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Instant aircraft recovery during disaster using ADS-B technology.

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Abstract— The traditional methods of search and rescue operation in the event of an aircraft disaster has a number of limitations and is highly time consuming and cost inefficient. Dependence on RADAR technology has its own limitations and does not allow continuous aircraft tracking over vast regions of ocean bodies. In this paper, we analyze how ADS-B can prove to be a vital breakthrough as it continuously monitors aircraft's geographical co-ordinates using a geosynchronous satellite with high accuracy and at any geographical location. Using this data, the search and rescue teams can find the aircraft in a matter of hours, and this increases the survival chances of the passengers if possible.

Index Terms— Air Traffic Control (ATC); automatic; ADS-B; GPS; RADAR; satellite; search; UAT;

1 INTRODUCTION

In recent years, the aviation industries have witnessed a variety of aircraft tragedies and disasters. For instance, the Air France 447 Flight that went missing in June 2009 and recovered only two years later or the MH370 Malaysian Airlines that went missing in March 2014 and is yet unknown. The major similarity in both these cases was that the aircraft had lost contact with the ATC. It could be due to lack of RADAR coverage or due to Transponder malfunction.

Automatic Dependent Surveillance-Broadcast (ADS-B) is a co-operative surveillance technology in which an aircraft determines its position by satellite navigation and periodically broadcasts it to the air traffic control. It can also be received by other aircrafts to provide situational awareness and preparation. ADS-B is a precise satellite based surveillance system. ADS-B Out uses GPS technology to determine an aircraft's location, airspeed and other data and broadcast that data to a network of ground stations, which relays the data to air traffic control displays and to nearby aircraft equipped to receive data via ADS-B In. Operators of aircraft equipped with ADS-B In can receive weather and traffic position information delivered directly to the cockpit.

ADS-B can be used as an alternative solution to the secondary RADAR as it overcomes its limitations of coverage and accuracy. ADS-B is "automatic" in that it requires no pilot or external input. It is "dependent" as it requires data from the aircrafts navigation system. The main advantage of using this technology is that it can easily cover the geographical regions that are unreachable by the RADARS and give continuous, uninterrupted and accurate location of the aircrafts geo-coordinates.

2 ARCHITECHTURE

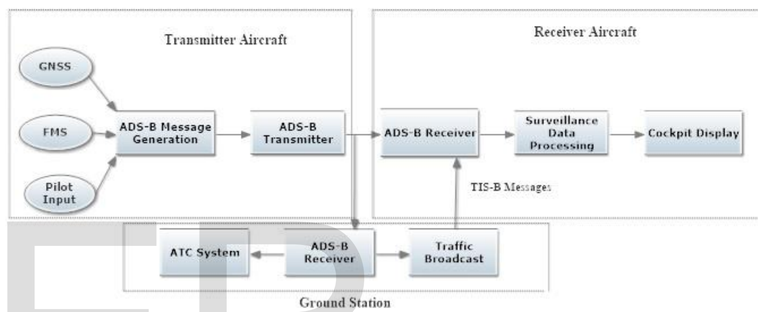

Fig 1. Architecture of ADS-B system.

The architecture of ADS-B system is as shown above. It operates on three main entities.

- Transmitter Aircraft
- Receiver Aircraft
- Ground Station.

The GNSS is a constellation of satellites that the aircrafts contacts to retrieve its location. Once, its location coordinates is known, the ADS-B Message Generator generates a message which consists of

a) Aircraft's Longitude and Latitude
b) Its barometric altitude.
c) Quality indicators
d) Aircraft identification:
    - Unique 24-bit aircraft address.
    - Aircraft identification number.
    - Mode A code.

e) Emergency status

This information is then transmitted to other aircrafts in the airspace and more importantly, to the Air Traffic Control on the ground by the ADS-B Transmitter. This entire process is automatic and needs no manual interference. Hence, even in the scenario of a hijack, its position cannot be hidden from the ground station.

The receiver aircraft uses the ADS-B receiver which decodes the transmitted messages sent by the transmitter. Using Surveillance data processing, the airspace traffic can be

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displayed on the cockpit display.

TIS-B is short for Traffic Information System-Broadcast. It's a traffic reporting system that uses ADS-B ground stations and radar data to transmit aircraft position data to aircraft cockpit displays. In essence, TIS-B will allow the pilots in the cockpit to see what the air traffic controller sees. It allows aircraft operators to receive traffic information in almost real time. Along with its partner system FIS-B, TIS-B is being offered at no cost to ADS-B users as part of the FAA's Next Generation Air Transportation System. Thus, the pilots can also locate other planes in the airspace thereby avoiding mid-air collision.

