



Progress to Pinpoint an Aircraft's Position

There are currently around 33 million commercial flights a year and this figure is expected to double in the next 15 years. An aircraft arriving safely at its destination, and within a predictable time, is an expectation of both its crew and passengers. A growing number of apps are also available to the public that show an aircraft's journey from departure to arrival, even providing seemingly real-time data for an aircraft's speed, altitude and heading. With the technological leaps that have provided all of this information to hand and visible on our smart phones, it is not unreasonable for members of the public and media to ask, "How can we lose track of a large aircraft flying today?"

All actors across the entire Air Transport System have been working together on improving the tracking of aircraft and recovery of the “black boxes” since it took two years to recover the flight data recorders from the AF447 wreckage in the Atlantic Ocean and following the disappearance of MH370 in 2014. This article outlines the recommendations and proposed regulations, as well as the products that are available or under development, which will allow operators of Airbus aircraft to comply with these changes. It also describes the opportunities to enhance flight tracking and localisation of aircraft in the event of an accident for more rapid search and rescue, as well as the timely recovery of the flight data.

Analysis of all aviation accidents since 1958 shows that less than ten percent of all fatal accidents occur in the cruise phase of flight. This is when an aircraft, flying at around 39,000ft over oceanic or remote areas, is more likely to be outside of the range of radar and ground tracking infrastructure. Therefore, there are only few events where it is difficult to determine the last position of the aircraft, locate the wreckage and then recover the flight data recorders. In the last 20 years, 24 large commercial aircraft required underwater recovery, and only one has not yet been located.

AIRCRAFT FLIGHT TRACKING

Commercial aircraft flights are safer today than ever before. On the rare occasions when accidents occur, locating the wreckage by the quickest means possible is a priority to first rescue survivors and then retrieve the flight recorders or “black boxes”.

Capabilities and Limitations

Tracking aircraft increases any chances of finding survivors by providing an early response alert and locating the end-of-flight aircraft position more accurately to launch the Search And Rescue (SAR) operation. This can also support the retrieval of the flight data recorders, aiding the investigators in determining the contributing factors that may lead to industry actions that could potentially prevent a reoccurrence of the accident.

The aircraft tracking capability in the past mainly relied on land based infrastructure and limited satellite coverage. In fact, this has meant it was difficult to track aircraft when flying over oceans or where tracking infrastructure is not in place, including remote areas and flying over the earth's poles. Primary radar used for Air Traffic Control surveillance often only extends roughly 200 nautical miles (or just under 400 km) over the oceans from the coast of most countries.

Today, when aircraft are flying in oceanic or remote areas without radar or ADS-B coverage, pilots use radio to report the position of their aircraft to the air traffic control. Or it can be transmitted using ADS-C via SATCOM or HF, which are long-range communication means. VHF Datalink is fitted to all aircraft in the Airbus fleet. For the A320 fleet, where operations are over oceanic or remote areas, then HF and SATCOM options are selectable (**Fig.1**).

“ ... it was difficult to track aircraft when flying over oceans or where tracking infrastructure is not in place, including remote areas and flying over the earth's poles. ”

COMMUNICATION SYSTEMS Geographical Coverage			
VHF Continental areas	Basic	Basic	Basic
SATCOM Inmarsat Worldwide except polar area	Option	Basic	Basic
SATCOM Iridium Worldwide	Option	Option	Under Definition
HF Worldwide	Option	Basic	Basic

(fig.1)

Datalink Communication means available on the Airbus Fleets

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Airbus has defined solutions ready for implementation by operators that help them comply with the latest aircraft tracking regulations.

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Regulation Drivers for Tracking Aircraft

Aircraft tracking is utilising aircraft position information during all phases of flight. This supports the timely and accurate location of an aircraft accident site, and recovery of flight data. ICAO issued new recommendations for flight tracking, which will be applicable for all commercial aircraft. The responsibility to track an aircraft lies with the aircraft operator.

Airbus has defined solutions ready for implementation by operators that help them comply with the latest aircraft tracking regulations. Each National Aviation Authority (NAA) can define their own regulation based on ICAO recommendations. Operators should check with their respective NAA to know what regulation regarding aircraft tracking is applicable for them.

Evolution of Recommendations and Regulations

Airbus is a key contributor to the various task forces launched by ICAO and IATA since 2014 and continues to contribute to the evolution of regulations as a key industry stakeholder.

