Autonomous Distress Tracking (ADT)

Architecture Studies

Automatic Dependent Surveillance – Broadcast (ADS-B) Architecture

ARINC REPORT 6XX

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FOREWORD
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> An Errata Report solicits any corrections to existing text or diagrams that may be included in a future Supplement to this ARINC Standard.
>
> An ARINC IA Project Initiation/Modification (APIM) form solicits any proposals for the addition of technical material to this ARINC Standard.

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose of this Document

This document documents the architectural options to support an Autonomous Distress Tracking (ADT) System that are being levied by the International Civil Aviation Organization (ICAO) and individual Civil Aviation Authorities (CAAs) (both at the aircraft-level and on-ground systems). All derived system-level requirements are also documented within this report.

In addition, a System Functional Block Diagram, allocating the requirements to each functional block, is also documented.

COMMENTARY

The difficulty in locating the crash sites of Air France Flight 447 in June 2009 and Egypt Air Flight 804 in May 2016, and the disappearance of Malaysia Airlines Flight 370 in March 2014, has prompted significant international effort to provide means for a global aircraft tracking capability. Since 2015, ICAO has worked to amend ICAO Annex 6 standards to include requirements for tracking commercial planes during all flight phases, including functionality of autonomous identification and reporting of distress situations (Autonomous Distress Tracking). In addition, the European Commission has published Commission Regulation (EU) 2015/2338 with similar, but in some cases differing, requirements.

1.2 Scope

The scope of this document is limited to documenting the system-level requirements for an Autonomous Distress Tracking (ADT) System and a survey of potential architectures to support these requirements.

Requirements associated with Normal or Abnormal Tracking, as identified in ICAO or CAA documents, are not part of the ADT requirements.

1.3 Objectives

The objective of this ARINC report is to:

1. Capture all documented ICAO and regulatory system-level requirements for an ADT system
2. Integrate these and derive a requirements set to use in evaluating a range of potential ADT architectures.
3. Perform a study of applicable ADT architectures to support the follow-on characteristics development work.

1.4 Related Documents

These documents provide source requirements for the ADT system.

COMMISSION REGULATION (EU) 2015/2338 of 11 December 2015 amending Regulation (EU) No 965/2012 as regards requirements for flight recorders, underwater locating devices and aircraft tracking systems

EU No. 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No. 216/2008 of the European Parliament and of the Council

Annex II to Executive Director (ED) Decision 2015/XXX/R 'AMC and GM to Part-CAT — Issue 2, Amendment X' (DRAFT dated Feb. 2016)

ICAO Annex 6, "Operation of Aircraft", Part I, "International Commercial Air Transport – Aeroplanes"

ICAO Annex 11, "Air Traffic Services"

ICAO Document, "Concept of Operations – Global Aeronautical Distress & Safety System" (Ver 6.0, 7 June 2017)

ICAO Document 10054, "Manual on Location of Aircraft in Distress and Flight Recorder Data Recovery" *(Not yet released)*

2.0 Autonomous Distress Tracking (ADT) Architecture Study

2.1 Space-Based Automatic Dependent Surveillance – Broadcast (ADS-B) Architecture Study

2.1.1 Description of Architecture

Automatic Dependent Surveillance – Broadcast (ADS-B) Out (aka Extended Squitter) is a surveillance function which has been installed on all commercial air transport airplanes since the 2004 timeframe. ADS-B transmits aircraft data, including aircraft identification, horizontal position, altitude, velocity, and other parameters. Since the release of the RTCA DO-260 ADS-B Minimum Operational Performance Standards (MOPS) in 2000, there have been two revisions to the MOPS: DO-260A (in 2003) and DO-260B (in 2009). **Some Air Navigation Service Providers (ANSPs) (e.g. NavCanada, AirServices Australia and certain ANSPs in Southeast Asia) have implemented ground ATC systems to track aircraft that meet any version of DO-260.** The U.S. Federal Aviation Administration (FAA) has mandated that all aircraft (forward-fit and retrofit) be equipped with DO-260B complaint ADS-B Out functionality by Jan. 1, 2020. The European Union has mandated that air transport aircraft (forward-fit and retrofit) be equipped with DO-260B complaint ADS-B Out functionality by June 7, 2020. Other regions of the world have already mandated, or are in the process of mandating, ADS-B Out. Therefore, it is expected that nearly all air transport aircraft worldwide will have ADS-B Out functionality installed by 2020.

