be broadcast (in Aircraft Target State and Status Messages, §2.2.3.2.7.1) when current Target State information is available. The Target State Report contains information that is required from only certain classes of ADS-B equipped aircraft. (See §2.2.8.3.1 for the format of the Target State Report.)

#### 1.2.7.4 Air Referenced Velocity Report

The Air Referenced Velocity Report (§2.2.8.3.2) contains velocity information that is broadcast by some ADS-B equipped aircraft. This report is only generated when Air Referenced Velocity information is received from the ADS-B Wx – Subtype=1 Message (§2.2.3.2.7.6.4) or Alternate Weather State information is received from the ADS-B Wx – Subtype=2 Message (§2.2.3.2.7.6.5).

*Note: Air referenced velocity information may be received from airborne aircraft that are also broadcasting messages containing ground referenced velocity information. ADS-B Receiving Subsystems conformant to these MOPS are required to receive and process ground referenced and air referenced velocity from the same aircraft and output the corresponding reports.*

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#### 1.2.7.5 ADS-B Wx Air Report (AIREP)

The ADS-B Weather Air Report (AIREP) (§2.2.8.3.3) contains information about the state of the atmosphere at the aircraft's location. Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant. This report is only generated when Weather State information is received from the ADS-B Wx AIREP – Subtype=1 "Weather State" Message (§2.2.3.2.7.6.4), Alternate Weather State information is received from the ADS-B Wx – Subtype=2 Message (§2.2.3.2.7.6.5), or weather information (EDR or Water Vapor) is received from the Aircraft Status – Subtype= 1 Message (§2.2.3.2.7.8.1).

#### 1.2.7.6 ADS-B Aircraft State Report

The ADS-B Aircraft State Report (§2.2.8.3.4) contains information about the aircraft and its systems. Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant. This report is only generated when Aircraft State information is being broadcast in the ADS-B Wx AIREP – Subtype=0 "Aircraft State" Message (§2.2.3.2.7.6.3).

### 1.3 Operational Applications

The various equipment classes defined within this document are intended to provide a level of capability appropriate to a set of expected operational applications. Operational approval for specific applications should consider the total capability of all associated equipment installed in the aircraft. All airborne equipment will require a source of state vector data, such as a GNSS (GPS) receiver, an inertial/multisensor navigation system, or Flight Management System (FMS). Additional concepts, algorithms, procedures, and standards not defined within this document will also be required. This section describes several examples of applications that make use of ADS-B supplied information.

#### 1.3.1 General Support for Surveillance

ADS-B is a cooperative system. All participating Aircraft and Vehicles (A/V) are required, at a minimum, to broadcast ADS-B Messages as specified in Section 2.2 of this document for each applicable equipment class. The broadcast of these messages provides the basic surveillance data necessary to support all other ADS-B applications.

#### 1.3.2 'ADS-B Out' Applications

The term 'ADS-B Out' is associated with the broadcast of position, velocity, identity, and status data from an aircraft, ground vehicle, or stationary object. 'ADS-B Out' is also associated with the use of ADS-B surveillance data by ground users, in particular by Air Navigation Service Providers (ANSPs). ADS-B is a source of surveillance data used to support services provided by ANSPs. Ground systems with supporting infrastructure receive and disseminate ADS-B data to support such services.

##### 1.3.2.1 ATC Surveillance Service

The ATC surveillance service is that part of air traffic service (ATS) for which the air traffic controller is utilizing surveillance data, in particular for the separation of aircraft in En Route,

terminal maneuvering area (TMA) and final approach airspace. ADS-B surveillance data can be used as another layer of surveillance, or the sole means of cooperative surveillance, in low, medium, and high-density airspace.

ADS-B may also 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. 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 unauthorized aircraft does not enter or leave a specific airspace.

Conformance monitoring of airborne traffic includes monitoring of simultaneous approaches to multiple runways. Here, ADS-B may offer a viable alternative to expensive Precision Runway Monitoring (PRM) systems 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.

#### 1.3.2.2 Airport Surface Surveillance

ADS-B surveillance information also supports the provision of airport traffic situational awareness through the identification, position, and tracking of aircraft and vehicles within a predefined coverage volume. The surveillance data will support the controller in performing the aerodrome control service tasks, including in the detection of runway incursions. This is expected to bring substantial benefits in poor visibility conditions, when visual observation may become difficult and the air traffic controller becomes more reliant on voice and other aids. As for the ATC surveillance service, ADS-B may form one of other cooperative surveillance layers on airports or may establish a sole cooperative surveillance source, possibly supported by a primary surface movement radar (SMR).