During the high level safety conference held in 2015, ICAO encouraged states and the International Telecommunications Union (ITU) to urgently adopt regulations that provide the necessary spectrum allocations for global air traffic services where the terrestrial ADS-B signals broadcast by aircraft can be received by satellite. This led to consideration of the spectrum needs and regulatory provisions for the introduction and use of the ICAO Global Aeronautical Distress and Safety System (GADSS). ICAO subsequently released the Concept of Operations (or ConOps) document that specifies the high-level requirements and objectives for the GADSS.

The regulation process for Aircraft Tracking was initiated by the ICAO GADSS ConOps document and its recommendations were then transferred to ICAO performance-based Standards And Recommended Practices (SARPs). The SARPs for Normal Flight Tracking are applicable from November 2018. Individual National Aviation Authorities (NAA) will define and implement their regulations based on the ICAO SARPs.



Aircraft Tracking - 4D

An aircraft's position is defined by transmission of its 4D (or four dimensions of Latitude, Longitude, Altitude, and Time data every 15 minutes, together with the aircraft's identifier. Aircraft tracking refers to both normal tracking and abnormal tracking **(Fig.2)**.



(fig.2)

Aircraft Tracking 4D or the four dimensions of Latitude, Longitude, Altitude, and Time data

“ Some examples of abnormal events may include unusual aircraft attitude, unusual speed or an engine failure in flight. ”

(fig.3)

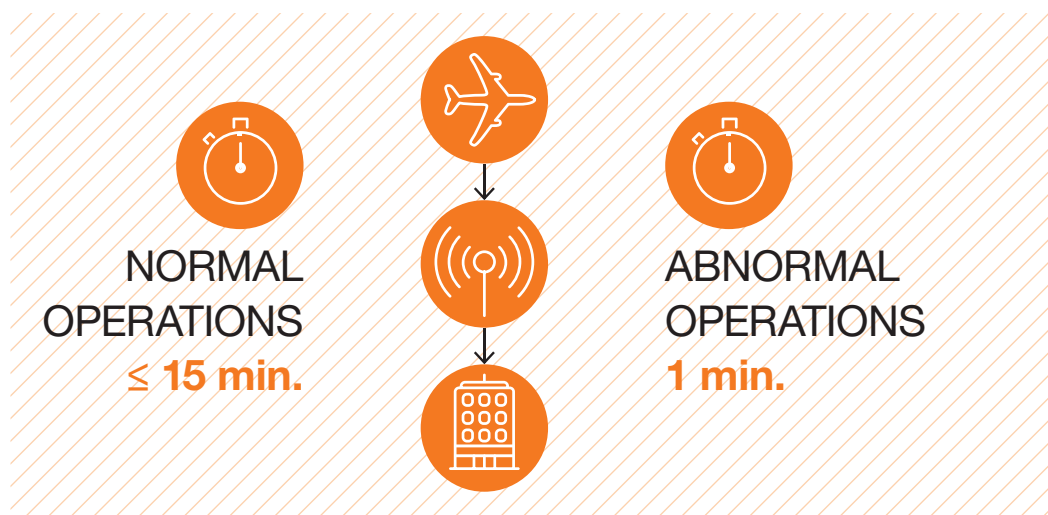
Aircraft Tracking for Normal Operations and Abnormal Operations

Tracking Aircraft During Normal & Abnormal Operations

Normal tracking is currently defined in ICAO and EC regulation projects. Abnormal tracking is not yet formally included in the regulation, but it is part of the guidance materials for aircraft tracking. Airbus endorses the implementation of abnormal tracking as it may become an industry requirement in the near future, or it can be implemented by the operator's own initiative.

Tracking during “Normal Operations” requires an aircraft to transmit its 4D data at least once every 15 minutes. In a case where unexpected aircraft behaviour is detected, the “Abnormal Operations” mode automatically increases the position reporting frequency based on certain triggering parameters. If the conditions that led to the increased reporting rate cease to exist, the reporting would revert to the data transmission intervals of once every 15 minutes **(Fig. 3)**.

Some examples of abnormal events may include unusual aircraft attitude, unusual speed or an engine failure in flight.



Autonomous Distress Tracking

The objective of Autonomous Distress Tracking (ADT) is to provide the end-of-flight aircraft position with greater accuracy that will enable the location of the accident site within a range of six nautical miles or a search and rescue region of less than roughly 100 square kilometres. The first priority is to search for survivors and after the search and rescue phase is completed, the second priority is to recover flight data and cockpit voice recorders.