From an air transport aircraft installation perspective, the ADS-B Out function resides in the same Line Replaceable Unit (LRU) (e.g. a standalone Air Traffic Control (ATC) transponder, an Integrated Surveillance System Processor Unit (ISSPU), a T2CAS unit, or a T3CAS unit), that contains the ATC transponder function. Each airplane has (2) ADS-B Out systems installed with one system being selected and active at any given time while the other ADS-B Out system is in standby mode (aka hot-spare). Each ADS-B Out system receives specific aircraft data parameters from other aircraft systems and alternately transmits the data in ADS-B Out registers in 1090 MHz Extended Squitter (ES) messages via the top and bottom ATC antennas (i.e. the ADS-B messages are transmitted out the top antenna, and then the bottom antenna). Air Traffic Services (aka Air Navigation Service Providers (ANSPs)) which have ground-based ADS-B receiving stations (e.g. the FAA's network of ADS-B stations) receive the transmitted ADS-B data, and provide the data to ATS automation for use in aircraft separation services.

In addition, *Aireon* has developed a Space-Based ADS-B receive capability which will provide worldwide ADS-B aircraft tracking services that can be interfaced to any **Service Provider (e.g.** ANSP/ATS Unit**, FlightAware, or SITAinair)**. Figure 1 provides a general overview of *Aireon's* Space-Based ADS-B Network, which serves as a reference architecture for any given Space-Based ADS-B Network.