### 1.3.3 'ADS-B In' Applications

The term 'ADS-B In' is associated with the use of ADS-B surveillance data by other aircraft and ground vehicles. 'ADS-B In' applications are contained in the latest revisions of the MOPS for the Aircraft Surveillance Applications (ASA) System, RTCA DO-317/ EUROCAE ED-194.

#### 1.3.3.1 Situational Awareness

The list of situational awareness applications that have already been standardized, comprise a number of environments (continental airborne, airport surface and oceanic) and user categories (air transport and general aviation). The pertinent operational requirements can be found in safety and performance requirements standards (SPR) and system requirements in minimum operational performance standards (MOPS). These applications are summarized as follows, mostly relying on the Cockpit Display of Traffic Information (CDTI) function that provides the pilot with awareness of proximate traffic.

Enhanced Visual Acquisition (EVAcq): The CDTI provides traffic information to assist the flight crew in visually acquiring traffic as part of the normal see-and-avoid operations. This application is expected to improve both safety and efficiency. Visual acquisition is applicable under visual meteorological conditions (VMC) regardless of whether the operations are being

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conducted under IFR or VFR. ADS-B Version 3 enhances earlier versions' aid to visual acquisition by including aircraft type information in the Aircraft State Message.

Basic Airborne Situation Awareness (AIRB): The CDTI provides traffic information to assist the flight crew in visually acquiring traffic out the window and provide traffic situational awareness beyond visual range. In addition to EVAcq, this application also provides the flight identification and ground speed of selected traffic. In addition, this application allows for the display of ground traffic including ownship.

Traffic Situation Awareness with Alerts (TSAA): This application is intended to reduce the number of mid-air collisions and near mid-air collisions involving general aviation aircraft. In support of their see-and-avoid responsibility, TSAA provides synthetic voice annunciations to flight crews to draw attention to target aircraft and also adds visual cues to the underlying AIRB information. The TSAA application may also be implemented without a CDTI.

Basic Surface Situation Awareness (SURF): In this application, the CDTI includes an airport surface map underlay, and is used to support the flight crew in making decisions about taxiing, takeoff and landing. The underlaying map may depict runways only, or runways, taxiways, and other movement areas. This application is expected to increase efficiency of operations on the airport surface and reduce the possibility of runway incursions and collisions.

Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts (SURF IA): The SURF IA application aims at decreasing the likelihood and severity of runway incursions and collisions on or near the airport surface. To this goal, the SURF IA application adds two distinct components to the SURF application. These are 'indications', which are provided for nominal operational situations where potential collision hazard exists, and 'alerts', which are provided for non-nominal operational situations where a collision hazard exists or a collision appears imminent.

Visual Separation on Approach (VSA): The CDTI is used to assist the flight crew in acquiring and maintaining visual contact during visual separation on approach. The CDTI is also used in conjunction with visual, out-the-window contact to follow the preceding aircraft during the approach. The application is expected to improve both the safety and the performance of visual separation on approach. It may allow for the continuation of visual separation on approach when they otherwise would have to be suspended due to the difficulty of visually acquiring and tracking the other preceding aircraft.

CDTI Assisted Visual Separation (CAVS): Similar to VSA, the CDTI is used to assist the flight crew in acquiring and maintaining visual contact with a preceding aircraft (designated traffic) while performing a visual separation on approach procedure in visual meteorological conditions (VMC). The fundamental difference between VSA and CAVS is that the flight crew is authorized to use the information provided by the CDTI for the preceding aircraft, after visual acquisition and cross correlation on the CDTI, as a substitute for out the window information while performing the CAVS procedure. Therefore, once the preceding aircraft has been acquired by correlating the traffic on the CDTI with a visual acquisition of the traffic out-the-window, the CAVS procedure can continue through the use of the CDTI when the traffic information out-the-window is no longer available (for example, lost in lights during approach at night).

In-Trail Procedure (ITP): The objective of the In-Trail Procedure (ITP) is to enable aircraft that desire flight level changes in procedural, typically oceanic airspace to achieve these

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changes on a more frequent basis, thus improving flight efficiency and safety. The ITP application achieves this objective by permitting a climb-through or descend-through maneuver between properly equipped aircraft, using a new distance-based longitudinal separation minimum during the maneuver. The ITP requires the flight crew to use information derived on the aircraft to determine if the initiation criteria required for an ITP are met. The initiation criteria are designed such that the spacing between the estimated positions of ownship and surrounding aircraft is no closer than an approved distance throughout the maneuver. ITP requires specific application-unique processing and display parameters.

#### 1.3.3.2 Spacing / Interval Management

The Interval Management (IM) application improves the precision and consistency of inter-aircraft spacing and decreases controller workload by allowing flight crews to achieve, capture, and/or maintain a given spacing from designated traffic through the use of the on-board IM equipment. The IM application is to be implemented together with the AIRB application.