The ADT signal shall be triggered automatically by detecting in flight behaviours that are likely to lead to an accident if not corrected, or it can be triggered manually by the crew. Deactivation of the ADT can only be possible using the same activating mechanism that initially activated the ADT transmission. The system should be autonomous so the transmitting system has a back-up power supply, separated from the aircraft's power in case there is an electrical system failure. This means using a battery with suitable life to sustain the transmission over a given time. It also requires means to autonomously transmit position information if this no longer available from the aircraft.

ICAO's performance-based Standards And Recommended Practices (SARPs) for ADT are applicable from January 2021 for all newly manufactured aircraft. This requires that 3D position information (the altitude parameter is not mandatory for ADT to remain compatible with existing systems), is transmitted at least once every minute.

“ Deactivation of the ADT can only be possible using the same activating mechanism that initially activated the ADT transmission. ”

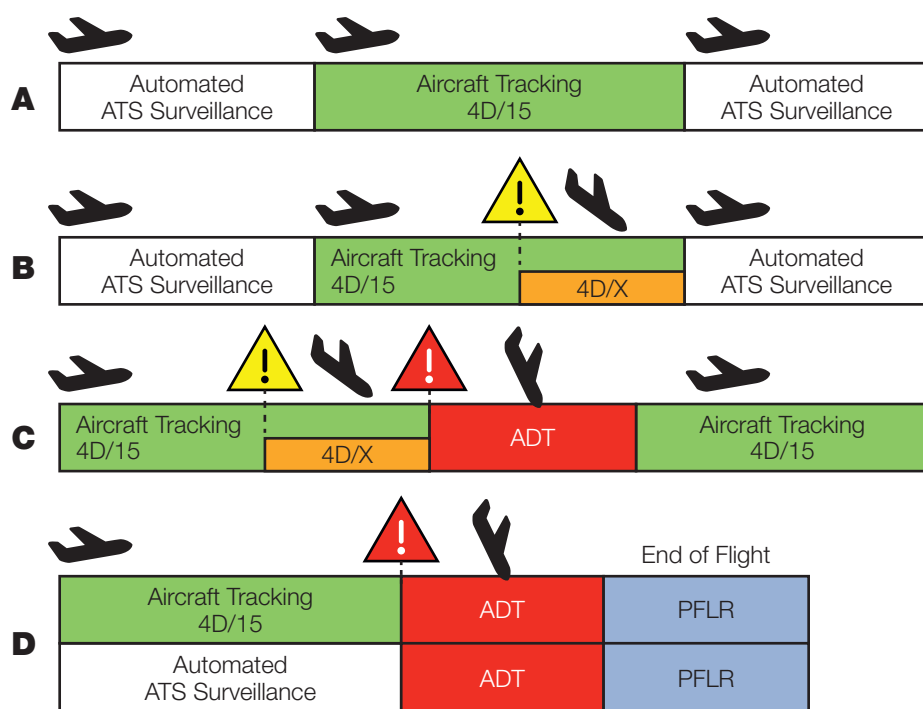
ADT Triggered Transmissions

Triggered Transmission is when predefined operational parameters of an aircraft in flight are monitored and data is transmitted automatically if the aircraft is in an uncertain situation, or when an aircraft in distress, meaning that it is in a situation, which if not corrected, will most probably result in an accident. The triggers are defined in the Eurocae Minimum Aviation System Performance Specifications (MASPS ED 237).

(fig.4)

Source: ICAO GADSS ConOps

Examples of Aircraft Tracking Scenarios



A. Nominal flight from an area under Air Traffic Services (ATS) surveillance to an areas outside of ATS coverage with normal mode 4D/15 Aircraft Tracking (AT) until ATS surveillance is reinstated.

B. A flight with an abnormal tracking condition (4D/X) triggered and transmitted outside of ATS surveillance area prior to reinstating ATS surveillance.

C. (i) A flight with an abnormal tracking condition (4D/X) triggered and transmitted outside of ATS surveillance area. (ii) A mechanism triggers the Automated Distress Tracking (ADT) transmission. (iii) ADT deactivated but ONLY by the SAME mechanism that activated the ADT.

