ICAO

Doc 10054

Manual on Location of Aircraft in Distress and Flight Recorder Data Recovery

First Edition, 2019

Approved by and published under the authority of the Secretary General

INTERNATIONAL CIVIL AVIATION ORGANIZATION

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Published in separate English, Arabic, Chinese, French, Russian
and Spanish editions by the
INTERNATIONAL CIVIL AVIATION ORGANIZATION
999 Robert-Bourassa Boulevard, Montréal, Quebec, Canada H3C 5H7

For ordering information and for a complete listing of sales agents
and booksellers, please go to the ICAO website at www.icao.int

First edition, 2019

Doc 10054, ***Manual on Location of Aircraft in Distress and Flight Recorder Data Recovery***
Order Number: 10054
ISBN 978-92-9258-654-6

AMENDMENTS

Amendments are announced in the supplements to the *Products and Services Catalogue;* the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

CORRIGENDA		
No.	Date	Entered by

FOREWORD

This manual has been developed to provide guidance on Standards and Recommended Practices (SARPs) contained in Annex 6 — *Operation of Aircraft*, Part I — *International Commercial Air Transport — Aeroplanes*, relating to the location of an aircraft in distress and flight recorder data recovery.

TABLE OF CONTENTS

GLOSSARY

ABBREVIATIONS AND ACRONYMS

ADFR	Automatic deployable flight recorder
ADPCM	Adaptive differential pulse-code modulation
ADRS	Aircraft data recording system
ADS-B	Automatic dependent surveillance — broadcast
ADS-C	Automatic dependent surveillance — contract
ADT	Autonomous distress tracking
AIA	Accident investigation authority
AIR	Airborne image recorder
AMS	Aeronautical mobile satellite
ARINC	Aeronautical Radio, Incorporated
ASR	Air Safety Report
ATC	Air traffic control
ATS	Air traffic services
ATSU	Air traffic service unit
CAM	Cockpit area microphone
CONOPS	Concept of operations
CVR	Cockpit voice recorder
DFL	Data frame layout
DLR	Data link recorder
DTR	Distress tracking data repository
ELT	Emergency locator transmitter
FDA	Flight data analysis
FDAP	Flight data analysis programme
FDAPM	Flight data analysis programme manual
FDR	Flight data recorder
FIR	Flight information region
GADSS	Global Aeronautical Distress and Safety System
GNSS	Global navigation satellite system
GPWS	Ground proximity warning system
IIC	Investigator-in-charge
MASPS	Minimum aviation system performance specification
MOPS	Minimum operational performance specification
MRO	Maintenance, repair and overhaul
MSS	Mobile satellite service
RCC	Rescue coordination centre
SAR	Search and rescue
SARP	Standard and Recommended Practice
ULD	Underwater locating device

PUBLICATIONS

(*Referred to in this manual*)

ICAO Publications

Annex 2 — *Rules of the Air*

Annex 6 — *Operation of Aircraft*
  Part I — *International Commercial Air Transport — Aeroplanes (Amendment 43)*

Annex 11 — *Air Traffic Services*

Annex 12 — *Search and Rescue*

Annex 13 — *Aircraft Accident and Incident Investigation*

Annex 19 — *Safety Management*

Circular 347 — *Aircraft Tracking Implementation Guidelines*

Global Aeronautical Distress and Safety System (GADSS) — Concept of Operations — Version 6.0

Other Publications

European Organisation for Civil Aviation Equipment (EUROCAE) Document ED-112A — *Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems*

EUROCAE Document ED-237 — *Minimum Aviation System Performance Specification for Criteria to Detect In-Flight Aircraft Distress Events to Trigger Transmission of Flight Information*

Chapter 1

INTRODUCTION

1.1 BACKGROUND

1.1.1 Aviation continues to enjoy a high level of safety due to the willingness to learn from past events, among other things. Fundamental to this approach is the ability to recover information from flight recorders after an accident.

1.1.2 Two high-profile events have highlighted limitations in the air navigation system which have both hampered search and rescue efforts and led to a delay in retrieving, or inability to retrieve, flight recorder data from the aircraft involved.

1.1.3 In June 2009, Air France Flight 447, a scheduled flight from Brazil to France, went missing in the Atlantic Ocean. The aircraft's flight data recorders were recovered after several search operations, which lasted nearly two years. Due to this and other such occurrences, several safety recommendations have been addressed to ICAO related to locating accident sites, locating aircraft in distress and the recovery of flight recorder data. These recommendations resulted in proposals for amendments to Annex 6 — *Operation of Aircraft*; however, the proposals were not adopted.

1.1.4 The disappearance on 8 March 2014 of a Malaysia Airlines Boeing 777, operating as Flight MH370, in the Indian Ocean triggered the most comprehensive and costly search operation in aviation history. At the time of publication of this manual, the main wreckage had not yet been discovered, nor had the flight recorders been recovered.

1.1.5 Shortly after the Malaysia Airlines event, a special Multidisciplinary Meeting on Global Flight Tracking (MMGFT) was convened in May 2014 at ICAO Headquarters in Montréal, Canada, so that recommendations for future actions could be proposed. One of the main decisions reached was the need for operators to pursue aircraft flight tracking at a faster pace. The MMGFT concluded by recommending that a final high-level concept of operations (CONOPS) should be delivered to the forthcoming ICAO High-level Safety Conference. It further recommended that ICAO provisions should be developed through a multidisciplinary approach, to support the location of an accident site in a timely manner for the purpose of search and rescue and accident investigation.

1.1.6 The Global Aeronautical Distress and Safety System (GADSS) CONOPS was initiated at a subsequent meeting of an ad hoc working group. The GADSS concept describes, in an evolutionary manner, the execution of actions in the short, medium and long terms with each action resulting in benefits. The CONOPS document specifies the high-level requirements and objectives of the GADSS, which is a system of systems and procedures intended to apply initially to commercial air transport operations (Annex 6, Part I — *International Commercial Air Transport — Aeroplanes* applicability). The CONOPS takes an overall system approach, however, and is consequently not restricted to a particular type of operation. The first steps in implementing the GADSS were taken in the short term by implementing aircraft tracking solutions as proposed by the industry-led Aircraft Tracking Task Force (ATTF) for commercial air transport and by addressing the areas of improvement identified in the GADSS CONOPS.

1.1.7 Further developments included proposals to incorporate provisions for the location of aircraft in distress and the recovery of flight recorder data.

1.2 OBJECTIVES AND SCOPE

1.2.1 Amendment 40A to Annex 6, Part I, which introduced provisions for locating an aircraft in distress and the timely recovery of flight recorder data, was adopted by the ICAO Council on 2 March 2016 and became applicable on 10 November 2016. These provisions, however, have embedded applicability dates of 1 January 2021. The objective of this manual is to provide guidance on the implementation of these provisions.

Note.— The references to Annex 6 in this document reflect the latest version of the Annex at time of publishing (up to and including Amendment 43).

1.2.2 The guidance in this manual is intended to support the provisions in Annex 6, Part I, only. Other proposals contained in the GADSS CONOPS are not addressed in this manual. It is to be noted that the GADSS CONOPS is meant to serve as a high-level road map providing context to the elements which are included in the Annexes and does not in itself imply any obligations on the part of States.

1.3 GLOBAL AERONAUTICAL DISTRESS AND SAFETY SYSTEM (GADSS)

1.3.1 As discussed in 1.2, the adopted Standards related to the location of aircraft in distress and timely recovery of flight recorder data were developed using the GADSS CONOPS as a high-level road map. It is useful to review the GADSS concept to understand the context of these provisions.

1.3.2 On the rare occasions when accidents occur, rescuing survivors has the highest priority, followed by the recovery of casualties, flight recorders and wreckage. The analysis of data from these recorders is very important in supporting accident investigations, which, through identification of the causes and contributing factors of accidents, may contribute towards enhancing safety. To achieve this, an effective and globally consistent approach to improve the alerting of search and rescue services is essential.

1.3.3 As the GADSS addresses all phases of flight under all circumstances including distress, the effectiveness of the current system for alerting search and rescue services should be enhanced by addressing a number of key improvement areas identified within the GADSS. This will result in maintaining an up-to-date record of aircraft progress and, in the case of a crash, forced landing or ditching, the location of survivors, recoverable flight data and the aircraft.

1.3.4 The high-level objectives of the GADSS are therefore defined as follows:

a) ensure timely detection of aircraft in distress

   – Timely initiation of search and rescue (SAR) actions;

b) ensure tracking of aircraft in distress and timely and accurate location of end of flight

   – accurate direction of SAR actions;

c) enable efficient and effective SAR operations; and

d) ensure timely retrieval of flight recorder data.

1.3.5 The GADSS identifies three specific functions needed to achieve the high-level objectives. Figure 1-1 gives an overview of the GADSS and identifies these primary functions.

1.3.6 Aircraft tracking

1.3.6.1 The aircraft tracking function provides the aircraft operator with aircraft position information directly when air traffic services (ATS) surveillance services obtain the aircraft position at greater than 15-minute intervals. Where it can be confirmed that ATS obtain an aircraft position at 15-minute intervals or less, the aircraft operator does not need to track the aircraft.

1.3.6.2 The aircraft tracking function:

a) does not introduce any change to current air traffic control (ATC) alerting procedures;

b) establishes operator responsibilities for tracking based on areas of operation;

c) is not technology-specific and can be achieved using existing on-board equipment; and

d) establishes communication protocols between operators and ATC.

1.3.6.3 More details regarding aircraft tracking can be found in Circular 347 — *Aircraft Tracking Implementation Guidelines*.

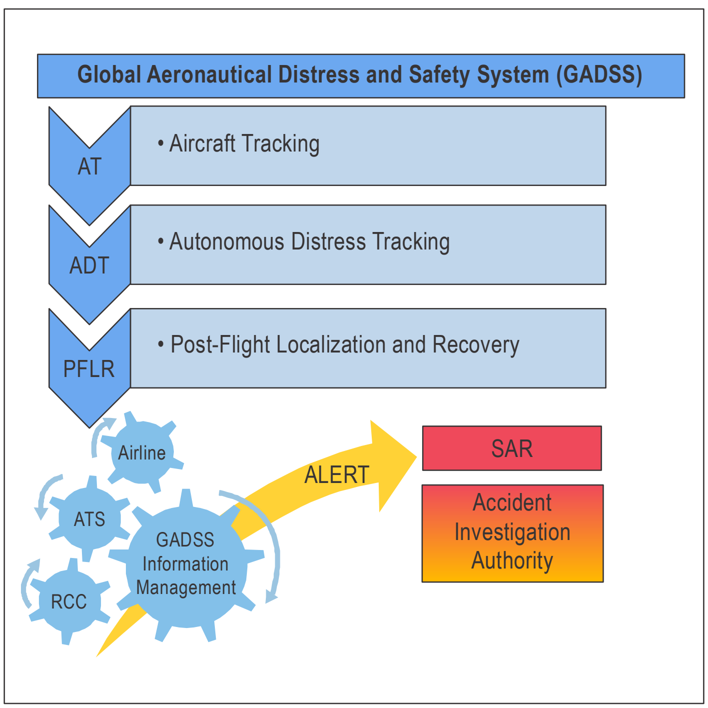

Figure 1-1. Primary functions of the GADSS

1.3.7 Autonomous distress tracking (ADT)

1.3.7.1 The autonomous distress tracking (ADT) function will be used to identify the location of an aircraft in distress with the aim of establishing, to a reasonable extent, the location of an accident site within a 6 NM radius.

1.3.7.2 The ADT function uses on-board systems to broadcast information from which the aircraft position (latitude, longitude and time) can be derived. The aircraft position information will be transmitted, without the need for flight crew action, at least once every minute when an aircraft is in a distress condition. An aircraft is in a distress condition when it is in a state that, if the aircraft behaviour event is left uncorrected, can result in an accident.

Note.— ADT is discussed in detail in Chapter 2.

1.3.8 Post-flight localization and recovery

1.3.8.1 In the event of an accident, the rescue phase to locate possible survivors has the immediate and highest priority. The goal of the post-flight localization function is to guide search and rescue to the accident site.

1.3.8.2 Following an accident, it is beneficial for the accident investigation authority (AIA) to recover the aircraft's structure, components and critical flight data in a timely manner. When the accident occurs over an oceanic area, the task of localizing the aircraft's structure, and particularly its flight recorders, can be difficult.

1.3.8.3 To assist the localization of the wreckage and recovery of flight recorder data after an accident, the post-flight localization and recovery function specifies a number of requirements for emergency locator transmitters (ELTs), underwater locator devices (ULDs) and flight recorders, which are incorporated in Annex 6 provisions

Note.— Post-flight localization (using ADT) is discussed in Chapter 2. Flight recorder data recovery is discussed in detail in Chapter 3.

Chapter 2

GUIDANCE FOR LOCATION OF AIRCRAFT IN DISTRESS

2.1 INTRODUCTION

2.1.1 This chapter provides guidance aimed at helping States and operators to comply with ICAO Standards and Recommended Practices (SARPs) related to the location of an aeroplane in distress and one of its primary components, autonomous distress tracking (ADT).

2.1.2 Throughout this chapter, clarifications to specific excerpts of SARPs are made to promote understanding, explain intent and illustrate potential means of compliance and methods of implementation. The means of compliance are not limited to the methods that are described in this document. States may approve other means of compliance with the applicable SARPs.

2.2 APPLICABILITY AND INTENT OF THE PROVISIONS

2.2.1 General

On 2 March 2016, the ICAO Council adopted Amendment 40A to Annex 6, Part I which included, among other elements, SARPs relating to the location of an aeroplane in distress. These SARPs address the GADSS ADT function. The SARPs became effective on 11 July 2016 and will be applicable on 1 January 2021.

Note.— The references to Annex 6 in this document reflect the latest version of the Annex at time of publishing (up to and including Amendment 43).