An air traffic controller may use IM Operations to manage the spacing between aircraft when the aircraft need to be spaced closely together in an orderly manner. This is accomplished by the assignment of an assigned spacing goal to the IM aircraft and the location of an achieve-by point (as appropriate). The controller may also include a planned termination point at which the IM Operation is terminated, or an intercept point toward which the aircraft turns in case of an IM Turn procedure.

The controller instructs the IM Aircraft to manage their spacing relative to the designated traffic using either speed alone, or a single turn combined with speed adjustments. The IM equipment enables these objectives by providing flight crews with IM speeds and IM turn point information, both during an achieve stage and a maintain stage. In addition to the clearance type and any special points, route information for the designated traffic is communicated by the controller to the IM Aircraft in the form of intended flight path information (IFPI). Wind and temperature information greatly improve the application's performance by improving the quality of the predicted trajectories of ownship and the designated traffic.

#### 1.3.3.3 Separation

In the future, 'ADS-B In' may also support air-to-air conflict management and airspace de-confliction functions. Aircraft conflict management functions would be used to support cooperative separation during the periods that separation responsibility has been delegated to the aircraft. Ground conflict management functions may also be in place, both as a backup and as the primary tool to monitor aircraft for conflict detection. In addition, airspace de-confliction based on the exchange of intent information may be used for strategic separation. Currently, no 'ADS-B In' application and system standards are available to support such 'free flight' concepts.

### 1.3.4 Collision Avoidance Systems

ADS-B data can be used by a Collision Avoidance System (CAS) to improve surveillance performance as well as reduce spectrum usage. ADS-B Version 3 includes support that

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enhances operation of CAS. ADS-B information in support of CAS includes identifying different coordination capabilities that enables interoperability between diverse CAS.

### 1.3.5 ADS-B Weather Applications

ADS-B Version 3 includes ADS-B Weather (ADS-B Wx) providing support for flight-deck based applications including interval management, hazardous weather avoidance, hazardous wake avoidance and wake surfing. Ground reception of ADS-B Wx parameters is not specified in these MOPS, but is anticipated to support applications for aviation weather forecasting, air traffic control and management, and wake turbulence separation.

#### 1.3.5.1 Aviation Weather Forecasting

ADS-B Wx supports a range of aviation weather forecasting applications. Automatic sensing and frequent broadcasting of ownship meteorological information such as in-situ temperature, pressure, winds, water vapor, and turbulence is implemented using the ADS-B Wx AIREP messages. Manual entry and sending of similar data is implemented through the on-condition ADS-B Wx PIREP messages. ADS-B Wx AIREP message information improves aviation weather numerical prediction model performance for nowcasts (0-6 hours look ahead) through medium-range forecasts (2-7 days look ahead). ADS-B Wx AIREP and ADS-B Wx PIREP messages can support validation of aviation weather forecasts and models, increasing the accuracy of numerical weather forecasts. ADS-B Wx AIREP messages provide additional observation data for numerical weather prediction models, which may allow them to be updated more frequently.

#### 1.3.5.2 Weather Awareness and Avoidance

ADS-B Wx AIREP and PIREP information supports applications for weather awareness and avoidance by broadcasting automatically sensed and/or manually entered ownship meteorological information. Such information can be used in real time to identify and avoid areas of hazardous weather such as turbulence and icing. Aircraft-based observations provide measurable benefits to aviation weather forecast performance from nowcasts (0-6 hours) through medium-range forecasts (2-7 days).

##### 1.3.5.2.1 Turbulence Awareness and Avoidance

ADS-B Wx AIREP and PIREP information supports applications for turbulence awareness and avoidance by broadcasting automatically sensed and/or manually entered ownship meteorological information. The receipt of Eddy Dissipation Rate (EDR) information, derived and broadcast by proximate aircraft, will allow aircraft intending to proceed into the same area to make real time decisions about their potential to encounter hazardous turbulence and take appropriate actions, if necessary, to avoid such encounters. EDR information, received and processed on the ground, will provide forecast validation and improve future turbulence forecasts. ADS-B Wx PIREP messages with turbulence information, received and processed on the ground, will make turbulence information available to air traffic controllers, Flight Service Station specialists, dispatchers, and pilots in near real time. This information may then be used for preflight planning and in-flight awareness through distribution by air traffic controllers, Flight Service Station specialists, and reception of coded PIREPs via Flight Information Services- Broadcast (FIS-B) by appropriately equipped aircraft.