D. (i) A flight with normal tracking or ATS surveillance. (ii) Aircraft situation triggers ADT transmission until the end of flight. (iii) Post Flight Location Recovery (PFLR)

4D/15 NORMAL TRACKING: Latitude/Longitude/Altitude/Time transmitted at least once every 15 minutes

4D/X ABNORMAL TRACKING: Latitude/Longitude/Altitude/Time transmitted at least once every minute



“ ... ADT triggering logics were validated using a database of flight parameters collected from more than 50-thousand flights ... ”

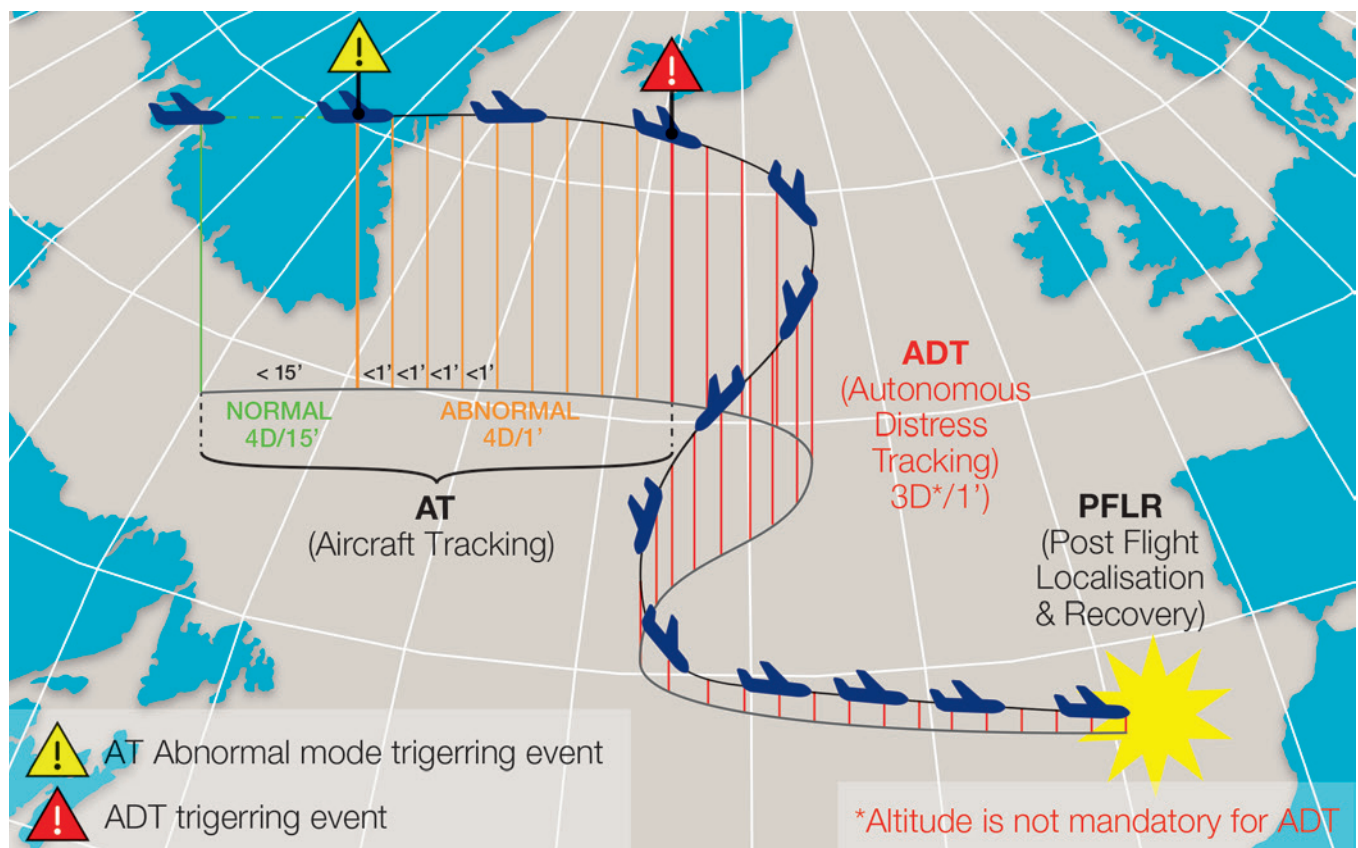
Avoiding any false alerts

When defining triggering logic, the challenge was to both ensure that all distress events are captured and avoid any “false positives” that could cause unnecessary reactions to a false alarm. In answer to this, Airbus conducted intensive analysis to validate that the parameters and the defined thresholds that would activate a triggered transmission were appropriate.