3 Motivation

The present day technology is largely dependent on secondary RADAR to track planes and find the last known location. However, the coverage is limited due to geographical factors and transmission can be lost for hours in a stretch. Using ADS-B, the pilot can be assured of its location transmission being uninterrupted.

The ADS-B is equipped with a Universal Access Transceiver (UAT). UAT uses the 978 MHz frequency that has been reserved for ADS-B. The UAT allows additional information to be uplinked to aircraft from ground stations through FIS-B (Flight Information System - Broadcast).

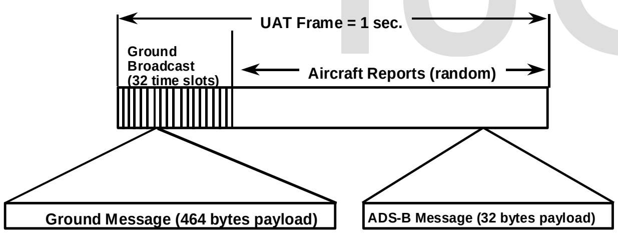

Fig 2. UAT Media Access

ADS-B messages contain either 128 or 256 bits of "payload"—the portion conveying ADS-B information. This allows every transmitted message to include a full-uncompressed State Vector. The State Vector is the information related to position and velocity—the most dynamic of the ADS-B information. This allows every transmitted ADS-B message to "stand-alone" in that every received message can be used directly to update the traffic display without the need for tracking, message reassembly or ambiguity resolution of the compressed latitude and longitude as is required in other systems. Furthermore, each message includes adequate error checking power that the applications are not required to perform any integrity checks.

There have been incidents of air crashes where finding the location of the debris has been most difficult and tedious task for the search team. Using ADS-B, we can easily find the last known location, just a moment before the crash actually took place. Thus, the search and rescue team can directly arrive at the crash site and this increases the chances of survival for the passengers.

In case of the missing MH370 Boeing 777-200ER that had supposedly crashed on the 8th of March 2014, the debris is yet to be located. The plane has been assumed to have crashed in the Indian Ocean and its last known location was over the South China Sea. Reports suggest that the transponder had been switched off manually and the aircraft lost contact with the RADAR. If we had instead, replaced the RADAR with ADS-B technology, we could have known the last coordinates just before the moment of the crash. Thus, preventing months of expensive search operations and agony amongst the family members of the deceased.

Another incident involves the Air France flight 447 that crashed into the Atlantic Ocean in 2009. The black boxes were not recovered until 2011. This is due to the fact that the aircraft had lost contact with the RADAR when it was over the deserted Atlantic Ocean and location was hard to determine after the crash. Using ADS-B, we could have easily detected the last coordinates moment before the crash, even in the remote locations and harsh geographical factors. This is because the aircraft can be in constant, uninterrupted contact with the GNSS satellites, broadcasting its location each second to the ATC and other aircrafts in its airspace.

4 Proposed Approach

The following method is used to describe the proposed sequence of events in the transmission process.

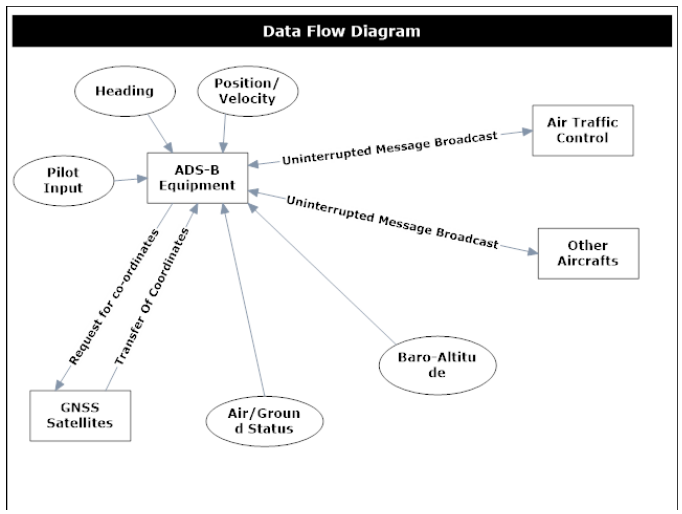

Fig 3. This figure shows the data flow diagram. Data flow diagrams are helpful in determining the flow of data between the entities used in ADS-B.