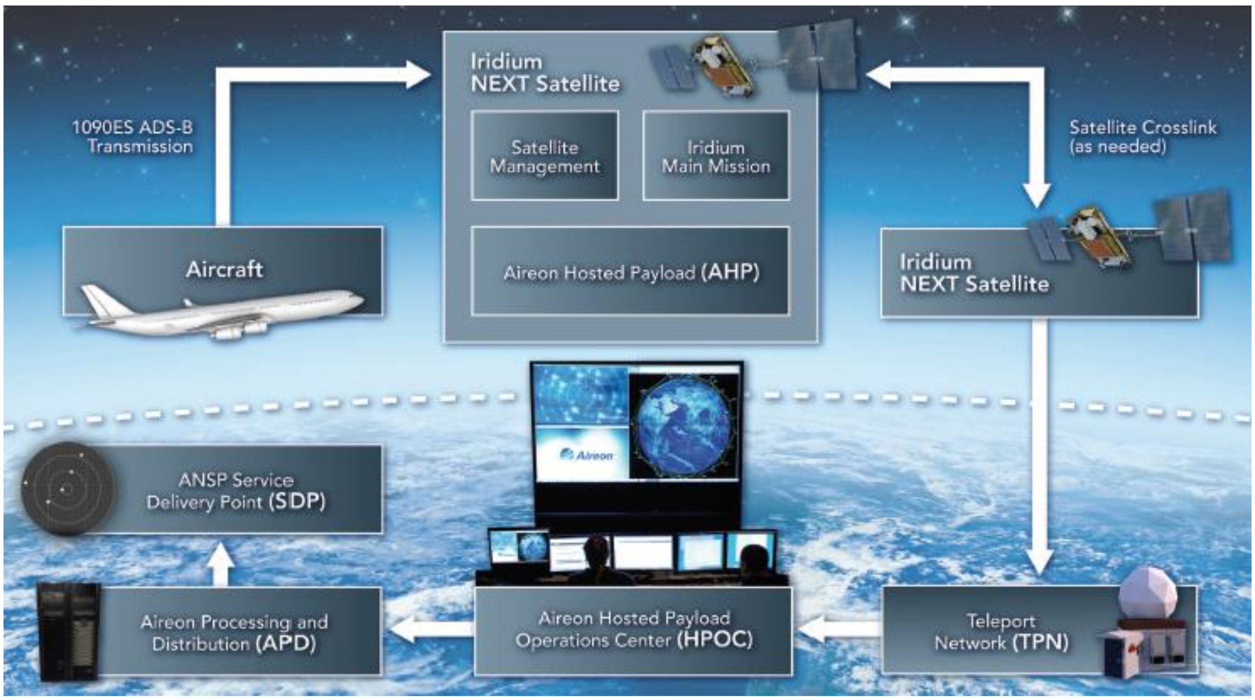

Figure 1. Space-Based ADS-B Network

Figure 2 provides an end-to-end architecture overview of the ~~Space-Based~~ ADS-B Architecture for Distress Tracking.

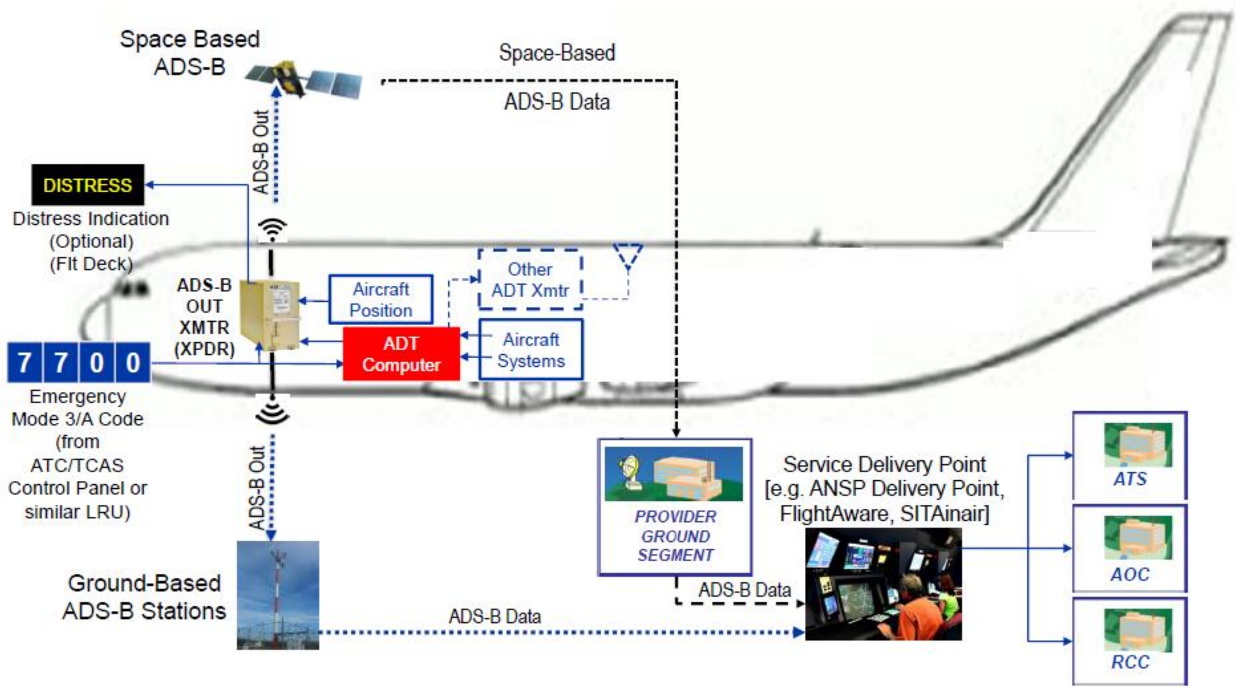

Figure 2. ~~Space-Based~~ ADS-B Architecture for Distress Tracking (Example)