For each of the Airbus aircraft families (A320, A330, A380, A350) the selected ADT triggering logics were validated using a database of flight parameters collected from more than 50-thousand flights of different aircraft types that were flown by several airlines and on a variety of routes. ■

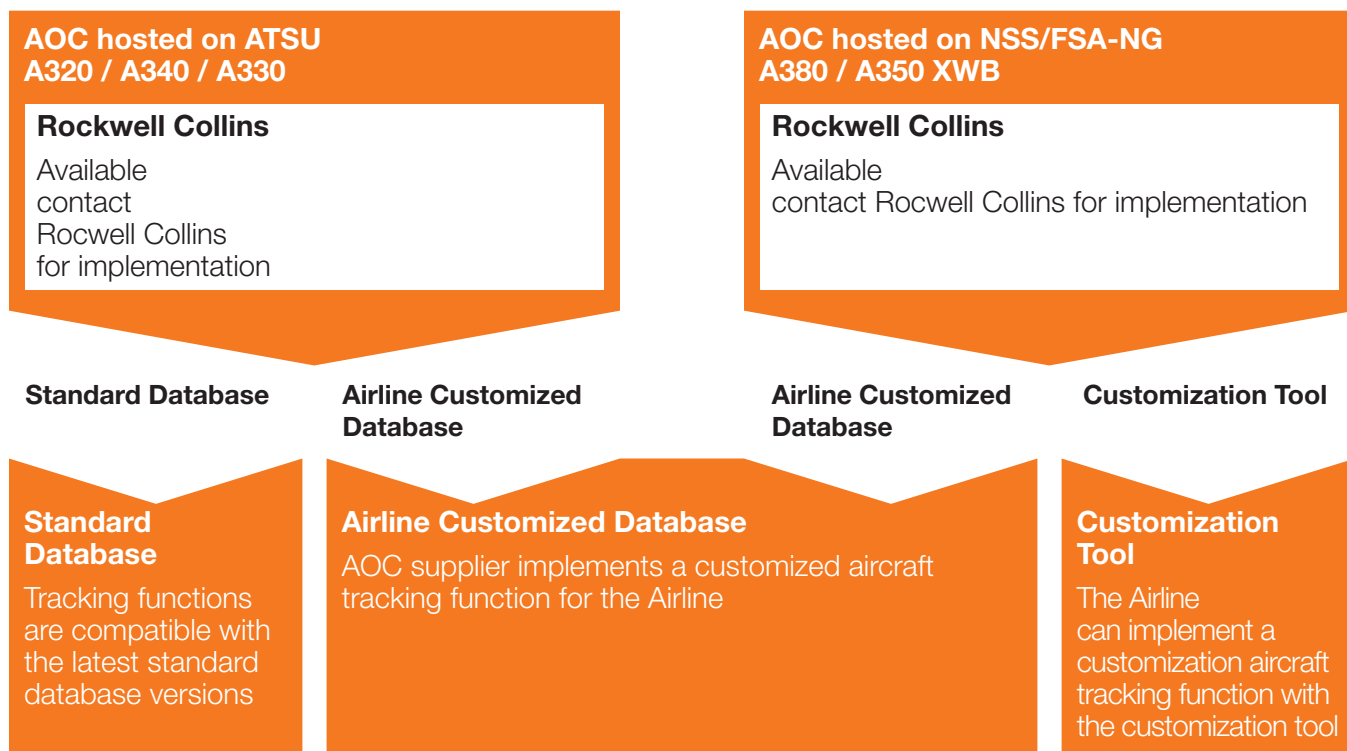
(fig.5)

Example of Normal and Abnormal Aircraft Tracking, Autonomous Distress Tracking and Post Flight Localisation & Recovery



AIRBUS SOLUTIONS FOR AIRCRAFT TRACKING

Airbus together with Rockwell Collins have developed an Aircraft Tracking Solution ready for Airlines to implement on the existing Airline Operational Control (AOC) function on Airbus aircraft with ACARS (Aircraft Communications Addressing and Reporting System) communication means. This requires no flight crew action, both for aircraft tracking in Normal mode (sending position at least every 15 minutes) and uses an Airbus optimized triggering logic for tracking Abnormal operations. This is implemented directly in the Rockwell Collins AOC dataframe on all A380 or A350 aircraft and A320 family, A330 and A340 aircraft furnished with Rockwell Collins ATSU **(Fig. 6)**.



A320 / A330 / A340 Aircraft Tracking

The AOC application is hosted on the Air Traffic Service Unit (ATSU) for these aircraft. For aircraft fitted with Rockwell Collins furnished ATSU, operators can implement tracking functions compatible with the latest standard database versions, or implement a customised aircraft tracking function specifically defined for the operator.