2.2.2 SARPs related to location of an aeroplane in distress

2.2.2.1 The essential requirements related to the location of an aeroplane in distress are in Annex 6, Part I, 6.18.1 and 6.18.2, while additional requirements are contained in Appendix 9 to the Annex.

> 6.18.1 All aeroplanes of a maximum certificated take-off mass of over 27 000 kg for which the individual certificate of airworthiness is first issued on or after 1 January 2021, shall autonomously transmit information from which a position can be determined by the operator at least once every minute, when in distress, in accordance with Appendix 9.
>
> 6.18.2 **Recommendation.—** *All aeroplanes of a maximum certificated take-off mass of over 5 700 kg for which the individual certificate of airworthiness is first issued on or after 1 January 2021, should autonomously transmit information from which a position can be determined at least once every minute, when in distress, in accordance with Appendix 9.*

2.2.2.2 This Standard applies to all new aeroplanes with a take-off mass of greater than 27 000 kg, from the applicability date of 1 January 2021. Paragraph 6.18.2 recommends that this provision apply to all new aeroplanes with a take-off mass of greater than 5 700 kg from the same date.

2.2.2.3 Regardless of the functionality of the ADT system there is still a requirement to carry an ELT in addition to the ADT. The ADT cannot be used to replace both the automatic ELT and the second ELT. While the note included under 6.17.3 clarifies that removal of the automatic ELT is permitted when an ADT is carried, 6.17.1 still recommends that all aircraft be fitted with an automatic ELT. If an automatic ELT is replaced by an ADT system as described in Annex 6, Part I, 6.17.3 b), it is possible that there will be no homing signal for post-accident localization other than a manually activated ELT. In this case, appropriate mitigation measures would need to be in place to ensure the effective response of SAR resources, such as standard operating procedures for manual activation of the ELT.

2.2.2.4 Although these SARPs apply to newly manufactured aeroplanes, there is an incentive to retrofit older aeroplanes by replacing one of the two required ELTs with an ADT device that provides autonomous position information when the aeroplane's distress condition is first detected (see Annex 6, Part I, 6.17.3 b)). The detection of an aeroplane in distress is explained in detail in Section 2.3 of this manual.

2.2.2.5 An *autonomous* distress tracking system continues to operate while the aeroplane is in distress and is resilient to failures of the aeroplane systems. Further details on the meaning of the term "autonomous" can be found in Section 2.5.4 of this manual.

2.2.2.6 The SARPs are not technology-specific and allow for various solutions including a system providing position information directly or the capability to transmit information from which the position may be determined at intervals of one minute or less.

2.2.2.7 The information from which a position can be determined can include the aeroplane position and/or information necessary for systems external to the aeroplane to be able to determine the aeroplane position (e.g. triangulation, trilateration).

2.2.2.8 The phrase "at least once every minute" means that the system must either transmit the position of the aeroplane every minute or transmit sufficient information such that the position can be determined at least every minute. Analysis has shown that in approximately 95 per cent of the cases surveyed, when the position was accurately known within the last minute prior to the crash, the accident site was located within a 6 NM radius of the last known position.

2.2.2.9 Annex 6 also includes a requirement to make the ADT data available:

> 6.18.3 The operator shall make position information of a flight in distress available to the appropriate organizations, as established by the State of the Operator.

Note.— Refer to 4.2.1.3.1 for operator responsibilities when using third parties.

2.2.2.10 Paragraph 6.18.3 establishes that aeroplane operators are responsible for ensuring that ADT data are made available to applicable stakeholders, and that the State of the Operator determines who may have access to these data.

2.2.2.11 The minimum requirements are for the information to be made available to air traffic service units (ATSUs) and SAR rescue coordination centres (RCCs), as described in Appendix 9, 2.4.

2.2.2.12 Operators retain that responsibility even if third parties perform work on their behalf. In such cases, operators should make sure that policies and procedures are in place to ensure that ADT data are appropriately delivered and readily available to applicable stakeholders.

2.2.2.13 The requirements of the basic provisions are supplemented by additional requirements detailed in Appendix 9. A general statement on the intent of the requirements is stated below:

1. PURPOSE AND SCOPE

> *Location of an aeroplane in distress* aims at establishing, to a reasonable extent, the location of an accident site within a 6 NM radius.

2.2.2.14 While the intent is to provide the location of an accident site to within 6 NM, this is not the requirement. The requirement detailed in Section 6.18 is to provide information from which a position can be determined at one-minute intervals or less.

2.2.2.15 Paragraph 2.1 reiterates the basic requirement and provides additional information:

> 2.1 An aeroplane in distress shall automatically activate the transmission of information from which its position can be determined by the operator and the position information shall contain a time stamp. It shall also be possible for this transmission to be activated manually. The system used for the autonomous transmission of position information shall be capable of transmitting that information in the event of aircraft electrical power loss, at least for the expected duration of the entire flight.

2.2.2.16 This clarifies the requirement that the ADT transmission can be started by the flight crew or is automatically activated without requiring any action by the flight crew. It should be noted, however, that the requirement for manual activation is for the flight crew only and does not extend to activation by any ground-based personnel. This functionality may be included in some solutions; however, it is not a requirement. Where ground activation is included in the ADT system, due consideration will need to be given to the security of this link and the potential for malicious use of this function. The deactivation of an ADT transmission is covered in Appendix 9, 2.5, and is described below.

2.2.2.17 Paragraph 2.1 specifies performance criteria such that the autonomous transmission of position information needs to be capable of transmitting that information in the event of aeroplane electrical power loss *at least for the expected duration of the entire flight*. This is to be interpreted to mean that the ADT system must be able to operate in whatever state the aeroplane is in for as long as it would be realistic for the aeroplane to remain in flight in that condition. More information on the power considerations is included in Section 2.5.4 of this manual.

2.2.2.18 Annex 6, Part I, Appendix 9, 2.2, provides additional information on the nature of the distress event itself and refers to the operational intent stated in Appendix 9, 1, which is to provide a high probability of finding the location of the aeroplane within 6 NM:

> 2.2 An aircraft is in a distress condition when it is in a state that, if the aircraft behaviour event is left uncorrected, can result in an accident. Autonomous transmission of position information shall be active when an aircraft is in a distress condition. This will provide a high probability of locating an accident site to within a 6 NM radius. The operator shall be alerted when an aircraft is in a distress condition with an acceptable low rate of false alerts. In case of a triggered transmission system, initial transmission of position information shall commence immediately or no later than five seconds after the detection of the activation event.
>
> *Note 1.— Aircraft behaviour events can include, but are not limited to, unusual attitudes, unusual speed conditions, collision with terrain and total loss of thrust/propulsion on all engines and ground proximity warnings.*
>
> *Note 2.— A distress alert can be triggered using criteria that may vary as a result of aircraft position and phase of flight. Further guidance regarding in-flight event detection*

and triggering criteria may be found in the EUROCAE ED-237, Minimum Aviation System Performance Specification (MASPS) for Criteria to Detect In-Flight Aircraft Distress Events to Trigger Transmission of Flight Information.

2.2.2.19 Paragraph 2.2 and Note 1 provide the general definition of a distress event. Note 2 refers to distress event triggering, which is explored in more depth in Section 2.3 of this manual.

2.2.2.20 For a triggered transmission, the ADT system is required to commence transmission within five seconds of the detection of the event; analysis has shown that this normally ensures that at least one position report is received.

2.2.2.21 This section also establishes the requirement for operators to be alerted (warned) when an aeroplane is in distress with an acceptable low rate of false alerts (warnings). The operator would have to determine, based on its processes and procedures, what an acceptable level of false alerts (warnings) would be. Further details on operator processes and procedures are contained in Section 2.6 of this manual.

2.2.2.22 It is important to remember that the term “alerts” in this section refers to the notifications received by the operator. It should not be confused with alerts to RCCs or ATSUs. False alerts to RCCs are described in EUROCAE ED-237. To avoid confusion, “alerts” as referred to in 2.2 will be expressed as “warnings” in this manual.

2.2.2.23 In 2.3, the requirement to establish contact between an operator and the ATSUs is explicitly stated:

> 2.3 When an aircraft operator or an air traffic service unit (ATSU) has reason to believe that an aircraft is in distress, coordination shall be established between the ATSU and the aircraft operator.

2.2.2.24 Both the operator and ATSU have a responsibility under this provision. For information on ATSU and operator processes, see Sections 2.6 and 2.8 of this manual.

2.2.2.25 Annex 6, Part I, 6.18.3, establishes that aeroplane operators are responsible for ensuring that ADT data are made available to applicable stakeholders. Appendix 9, 2.4, specifies that the position information of the aeroplane must be made available to certain organizations:

> 2.4 The State of the Operator shall identify the organizations that will require the position information of an aircraft in an emergency phase. These shall include, as a minimum:
>
> a) air traffic service unit(s) (ATSU); and
>
> b) SAR rescue coordination centre(s) (RCC) and sub-centres.
>
> *Note 1.— Refer to Annex 11 for emergency phase criteria.*
>
> *Note 2.— Refer to Annex 12 for required notifications in the event of an emergency phase.*

2.2.2.26 As a minimum requirement, the position information of an aeroplane in distress is to be made available to ATSUs and RCCs. The State of the Operator will identify other organizations that will require the position information of aeroplanes in distress, including aeroplanes considered to be in an emergency phase as described in Annex 11 — *Air Traffic Services*.

2.2.2.27 Although Appendix 9, 2.4, is included in the provisions for distress tracking, it should be noted that the reference to “emergency phase” as defined in Annex 11 means that this requirement applies not only to aeroplanes in a distress condition, but also to those which are subject to a declared emergency phase for any reason. In all such cases, the organizations identified need to be supplied with any and all position information for the aeroplane. This might include not only distress tracking data, but also aircraft tracking data (4D/15 position, as defined in Annex 6, Part I, Section 3.5) and other position information, as applicable.

2.2.2.28 Appendix 9, 2.5, clarifies that the ADT transmission may only be deactivated by the same mechanism that activated it:

> 2.5 When autonomous transmission of position information has been activated, it shall only be able to be deactivated using the same mechanism that activated it.

2.2.2.29 This means, for example, that when ADT transmission is triggered by the in-flight detection of a distress event, only by no longer meeting the criteria of the distress event will the ADT system stop transmitting. It cannot, for example, be deactivated manually following an automatic activation. Similarly, a manually activated transmission can only be deactivated manually.

2.2.2.30 Finally, Appendix 9, 2.6, sets out the accuracy requirement for the ADT position information:

> 2.6 The accuracy of position information shall, as a minimum, meet the position accuracy requirements established for ELTs.

2.2.2.31 The purpose of this requirement is to facilitate the location of an aeroplane in distress. By matching or exceeding the position accuracy of an ELT position, the accuracy performance is maintained while the reliability of the transmission being sent is improved. Typically, a global navigation satellite system (GNSS)-based position encoded ELT can provide position accuracy within 100 m.

2.3 AEROPLANE IN A DISTRESS CONDITION

2.3.1 As described in Annex 6, Part I, Appendix 9, an aeroplane is in a distress condition when it is in a state that, if the aeroplane behaviour event is left uncorrected, can result in an accident. The provisions are not prescriptive in defining precisely what criteria should be employed; this must be determined by the operator and approved by the State of the Operator.

2.3.2 An ADT system may detect a distress event using on-board triggering or using ground-based logic to analyze the data received from the aeroplane to detect the distress condition, or a combination of both systems.

2.3.3 When approving an ADT system, it should be considered that, in all cases, the intent is for an aeroplane in distress to be identified as early as possible. The validity of the triggers used in this system should be demonstrated by suitable means, for example with reference to historical accident data. Such methodology is described in EUROCAE ED-237. This should ensure that in plausible scenarios, such as those described in EUROCAE ED-237, the system will identify the distress event.

2.3.4 An aeroplane that is declared to be in a distress phase according to Annex 11, Chapter 5, does not necessarily mean that it is in a distress condition as determined by the ADT since the problem may not be related to the physical state of the aeroplane. The location of an aeroplane in distress, as it pertains to ADT, does not primarily consider aeroplanes that are operating within normal parameters, even though the aeroplane status could have entered one of the three emergency phases and requires immediate assistance as defined in Annex 11 (e.g. a hijacking scenario).

2.3.5 An ADT system may be configured to commence transmission or send a warning to the operator when it is identified as likely to enter a distress condition, but before the condition actually occurs. This could be used to ensure that when in that condition, the ADT system will be transmitting.

2.3.6 Example 1 — Distress event detection based on EUROCAE ED-237 criteria

2.3.6.1 One potential way to implement an ADT system would be to use in-flight detection and triggering. Examples of distress conditions include those identified in EUROCAE ED-237:

Scenario 1: Unusual attitude

The conditions may include, but are not limited to, excessive roll, pitch or yaw values and their corresponding rates of change.

Scenario 2: Unusual speed

The conditions may include, but are not limited to, excessive vertical speed, stall condition, low airspeed, overspeed or other speed conditions.

Scenario 3: Collision with terrain

The conditions may include, but are not limited to, high rate of closure to terrain or inappropriate altitude for the current position.

Scenario 4: Total loss of thrust/propulsion on all engines

The parametric data used to define this condition may be engine performance parameters or other parameters that result from loss of thrust.

Note.— Compliance with the specifications in EUROCAE ED-237 is one means of assuring that the criteria will meet the intended function(s) satisfactorily under the specific conditions encountered in distress conditions, as well as under conditions normally encountered in routine aeronautical operations for the environments intended.

2.3.7 Example 2 — Distress event detection with continuous transmission of position

2.3.7.1 An alternative solution might be to implement a system that continuously transmits position and uses distress event detection solely for the purpose of warning the operator in accordance with Appendix 9, 2.2. In that case, the system must ensure that the broadcast starts at commencement of flight (i.e. weight off wheels).

2.3.7.2 The warning triggering logic may operate differently, and it is likely that the delay between the commencement of the distress event and its detection would be different for a system with in-flight triggering. In any case, the detection should occur shortly after the event commences. The fact, however, that this system transmits continuously means that the data for the whole flight would be available. As soon as the warning is received, these data need to be made available to the relevant organizations.