In this architecture, the ATC Transponder (shown as ADS-B OUT XMTR (XPDR) in Figure 2) is the Distress Tracking transmitter. The XPDR receives position data from an onboard position source(s). The position source will most likely be the Global Navigation Satellite System (GNSS) receiver (which is typically housed within a Multi-Mode Receiver (MMR) on many air transport aircraft). The GNSS provides worldwide, high accuracy, and high integrity horizontal position (latitude and longitude) data which is already provided to the XPDR to support the ADS-B Out function. The position data is transmitted in an ADS-B message (Airborne Position BDS register 05H) every 500 msec, alternating transmissions between the top ATC antenna and the bottom ATC antenna. Therefore, the ADS-B position data is transmitted from the top antenna once per second. In addition, the XPDR receives uncorrected barometric altitude data from an onboard air data source(s). The altitude data is transmitted in the same Airborne Position message (BDS register 05H) as the position data, and therefore, the altitude data is also transmitted from the top antenna once per second.

In the example architecture shown in Figure 2, the ADT Computer function contains the Distress Detection Logic and the Triggering Criteria Logic for determining whether an onboard distress event is occurring and whether a distress event has been cancelled. Alternatively, the ADT Computer function could be incorporated into the XPDR, but this is left to the implementer to decide whether this is feasible. For the purposes of this architecture study, the ADT Computer will be shown as a separate LRU.

When a distress event is active, a signal is sent to the XPDR to indicate that a distress event is currently active. The XPDR would register the distress event by encoding a **"General Emergency"** in the Emergency State field in the existing ADS-B "Emergency/Priority Status" message (BDS register 61H – Subtype 1). This message is transmitted every 800 msec, alternating between the top ATC antenna and the bottom ATC antenna. Therefore, the distress event in the Emergency State field is transmitted from the top antenna every 1.6 seconds. Figure 3 shows the Emergency State field coding (bits 11-9) within the Emergency/Priority Status message (BDS register 61H – Subtype 1).

Coding (Bits 11-9)		**Meaning**
(Binary)	(Decimal)	
000	0	No Emergency
001	**1**	**General Emergency**
010	2	Lifeguard/Medical Emergency
011	3	Minimum Fuel
100	4	No Communications
101	5	Unlawful Interference
110	6	Downed Aircraft
111	7	Reserved

Figure 3. Emergency State Field of the Emergency/Priority Status Message (BDS 61H Subtype 1)

Discussion item: The Figure 3 Emergency/Priority Status table is limited by the use of Subtype code 1. Per DO-260B, there are 5 unassigned Subtypes available (3-7). Would it be desirable to utilize a new Subtype code to identify the transmission to be of ADT origin? If so, one (or more) new message matrices could be defined to precisely identify the reason for the transmission.

Coding (Bits 11-9)		***Meaning***
(Binary)	***(Decimal)***	
000	***0***	***No ADT Activation***
001	***1***	***Automatic ADT Activation***

010	***2***	***Manual ADT Activation***
011	***3***	***See below****
100	***4***	***See below****
101	***5***	***See below****
110	***6***	***ADT Condition Cancelled/Cleared***
111	***7***	***Reserved***

Messages such as Unusual Attitude, Unusual Altitude, Unusual Airspeed, Impact Imminent, Loss of Primary Electrical Power, EGPWC Warning, etc could be used here. The possibilities are limited by the functionality of the ADT LRU (however that may be employed). If there are multiple causes for the activation, the ADT LRU could cycle the coding bits from, for instance 'Automatic ADT Activation / Unusual Attitude / Automatic ADT Activation / Unusual Attitude' and so on. When the condition is corrected, bits 110 'ADT Condition Cancelled/Cleared' is transmitted. Note also that the Surveillance Status bit in Register 5 must change to terminate the emergency state in Register 61.