A380 / A350 Aircraft Tracking

The AOC application is hosted on the Network Server System (NSS) for the A380 and the A350's FSA-NG (FlySmart by Airbus - New Generation). Operators can implement a customised aircraft tracking function with the customisation tool with the implementation of this function by Rockwell Collins.

A300 / A310

Aircraft tracking for the A300 and A310 aircraft can be analysed by Airbus experts on request of the operator to determine a solution that is most suitable for each aircraft's configuration.

Other Aircraft Tracking Solutions

Space Based ADS-B

All air transport aircraft will be equipped with ADS-B (Automatic Dependent Surveillance – Broadcast) transponders according to various mandates. Recently launched communications satellite constellations are capable of tracking ADS-B signals and global coverage is expected to be in place from 2018 when Aireon completes the placement of space ADS-B receivers on the Iridium NEXT constellation, consisting of 66 Low Earth Orbit (LEO) satellites. A space-based ADS-B receiver network will relay signals from the aircraft to a service provider on the ground. This service will be capable of global real-time ADS-B

(fig.6)

Airbus Aircraft Tracking Solutions that can be implemented on the existing Airline Operational Control (AOC) function

surveillance, even when flying over oceanic, polar and remote regions, and no modifications or changes should be necessary for aircraft already equipped with ADS-B transponders.

What about GPS navigation?

GPS is prolific in our daily lives and modern smart phones give us its locating capabilities in our hands. It is true that most commercial aircraft today have 'global navigation satellite system' (GNSS) receivers on board to aid pilots with positioning and navigation. However, this information is telling the crew where their aircraft is but it does not send that information to the ground. GPS (or GNSS position) is however used by many systems on-board the aircraft, ADS-B being one of them.

How do flight tracking services show aircraft position for a flight, even over oceans?

Flight tracking services, many available as apps on our smartphones, primarily use ADS-B data transmitted by aircraft to ground receivers. Some services also combine data from several data sources to increase the accuracy of their service including ADS-B, multi-lateration (or MLAT) and radar data. While this can often provide the first notification of an event or incident, there are limitations regarding the accuracy of the data as some of the displayed values may be aggregated or estimated depending on the service provider – especially for aircraft shown in the more remote areas with only ADS-B or no coverage. This kind of application alone may not be sufficient for meeting the aircraft tracking objectives of recently defined regulations and ICAO's recommendations and operators should check with their respective National Aviation Authorities. ■

POST FLIGHT LOCALISATION AND RECOVERY

The aim of tracking aircraft in distress is to more precisely establish the location of the aircraft's end-of-flight, marking the accident site, within a 6 nautical miles radius (roughly 11 kilometres or 7 miles). ICAO requests implementation of means for localising an aircraft in distress from January 2021 for all new manufactured aircraft, and improvements to underwater locator beacons that will increase the chances of locating the wreckage underwater from January 2018.

Aids to Locating an Accident Site

It is the Autonomous Distress Tracking function that will help to determine the accident site and to launch the search and rescue operations. There is additional equipment installed on the aircraft itself that can aid in pinpointing the precise location of the wreckage and the flight data recorders.

Emergency Locator Transmitter (ELT)

This article only refers to the automatic fixed ELT and not the portable or survival ELTs that can be found in the cabin.

The current fixed ELT is an autonomous beacon including a battery that is fixed to the top of the aircraft's structure and triggered by impact sensors or the pilot from

“ The aim of tracking aircraft in distress is to more precisely establish the location of the aircraft's end-of-flight, marking the accident site, within a 6 nautical miles radius. ”

the cockpit. Analysis of past accidents show that the ELT can often be destroyed in the crash or sink too far under water before the Cospas-Sarsat satellites* can pick-up the signal and determine the aircraft's end-of-flight position.

The regulations are evolving to propose improvements to the current ELT and may include pre-crash activation to transmit its position before impact. New generation ELT are currently under definition and development to be ready for implementation from 2021.

Underwater Locator Beacon (ULB)

ULBs are acoustic beacons that are activated when the aircraft is immersed in water. A ULB is attached to the each flight recorder.