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#### 1.3.5.2.2 Icing Awareness and Avoidance

ADS-B Wx supports applications for icing awareness and avoidance by broadcasting automatically sensed and/or manually entered ownship meteorological information. The receipt of icing status information, derived and broadcast by proximate aircraft, will allow aircraft intending to proceed into the same area to make real time decisions about their potential to encounter hazardous icing and take appropriate actions, if necessary, to avoid such encounters. Icing status information, received and processed on the ground, will provide forecast validation and improve future icing forecasts. ADS-B Wx PIREP messages with icing information, received and processed on the ground, will make icing information available to air traffic controllers, Flight Service Station specialists, dispatchers, and pilots in near real time. This information may then be used for preflight planning and in-flight awareness through distribution by air traffic controllers, Flight Service Station specialists, and reception of coded PIREPs via Flight Information Services- Broadcast (FIS-B) by appropriately equipped aircraft.

### 1.3.5.3 Air Traffic Management and Control

ADS-B Wx supports applications for air traffic management and control. The receipt of ADS-B Wx parameters will increase air traffic controllers' situational awareness of both weather and aircraft performance through delivery of meteorological information such as turbulence and icing, and aircraft state information, such as gross weight, wingspan, and configuration. ADS-B Wx supports delivery of Enhanced Surveillance (EHS) parameters over Extended Squitter, including airspeed, heading, and roll angle data. ADS-B Wx supports interval management applications involving cooperative decision making and delegation of spacing authority to the flight deck.

### 1.3.5.4 Wake Turbulence Applications

ADS-B Wx supports applications that predict the strength and position of wake turbulence created by aircraft. Advances in the understanding of the evolution of wake turbulence in the near- and far-stream following aircraft has allowed the development of applications that both seek and avoid wake turbulence for operational efficiency and safety reasons. Wake turbulence applications depend on both the position surveillance and weather surveillance aspects of ADS-B Version 3.

#### 1.3.5.4.1 Wake Turbulence Avoidance

ADS-B Wx supports applications for wake turbulence avoidance. Wake turbulence encounters have the potential to cause injury to aircraft occupants, damage to aircraft, and loss of aircraft control. Flight-deck and ground-based applications have been developed that estimate the strength and position of wake turbulence generated by aircraft and provide information to pilots and controllers to allow them to enhance safety by avoiding areas of hazardous wake turbulence while maximizing efficiency by reducing operational separation.

#### 1.3.5.4.2 Wake Surfing

ADS-B Wx supports applications for wake surfing. Wake surfing takes advantage of the updraft portion of wake turbulence in the formation of wake vortices to improve the operational efficiency of aircraft closely following preceding aircraft. Wake surfing

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applications estimate the track of wake turbulence from preceding aircraft and provide guidance that allows ownship to fly in the updraft portion of the wake turbulence, reducing ownship power requirements by 5-15%.

#### 1.3.5.4.3 Wake Encounter Reporting

ADS-B Wx supports the collection of wake encounter reports via ADS-B Wx PIREP messages. Wake encounter reporting will assist air traffic managers in understanding the dynamics associated with ATM modernization programs, such as SESAR and NextGen, intended to increase the efficiency of air traffic by reducing separation while maintaining safety, including through the introduction of reduced static and dynamic wake separation criteria.

### 1.3.6 Optional Additional Features

Some ADS-B systems may support additional features:

- **Interrogation/Reply Monitor (IRM) Capability** – ADS-B equipment implementing IRM adhere to the requirements contained in §2.2.3.2.7.4.4 and §2.2.3.2.7.4.5.
- **Phase Overlay** – ADS-B equipment implementing phase modulation adhere to the requirements in §2.2.3.5 and §2.2.4.3.4.8 for Class A equipment.
- **Advanced Range Class A3 Receiver** – ADS-B receivers implementing advanced reception range adhere to the requirements provided in §2.2.4.4.4.
- **High Velocity and/or Altitude Operation** – ADS-B equipment implementing support for high velocity and/or high altitude operations adhere to the requirements in §2.2.3.2.7.5.
- **Unmanned/Remotely-Piloted Aircraft Systems (UAS/RPAS)** – ADS-B equipment implementing support for unmanned or remotely piloted aircraft operations will adhere to the requirements in §2.2.3.2.8.1.3.
- **ADS-B Wx AIREP Support** – ADS-B equipment implementing support for broadcast of ADS-B Wx AIREP data adhere to the requirements in §2.2.3.2.7.6 and §2.2.3.2.7.8.1.4 – §2.2.3.2.7.8.1.7.
- **ADS-B Wx PIREP Support** – ADS-B equipment implementing support for broadcast of ADS-B Wx PIREP data adhere to the requirements in §2.2.3.2.8.2.