2.3.7.3 The operator should have policies and procedures in place to analyze notifications from the ADT system and determine the proper time to alert the ATSU of a distress condition. Although operators must be careful to avoid false alerts, an early alert from the ATSU to the RCC of a potential situation that can lead to an accident may improve search and rescue efforts towards rescuing potential survivors. More information on operator processes is included in Section 2.6 of this manual.

2.3.8 Nuisance notification

2.3.8.1 A nuisance notification is any notification that is generated by the event detection logic when there is no potential for an accident. Keeping the rate of nuisance notifications low is paramount to maintaining user confidence in the overall system.

2.3.8.2 The process to validate distress event detection can help to reduce the number of nuisance alerts that are passed on to search and rescue services. This is described in 2.6.6 of this manual. On the subject of potential additional nuisance alerts passed on to search and rescue services, experience shows that the rate of nuisance alerts to search and rescue should not exceed more than two per 100 000 flight hours.

2.4 ADT SYSTEM OVERVIEW

2.4.1 General

2.4.1.1 There are two high-level functional objectives for an ADT system. They are to:

a) receive timely notice of an aeroplane in a distress condition to facilitate timely search and rescue operations; and

b) locate an accident site with high probability after a crash based on last known position of the aircraft.

2.4.1.2 ADT functions help flight crews, operators, ATSUs and search and rescue coordination personnel to quickly identify and respond to aeroplanes that are in distress and accurately deploy search and rescue resources.

2.4.1.3 An ADT system is composed of a set of elements organized around providing the functional objectives described above. Many different technological solutions are possible. However, all system architectures will include an airborne segment, an air-ground communications link, ground-based systems and terrestrial communications networks.

2.4.1.4 For the sake of defining functional responsibilities and to generically define requirements that are relevant for any type of ADT system, it is convenient to view the ADT system as two subsystems: the operator ADT subsystem and the information management subsystem. The operator subsystem is further divided into the airborne segment and the ADT service segment. This is illustrated in Figure 2-1.

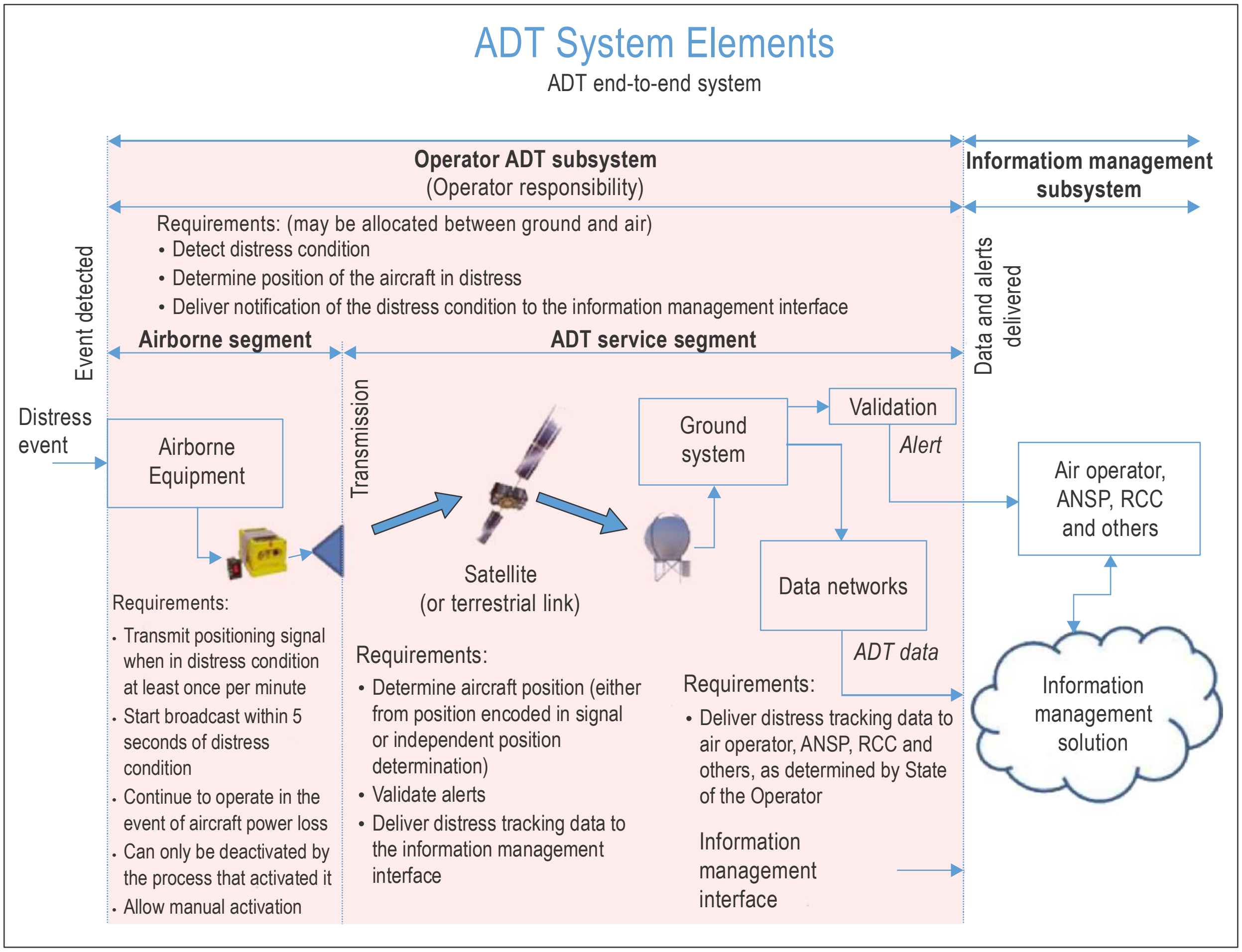

Figure 2-1. ADT System elements

2.4.1.5 The airborne segment, together with the ADT service segment, make up the operator's ADT subsystem. The operator is responsible for the operator ADT subsystem. In a typical system, this would include the aircraft equipment, ground equipment and any processes needed to support the validation of a warning received from the ADT system. This is indicated in Figure 2-1 above as the portion shaded in red.

2.4.1.6 The ADT airborne segment includes the ADT transmitter and any airborne systems that support the ADT function (e.g. systems involved in distress detection, such as attitude sensors).

2.4.1.7 The ADT service segment encompasses everything from the time the transmission leaves the airborne antenna until the time at which the position data and/or warnings are delivered to the interface of the information management subsystem (shown as a cloud in Figure 2-1).

2.4.1.8 One solution could be to establish a centralized distress tracking repository; however, the only requirement from Annex 6, Part I, provisions is for the information to be made available, and other distribution methods might be implemented. It should be noted that, while there may be many ADT solutions for operators, the means for making the information available to ATSUs, RCCs and others, as specified by the State of the Operator, need to be standardized. Work is underway at ICAO to establish a global Standard for the delivery of ADT information (see Section 2.7 of this manual).

2.4.1.9 The requirement to validate the ADT distress event detection is shown within the ADT service segment. As described in Section 2.6.6 of this manual, validation might be an operator process or might be handled by a service provider that uses its own processes to limit the occurrence of false alerts transmitted to search and rescue.

2.4.2 Validation of ADT performance

2.4.2.1 Tracking an aeroplane in distress is the responsibility of the operator. The operator may contract part or all of the ADT functionality out to a third party such as a service provider. In this case, the operator is responsible for evaluating the performance of the system to ensure it meets the requirements of the provisions of Annex 6, Part I.

2.4.2.2 The State of the Operator is responsible for approving the system to be used for tracking an aeroplane in distress. In this approval process, it must be shown that the operator ADT subsystem meets performance and functional requirements. Appendix A to this Chapter provides suggested performance metrics which could be considered when evaluating an ADT system.

2.4.3 Frequency spectrum

2.4.3.1 In order to ensure global interoperability and lawful operation of on-board radio equipment, the equipment will conform to agreed performance standards, will operate in correct frequency bands, must be licensed by appropriate authorities and must be operated by trained flight crew.

2.4.3.2 Table 2-1 lists frequency bands that may be considered for the various categories of functions specified under the GADSS.

Table 2-1. Frequency band use

Function	*Spectrum Category*	*Examples of possible radio services and/or technologies that may comply*
Aircraft tracking	A	Mobile satellite service (MSS) (e.g. Inmarsat, Iridium) Space-based automatic dependent surveillance – broadcast (ADS-B) HF data radio
ATC surveillance systems	B	MSS (automatic dependent surveillance – contract (ADS-C)) ADS-B Secondary surveillance radar (SSR)
Autonomous distress tracking (ADT)	C	MSS (e.g. Inmarsat, Iridium) Space-based ADS-B ELT
Post-end of flight (Focus: rescue and recovery)	C	Aeronautical mobile satellite (AMS) MSS ELT
Post-end of flight (Focus: recovery)	A	ELT

A: Any type of spectrum properly allocated, on a primary basis, to the function being performed.
B: Only a protected aeronautical safety spectrum can be used.
C: Only a protected aeronautical safety spectrum, or protected distress spectrum (e.g. 406.1 MHz), can be used.

Note.— This chart is not intended to imply that any new spectrum allocations are necessary to support the GADSS.

2.5 GENERAL REQUIREMENTS

2.5.1 Some key performance requirements are specified. However, a great deal of flexibility was retained to enable different end-to-end system designs to be employed.

2.5.2 This section will review the general requirements for an ADT system and discuss the ramifications of those requirements.

2.5.3 Although detailed specifications of the system are outside of the scope of this document, it is intended that in order to support the location of an aeroplane in distress, the system should be capable of processing the position information such that it is available for use within a few minutes after transmission from the aeroplane.

2.5.4 Requirement to autonomously transmit during distress condition

2.5.4.1 An important requirement for the ADT system is that it must autonomously transmit information, without the need for flight crew or ground personnel action, from which a position can be determined (by the operator) at least once every minute, when an aircraft is in distress.

2.5.4.2 The term "autonomously" means that no action is required from the flight crew and refers to both the power supply of the ADT equipment and the communication and navigation equipment used to determine and transmit information. For the sake of simplicity, these elements have been split and will be described separately.

Power supply

2.5.4.3 It is intended that ADT can be used to determine the position of an aeroplane in distress using on-board systems in a manner that is resilient to failures of the aeroplane electrical power. No human intervention should be required, and the aeroplane systems should be designed to ensure a high probability of successful ADT transmission, even in the event of equipment failures that may occur when an aeroplane is in a distress condition.

2.5.4.4 In some cases, the most straightforward way to achieve adequate autonomy may be to employ a fully independent power source for ADT that is capable of providing power for the entire flight. Alternatively, airborne ADT systems can make use of primary and backup aeroplane systems. In all cases, the suitability of airborne equipment must be assessed based on the overall system architecture and in view of the resulting impact on end-to-end system reliability.

2.5.4.5 The airborne ADT equipment should transmit at a rate that enables the aeroplane position to be determined at least once per minute for the entire time that the aeroplane is in the distress condition. For a distress condition that ends in an aeroplane accident, the ADT must be able to continue transmitting for the expected duration of the remaining flight, even in the event of aeroplane electrical power loss (as stated in Annex 6, Part I, Appendix 9).

2.5.4.6 Options for powering the ADT system should take into account that the distress condition may vary in length from a few minutes to several hours, and the design solution must ensure that the probability of the ADT system failing to transmit during the distress condition is as low as practicable.

2.5.4.7 The intent of this requirement is to ensure that the availability of the information is maintained during the entire time during which the aeroplane is physically able to continue to fly in the distress condition. Therefore, the period of time during which on-board ADT equipment may need to be self-powered depends on how long the aeroplane can remain airborne after a loss of the power system that the ADT would otherwise be using.

2.5.4.8 For example, if the on-board ADT equipment is connected to the standby power on a fly-by-wire aeroplane, only a short amount of operating time will be required after loss of the standby power. If there were complete loss of all electrical power on board the aeroplane such that the aeroplane would be expected to remain airborne for only a limited amount of time (i.e. minutes), the ADT system would need a power supply capable of providing power for the expected duration of the entire flight (i.e. the remaining few minutes).

Navigation and communication

2.5.4.9 As for the electrical system, the intent of Annex 6, Part I, Standards is to ensure that the ADT system is resilient to failures in communication and navigation equipment. There are a number of ways that this could be accomplished; however, the requirement in all cases is to produce a system that continues to transmit information from which the position may be determined every minute until the end of either the distress condition or the flight.

2.5.4.10 The airborne ADT equipment may be self-contained with its own position and communication functions. Alternatively, it may take navigational position information from the aeroplane's main systems and use other communication systems to transmit this information. In this scenario, it should be noted that failures of these systems due to the distress event should not result in a loss of function of the ADT.

2.5.5 Transmission requirements

2.5.5.1 When in a distress condition, the aeroplane must transmit information from which a position can be determined at least once per minute. In order to meet this requirement, the aeroplane transmissions may or may not be initiated by the triggering criteria discussed in Section 2.3 of this manual. Some systems may transmit at one-minute intervals (or less) at all times, thereby guaranteeing that there will be transmissions during the distress condition.

2.5.5.2 Given that the nature of some distress events may make the reception of transmitted signals difficult or impossible for brief moments, it should be considered that it may be prudent to transmit more regularly than every minute in order to ensure that enough transmissions are received to meet the minimum requirement of one-minute position fixes.

2.5.6 Requirement to commence transmission within five seconds of detection of a distress condition

2.5.6.1 Annex 6, Part I, Appendix 9, 2.2, requires that in case of a triggered transmission system, initial transmission of position information shall commence immediately or no later than five seconds after the detection of the activation event.

2.5.6.2 The reason for this requirement is that a survey of historical accidents has indicated that, in many cases. very little time had passed between the occurrence of the distress event and subsequent crash. A maximum of five seconds between the detection of a distress condition and the first triggered transmission will improve the likelihood that at least one transmission occurs before a crash.