Defining the transmission to be of ADT origin and providing the actuation type and cause could provide investigators with immediate knowledge for the reason the aircraft emergency. Could this type of information be useful to the AOC, RCC, or SAR? This would also be beneficial in the event the FDR data could not be recovered.

This code is received by all ADS-B receivers within range (from terrestrial and Space-Based systems) and can signify a distress condition to ATS, AOCs, and RCCs that are subscribed to the ADS-B data from these systems. In fact, the FAA's ATC automation systems already process the data within the Emergency State field (bits 9 through 11) in Emergency/Priority Status messages and will provide an ATC emergency alert if the field is set to "1" (001). In addition, the "Downed Aircraft" code could also be set for certain distress conditions.

Several companies such as FlightAware and SITAonair will be connected to ADS-B sensor networks of their own, as well as to Space-Based ADS-B, and distribute the data with applications that are configurable to alert AOCs and/or RCCs to several common distress conditions (e.g. emergency Mode 3/A codes, sudden changes in altitude or speed, etc.). Additionally, Aireon will provide a service called Aircraft Locating and Emergency Response Tracking (ALERT) for contingency conditions, however this service by itself is not designed to support ADT.

A Manual Distress Trigger capability in the flight deck could also allow the flight crew to manually activate a distress event. The XPDR is already connected to a flight deck control head (e.g. an ATC/TCAS control panel or similar LRU) where the Mode 3/A code (aka "squawk code") is selected by the flight crew. When the Mode 3/A code is set to the General Emergency code (7700), then the XPDR transmits the Emergency State field in the Emergency/Priority Status message (BDS register 61H, subtype 1) with an encoding of “1” (001) which represents a General Emergency.

In addition, the XPDR could also provide an input to an optional Flight Deck “DISTRESS” indicator (e.g. annunciator light or crew alerting message) to alert the flight crew when a distress signal (Emergency State Field = “1” (001)) is being transmitted by the XPDR. However, this type of indication is dependent upon the aircraft implementation, and should take into account human factors considerations and the overall flight deck philosophy for that aircraft platform.

Note that with the ADS-B architecture, there is no “uplink” function that would enable the ground to initiate an airborne distress signal.

2.1.2 Architecture Mapped to the Architecture Frame Work

Figure 4 is the ADT Functional Block Diagram. It explains each of the ADT system's functions and their interconnections.