These additional features and corresponding identification codes (may be used by certification authorities for equipment marking purposes) are summarized in Table 1-1.

**Table 1-1: ADS-B Optional Additional Features**

| Additional Features | ID Code |
|---|---|
| Interrogation/Reply Monitor | m |
| Phase Overlay | o |
| Advanced Reception Range | r |
| High Velocity and/or Altitude Operation | v |
| Unmanned/Remotely-Piloted Aircraft Systems | u |
| ADS-B Wx AIREPs | w |
| ADS-B Wx PIREPs | p |

### 1.3.7 ADS-B Configuration Identification

Each ADS-B system configuration is described by its equipage class and its optional features. The equipage classes are defined in Table 2-1. The optional additional features are defined in §1.3.6, with the corresponding ID Codes shown in Table 1-1. The current ADS-B system configuration is identified by the equipage class followed by the ID codes for the optional features.

*Example 1 – For a Class A3 ADS-B transmitter/receiver that incorporates Phase Overlay and Advanced Reception Range: the ADS-B system configuration would be identified as "Class A3,or."*

*Note: For ADS-B systems where "Class" or "additional features" might be changed through an approved software update, a means to display the ADS-B system equipage identification electronically may be necessary.*

## 1.4 ADS-B Functions

The 1090 MHz ADS-B System can be viewed as being comprised of three major functions. These functions are the ADS-B Message Generation Function, the ADS-B Message Exchange Function, and the ADS-B Report Assembly Function.

The ADS-B Message Generation Function is responsible for assembling the data to be delivered via the 1090 MHz Extended Squitter. The ADS-B Message Exchange Function is then responsible for transferring this data at the required rate across the 1090 MHz frequency link. This function encompasses both the transmission and reception of the data. The ADS-B Report Assembly Function is responsible for structuring the received data into the appropriate ADS-B Reports for use by onboard applications.

### 1.4.1 ADS-B Message Generation Function

#### 1.4.1.1 Avionics Input Bus

The information required for the various ADS-B reports are provided to the message generation function via avionics digital communication buses or a General Aviation interface. The majority of the information for air carrier installations may be obtained from avionics buses that contain ARINC 429 data labels for the required information.

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#### 1.4.1.2 Input Interface

For the transponder case, the Mode S transponder will provide the input interface for the required ADS-B Message data. This input should come directly from the source that supplies the data to reduce latency.

#### 1.4.1.3 Message Assembly/Encoder

These subfunctions accept input data from the input interface and process this data into the appropriate format. For a Mode S Transponder-Based ADS-B system, this formatted data will then be inserted into DF=17 for transmission over the 1090 MHz frequency link. For a Non-Transponder-Based ADS-B system, the formatted data will be inserted into DF=18 for transmission.

### 1.4.2 ADS-B Message Exchange Function

The ADS-B Message Exchange Function provides for transmission and reception of the ADS-B Message over the 1090 MHz medium. The message exchange function also provides suitable integrity for ADS-B Messages.

#### 1.4.2.1 Modulation/Transmission Subfunction

The modulation of the ADS-B Message transmission is Pulse Position Modulation (PPM) as specified in RTCA DO-181F (EUROCAE ED-73F). This modulation scheme is inherently resistant to ATCRBS interference. The information content of the transmission is further protected by parity check bits generated by a cyclic coding algorithm.

The transmitter subfunction generates the 1090 MHz carrier frequency and impresses the ADS-B information onto the carrier frequency. For Mode S Transponder-Based implementations, the transmitter requirements for transmission of the ADS-B data are defined in RTCA DO-181F (EUROCAE ED-73F). For Non-Transponder-Based implementations, transmitter requirements are contained in this document.

An optional Phase Overlay capability utilizing phase modulation was introduced in Version 3 1090 MHz Extended Squitter. This modulation is overlaid onto the standard PPM signal to provide additional data capacity. For these MOPS, some initial message formats have been defined to support early adoption. This capability may be required in future MOPS versions in order to accommodate future additional data elements that would otherwise require broadcast of additional PPM messages.

#### 1.4.2.2 Transmit/Receive/Antenna Subfunction

The ADS-B transmit and receive subfunctions are supported by one or two antennas depending upon aircraft installation for the operational unit. Two antennas are required if the transponder is coupled with an on-board TCAS/ACAS X/ACAS II, or if the aircraft's weight or maximum airspeed is such that diversity is required. Details on antenna requirements including installation guidance are given in Sections 2.2 and 3.

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#### 1.4.2.3 Receiver/Demodulator Subfunction

The ADS-B Message is received over the 1090 MHz frequency link, demodulated, and output to the Report Assembly function. The minimum trigger level (MTL) defines the minimum input power that results in reliable reception and is suitable for receiving the information necessary for an ADS-B report. The MTL may vary to effectively increase or reduce the range depending on the phase of flight. Dynamic MTL may be used to reject low level multipath and interference.