2.5.6.3 In order to meet the requirements, a solution may be to activate the ADT system just before the aeroplane enters the distress condition, thereby ensuring that the transmission will have started as soon as the distress condition is fulfilled.

2.5.6.4 For systems that are transmitting at least once per minute prior to the detection of the distress condition, the existence of a transmission within one minute prior to the accident is ensured; however, the operator must still be notified of the distress condition of the aeroplane.

2.5.7 Requirements for manual activation/notification

The ADT system must also provide a means for the crew to manually activate the airborne ADT components, initiating transmission of information from which position may be determined and/or notification to the operator, as described in Annex 6, Part I, Appendix 9, 2.1. Manual activation by the crew is intended as a means for the crew to ensure that the information is being transmitted if they consider that the aeroplane is, or will shortly be, in a distress condition.

2.5.8 Requirement for deactivation

Once activated, the system can only be deactivated by the same mechanism that activated it. This means that where an ADT transmission is triggered by the in-flight detection of a distress event, for example, only by no longer meeting the criteria of the distress event will the ADT stop transmitting. It cannot, for example, be deactivated manually following an automatic activation. Similarly, a manually activated transmission can only be deactivated manually.

2.5.9 Accuracy requirement

Annex 6, Part I, Appendix 9, 2.6, stipulates that the accuracy of the ADT position information shall, at a minimum, meet the position accuracy requirements established for ELTs. Typically, a GNSS-based position encoded ELT can provide position accuracy within 100 m.

2.5.10 Time stamp requirement

2.5.10.1 Annex 6, Part I, Appendix 9, 2.1, requires that the position information (determined by the operator) shall contain a time stamp. The time reported in the time stamp should be the time when the aeroplane was at the position determined from the transmitted information.

2.5.10.2 This is a total system requirement that may impact the on-board equipment in different ways depending on the ADT system architecture and technology used. The time of transmission may be determined in a variety of ways. In some system designs, the transmitted messages will include explicit time stamp information indicating the time at which the indicated position was determined. In other cases, the time stamp may be added by systems other than the airborne equipment (e.g. space-based independent location determination in the new COSPAS-SARSAT Medium Earth Orbit SAR (MEOSAR) system). The most important requirement is that the overall ADT system must produce at least two-dimensional plus time position fixes (i.e. latitude, longitude and time).

2.6 OPERATOR PROCESSES

2.6.1 The operator process begins when the operator receives notification of a distress condition.

2.6.2 Annex 6, Part I, 4.6.1, requires the flight operations officer/flight dispatcher to notify the appropriate ATSU when the position of the aeroplane cannot be determined by an aeroplane tracking capability and when attempts to establish communication are unsuccessful. Additionally, Appendix 9, 2.3, requires the operator to contact the ATSU when it has reason to believe that an aeroplane is in distress. In such case, the operator should use the contact directory service, which has been established to facilitate communication between operators and ATSUs.

2.6.3 A review of the typical sequence of events before and after the ATSU declaration/escalation of an emergency phase is useful to highlight the importance of early ATSU and/or operator identification of aircraft experiencing distress events.

2.6.4 Operator activities related to the identification of an aeroplane that is potentially in distress are undertaken by the operator in addition to and to supplement the actions taken by an ATSU or flight crew, in accordance with Annex 2 — *Rules of the Air*, Annex 6 and Annex 11, as applicable.

2.6.5 Responsibilities, duties and tasks of operational control personnel

2.6.5.1 Annex 6, Part I, provisions define the distress monitoring responsibilities that are to be assigned to flight operations officers/flight dispatchers, if they are used, in conjunction with a method of control and supervision of flight operations. For operators using flight operations officers/flight dispatchers, the following SARPs define responsibilities related to distress situations:

a) Paragraph 3.1.5 states: "If an emergency situation which endangers the safety of the aeroplane or persons becomes known first to the flight operations officer/flight dispatcher, action by that person in accordance with 4.6.2 shall include, where necessary, notification to the appropriate authorities of the nature of the situation without delay, and requests for assistance if required";

b) Paragraph 4.6.1 states: "A flight operations officer/flight dispatcher in conjunction with a method of control and supervision of flight operations in accordance with 4.2.1.3 shall […] notify the appropriate ATS unit when the position of the aeroplane cannot be determined by an aeroplane tracking capability, and attempts to establish communication are unsuccessful";

c) Paragraph 4.6.2 states: "In the event of an emergency, a flight operations officer/flight dispatcher shall: a) initiate such procedures as outlined in the operations manual while avoiding taking any action that would conflict with ATC procedures; and b) convey safety-related information to the pilot-in-command that may be necessary for the safe conduct of the flight, including information related to any amendments to the flight plan that become necessary in the course of the flight."

2.6.5.2 In addition to the aforementioned SARPs, Annex 11 contains SARPs that address coordination between operators and ATSUs from an ATSU perspective. In order to support such coordination, operators need to assign the responsibilities to do so to appropriately qualified individuals. They should respond to requests for information from ATSUs and obtain information from a relevant ATSU when needed (to fulfil monitoring requirements).

2.6.5.3 Such coordination can be accomplished by a flight operations officer or an appropriately qualified individual, as applicable. In either case, appropriate coordination is fundamental to support ATSU alerting and RCC coordination activities.

2.6.6 Validation of a distress event

2.6.6.1 The validation of a distress event is required by the operator; however, the operator may outsource validation to an ADT service provider. In this case, it is the ADT service provider that implements its own processes to ensure that false alerts to search and rescue are kept to acceptably low levels.

2.6.6.2 The current operator systems that allow for operator validation of an aeroplane experiencing a distress event predominantly rely on communication with the flight crew through either voice or data communications. A number of aeroplane systems may be available to determine the operational state of a flight, including VHF, HF and SATCOM voice or data communication. Other existing communication and data-gathering technologies associated with the aircraft tracking capability of an operator can also be leveraged to provide actionable information or data.

2.6.6.3 Attempts to communicate with the aeroplane should begin immediately; the time it takes to communicate with the aeroplane is a key factor to be considered by operators when developing policies and procedures. Operators with access to rapid and reliable communications systems will, for example, be able to determine the operational state of an aeroplane much faster than those with less developed communication capabilities. The operator's procedure for validating a distress event should therefore take into account the operator's capability to communicate with its aeroplanes. The operator may also determine when the assistance and support of a relevant ATSU is required to determine the operational state of an aeroplane.

2.6.7 ATSU notification and coordination

2.6.7.1 When a distress event is validated by the operator, or the operational state of the aeroplane cannot be determined, the operator contacts the relevant ATSU(s) using the latest known position and expected track of the aeroplane. The operator may use the contact directory service for obtaining the ATSU identification (ID) and point of contact. Once the operator has contacted the ATSU and it is established that there may be an emergency, the operator must ensure that all information that may be of use to the ATSU and/or RCC is available on request, including all aeroplane tracking information.

2.6.7.2 As soon as the operator is made aware that the aeroplane has resumed normal operations or has safely landed, the operator should notify the ATSU that the aeroplane's distress condition has been cancelled.

2.6.8 Activation of aeroplane operator contingency procedures

Once it is confirmed that the aeroplane is in a distress situation, the operator should activate its contingency procedures and maintain close coordination with the ATSU until the distress event is resolved.

2.6.9 Availability of data

The operator must ensure that the data received from the ADT system are made available to appropriate organizations, as identified by the State of the Operator. If the distress event results in an accident or serious incident, retention of the data is governed by the requirements of Annex 13 — *Aircraft Accident and Incident Investigation*. If the aeroplane recovers and lands safely, there may be no requirement to retain the data. However, it may be useful to retain these data for a given period of time (e.g. 30 days). This may also be required by the State, as described in its national regulations.

2.7 ADT INFORMATION MANAGEMENT

2.7.1 ADT data need to be managed and distributed. There are many solutions to do so; however, the preferred option relies on the use of a distress tracking repository (DTR), which is a centrally managed facility that would function as a single point of access to the ADT position data.

2.7.2 The essential functions of a DTR would include the ability to:

a) enable contributors (e.g. ADT system operators) to submit position data to the repository;

b) store the data for a predetermined interval (e.g. 30 days); and

c) access the position data when required (by registered users).

2.7.3 Detailed requirements for such a DTR need to be defined. The latest information regarding these specifications can be found on the ICAO website at www.icao.int/safety/globaltracking/Pages/Homepage.aspx.

2.8 ATSU PROCESSES

2.8.1 Existing processes as described in Annex 11 are still applicable. The introduction of distress tracking does not alter these processes except with regards to the availability of additional data on the position of the aeroplane.

2.8.2 When an ATSU has reason to believe that an aeroplane is in distress, coordination will be established between the ATSU and operator. Flight crews of flights operating under instrument flight rules (IFR) flight plans would advise ATC as soon as a distress or unusual situation is detected on board.

2.8.3 The current adopted ATC emergency phases (as specified in Annex 11, 5.2) are as follows:

a) *Uncertainty phase* when:

1) no communication has been received from an aircraft within thirty minutes after the time a communication should have been received from an aeroplane, or from the time an unsuccessful attempt to establish communication with such aeroplane was first made, whichever is the earlier, or when

2) an aircraft fails to arrive within thirty minutes of the estimated time of arrival last notified to or estimated by air traffic services units, whichever is the later,

except when no doubt exists as to the safety of the aircraft and its occupants.

b) *Alert phase* when:

1) following the uncertainty phase, subsequent attempts to establish communication with the aircraft or inquiries to other relevant sources have failed to reveal any news of the aircraft, or when

2) an aircraft has been cleared to land and fails to land within five minutes of the estimated time of landing and communication has not been re-established with the aircraft, or when

3) information indicates that the operating efficiency of the aeroplane is impaired, but not to the extent that a forced landing is likely,

except when evidence exists that would allay apprehension as to the safety of the aircraft and its occupants, or when

4) an aircraft is known or believed to be the subject of unlawful interference.

c) *Distress phase* when:

1) following the alert phase, further unsuccessful attempts to establish communication with the aircraft and more widespread unsuccessful inquiries point to the probability that the aircraft is in distress, or when

2) the fuel on board is considered to be exhausted or insufficient for aeroplane to reach safety, or when

3) information is received which indicates that the operating efficiency of the aeroplane is impaired to the extent that a forced landing is likely, or when

4) information is received or it is reasonably certain that the aeroplane is about to make or has made a forced landing,

except when there is reasonable certainty that the aircraft and its occupants are not threatened by grave and imminent danger and do not require immediate assistance.

2.8.4 If the above information or event is received or detected by ATC, a confirmation attempt would follow, confirming, escalating or terminating the emergency phase. During the distress phase, the information, including known coordinates, would be relayed via operational hierarchy to the appropriate RCC for further action.

2.9 RCC PROCESSES

2.9.1 The RCC will greatly benefit from ADT, which enables the timely detection of an aeroplane in distress and provides the last known location of the aeroplane. Current RCC processes are established under the provisions of Annex 11 and Annex 12 — *Search and Rescue*, and apply to aeronautical RCCs (ARCCs). The International Convention on Maritime Search and Rescue establishes a global maritime search and rescue system applicable to maritime RCCs (MRCCs). To ensure close coordination between aeronautical and maritime search and rescue services, States are expected to either establish joint RCCs (JRCCs) or ensure the closest practicable coordination between ARCCs and MRCCs.

Note.— In this manual, the term "RCC" will be used to apply to either an ARCC or MRCC.

2.9.2 Although the ADT process is new, it is anticipated that the alerting process for the RCC will not fundamentally change.

2.9.3 The distress alert notification processes associated with ADT, based on Annex 11, Chapter 5, can be summarized as follows:

a) if an ATSU detects an aeroplane in distress, it will notify the RCC and operator;

b) if the operator detects an aeroplane in distress, it will notify the ATSU, which will in turn notify the RCC; and

c) if an ELT is activated, the RCC will be notified via the COSPAS-SARSAT system and will subsequently notify the ATSU.

2.9.4 As specified in Annex 11, Chapter 5, the ATSU is expected to notify the RCC immediately when an aeroplane is considered to be in a state of emergency. In addition, the notification is expected to contain as much information as is available. Such information, listed in Chapter 5, closely aligns with the contents of the *Missed 4D/15 Position Report Form for Operator*, which the operator should provide when notifying the ATSU, as indicated in Circular 347, Chapter 8, "Operator Missed Reports Notification to ATS Unit".

2.9.5 Once notified of a distress event, the RCC will initiate action based on the preparatory measures and operating procedures set forth in Annex 12. With regard to preparatory measures, the RCC is required to have readily available at all times up-to-date information concerning its search and rescue region, including ATSUs and addresses and telephone numbers of all operators, or their designated representatives, engaged in operations in the region.

2.9.6 If the ATSU was not the notification source, the RCC should contact the ATSU to confirm the possible distress event and have the ATSU gather further information, which would be the list of information in Annex 11 and the most recent 4D aeroplane position data leading up to the ADT activation. These actions are taken concurrently as the RCC immediately initiates search and rescue actions. When the information concerning the emergency is received from another source, such as the ELT alert sent directly to the RCC via the COSPAS-SARSAT system, the RCC will notify the associated ATSU and also notify the operator, where possible, and keep the operator informed of all developments.

2.9.7 The responsible RCC and associated ATSU serving the flight information region (FIR) in which the aeroplane is operating coordinate their activities and work closely together. The RCC is expected to provide the ATSU with information on the planned search and rescue actions initiated by the RCC so that such information can be passed on to the aeroplane.

2.9.8 If the aeroplane in distress continues in flight and crosses into another or multiple other search and rescue region(s), the first RCC originally notified will contact and coordinate with the other RCC(s) to decide which RCC will be responsible for coordinating the search and rescue operation. If coordination is handed off to another RCC, then its associated ATSU would be expected to support that RCC.

2.9.9 The RCC and ATSU will keep each other informed as to changes in the emergency phase after the initial declaration and as to whether the aeroplane has resumed normal operations or has safely landed, and, as soon as practicable, notify the operator concerned.