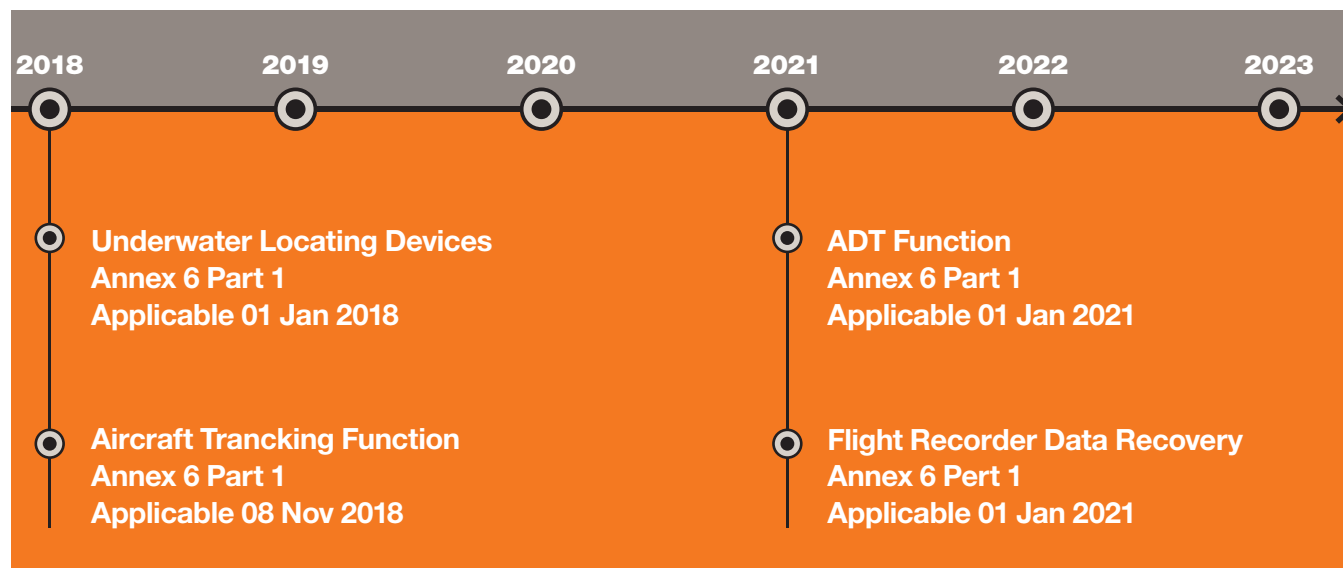
ICAO annex 6 requests ULB with minimum of 90 days operation should be fitted to replace the current standard of ULB with 30 days of battery-life at the earliest practical date, but no later than January 2018. Airbus is fitting 90 day ULB to all newly manufactured aircraft and have launched a retrofit campaign with Operators for the existing fleet to install new standard ULB.

In addition, ICAO recommends that all operators install the low frequency ULB for all aircraft operating over water from January 2018 and EU regulation makes it mandatory for all aircraft operating over water from January 2019. This new low-frequency (LF) ULB transmits a signal at 8.8 kHz and will be fitted to all new Airbus aircraft from this year. Retrofit of the existing fleet is also planned. When compared with the existing 37.5 kHz ULB, the detection range of the new LF-ULB is increased fourfold, up to 16nm or 29km based on a depth of 3500m and depending on the surface conditions of the ocean. ■

*Cospas-Sarsat Programme is a satellite-based search and rescue (SAR) distress alert detection and information distribution system, best known for detecting and locating emergency beacons activated by aircraft, ships and backcountry hikers in distress

(fig.7)

ICAO Annex Provisions with initial applicability in 2018-2021



“ Airbus will fit a deployable recorder device on its entire fleet of long range aircraft. ”

FINDING THE ‘BLACK BOXES’

There are cases, although rare, where the flight data and cockpit voice recorders, or “black boxes”, were submerged in the ocean and not recovered from the wreckage. In some other cases it took a long time to finally locate the recorders and then retrieve them from the ocean floor three to five kilometres below the surface. To avoid these scenarios in future, Airbus will fit a deployable recorder device on its entire fleet of long range aircraft with an aim to first install it on the A350XWB from 2019.

Regulation Drivers for Enhancing Flight Data and Cockpit Voice Recorders

Two types of recorders are currently required by the regulations on aircraft flying today. One is the Cockpit Voice Recorder (CVR), which must store the recordings of the cockpit voices and the text messages transmitted between the crew and controllers for the two hours prior to a serious incident or crash. The other is a Digital Flight Data Recorder (DFDR) that must retain the previous 25 hours of recorded flight parameters.

The CVR & DFDR are housed in separate units installed in the aircraft. Both are designed to resist impact forces of over 3,400G for 6.5 milliseconds and withstand temperatures of 1,100 degrees Celsius for 60 minutes. The recorders have an integrated Underwater Location Beacon (ULB) (**Fig. 8**).