### 1.4.3 ADS-B Report Assembly Function

#### 1.4.3.1 Decoder/Report Assembly

Once the ADS-B Message is received, the decoder and message assembly subfunctions provide all control, decoding, and formatting functions needed to convert the received messages into the appropriate formatted reports for use by client applications. These subfunctions may be performed in the 1090 MHz receiver unit itself or an external processing unit that interfaces to the receiver.

Since the ADS-B information will be transmitted in multiple messages, the message assembler may require the use of a tracker. The message assembly and tracking processor will structure the received messages into the appropriate output data reports. It may also verify that the output data reports are valid prior to delivery to the Output Interface subfunction.

#### 1.4.3.2 Output Interface

The Report Assembly function will output information through the interface for use by client applications. The Report Assembly/output processor serves as the output control for ADS-B Message data and transfers this data to client applications.

#### 1.4.3.3 Avionics Output Bus

The information required for the various client applications is provided by the Report Assembly function, via avionics digital communication buses or a General Aviation interface. The majority of the information for air carrier installations may be delivered with avionics buses that contain ARINC 429 data labels for the required information.

## 1.5 Operational Goals

ADS-B supports many airborne and surface applications to enhance safety and improve the efficiency and capacity of the air traffic system. This version of these MOPS supports additional capabilities over previous versions including support of enhanced ADS-B In applications, UAS/RPAS operations, weather applications, additional collision avoidance system interoperability, and high velocity and altitude vehicle surveillance. ADS-B will continue to be an enabler for future surveillance airborne and ground system development and interoperability.

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## 1.6 Assumptions and Rationale

This document assumes that the aircraft/vehicle in which the equipment will operate are equipped with the proper data sources to support the intended operations. This document assumes that the only position sources that provide the necessary integrity and accuracy are GNSS and GNSS based navigation solutions (e.g., Hybrid GNSS/Inertial Systems); however, other solutions that provide the necessary integrity and accuracy of the information are also acceptable. 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 through ICAO standardization. Since 1090 MHz is a shared frequency with multiple systems operating on the frequency, assumptions regarding levels of signals from other systems have been made in this document to achieve expected performance.

## 1.7 Test Procedures

The test procedures specified in Sections 2.4 and 3 are intended to be used as recommended means of demonstrating compliance with the minimum acceptable performance requirements specified herein. Although specific test procedures are cited, it is recognized that other methods may be suitable. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

### 1.7.1 Environmental Tests

Environmental tests are specified in Section 2.3. These tests, like bench tests, are performed at the equipment level. The procedures and their associated requirements provide a laboratory means of determining the electrical and mechanical performance of the equipment under conditions expected to be encountered in actual aeronautical operations. Test results may be used by equipment manufacturers as design guidance, in preparation of installation instructions and, in certain cases, for obtaining formal approval of equipment design and manufacture.

### 1.7.2 Qualification Tests

The test procedures specified in Section 2.4 provide a means to demonstrate equipment performance in a simulated environment. Test results may be used as design guidance for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design and manufacture.

Test procedures contained in Section 2.4 apply to the minimum system requirements in accordance with the minimum performance parameters specified in these MOPS.

### 1.7.3 Installed Tests

The installed test procedures and their associated limit requirements are in Section 3. Although bench and environmental test procedures are not a part of installed tests, their successful completion is normally a precondition to the completion of the installed tests. Installed tests are normally performed on the ground and in flight.

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The test results may be used to demonstrate equipment functional performance in the environment in which it is intended to operate and with the minimum service to be provided.

## 1.8 ADS-B MOPS Version 3 Overview

The data provided by ADS-B transmitting systems includes the ADS-B MOPS version number which allows ADS-B receiving systems to correctly interpret the data content of the messages over the data link. With the MOPS version information, receivers of earlier MOPS versions can correctly decode later versions as long as later versions do not redefine existing message parameters. Additional data parameters placed in newly defined messages or in previously unused or reserved fields of messages are not processed by earlier link versions so do not disrupt decoding of ADS-B data.

This MOPS contains requirements for ADS-B MOPS Version 3. Previous versions of these MOPS were based on Minimum Aviation System Performance Standards (MASPS) for Automatic Dependent Surveillance-Broadcast (ADS-B). The initial ADS-B MASPS was published as RTCA DO-242 and is aligned with ADS-B MOPS Version 0. It was updated to RTCA DO-242A to align with ADS-B MOPS Version 1. The MASPS for ADS-B Traffic Surveillance Systems and Applications (ATSSA) was published as RTCA DO-338 and is aligned with ADS-B MOPS Version 2. RTCA DO-338 also contains information previously provided in the MASPS for Aircraft Surveillance Applications (ASA) (RTCA DO-289) and the MASPS for Traffic Information Service – Broadcast (TIS-B) (RTCA DO-286B).