Appendix A to Chapter 2

OPERATOR ADT SUBSYSTEM PERFORMANCE METRICS

1. Performance metrics may have to be quantified to assess the suitability of an ADT system.

2. No specific quantitative requirements have been defined for these performance requirements. However, in order to assess the overall operator end-to-end system performance, these performance requirements will need to be known:

a) Pr (failure to transmit): Probability that the airborne segment fails to perform the intended function of transmitting while the aeroplane is in a distress condition;

b) Pr (transmitting corrupt, erroneous or missing data): Probability that the airborne system does transmit at the appropriate time, but that the data in the transmission are incorrect or corrupted;

c) Pr (failure to detect distress condition): Probability that a distress condition exists but is not properly detected;

d) Pr (message loss): Pr (message is received and detected as corrupt) + Pr (message not received);

e) Message latency: Total time between the aeroplane transmission and delivery of position data to the ADT information management system;

f) Integrity: 1- Pr (undetected corrupted message);

g) Service availability: $(T_{total}-T_{out\_of\_service})/T_{total}$

Where $T_{out\_of\_service}$ = total time that the system is unable to perform its intended function;

h) Service continuity: 1-Pr (system stops working in a given time interval during which it was expected to be available);

i) Pr (service generated false warning): Probability that an indication of a distress condition is delivered to the ADT information management system when no distress condition was indicated by the airborne transmissions;

j) Pr (successful function): Pr (message is received uncorrupted | aeroplane was in distress);

k) Total system warning latency: Time between distress event detection and ADT being available in the ADT information management system;

l) Total system data latency: Time between distress event detection and delivery of position data and/or warning to the information management interface; and

m) Pr (false warning): Probability that an indication of a distress condition is delivered to the information management interface when no distress condition existed.

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Chapter 3

GUIDANCE FOR FLIGHT RECORDER DATA RECOVERY

3.1 INTRODUCTION

3.1.1 This chapter provides guidance aimed at helping States to incorporate ICAO SARPs on flight recorder data recovery into their national regulations. The primary principle discussed is the necessity for and means of compliance with national regulations on flight recorder data recovery capability.

3.1.2 The solutions satisfying the purpose of flight recorder data recovery are not limited to those described in this document. These solutions are often called “acceptable means of compliance” when they adhere to national regulations. However, States or national authorities approve any means of compliance for operators’ equipment and procedures that are put into place and ensure compliance with national regulations.

3.2 STANDARDS AND PROVISIONS

3.2.1 Annex 6, Part I, contains the following Standards:

6.3.6 Flight recorder data recovery

> 6.3.6.1 All aeroplanes of a maximum certificated take-off mass of over 27 000 kg and authorized to carry more than nineteen passengers for which the application for type certification is submitted to a Contracting State on or after 1 January 2021, shall be equipped with a means approved by the State of the Operator, to recover flight recorder data and make it available in a timely manner.
>
> 6.3.6.2 In approving the means to make flight recorder data available in a timely manner, the State of the Operator shall take into account the following:
>
> a) the capabilities of the operator;
>
> b) overall capability of the aeroplane and its systems as certified by the State of Design;
>
> c) the reliability of the means to recover the appropriate CVR channels and appropriate FDR data; and
>
> d) specific mitigation measures.
>
> *Note.— Guidance on approving the means to make flight recorder data available in a timely manner is contained in the* Manual on Location of Aircraft in Distress and Flight Recorder Data Recovery *(Doc 10054)*.

3.3 GENERAL PRINCIPLES

3.3.1 Intent of the Standards

3.3.1.1 The intent of the Standards of Annex 6, Part I, Section 6.3.6, is to ensure that flight recorder data are recovered and made available in a timely manner after an accident.

3.3.1.2 The objective of recovering flight recorder data in a timely manner is to enable and support the early identification of safety issues and avoid accident investigation delays due to prolonged search operations. The availability of flight recorder data soon after an accident, with enough information to provide an indication of what events may have led to the accident, is crucial for the early identification of safety issues and the implementation of appropriate preventative safety actions.

3.3.1.3 The timely recovery of flight recorder data would also facilitate the location of accident sites and consequently shorten the duration of any subsequent underwater search and recovery that may be required. Appendix A to this Chapter lists past underwater recovery operations for aeroplanes of more than 15 tons in commercial air transport flights. The timely recovery of flight recorder data may also make the retrieval of wreckage and fixed flight recorders unnecessary for accident investigation purposes.

3.3.2 Definition of "timely recovery"

3.3.2.1 Timely recovery means as soon as possible for a specific situation.

3.3.2.2 It is not possible to define a maximum duration because the recovery time frame is a function of the specific situation, technology used and circumstances of the accident.

3.3.2.3 However, the timely recovery of data should not require search and rescue capabilities and investigation capabilities beyond those recommended in ICAO's Annexes; the need for authorities to rely on non-conventional and expensive means to recover data should therefore be generally limited.

3.3.2.4 Flight recorder data must be recovered and made available to the appropriate AIA without unnecessary delays (e.g. delays due to technical, legal, authorization-related or personnel-related issues).

3.3.3 Definition of flight recorder data

3.3.3.1 According to the definitions in Annex 6, Part I, Chapter 1, the term "flight recorder" refers to "any type of recorder installed in the aircraft for the purpose of complementing accident/incident investigation." In addition, Note 1 in Section 6.3, on flight recorders, indicates that crash-protected flight recorders comprise one or more of the following systems: a flight data recorder (FDR), a cockpit voice recorder (CVR), an airborne image recorder (AIR) and a data link recorder (DLR). It also states that image and data link information may be recorded on either the CVR or the FDR.

3.3.3.2 Standard 6.3.6.1 is applicable to aeroplanes with a maximum certificated take-off mass of over 27 000 kg. The flight recorder data referred to in this Standard should be understood as the data to be recorded by all crash-protected recorders required to be installed according to the Standards of Section 6.3. Such data include the parameters specified for FDRs, the audio channels specified for CVRs, data-link communications messages specified for DLRs and the images specified for AIRs, as indicated in Section 6.3.

3.3.3.3 However, "flight recorder data recovery" does not imply that these data must be retrieved from the memories of the flight recorders; it is sufficient if these data are the same as the data sent to the flight recorders.

3.3.4 Data set to recover

The system for the timely recovery of flight recorder data has to provide, at a minimum, the data from the time the aeroplane enters the distress conditions to the end of the flight. Also, to the extent possible, historical data prior to the time the flight enters the distress conditions should be provided with the most recent data being given the highest priority. Nevertheless, the objective is to recover the complete contents of flight recorder data, as defined in Annex 6, Part I, Section 6.3, in a timely manner.

Data from flight data recorders (FDRs)

3.3.4.1 The required FDR parameters to be recorded, as listed in Annex 6, Part I, Appendix 8, Table A8-1, depend on the date of the individual certificate of airworthiness of each aeroplane and are listed in Standards of Section 6.3.1 on flight data recorders and aircraft data recording systems.

3.3.4.2 The objective is to recover, in a timely manner, the complete set of required FDR parameters for the duration as defined in Standard 6.3.1.3 (the last 25 hours of operation).

3.3.4.3 The required FDR parameters to be recorded, as listed in Table A8-1, have been established based on accident investigation experience accumulated since the 1960s. Most parameters in this list have been subject to specific safety recommendations. This list is kept up-to-date to reflect evolving aviation technology.

Data from cockpit voice recorders (CVRs)

3.3.4.4 The requirements for CVR audio to be recorded on a flight recorder are detailed in the Standards of Section 6.3.2, on cockpit voice recorders and cockpit audio recording systems.

3.3.4.5 The objective is to recover, in a timely manner, the complete contents of CVR audio as defined in the Standards of Section 6.3.2, for the duration as defined in Standard 6.3.2.3 (the last 25 hours of operation).

Data from data link recorders (DLRs)

3.3.4.6 The requirements for DLR messages to be recorded on a flight recorder are detailed in the Standards of Section 6.3.3, on data link recorders.

3.3.4.7 The objective is to recover, in a timely manner, the complete contents of DLR recordings as defined in the Standards of Section 6.3.3, for the duration as defined in Standard 6.3.3.2 (the last 25 hours of operation).

Data from airborne image recorders (AIRs)

3.3.4.8 The requirements for flight crew-machine interface recordings to be recorded on a flight recorder are detailed in Section 6.3.4 and Appendix 8, Section 6. These requirements may be complied with either by data recorded on an FDR or data recorded on an AIR, which would implicate different levels of protection of the FDR data in relation to the AIR data.

3.3.4.9 The objective is to recover, in a timely manner, the complete contents of the flight crew-machine interface recordings as defined in the Standards of Section 6.3.4, for the duration as defined in Standard 6.3.4.2 (the last two hours of operation).

3.3.5 Description of the means approved by the State of the Operator

3.3.5.1 The State of the Operator may complement its regulations on the timely recovery of flight recorder data with appropriate acceptable means of compliance and guidance material/advisory circulars. In order to achieve global harmonization, such material should be established in line with ICAO Standards and this manual. The Standards of Annex 6, Part I, Section 6.3.6 are performance-based; therefore, States approving means for the timely recovery of flight recorder data should understand the overall objectives of the Standards as well as the desired overall system performance. The overall system performance of the means to be approved by the State of the Operator must be understood and assessed relative to those performance standards and objectives.

3.3.5.2 Section 3.4 of this document provides some solutions that may be considered as examples of acceptable means of compliance with regulations requiring timely recovery of flight recorder data.

3.3.5.3 Due to the anticipated complexity, it is expected that the design of the modification will be performed by aircraft manufacturers or by maintenance, repair and overhaul (MRO) companies. In such cases, the authorization of the design and its airworthiness approval will be granted by airworthiness authorities of the State of Design. The authorization by the State of Design should include details of operational provision and capabilities utilized to comply with the Standards of Annex 6, Part I, Section 6.3.6.

3.3.5.4 Installation of the equipment will be performed by persons acceptable to the State of Registry. The State of Registry will need to approve the installation, including instructions for operation and continued airworthiness.

3.3.5.5 The State of the Operator should be in the position to validate the adequacy of the system's performance in accordance with the authorization provided by the State of Design. When applying for approval by the State of the Operator, the operator should be able to reference documentation showing that the performance of the system, in conjunction with the policies and procedures for use of the system by the operator, will meet the performance objectives consistent with the Standards and applicable State regulations.

Note.— It must be demonstrated that, in addition to being airworthy, the equipment meets its intended function when used in accordance with the policies and procedures adopted by the operator.

3.3.6 Description of operator capabilities

3.3.6.1 The operator should establish policies and procedures regarding the operation of the system intended for the timely recovery of flight recorder data. The policies and procedures should specify how the data will be protected and provided to the AIA in charge of the investigation. In addition, the policies and procedures should cover the normal operation and maintenance of the system or systems to support timely recovery of flight recorder data. If services are involved, the operator should be able to reference service agreements and performance specifications, as necessary.

3.3.6.2 Where the flight recorder data recovery system includes transmission from the aeroplane, the policies and procedures should include, at a minimum:

a) contracting minimum performance standards and quality of service (availability of services, advance notification of outages, and geographical coverage of planned, alternative and emergency flight routes);

b) data-capturing procedures ensuring the protection and integrity of information;

c) data retention and access control; and

d) agreement on principles for granting the AIA in charge of the investigation access to the data.

3.3.6.3 The operator should establish the end-to-end performance of the flight recorder data recovery system. Such performance assessment should include the quantification of the availability and integrity of the recorded data and accessibility of the data by the AIA in charge of the investigation. The technical information regarding availability, integrity and accessibility is detailed in this document.

3.3.6.4 According to the Standards of Annex 6, Part I, when using third parties for the conduct of flight recorder data recovery, the operator should develop policies and procedures for third parties that perform work on its behalf.

3.3.6.5 Flight recorders contain sensitive information; access should therefore be subject to restrictions. Provisions on the use and protection of investigation records and related sources during accident and incident investigations are included in Annex 13. Provisions on the use of safety data and safety information as part of the safety management system are included in Annex 19 — *Safety Management*. In particular, CVR audio data and AIR image data are protected because of their privacy content. Transmitting such information to unauthorized parties may infringe on national legislation and regulations. It is therefore strongly recommended to take due account of these restrictions when using flight recorder data recovery for the ADT function.

3.3.7 Flight recorder data recovery system used for the ADT function

The ADT function is used to determine the location of an aeroplane in distress. The flight recorder data recovery means may also be used for the purpose of locating an aeroplane in distress provided that the applicable provisions of Annex 6, Part I, are complied with.

3.3.8 End users of flight recorder data recovered after an accident or incident

3.3.8.1 Annexes 6 and 13 specify that flight recorders are installed in the aeroplane for the purpose of conducting accident and incident investigations. Hence, the end user of the flight recorder data recovered after an accident or incident is the AIA of the State conducting the investigation. It should be noted that Annex 13, 3.2, states: "[a] State shall establish an accident investigation authority that is independent from State aviation authorities and other entities that could interfere with the conduct or objectivity of an investigation."

3.3.8.2 Annex 13 stipulates that, when an accident or incident occurs, the State of Occurrence shall institute an investigation into the circumstances of the accident or serious incident and be responsible for the conduct of the investigation.

3.3.8.3 In addition, Annex 13 specifies that the State conducting the investigation shall arrange for the read-out of the flight recorders without delay. When investigating an accident or incident, the investigator-in-charge of the AIA of the State of Occurrence is responsible for obtaining and effectively using the flight recorder data. Any State, on request from the State conducting the investigation, will furnish the latter State with the flight recorder data and any other relevant material.

3.3.9 Description of the overall capability of the aeroplane and its systems

3.3.9.1 There are at least two categories of solutions meeting the Standards of Annex 6, Part I, 6.3.6. These categories are:

a) to recover flight recorder data in addition to the fixed flight recorders (e.g. through satellite transmission); and

b) to use a flight recorder that complies with the basic requirements of flight recorders but, at the same time, complies with the requirements of flight recorder data recovery (e.g. automatic deployable flight recorder).