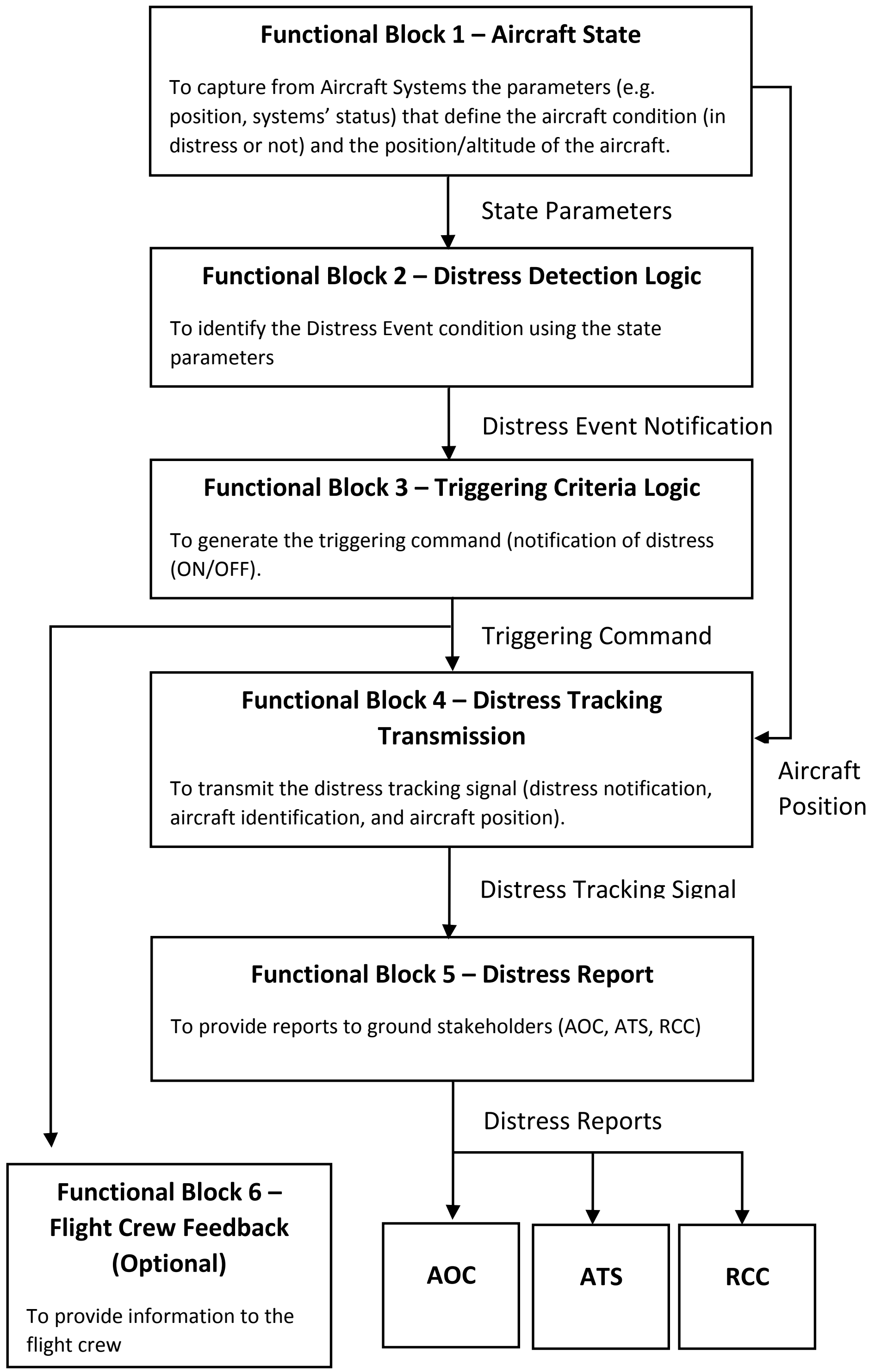

Figure 4. ADT Functional Block Diagram

Figure 5 is the ADS-B Implementation Architecture that maps to each of the ADT system functional blocks (Functional Blocks 1 through 6) of the ADT Functional Block Diagram (Figure 4).