ADS-B MOPS Version 3 introduces new capabilities not supported by previous versions. At the time of publication of these MOPS, it did not have a corresponding MASPS defining system level requirements for these additional capabilities. However, various safety and performance requirement (SPR) standard material is available as referenced in the ASA MOPS (RTCA DO-317()/ EUROCAE ED-194()) and FIM MOPS (RTCA DO-361()/ EUROCAE ED-236()).

ADS-B MOPS Version 3 supports additional capabilities over previous versions along with improvements in existing capabilities. Version 3 provides support for the Flight-deck Interval Management (FIM) ADS-B application. A higher performing receiver more capable than the previous Class A3 receiver is defined to support applications requiring longer range operational performance. Enhancements to receiver CPR decoding to improve track acquisition have been included.

Due to observed shortcomings in altitude reporting in version 2 and earlier MOPS, improvements have been incorporated in Version 3.

When broadcasting Airborne Position Type Codes 20-22 that report geometric altitude, the associated high NIC values for Type Codes 20 and 21 resulted in mostly reporting Type Code 22. Any application requiring NIC are unable to utilize Type Code 22 position data. Based on existing applications minimum NIC criteria, Type Codes 20-22 NIC assignments for Version 3 have been changed so that Type Code 21 is assigned the highest known NIC requirement. Additional NICs for Type Codes 20-22 are provided in version 3 by using previously reserved bits in the Airborne Velocity Message to expand NIC reporting.

Also, the Version 2 limit of 3125 feet difference between barometric and geometric altitude reporting is increased to 4350 feet. The resolution of this altitude difference is also improved to 12.5 feet from 25 feet. Also in Version 3, altitude reporting above 70,000 feet altitude

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requires broadcast of Position Messages (Type Codes 20-22). This provides geometric altitude reporting for these altitudes where barometric altitude utility is typically questionable. Version 3 provides the ability to report altitude above the Version 2 limit of 129,725 feet to 1,051,000 feet to support commercial space requirements using the High Velocity and/or Altitude (HVA) Messages described below.

Version 3 supports the broadcast of weather and aircraft parameters in support of air-to-air and air-to-ground weather applications including wake turbulence, air traffic management, and weather forecasting applications. RTCA DO-364 provides MASPS for Weather Surveillance.

Among the other capabilities provided in Version 3 are support for Unmanned Aircraft Systems/Remotely-Piloted Aircraft Systems (UAS/RPAS) operations including Detect and Avoid (DAA). Additional support for new and future collision avoidance systems is provided. High velocity and high altitude vehicles including commercial space / supersonic vehicles are supported with the addition of newly defined High Velocity and/or Altitude (HVA) Position and Velocity Messages. Standard position reporting using CPR is limited by decoding constraints of high velocity participants so direct position reporting has been provided to overcome this limitation. For Version 3, no provisions have been included for receiving HVA Messages.

Version 3 enhances requirements for selection of airborne or surface message formats to transmit. Emitter category classifications and descriptions have been improved as well as an indication as to whether the aircraft is conducting manned or unmanned operations.

In conjunction with a Mode S Transponder providing interrogation and reply statistics (see Appendix F of RTCA DO-181F/EUROCAE ED-73F), Version 3 supports the broadcast of such transponder 1030 MHz and 1090 MHz monitoring data. An indication of Mode S reply rate limiting status is also supported.

Version 3 introduces Phase Overlay which modulates the phase of the 1090ES PPM pulses to convey additional data. Due to the high utilization of 1090 MHz frequency, the ability to increase the 1090ES message rate is limited. Phase Overlay technique provides additional data capacity on existing transmitted messages so will not require additional activity on the frequency. Future need for any significant additional ADS-B data should be met by the use of the Phase Overlay technique. For Version 3, implementation of Phase Overlay is optional but may be required in future versions of this MOPS if additional data elements are required that could not otherwise be provided without defining new message(s) that would exceed the maximum squitter rate permitted by ICAO standards.