3.3.9.2 The reliability and serviceability of the flight recorder data recovery system installed on the aeroplane is not expected to exceed the reliability and serviceability of operating the fixed crash-protected flight recorder system.

3.3.9.3 There are specific objectives related to the individual solutions, as explained in Section 3.4 of this document.

3.3.10 Robustness of the power supply

3.3.10.1 The robustness of the power supply for the flight recorder data recovery system installed on the aeroplane is expected to be of the same level as for operation of the fixed crash-protected flight recorder system. The alternate power source for the CVR does not apply to the flight recorder data recovery system.

3.3.10.2 Guidance may be taken from Annex 6, Part I, Appendix 8, 1.5, which states:

> 1.5 The flight recorder systems shall be installed so that they receive electrical power from a bus that provides the maximum reliability for operation of the flight recorder systems without jeopardizing service to essential or emergency loads.

3.3.11 Tamper resistance

There are no ICAO provisions for the tamper resistance of fixed crash-protected flight recorders. The tamper resistance of the flight recorder data recovery system installed on the aeroplane is expected to be of the same level as for operation of the fixed flight recorder system. In addition, these fixed flight recorders are clearly identified with their part numbers and serial numbers. The traceability procedures in place at the level of the operator in combination with the measures related to the protection of evidence set up by the AIA (and often by the judicial authorities) represent de facto tamper resistance provisions.

3.3.12 Evaluation of specific mitigation measures

3.3.12.1 Where real-time transmission of flight recorder data is used in a flight data monitoring programme that may reduce the probability of an accident, it is expected that this capability should be included in the evaluation of the overall capabilities.

3.3.12.2 In approving the means for making flight recorder data available in a timely manner, the State of the Operator shall take into account the operator's specific mitigation measures after the criteria listed in Annex 6, Part I, Standard 6.3.6.2 a), b) and c) have been exhausted. However, there are other means of compliance that the operator may implement to obtain the approval of the State of the Operator. These would be considered as "specific mitigation measures". An example would be if the operator's capabilities are lacking. There might be other means that the operator is able to implement to obtain the approval of the State of the Operator.

3.4 EXAMPLES OF TECHNOLOGIES

This section provides a few examples of technologies that can be used to satisfy Annex 6, Part I, 6.3.6. The purpose of this section is not to indicate preferences between various technologies, but rather to illustrate how the recommendations in this document could be addressed. It should also be noted that these technologies are not mutually exclusive and could be combined to address these recommendations.

3.4.1 Automatic deployable flight recorder (ADFR)

3.4.1.1 An automatic deployable flight recorder (ADFR) may be used to satisfy Annex 6, Part I, 6.3.6. Requirements can be found in Appendix 8, under the sections on general requirements and ADFR operation. Technical specifications for the design and installation are provided in EUROCAE ED-112A (or the latest version), which also includes a determination of deployment cases.

3.4.1.2 An ADFR unit contains memory media for the storage of the required flight recorder data as defined by the Standards of Annex 6, Part I, 6.3, and storage of other optional data.

3.4.1.3 An ADFR is designed to be deployed upon the detection of impact or water immersion. It is designed to separate from the zone of exposure effects (e.g. fire) and to float (the unit is buoyant).

3.4.1.4 The trigger logic of the deployment event is fully autonomous; i.e. there are no manual capabilities for disabling or activating the triggers.

3.4.1.5 The deployed unit also contains an integrated ELT, which is designed to be activated simultaneously with the deployment. Subsequently, the ELT transmits an emergency signal with aeroplane position information to enable search and rescue teams to locate the accident site and rescue potential survivors. The transmission of emergency signals, including the location, will be updated continuously for a period of time. These frequent updates of the actual location enable tracking of the buoyant unit as it drifts. This tracking information will provide significant information, including drift over time, to aid in the location and recovery of potential survivors, assuming they will drift along the same course.

3.4.1.6 Finally, an ADFR unit may be located and recovered by the team of the AIA looking for the flight recorder data even if, historically, search and rescue authorities have recovered the ADFRs. The retrieval of the unit will be supported by search features such as a homing radio at 121.5 MHz and at 406 MHz with GNSS-based location information, the painted colour (one side is bright orange) and its reflective material.

3.4.1.7 An accident investigation and root cause analysis may be launched immediately after the ADFR unit has been found and its flight recorder data have been retrieved. It is assumed that the ADFR unit could be found during the same time period as the search and rescue mission (approximately 150 hours or 6 days).

3.4.2 Continuous transmission of flight recorder data to the ground

3.4.2.1 Continuous transmission of flight data for performance and health monitoring may be implemented, alone or in combination with other technologies, to satisfy Annex 6, Part I, 6.3.6. Continuous flight data transmission can significantly improve the probability of identifying critical anomalies early on, and can enable ground-based engineers and experts to render assistance to the flight crew experiencing an anomaly. Continuous flight data transmission also could enable the creation of a repository for flight data, which can be used by the original equipment manufacturer (OEM), MRO engineers and accident investigators to identify threats to continued fleet operations prior to an incident taking place.

3.4.2.2 In the event of an accident, the same repository can be used to identify historical trends that may assist accident investigators in reconstructing the chain of events that led to the accident and in identifying other aircraft which may exhibit anomalies similar to those of the accident flight. Flight data transmission repositories can be accessed immediately to identify potential safety and security threats, not relying exclusively on the recovery of the fixed flight recorders.

3.4.2.3 The flight recorder data transmission system includes memory media to buffer (store) real-time flight recorder data for later transmission should any interruption in connectivity occur (e.g. insufficient bandwidth, loss of link), as illustrated in Figure 3-1. Data is buffered during a connectivity interruption and when connectivity is re-established, until transmission can resume in real time (without buffering). Once connectivity is re-established, transmission of buffered data will have priority over transmission of data in real time.

3.4.2.4 The system is not required to be crash-protected as it operates continuously prior to the end of flight and is not required to operate after an accident. Flight recorder data transmission is expected to start automatically when the fixed flight recorders start recording, and the flight recorder data transmission terminates when the fixed flight data recorders stop recording. The manual activation and disabling of flight data transmission is not expected to be necessary except for the purpose of testing the system's functioning and for fault isolation.

3.4.3 Triggered transmission of flight recorder data to the ground

3.4.3.1 Triggered transmission of flight recorder data may be implemented to satisfy Annex 6, Part I, 6.3.6. The trigger logic for determining a distress event is automatic. Flight recorder data transmission offers a nearly immediate cache of data, which can be used by the AIA to assess the near-term threat to continued fleet operations, without having to recover the fixed flight recorders.

3.4.3.2 The flight recorder data transmission system includes memory media for buffering flight recorder data for the purposes of:

a) transmitting buffered real-time data (after the distress event) for later transmission should any interruption in connectivity occur, as illustrated in Figure 3-2; and

b) transmitting buffered real-time data prior to the distress event (referred to as "buffered historical data"), as illustrated in Figure 3-3.

3.4.3.3 Flight recorder data after the distress event are buffered during a connectivity interruption and when connectivity is re-established, until transmission can resume in real time (without buffering). Since historical data are already buffered, it does not require any additional buffering during the connectivity interruption. Once connectivity is re-established, the transmission of buffered data after the distress event will have priority over the transmission of data in real time and buffered historical data.

3.4.3.4 Flight recorder data are buffered prior to a distress event (trigger) to enable the transmission of data in real time and buffered historical data if a distress event is detected. Once the distress event is detected, the transmission of data in real time and transmission of buffered historical data occur in the order of priority discussed in 3.6.10.7 of this document. The memory media should accommodate a minimum of 20 minutes of buffered historical data.

3.4.3.5 The system is not required to be crash-protected as it operates prior to the end of flight and is not required to operate after an accident. The manual activation and disabling of flight data transmission is not expected to be necessary except for the purpose of testing the system's functioning and for fault isolation.

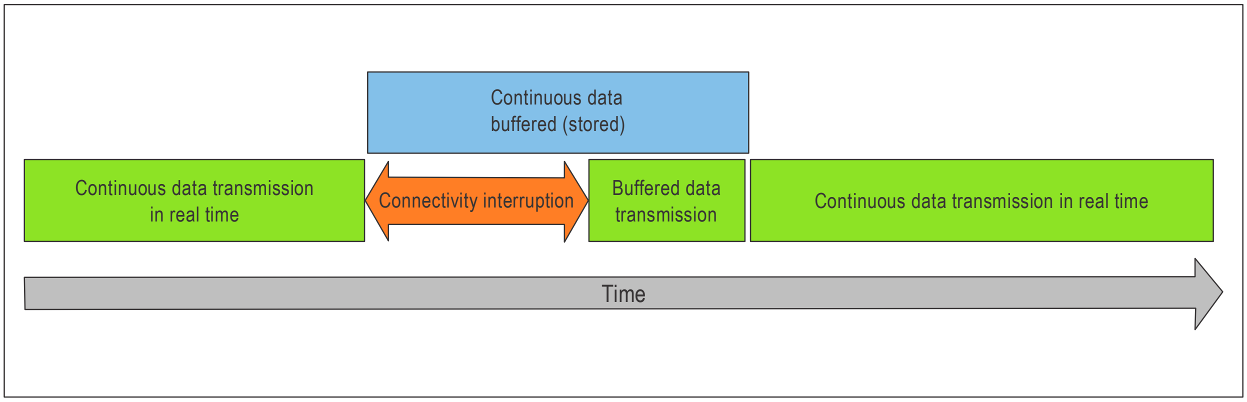

Figure 3-1. Buffering of continuous data in case of connectivity interruption

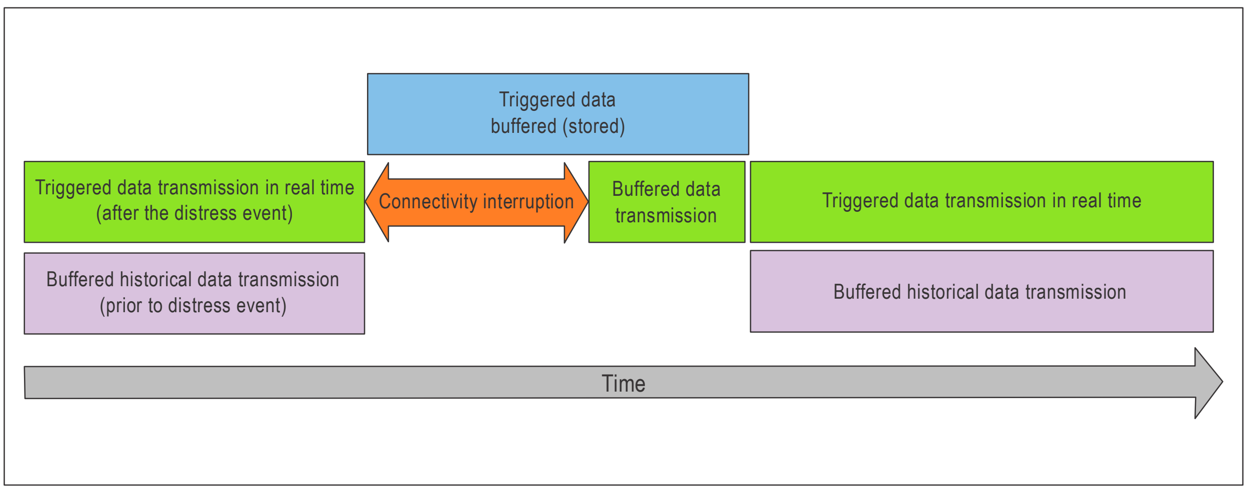

Figure 3-2. Buffering of triggered data in case of connectivity interruption

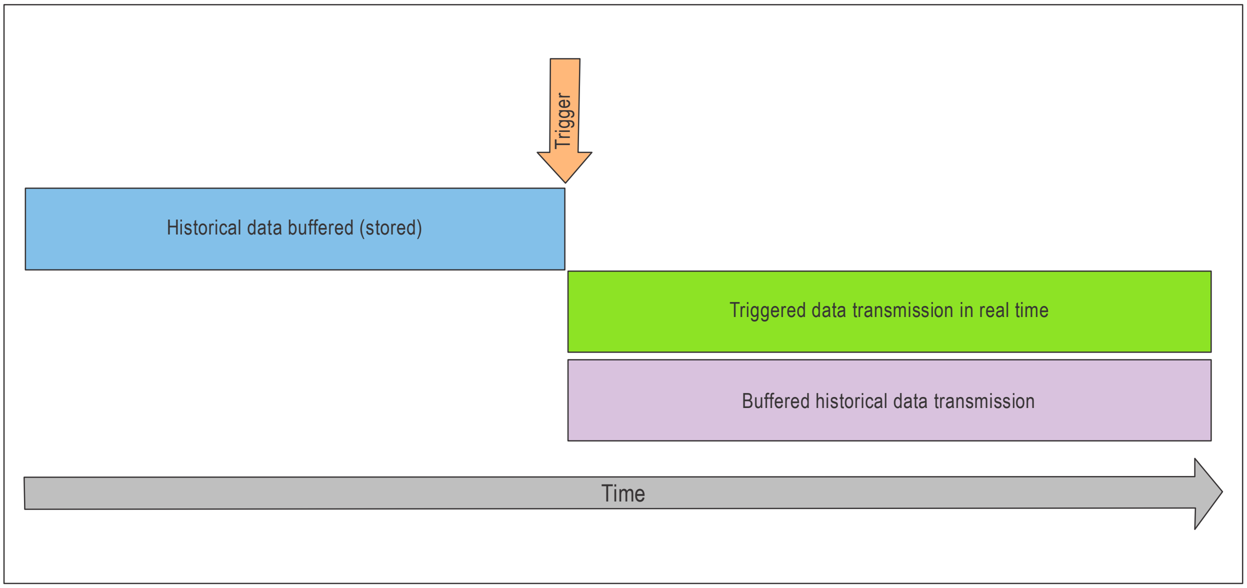

Figure 3-3. Buffering of historical data

3.4.4 Additional means of compliance

It should be understood that other solutions may also provide capabilities sufficient to satisfy the purpose of Annex 6, Part I, 6.3.6.1.