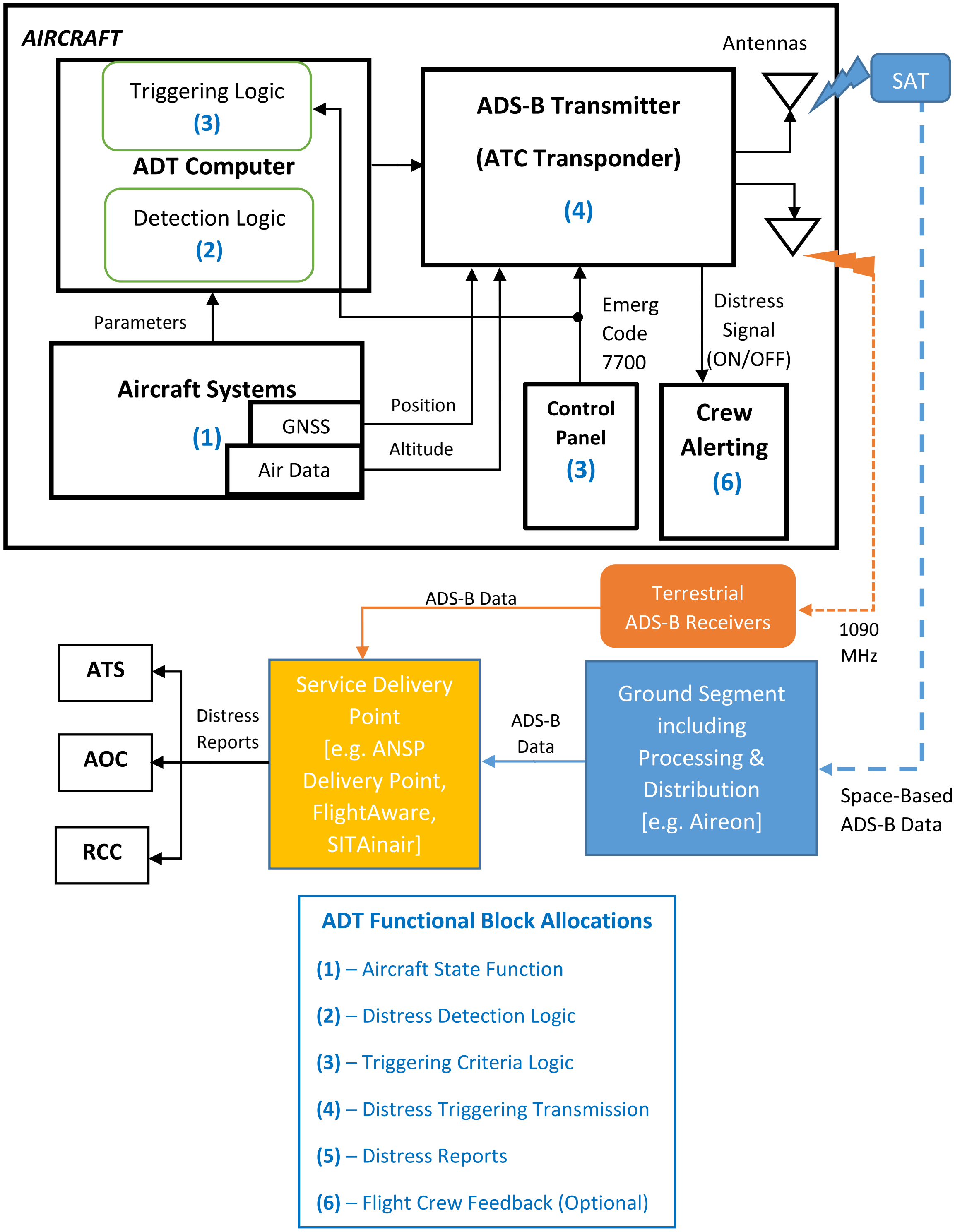

Figure 5. ADS-B Implementation Architecture

The ADT Triggering Logic (3) will generate a trigger event based on either:

- An automatic trigger based on the Detection Logic (2) being satisfied, or
- A manual trigger as set by the flight crew setting a XPDR Mode A code of '7700'

The ATC Transponder will transit a distress signal via both top and bottom ATC antennas, along with the aircraft's identification, horizontal position, and altitude. This data, which is contained within ADS-B Out messages, can be received any ADS-B receiver (including terrestrial ADS-B receivers as well as Space-Based ADS-B Receivers).

2.1.2.1 Key Architecture Assumptions and Dependencies

The ADS-B architecture has the following specific dependencies:

1. The aircraft ATC Transponders must be capable of transmitting ADS-B messages that meet the minimum operational performance standards (MOPS) of RTCA DO-260, DO-260A, or DO-260B.
2. In order to provide full-time, global ADS-B coverage, the Iridium Next satellites that carry the Aireon Hosted Payload and Main Mission L-Band antenna must be deployed. The current schedule for completing deployment of these satellites is July 2018.
3. The Aireon Ground-Based Network must be completed to the extent that high-integrity ADS-B data can be distributed to users of the data (e.g. FlightAware). The current schedule for completing the Aireon network that supports this level of functionality is July 2018.
4. FlightAware must be able to consume the Aireon ADS-B data and make it available to users of the data. FlightAware is currently receiving Aireon ADS-B data and performing beta testing. FlightAware is scheduled to provide Normal Tracking services by July 2018 and will provide ADT services by December 2018.
5. SITAinair currently provides Normal tracking using SATCOM and ACARS position reports. SITAinair plans on receiving Space-Based ADS-B data from FlightAware for use in Normal tracking services by July 2018 and for ADT services by December 2018.