The Data flow diagram is as shown in the above figure. The ADS-B Out equipment in the aircraft request for its Geographical co-ordinates to the GNSS satellites using GPS.

Other sensors in the aircrafts such as the speedometer and

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Barometric sensors add real time data to the ADS-B OUT equipment located inside the aircraft. The UAT adds additional information to be uplinked to aircraft from ground stations through FIS-B (Flight Information System- Broadcast).

The ADS-B message generator then encodes this entire data into a message signal. This signal is then transmitted to all the other aircrafts in the nearby region and also to the ATC.

The ADS-B IN is responsible for receiving the transmitted signal and its decoding. On aircraft, it is the TCAS computer that receives and treats the ADS-B information coming from ATC transponders of surrounding aircraft. The information is then displayed on the Navigation Display (ND) and the MCDU.

5 ACCURACY

The onboard navigation equipment supporting the airborne surveillance function requires conversion of navigation sensor measurement data into standard ADS-B data format. The following parameters specify navigation data quality requirement for determining position accuracy and velocity accuracy for ADS-B transmitting subsystem. The position accuracy parameters are usually called horizontal Estimated Position Uncertainty (EPU), NACp and Geometric Vertical Accuracy (GVA). The EPU is defined as the radius of a circle centered at the true horizontal position within which the measured horizontal position lies with 95% probability. A NACp is a 4-bit representation of a corresponding EPU in an ADS-B broadcast state vector report. For example a NACp with a decimal value 11 corresponds to an EPU of less than 3 meters. EPU is usually called Horizontal Figure of Merit (HFOM) if it is reported by GPS or other GNSS. A GVA is a 2-bit representation of geometric altitude accuracy. For example, a GVA with decimal value 2 corresponds to geometric vertical accuracy (95% accuracy bound) of 45 meters or less. The 95% accuracy bound is also called Vertical Figure of Merit (VFOM) if it is reported by a GNSS. Similarly, the NACv parameter describes the accuracy region about the relative velocity vector within which the true velocity is assured to be with a 95 percent probability at the reported time of applicability.

Tables 1, 2 and 3 show the values of the NACp, NACv and GVA. As shown, horizontal position accuracy is characterized with NACp and the corresponding horizontal EPU; horizontal velocity accuracy is characterized with the NACv; and GNSS vertical accuracy is characterized with the GVA.

Table 1. Navigation Accuracy Category for Position (NACp)

NACp	**95% Horizontal Accuracy Bound (EPU)**	**Comment**
0	EPU ≥ 10 NM	Accuracy unknown
1	EPU < 10 NM	RNP-10 accuracy
2	EPU < 4 NM	RNP-4 accuracy
3	EPU < 2 NM	RNP-2 accuracy
4	EPU < 1 NM	RNP-1 accuracy
5	EPU < 0.5 NM	RNP-0.5 accuracy
6	EPU < 0.3 NM	RNP-0.3 accuracy
7	EPU < 0.1 NM	RNP-0.1 accuracy
8	EPU < 0.05 NM	e.g., GPS (with SA)
9	EPU < 30 m	e.g., GPS (SA off)
10	EPU < 10 m	e.g., WAAS
11	EPU < 3 m	e.g., LAAS

Table 2. Navigation Accuracy Category for Velocity (NACv)

NACv	**Horizontal Velocity Error**
0	Unknown or ≥10 m/s
1	< 10 m/s
2	< 3 m/s
3	< 1 m/s
4	< 0.3 m/s

Table 3. Geometric Vertical Accuracy (GVA)

GVA Encoding	**Meaning (meters)**
0	Unknown or > 150 meters
1	≤ 150 meters
2	≤ 45 meters

6 CONCLUSION

In this paper, we have studied the advantages of using ADS-B technology over the traditional secondary RADAR and its accuracy. This method can help us pin-point the exact location of the air crash during a disaster as it accurately locates the co-ordinates of the aircraft just moments before the crash. This information helps the search & rescue operation team and increases the chances of finding survivors. The accuracy of ADS-B is very high and it has already begun implementation in some parts of the world such as Air

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Services Australia, EUROCONTROL CASCADE PROGRAMME, and many cities of Germany. The ADS-B is integrated along with the secondary radar in some airports.

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