3.5 AUTOMATIC DEPLOYABLE FLIGHT RECORDER (ADFR)

The specifications applicable to ADFRs are detailed in EUROCAE ED-112A on crash-protected airborne recorder systems.

3.5.1 Equipment necessary for locating and recovering ADFRs

3.5.1.1 The Standards of Annex 12, 2.6, state that search and rescue units shall be provided with equipment for locating promptly, and for providing adequate assistance at, the scene of an accident. Each search and rescue aeroplane shall be equipped with a device for homing on distress frequencies. In addition, each search and rescue aeroplane, when used for search and rescue over maritime areas, shall be equipped to be able to communicate with vessels.

3.5.1.2 There are no additional requirements for the operator regarding the equipment necessary for locating the ELT of an ADFR.

3.5.2 Responsibility for ADFR recovery

3.5.2.1 Annex 12, 2.1.1.1, states: "Those portions of the high seas or areas of undetermined sovereignty for which search and rescue services will be established shall be determined on the basis of regional air navigation agreements.

Contracting States having accepted the responsibility to provide search and rescue services in such areas shall thereafter, individually or in cooperation with other States, arrange for the services to be established and provided in accordance with the provisions of this Annex.”

3.5.2.2 Annex 13, 5.3, states: “When the location of the accident or the serious incident cannot definitely be established as being in the territory of any State, the State of Registry shall institute and conduct any necessary investigation of the accident or serious incident […]”.

3.5.2.3 The State of Registry will institute and conduct any necessary investigation of an accident in international waters. However, it may delegate the whole or any part of the investigation to another State by mutual arrangement and consent.

3.5.2.4 Annex 13, 5.3.1, states: “States nearest the scene of an accident in international waters shall provide such assistance as they are able and shall, likewise, respond to requests by the State of Registry.”

Note.— Even if an ELT integrated in an automatic deployable flight recorder assists in the location of the accident site and the potential survivors, it is not the responsibility of the search and rescue personnel to recover the ADFR or to preserve it. Therefore, search and rescue authorities should be made aware as early as possible by the operator (through the State of the Operator or the competent air navigation services provider) that the ELT signal is probably being emitted by an ADFR, which should be collected when possible.

3.6 RECOVERY OF FLIGHT RECORDER DATA THROUGH AIRCRAFT TRANSMISSION

3.6.1 Protection of data transmitted from aircraft to the ground

3.6.1.1 Annex 13, 5.12, requires that the State conducting the investigation of an accident or incident shall not make the CVR recordings, AIR recordings or any transcripts from such recordings available for purposes other than accident or incident investigation, unless the competent authority designated by that State determines, in accordance with national laws and subject to Annex 13, Appendix 2 and 5.12.5, that their disclosure or use outweighs the likely adverse domestic and international impact such action may have on that or any future investigations. If the recovery of flight recorder data is performed through transmission, the protection of the data has to be ensured in agreement with the provisions of Annex 13.

3.6.1.2 The means used for transmitting data from the aeroplane to the secure server are expected to include data encryption and signing techniques to ensure the protection and integrity of the data.

Note.— Some data may be transmitted for the purpose of surveillance (e.g. ADS-B or ADS-C) and are not protected. Therefore, no specific protection is needed for these particular data. The management of protected data should be separated from surveillance data. Likewise, systems dealing with the streaming of protected data and surveillance data should be segregated to reinforce protection measures.

3.6.1.3 One potential solution to prevent man-in-the-middle attacks is to implement robust procedures and policies for the management and protection of encryption keys shared between the airborne equipment transmitting the flight recorder data and the secure servers.

3.6.1.4 The State of the Operator will ensure that the operator has developed appropriate policies and procedures to ensure the protection of safety information and, in particular, to ensure that in case of an accident, the AIA in charge of the investigation retains full control over access to and use of flight recorder data in a usable (decrypted) format. These procedures have to be in place and agreed by the State of the Operator before an accident occurs. They will also have to cover cases whereby the AIA conducting the investigation is not known at the time of the accident.

3.6.2 Use of data transmission services

3.6.2.1 While services such as the secure data transmission from the aeroplane to the ground and the storage of the flight recorder data may be available, operators have to be made aware that they remain fully responsible for protecting these data against unauthorized access and for providing unaltered and unprocessed data to the appropriate authorities.

3.6.2.2 Hence, an operator is expected to carefully consider the guarantees offered by such services before subscribing to them. The State of the Operator may also define performance criteria to be met by a service provider in order for its service to be considered acceptable.

3.6.3 Principles for sharing data with AIAs

3.6.3.1 Table 3-1 provides a summary of the responsibilities of the different stakeholders with regards to the sharing of data with an AIA.

Table 3-1. Standards defining the responsibility of stakeholders to provide data to an AIA

<table>
<tr><td colspan="3">State conducting the investigation:

Annex 13, 5.7, states: "Effective use shall be made of flight recorders in the investigation of an accident or an incident. The State conducting the investigation shall arrange for the read-out of the flight recorders without delay."</td></tr>
<tr><td>State of Occurrence:

Annex 13, 3.3, states: "The State of Occurrence shall take all reasonable measures to protect the evidence and to maintain safe custody of the aircraft and its contents for such a period as may be necessary for the purposes of an investigation.

[…]

Note 2.— Protection of flight recorder evidence requires that the recovery and handling of the recorder and its recordings be assigned only to qualified personnel."</td><td>State of the Operator:

Considering Note 2 to 3.3 in Annex 13, the State of the Operator will need to ensure that complete, unaltered and unprocessed data are transmitted to the State conducting the investigation.</td><td>Other State:

Annex 13, 5.16, states: "When an aircraft involved in an accident or a serious incident lands in a State other than the State of Occurrence, the State of Registry or the State of the Operator shall, on request from the State conducting the investigation, furnish the latter State with the flight recorder records and, if necessary, the associated flight recorders.

Note.— In implementing 5.16, the State of Registry or the State of the Operator may request the cooperation of any other State in the retrieval of the flight recorder records."</td></tr>
<tr><td></td><td>Operator:

Annex 6, Part I, Section 11.6, states: "The operator shall ensure, to the extent possible, in the event the aeroplane becomes involved in an accident or incident, the preservation of all related flight recorder records and, if necessary, the associated flight recorders, and their retention in safe custody pending their disposition as determined in accordance with Annex 13."</td><td></td></tr>
</table>

3.6.3.2 Any operator will, on an official request made according to Annex 13, provide all the relevant information available to it.

3.6.3.3 After an accident, the State of the Operator of the aircraft involved should comply with the procedure for ensuring the safe custody of the data until the latter are delivered to the AIA of the State of Occurrence. The procedure should ensure protection and integrity during the transfer of data to the AIA of the State of Occurrence or to the AIA of the State conducting the accident or incident investigation.

3.6.3.4 If the AIA of the State of Occurrence does not have adequate facilities for analyzing the flight recorder data, the data may be sent to facilities made available by another State under the control of the AIA of the State of Occurrence.

If the State of Occurrence delegates an investigation to another State, then the AIA of the State conducting the investigation will define the procedure for properly transmitting data to the AIA.

3.6.4 Proper operation

To ensure the flight recorder data recovery systems are properly installed and to verify that the flight recorder data transmission achieves the acceptable level of recovery and quality, manually initiated transmission of the appropriate data during flight may be performed. The data retrieved from the secure server is expected to be evaluated to confirm acceptable level of quality during flight. For maintenance purposes, the operator is expected to periodically transmit flight recorder data to test system functioning in accordance with national regulations. To ensure proper data quality, the operator should periodically compare the transmitted data to the data recorded on the fixed flight recorders.

3.6.5 Cancellation of flight recorder data recovery transmission

3.6.5.1 In cases of system testing or recovery from distress conditions, the transmission of flight recorder data may be deactivated (cancelled) using the same mechanism that activated it. If transmission is cancelled and distress conditions reoccur on a given flight, the transmission of flight recorder data will again be activated; cancellation of the transmission does not disable the transmission activation logic.

3.6.5.2 A minimum transmission duration (20 minutes) after the distress event is detected should be used. A minimum transmission duration ensures that sufficient data are transmitted for any distress condition while protecting against the transmission of flight recorder data for an extended time owing to a nuisance condition.

3.6.6 Format of CVR data

3.6.6.1 Recorded CVR audio data are expected to be readily retrievable in an industry standard digital format without loss of audio data and quality or timing correlation, irrespective of the recording format. Silence editing will not be used for the cockpit area microphone (CAM) channel; the CAM recording is expected to be continuous regardless of input signal level.

3.6.6.2 The AIA is expected to receive the CVR audio data as recorded from the received transmission. No alteration of the data preserved on the secure server will be performed.

Note.— Information regarding the CVR audio recording format and audio quality specifications may be found in EUROCAE ED-112A (or the latest version).

3.6.7 Format of FDR data

3.6.7.1 Recorded FDR parametric data are expected to be readily retrievable in an industry standard digital format without loss of data or timing correlation.

3.6.7.2 The AIA is expected to receive the FDR parametric data as recorded from the received transmission. No alteration of the data preserved on the secure server will be performed.

Note.— ARINC 717 and ARINC 767 are examples of industry standard digital formats for FDR data.

Data frame layout (DFL)

3.6.7.3 The operator will have to provide a data frame layout (DFL) document necessary for the AIA to decode and convert the FDR parametric raw data to engineering units. This DFL could differ from the one used for fixed flight recorders. If multiple DFLs can be transmitted (e.g. required FDR parameters only, all FDR parameters), then each layout must be documented.

Note.— Information regarding the FDR recording format and parameter characteristics specifications may be found in EUROCAE ED-112A (or the latest version).

3.6.8 Format of DLR data

3.6.8.1 Recorded DLR messages are expected to be readily retrievable according to a standard defined by the industry without loss of data or timing correlation.

3.6.8.2 The AIA is expected to receive the DLR messages as recorded from the received transmission. No alteration of the data preserved on the secure server will be performed.

3.6.9 Format of flight crew-machine interface data

3.6.9.1 The recorded flight crew-machine interface recordings information is expected to be readily retrievable in an industry standard digital format without loss of data and quality or timing correlation, irrespective of the recording format.

3.6.9.2 The AIA is expected to receive the flight crew-machine interface recordings information as recorded from the received transmission. No alteration of the data preserved on the secure server will be performed.

3.6.10 Bandwidth necessary for transmitting the appropriate flight recorder data during flight

3.6.10.1 Bandwidth is a measure of how much data can be transmitted over a given period of time. The flight recorder data recovery systems used to transmit flight recorder data are expected to have sufficient bandwidth to transmit at least the minimum set of required FDR parameters as defined in Annex 6, Part I, Appendix 8, Table A8-1. This list of parameters depends on the date of the individual certificate of airworthiness of each aeroplane and is referred to in Annex 6, Part I, Section 6.3.1.

3.6.10.2 Data may be compressed to reduce the required transmission bandwidth. Data compression techniques for the transmission of flight recorder data have to be carefully designed so that discontinuities in the data stream or data corruption do not prevent the retrieval of the data from the secure server. It is expected that, when data are compressed, the word error rate should not exceed one error in 10^{-5} words.

3.6.10.3 The compression technique used for the CVR audio data has to provide, for example, an audio quality similar to that of data recorded on the CVR. The best compression technique to use for CVR CAM audio data is currently 3-bit adaptive differential pulse-code modulation (ADPCM). This example is not intended to limit the application of new technology or compression techniques. The objective is to achieve an equivalent level of data retrieval as when using modern solid-state memory fixed flight recorders. All forms of data compression have to be fully reversible.

3.6.10.4 As an example, the bandwidth necessary for flight recorder data transmission is estimated below. The values do not include communication overhead:

a) CVR audio uncompressed from CAM channel 16 kHz, 256 Kbits/second;

b) all required FDR parameters listed in Table A8-1 of Annex 6, Part I, Appendix 8, for a 1024 wps (words per second) data frame, as per ARINC 717, approximately 3 Kbits/second transmission; and

c) all FDR parameters for a 1024 wps data frame, as per ARINC 717, approximately 12.3 Kbits/second.

Note 1.— The actual bandwidth required will vary depending on FDR data frame content, size and industry standard (ARINC 717 versus ARINC 767).

Note 2.— The bandwidth required for CVR flight crew audio will vary to allow for silence editing and is not computed.

Transmission of flight recorder data

3.6.10.5 At a minimum, the required FDR parameters, CVR audio channels and DLR messages, as defined in Section 3.3.4 of this document, are transmitted upon a triggered event or remote activation.

3.6.10.6 An FDR data frame may consist of required parameters as contained in Table A8-1 of Annex 6, Part I, Appendix 8, and non-required parameters collected for flight data analysis reasons. It is recommended to transmit non-required FDR parameters if sufficient bandwidth is available.

Priority of flight recorder data transmission

3.6.10.7 As the duration of an event cannot be predicted, Table 3-2 presents the order of priority in which flight recorder data must be transmitted for an investigation.

Table 3-2. Priority of transmission of flight recorder data

Transmitted flight recorder data	*Priority*
Required FDR parameters — real time	1
CVR CAM audio — real time	2
Required FDR parameters — historical	3
CVR crew microphones audio — real time	4
CVR CAM and crew microphones audio — historical	5
Data link messages — real time and historical	6
Other data (non-required FDR parameters, AIR)	7

3.6.10.8 The system will include in the transmission the type of transmitted flight recorder data (e.g. required FDR parameters, non-required FDR parameters, etc.) such that the data stored on the secure server can be readily identified.

3.6.10.9 FDR transmission may be used by the operator to assist the flight crew in troubleshooting and resolving an issue in real time. If the flight recorder data are transmitted prior to entering the distress conditions, it will not be necessary to retransmit the data already sent when the aeroplane is in distress.