2.1.2.2 Key Airplane Infrastructure Support and Required Changes

Key Airplane Infrastructure Support

The aircraft must be capable of transmitting ADS-B messages that meet the requirements of RTCA DO-260, DO-260A, or DO-260B MOPS. In addition, the ATC transponder must have the ability to receive specific data parameters from qualified systems. Horizontal position (latitude and longitude), along with position accuracy and integrity parameters, must be supplied by a qualified position source (e.g. GNSS). In addition, data containing aircraft identification (Flight ID) and altitude data (uncorrected barometric altitude) must be received and transmitted by the ATC transponder. All air transport aircraft delivered after approximately 2004 meet the above requirements.

Required Changes

The aircraft must be updated as follows:

- Add an ADT Computer that provides the Detection and Triggering logic as outlined in Figures 4 and 5.

  Note: Alternatively, the Detection and Triggering logic could be added to the ATC Transponder LRU.

- Add wiring to connect the ADT Computer to the required aircraft systems to receive necessary data parameters
- Add wiring to connect the ADT Computer to the ATC Transponder so that a "Trigger ON/OFF" can be sent from the ADT Computer to the ATC Transponder.

2.1.2.4 Key Network Infrastructure Support and Required Changes

Discussion of key network support and changes required to support architecture.

- Aireon Network - Mike
- FlightAware - Mark
- SITAinair - Paul

2.1.2.4 Key Ground Segment Support and Required Changes

Discussion of key ground segment support and changes required to support architecture.

- Aireon Network - Mike
- FlightAware - Mark
- SITAinair - Paul

2.1.3 Compliance with Requirements

Evaluate the architectures support for the minimum and optional requirements described in Appendix B (minimum requirement set spreadsheet) and for the GADSS CONOPS (Ver 6.0) State of the Operator Approval Criteria Recommendations (section 3.2.10) using the matrices in Appendix C.

Identify and provide textual/graphic descriptions and discussions of any major shortcomings and if and how they are expected to be addressed.

Provide textual/graphic descriptions and discussions of any additional capabilities or opportunities for improved distress capabilities and services not addressed in the requirements.

Identify and discuss requirements that potentially impose a significant cost or impact for the architecture and discuss where changes in requirements or *alternative could potentially provide similar capabilities at a significantly reduced cost or impact.*

Identify and discuss requirements where there is potential opportunity for the architecture to significantly exceed or improve on the required levels with minor impact and cost.

2.1.4 Support for Related Services and Capabilities

Provide textual/graphic descriptions and discussions of any additional capabilities or opportunities for improved distress capabilities and services not addressed in the requirements. In particular address support for

1. Normal tracking
2. Abnormal and potential distress tracking
3. Implications for timely recovery of flight data
4. Post Flight Localization and Recovery

Appendix A. Architectural Framework

Adobe Acrobat
Document

Figure A-1 Architectural Framework

(embedded file:

Global Tracking_Emb_2017_ARINC_Seattle_reve.pdf

from August 2017 Seattle Meeting)

Appendix B. Minimum Requirements Set

Figure B-2 Minimum Requirements Set

(embedded file:

Requirements Tables - ICAO CONOPS+in-work Summary rev DRAFT 12 (20 Sept)_MAL9.xls)

Appendix C. Architecture Compliance/Support Matrix

Figure C-3 Architecture Compliance/Support Matrix

(embedded file:

Requirements Compliance Matrices (DRAFT 12 (20 Sept)_MAL9).xls)