To assure interoperability when introducing a new MOPS version, changes that would disrupt backward compatibility have been avoided. In Version 3, this is adhered to with minor exception. Certain data elements that were never operationally utilized have been eliminated. The Intent Change Flag has been eliminated in Version 3 and this bit in the Airborne Velocity Message is utilized in conjunction with other message bits to extend the difference from barometric altitude limit provided by Version 2 and earlier. Also, the Trajectory Change Report Capability, the Target State Report Capability and the Air Referenced Velocity Report Capability bits in the Operational Status Message have been eliminated as these report capability indications are not used or required by existing or envisioned ADS-B applications. These bits have been repurposed in Version 3 to report newly defined subfields. An additional bit, Receiving ATC Services had been previously reserved in the Operational Status Message

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for future use but it is no longer necessary to reserve for future use so it has been redefined in Version 3 to report Mode S Reply Rate Limiting Status.

## 1.9 Definition of Key Terms

Appendix B provides a glossary of the terms used in this document. This section expands upon the definitions of key terms in order to increase document clarity and establish a common foundation of terminology.

ADS-B Broadcast and Receive Equipment - Equipment that can transmit and receive ADS-B Messages. Defined as Class A equipment.

ADS-B Broadcast Only Equipment - Equipment that can transmit but not receive ADS-B Messages. Defined as Class B equipment. Although Transponder-Based equipment receives 1030 MHz SSR interrogations, for purposes of ADS-B classification, it is considered Class B equipment if the equipment does not receive ADS-B Messages.

ADS-B Message - A modulated packet of formatted data that conveys information used in the assembly of ADS-B reports.

ADS-B Receiver or 1090 MHz Receiver - An ADS-B Receiving Subsystem that is not part of a CAS 1090 MHz receiver.

ADS-B Report - Specific Information provided by the ADS-B user participant 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.

Non-Transponder-Based Implementation - An ADS-B Transmitting Subsystem that is not part of a Mode S transponder.

Transponder-Based Implementation - An ADS-B Transmitting Subsystem implemented as part of, or added capability to, a Mode S transponder.

## 1.10 Aircraft Equipment Information Vulnerabilities

Aircraft equipment information vulnerabilities (such as cybersecurity risks) have been present for digital systems since the development of the personal computer (PC) in the late 70's and even longer for RF systems, and the advent of internet connectivity has substantially increased those risks. Internet and Wi-Fi connectivity have become popular as a means for aircraft or equipment manufacturers to update installed avionics software, to update databases, or provide an alternate means of communicating with the flight crew or cabin (e.g., in-flight entertainment, weather, etc.).

In most countries, the State provides oversight of safety-of-flight systems (sometimes referred to as "authorized services") which provide information to aircraft, such as ILS, VOR, GNSS, and DME, to name a few. However, the State typically does not provide oversight on "non-

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trusted"[1] connectivity such as the internet, Wi-Fi, or equipment manufacturer-supplied equipment interfaces which permit input of externally-supplied data into aircraft systems. An equipment manufacturer may expose aircraft information vulnerability through equipment design, or become vulnerable as a result of being connected to a common interface. Therefore, it is important that equipment manufacturers consider aircraft information security risk mitigation strategies in their equipment design, particularly when the equipment is responsible for an interface between the aircraft and aircraft-external systems.

Apart from any specific aircraft-information-security-related performance requirements that are contained in these MOPS, it is recommended that equipment manufacturers look at a layered approach to aircraft information security risk mitigation that includes both technical (e.g., software, signal filtering) and physical strategies. From a technical perspective, for example, this could include signal spoofing detection capabilities or more stringent, multi-factored authentication techniques such as passwords, PINs, and digital certificates. From a physical perspective, for example, such as in an in-flight entertainment system in the cabin, an equipment manufacturer could consider connectors that require special tools to remove to prevent passenger tampering. And finally, but just as important, equipment manufacturers should consider supply chain risk management; for example, if an equipment manufacturer is outsourcing software code development, is the contractor and its staff properly vetted?

Civil Aviation Authorities (CAAs) have a regulatory interest when an applicant's design makes use of a non-trusted connectivity where the installation can potentially introduce aircraft information security vulnerability. This requires the applicant to address not only the information security vulnerabilities and mitigation techniques for the new installation, but to also consider how vulnerability could propagate to existing downstream systems. Therefore, it is recommended that equipment manufacturers reference their equipment aircraft information security review and mitigation strategies in the equipment's installation manual so that the applicant can consider them in meeting the installation regulatory requirements.

[1] A "non-trusted" connectivity (sometimes referred to as third-party system) is any frequency or service where an Air Navigation Service Provider (ANSP) is not providing direct monitoring/protection.

## 1.11 Additional Information

A supplement to this MOPS is available from RTCA and EUROCAE for digital download in the form of a single zip archive. The following supplementary items are contained in this archive:

- CPR Reference Implementation (in support of Appendix T)
- Broadcast Message Format Algorithm (BMFA) Sample Algorithm (in support of Appendix O)

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