3.6.10.10 If the transmission of the flight recorder data is utilizing commercial connectivity services, the transmission of flight data required for compliance with the timely recovery of flight data and aircraft tracking mandates takes precedence over the non-required communication services data to keep the maximum bandwidth for the safety purpose. Non-required communication services provide flight crew and passengers with air-ground/air-air voice and data communication service. The system does not support safety-related applications like ATS.

3.6.10.11 The transmission of flight recorder data required for compliance with the timely recovery of flight data and aircraft tracking mandates may use any type of spectrum properly allocated on a primary basis to the function being performed. However, the overall end-to-end reliability of recovering the flight recorder data is expected to not be worse than the reliability of the recovery of flight recorder data from a fixed flight recorder.

Transmission of CVR audio data

3.6.10.12 The system for timely recovery of flight recorder data has to provide, at a minimum, the two audio channels defined below.

3.6.10.13 The following is the subset of CVR audio that is expected to be transmitted, at a minimum, during distress conditions:

a) one channel for the aural environment of the flight deck (CAM); and

b) on a separate channel, a combination of the three flight crew audio channels, which encompass:

   1) voice communications transmitted from or received by the aeroplane by radio;

   2) voice communications of flight crew members on the flight deck using the aeroplane's interphone system, if installed; and

   3) voice or audio signals identifying navigation or approach aids introduced into a headset.

Alternatively, the flight crew audio channels could be transmitted separately.

3.6.11 Quality of transmission service in case of unusual attitude

3.6.11.1 The quality of transmission services is expected to be evaluated during unusual aeroplane attitude. A means to perform this evaluation is the use of historical aeroplane incident and accident data as compiled by the Bureau of Enquiry and Analysis for Civil Aviation Safety (BEA) or other database providers. Other methods are also acceptable.

3.6.11.2 In the framework of the investigation into the accident of the Air France Flight AF 447 Airbus A-330 on 1 June 2009, the BEA created an international working group. The aim of this group was to determine if the triggered transmission of flight recorder data upon the detection of an upcoming catastrophic event was a solution with good potential. Visibility to and connectivity with various satellite constellations were assessed as well.

3.6.11.3 A database of flight parameters (data sets) was created. This database contains 68 data sets from actual commercial air transport aeroplane accidents and incidents provided by official AIAs. The data sets were de-identified as no date or latitude/longitude parameters were provided. Information about aeroplane type, phase of flight and occurrence category is available for each file of the database. A report dated 18 March 2011 is available on the BEA website at www.bea.aero with information regarding type of aeroplane involved, breakdown by flight phase and occurrence category.

3.6.11.4 The BEA has agreed to make the database available upon request. All requests should be sent to accident.database@bea.aero. Access to the database is also possible through the ICAO global flight tracking website at www.icao.int/safety/globaltracking.

Availability of flight recorder data recovery services

3.6.11.5 Availability is the ability of the on-board flight recorder data recovery system to successfully transmit flight recorder data to the ground station.

3.6.11.6 The availability of flight recorder data recovery services has to be considered when selecting the service provider used in the area flown by the aeroplane. Whatever the method for assessing visibility, including the one described in Section 3.3.6 of this manual, the loss of data has to be minimized. In case of loss, it has to be quantified and, where possible, qualified.

Connectivity services

3.6.11.7 It is acceptable to utilize commercial connectivity services to transmit flight recorder data.

3.6.11.8 Flight recorder data may be transmitted through separate connectivity services (e.g. FDR parameters on one connectivity service, CVR audio on another connectivity service).

3.6.11.9 Once activated, the transmission of flight recorder data is to be continuous (streaming) or take place via high-speed periodic bursts. Such data transmission ensures that no data are lost as a result of buffering between two bursts. The high-speed periodic burst of data may be processed at the maximum rate of the interface employed in the digital communication system design, which is expected to have no adverse effect on the performance of the transmission.

3.6.12 Erasure of CVR audio or airborne image recordings

3.6.12.1 The flight recorder data recovery system provides non-crash protected storage of flight recorder data enabling the retransmission of flight recorder data to cover potential drop-outs. In addition, it will support transmission of historical data.

3.6.12.2 Annex 6, Part I, Appendix 8, 1.4 d), states: "[…] for aeroplanes for which the individual certificate of airworthiness is first issued on or after 1 January 2023, a flight crew-operated erase function shall be provided on the flight deck which, when activated, modifies the recording of a CVR and AIR so that it cannot be retrieved using normal replay or copying techniques. The installation shall be designed to prevent activation during flight. In addition, the probability of an inadvertent activation of an erase function during an accident shall also be minimized."

3.6.12.3 This erase function is intended to prevent access to CVR and AIR recordings by normal replay or copying means, but does not prevent AIAs from accessing such recordings through specialized replay or copying techniques.

3.6.12.4 The flight recorder data recovery system is expected to include a similar feature to initiate erasure of the transmitted CVR audio or AIR images stored at the ground station. Particular protection has to be considered as this feature may create a security failure.

3.6.13 Trigger for flight recorder data transmission

3.6.13.1 If transmission of flight recorder data via activation (trigger) logic is used, part of the means to recover flight recorder data and make it available in a timely manner, the activation logic should be designed so as to ensure successful data transmission as early as possible in the accident or incident sequence.

3.6.13.2 The flight recorder data recovery system is enabled to transmit as soon as the aeroplane is able to move under its own power and may continue until the termination of the flight, when the aeroplane is no longer capable of moving under its own power. Flight recorder data transmission that cannot be enabled in all airborne phases of the flight does not satisfy Annex 6, Part I, 6.3.6.

3.6.13.3 At a minimum, flight recorder data are expected to be transmitted when the aeroplane is in distress. In addition to this, the operator may choose to transmit flight recorder data more often. The most favourable case is whenever the aeroplane is capable of moving under its own power.

3.6.13.4 It is acceptable that some flight recorder data may be transmitted only when the aeroplane is in distress (e.g. CVR audio) and other data, for example, when the aircraft is in flight (e.g. FDR parameters and DLR messages).

Triggered transmission for aircraft in distress

3.6.13.5 Flight recorder data transmission trigger criteria has to be customized for each aeroplane by the manufacturer using the Minimum Aviation System Performance Specification for Criteria to Detect In-Flight Aircraft Distress Events to Trigger Transmission of Flight Information (EUROCAE ED-237) as guidance, and comply with minimum operational specifications. It is recommended that the manufacturer consider additional events (e.g. cabin depressurization, fire warning, terrain collision avoidance system resolution advisory, etc.) beyond those described in EUROCAE ED-237 to ensure that an adequate amount of flight recorder data are transmitted.

3.6.13.6 The capability to remotely activate the system via a ground station is not required. Depending on national regulations, manually initiated remote activation of transmission of CVR audio or AIR images may require the prior consent of the flight crew.

3.6.13.7 Historical flight recorder data prior to the time the flight enters the distress conditions are expected to be provided, with the most recent data being given the highest priority.

3.6.13.8 The system stops transmitting upon the completion of the flight or when the distress conditions are cancelled. In case of a triggered transmission, transmission of flight recorder data is expected to commence immediately or no later than five seconds after the detection of the distress conditions.

Appendix A to Chapter 3

LIST OF PAST UNDERWATER RECOVERY OPERATIONS

Accident date	*Aircraft type*	*Operator (flight number)*	*Location*	*Phase*	*Depth (m)*	*Distance from shoreline (NM)*	*Duration of CVR recovery (days)*	*Duration of FDR recovery (days)*	*Approximate cost (M USD)*
1969/12/04	B-707	Air France (212)	Off Caracas, Venezuela	Climb	50				
1971/11/21	Caravelle	China Airlines	Off Penghu Islands, Taiwan Province of China	Climb					
1973/07/22	B-707	Pan Am (816)	Off Papeete, Tahiti	Climb	700		Never found	Never found	
1974/03/05	Caravelle	Jat Airways	Off Funchal, Madeira	Approach	100				
1977/12/18	Caravelle	SATA (730)	Off Funchal, Madeira	Approach	110		Aircraft found on 25 October 2011		
1979/01/30	B-707	Varig	Off Tokyo, Japan (Pacific Ocean)	Climb			Aircraft never located		
1980/06/27	DC-9	Itavia (870)	Off Ustica, Italy	En-route	3500		2555	3650	
1982/02/09	DC-8	Japan Airlines	Off Tokyo, Japan	Approach	20		10	10	
1983/09/01	A-300	Iran Air (655)	Off Bandar Abbas, Iran	En-route					
1985/06/23	B-747	Air India (182)	Off Cork, Ireland	En-route	3250		17	18	

Accident date	*Aircraft type*	*Operator (flight number)*	*Location*	*Phase*	*Depth (m)*	*Distance from shoreline (NM)*	*Duration of CVR recovery (days)*	*Duration of FDR recovery (days)*	*Approximate cost (M USD)*
1987/11/28	B-747	South African Airways (295)	Off Mauritus	En-route	4400	135	840	Never found	4
1988/07/03	B-747	Korean Air (007)	Pacific Ocean	En-route					
1989/09/08	Convair 340/580	Partnair (394)	Off Hirtshals, Denmark	En-route	90	10			
1990/09/11	B-727	Faucett Perú	Off Newfoundland, Canada	En-route		180	Aircraft never located		
1993/04/02	DC-9	LAV	Off Isla de Margarita, Venezuela		30				
1996/02/06	B-757	Birgenair (301)	Off Puerto Plata, Dominican Republic	Take-off	2200	15	22	22	1.5
1996/05/11	DC-9	ValuJet (592)	Everglades, Florida, United States	Climb	2	1	15	2	1
1996/07/17	B-747	TWA (800)	Off New York, United States	Climb	40	8	7	7	10
1996/10/02	B-757	Aeroperú (603)	Off Pasamayo, Peru	Approach	230		17	17	
1996/11/23	B-767	Ethiopian Airlines (961)	Off Moroni, Comoros	Landing		0.5			
1997/12/19	B-737	SilkAir (185)	Off Palembang, Indonesia	En-route	8	0.2	20	5	

Accident date	*Aircraft type*	*Operator (flight number)*	*Location*	*Phase*	*Depth (m)*	*Distance from shoreline (NM)*	*Duration of CVR recovery (days)*	*Duration of FDR recovery (days)*	*Approximate cost (M USD)*
1998/03/18	Saab 340	Formosa Airlines	Off Hsinchu, Taiwan Province of China	Climb		11			
1998/09/02	MD-11	Swissair (111)	Off Halifax, Canada	En-route	55	5	9	4	25
1999/10/17	MD-11	FedEx (87)	Subic Bay, Philippines	Landing	10		2	2	
1999/10/31	B-767	EgyptAir (990)	Off Nantucket, United States	En-route	75	60	13	9	3.5
2000/01/30	A-310	Kenya Airways (431)	Off Abidjan, Côte d'Ivoire	Take-off	50	1.5	26	6	0.06
2000/01/31	MD-83	Alaska Airlines (261)	Off Los Angeles, United States	En-route	200	15	2	3	2.5
2000/02/03	B-707	Trans Arabian Air Transport	Lake Victoria, Tanzania	Landing	0				
2000/08/23	A-320	Gulf Air (72)	Off Muharraq, Bahrain	Approach	3	3	1	1	
2002/05/07	MD-82	China Northern Airlines (6163)	Off Dalian, China	Approach	10		7	14	
2002/05/25	B-747	China Airlines (611)	Off Penghu Islands, Taiwan Province of China	Climb	20		24	25	11.8
2002/12/21	ATR 72	TransAsia Airways (791)	Off Penghu Islands, Taiwan Province of China	En-route	60	10	23	22	2.5
2004/01/03	B-737	Flash Airlines (604)	Off Sharm el-Sheikh, Egypt	Climb	1030	1	13	12	1

Accident date	*Aircraft type*	*Operator (flight number)*	*Location*	*Phase*	*Depth (m)*	*Distance from shoreline (NM)*	*Duration of CVR recovery (days)*	*Duration of FDR recovery (days)*	*Approximate cost (M USD)*
2005/08/06	ATR 72	Tuninter (1153)	Off Palermo, Italy	En-route	1440		23	24	1
2006/05/02	A-320	Armavia (967)	Off Sochi, Russian Federation	Approach	505		20	22	
2007/01/01	B-737	Adam Air (574)	Off Parepare, Indonesia	En-route	1800		240	240	4
2008/11/27	A-320	XL Airways	Off Perpignan, France	Approach	40		2	3	0.5
2009/01/15	A-320	US Airways (1549)	Hudson River, New York, United States	Climb	20	0	3	3	0.1
2009/06/01	A-330	Air France (447)	Atlantic Ocean	En-route	3900	600	701	700	32
2009/06/30	A-310	Yemenia (626)	Off Moroni, Comoros	Approach	1200	3	60	60	2.5
2010/01/25	B-737	Ethiopian Airlines (409)	Off Beirut, Lebanon	Climb	45		20	13	
2011/07/28	B-747	Asiana Airlines (991)	Off Jeju, Republic of Korea	En-route	87		Never found	Never found	13.2
2013/10/16	ATR 72	Lao Airlines (301)	Mekong River near Pakse, Lao People's Democratic Republic	Landing	12		13	14	
2014/03/08	B-777	Malaysia Airlines (370)	Indian Ocean	En-route			Aircraft and recorders not yet located		

Accident date	*Aircraft type*	*Operator (flight number)*	*Location*	*Phase*	*Depth (m)*	*Distance from shoreline (NM)*	*Duration of CVR recovery (days)*	*Duration of FDR recovery (days)*	*Approximate cost (M USD)*
2014/12/28	A-320	Indonesia AirAsia (8501)	Java Sea	En-route	30		15	14	
2016/05/19	A-320	EgyptAir (804)	Mediterranean Sea	En-route	2960	100	28	29	

— END —

ISBN 978-92-9258-654-6