Recently adopted ICAO Annex 6 amendments propose new performance based requirements for large commercial aircraft applicable from January 2021. For all aircraft manufactured after this date, the CVR fitted must be able to store at least 25 hours of recordings to cover all phases of the flight and in all types of operations. Any aircraft delivered with new type certificate after January 2021 must also be equipped with the means for timely recovery of the flight data and cockpit voice recordings, avoiding the need for underwater retrieval.

(fig.8)

Flight recorder devices installed on aircraft flying today



A Combined Cockpit Voice and Flight Data Recorder

The ICAO requirement to increase voice recording time from 2 to 25 hours will be the new standard for recorders under development for all Airbus aircraft. These new recorders will combine the flight data and cockpit voice recording functions in a single device capable of storing 25 hours of voice, text communications and flight data.

There will be two combined Cockpit Voice and Data Recorders (CVDR) devices fitted to new Airbus aircraft. One CVDR device will be fixed to the structure in the forward area of the aircraft (Fig.8a). A320 family aircraft will have a second CVDR fixed to the structure in its aft area. The second CVDR that will be fitted to the long-range aircraft families (A330, A350 XWB, A380 and including A321-LR) will be an Automatic Deployable Flight Recorder (ADFR) installed in the vertical tail plane area **(Fig.9)**.

The Automatic Deployable Flight Recorder

Airbus is developing an Automatic Deployable Flight Recorder (ADFR) suitable for its entire fleet of long range aircraft where the aircraft will operate routes over remote areas or oceans for an extended period of time. ADFR will be available from 2019 on A350 XWB aircraft with the subsequent deployment for the remaining long range aircraft families.

It is not a new concept as deployable recorders have been used in both military aircraft and commercial helicopter operations for some time, but it is not precisely the same technology that is proposed for commercial aircraft. The principle is to install a lighter, more compact unit that combines the flight data recorder, cockpit voice recorder and an integrated Emergency Locator Transmitter (ELT), which will be deployed from the tail area of the aircraft using a spring loaded device moments before an accident. The device will be deployed if sensors detect airframe deformation or immersion in water. The crash protected recorder will be designed to survive the impact and float on the water, while transmitting its position and allowing the search and rescue services to more rapidly rescue any survivors and discover the wreckage.

“ ... new recorders will combine the flight data and cockpit voice recording functions in a single device capable of storing 25 hours of voice, text communications and flight data. ”

(fig.9)

Showing design concepts for (a) combined Cockpit Voice and Data Recorder (CVDR) – right; and (b) the Automatic Deployable Flight Recorder (ADFR) – left.



Data Streaming

Increasingly, aircraft seem to be constantly connected in a way that enables passengers to make phone calls in the air, stream live television and use the internet via on-board Wi-Fi. Therefore, is it feasible to stream the aircraft's Cockpit Voice Recorder and Flight Data Recorder via satellite?

Beyond the obvious ease of quickly recovering flight data, an advantage of a satellite streaming solution is the possibility of implementing a retrofit solution for aircraft flying today that are already equipped with the long range communication means. This can enable the timely recovery of flight data and cockpit voice recordings following a serious incident or accident, but the size and regularity of the data transmission over the available satellite bandwidth are to be defined. Although the cost of transmissions is constantly decreasing, agreements regarding usage and coverage of the available satellite constellations also need to be established.

Another issue to be addressed is the security of the transmitted data and also the privacy implications concerning streaming cockpit voice recordings. The questions of who owns the data, responsibility to store the data securely, what level of data encryption is required and who will manage the encryption keys for access in normal flight operations or restricted access for investigation of an accident are under discussion today within the ICAO led working groups, which are made up of representatives from all actors in the Air Transport System. ■

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More accurate determination of the end-of-flight location reduces the search and rescue perimeter with the hope of finding survivors faster. Improvements to the Underwater Locator Beacon, and installation of the deployable recorders, will increase the chances of locating the submerged wreckage and enable a more timely recovery of flight recorders. This will make data more rapidly available to investigators.

Regulations are evolving based on the ICAO recommendations already in place for performance based requirements related to the tracking, localisation and eventual recovery of an aircraft in distress. Airbus is continuing to contribute to the various international working groups and support the standardisation of various aircraft solutions to comply with regulations. Aircraft tracking can be implemented today with fast and simple solutions available now for Airbus aircraft. Aircraft tracking function adds no additional workload for the flight crew.

The probability of a aircraft accident occurring is very low today, but if such an event was to occur, for an aircraft fitted with the tracking and localising enhancements described in this article, it is unlikely to be lost.

Safety first

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