

Futuristic Black Box Design Considerations and Global Networking for Real Time Monitoring of Flight Performance Parameters

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Abstract—The aim of this research paper is to conceptualize, discuss, analyze and propose alternate design methodologies for futuristic Black Box for flight safety. The proposal also includes global networking concepts for real time surveillance and monitoring of flight performance parameters including GPS parameters. It is expected that this proposal will serve as a failsafe real time diagnostic tool for accident investigation and location of debris in real time.

In this paper, an attempt is made to improve the existing methods of flight data recording techniques and improve upon design considerations for futuristic FDR to overcome the trauma of not able to locate the black box. Since modern day communications and information technologies with large bandwidth are available coupled with faster computer processing techniques, the attempt made in this paper to develop a failsafe recording technique is feasible. Further data fusion/data warehousing technologies are available for exploitation.

Keywords—Flight data recorder (FDR), black box, diagnostic tool, global networking, cockpit voice and data recorder (CVDR), air traffic control (ATC), air traffic, telemetry, tracking and control centers ATTTCC).

I. INTRODUCTION

IN the field of aviation Flight data recorder (FDR) popularly referred to as “black box” is the main source of specific aircraft and flight performance data for accident investigation. The data recorded by FDR is also used for analyzing air safety issues, material degradation and engine performance.

Due to their importance in accidents investigation, these ICAO-regulated devices are carefully engineered and stoutly constructed to withstand the force of a high-speed impact and heat of an intense fire [1]. The unit is generally mounted in the aircraft’s empennage, where it is more likely to survive a severe crash. Following an accident, recovery of the “black boxes” is second in importance only to the rescue of survivors. They are designed to emit a locator beacon for up to 30 days, and can operate immersed to a depth of up to 6000 meters [2], [3].

II. HISTORICAL BACKGROUND AND NECESSITY

With the success story of FDRs, no single person could be credited with the invention of the flight data recorder. In 1939 earliest and proven attempts were made by Francois Hussonot

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and Paul Beaudouin at the Marignane flight test center, France with their type HB flight data recorder for altitude, speed etc. [4], [5]. A pre-production run of 25 HB recorders was introduced in 1941, remained in use in French test centers well into seventies [5, pp. 206&209]. In 1956 first prototype coupled FDR/CVR was designed by Dr. David Warren of the then Aeronautical Research Laboratories of Melbourne, Australia [6]-[8]. In 1965, the units were redesigned and moved to the rear of airplanes to improve the probability of successful data retrieval after a crash. The "Flight Recorder" was invented and patented in the United States by Professor James J. "Crash" Ryan, a professor of mechanical engineering at the Minnesota from 1931 to 1963. An early prototype of the Ryan Flight Data Recorder is described in the January 2013 *Aviation History Magazine* article "Father of the Black Box" by Scott M. Fisher [9]-[12].

With the advent of digital recorders, the FDR and CVR can be manufactured in one fireproof, shock proof, and waterproof container as a combined digital Cockpit Voice and Data Recorder (CVDR). Currently a CVDR is manufactured by L-3 Communications [13] as well as other manufacturers. Solid-state recorders became commercially practical in 1990, having the advantage of not requiring scheduled maintenance and making the data easier to retrieve. This was extended to the two-hour voice recording in 1995 [14].

The design of today’s FDRs is governed by the internationally recognized standards and recommended practices relating to flight data recorders which are governed by ICAO and other design requirements.

In many of the aviation accidents, it is very difficult to locate the black box and debris for finding out the real causes of accident. The following few accidents are quoted here for justification and necessity of this research paper.

- (a) Air France Transatlantic Flight 447 on 01 Jul 2009.
- (b) Malaysian Flight MH 370 on 12 Mar 2014.
- (c) BELL 206 Helicopter in India carrying Andhra Pradesh Chief Minister on 03 Sep 2009.
- (d) Indonesian Air Asia Flight 8501 on 28 Dec 2014.

The black box of Air France Flight was not found till 2011 in spite of huge efforts for retrieval from Atlantic Sea. The disappearance of Malaysian Flight MH370 is still a mystery. The Bell Helicopter crashed in India could not be located for 3-5 days in spite of deploying over 5000 security personnel, 8 helicopters, air borne imaging platforms and many local villages folk. Finally, the Air Asia Flight Black box retrieval took many days and reasons for crash are still finding rounds.

The efforts involved in search operations are very costly; a part of this sum is enough to fund research, and development of proposed real time solution in this paper. Thus necessity for this research solution is highly appropriate.

III.METHODOLOGY

Here in this research paper methodology for development of futuristic black box design and global networking for real time monitoring of flight performance parameters involves two steps. Here the attempt is to propose a new methodology to real time surveillance and monitoring of flight safety parameters through new design and global networking. The steps involved are:

- (a) Design of new flight data recorder and
- (b) Global networking for real time monitoring of flight performance and GPS parameters.

A. Design of New Flight Data Recorder

Presently design standards, for example EUROCAE specifies that a recorder must be able to withstand an acceleration of 3400g (33 km/s²) for 6.5 milliseconds. This is roughly equivalent to an impact velocity of 270 knots and a deceleration or crushing distance of 450 cm. additionally, there are requirements for penetration resistance, static crush, high and low temperature fires, deep-sea pressure, sea water immersion, and fluid immersion.

Current day FDRs receive inputs via specific data frames from the FDAU units. They record significant flight parameters including the control and actuator positions, engine information and time of the day. There are 88 parameters required as a minimum under current US federal regulations, though only 29 were required until 2002. Normally each parameter is recorded a few times per second, though some units store "bursts" of data at a much higher frequency if data begins to change quickly. Most FDRs record approximately 17-25 hours' worth of data in a continuous loop. The proposed new FDR design is to have the following features.

- (a) The new FDR should include a transmission section.
- (b) The flight performance parameters are to be recorded few times per second.
- (c) The recorded parameters need to be transmitted to the controlling air traffic ground station every second in real time.
- (d) The received parameters are to be monitored by ground crew.
- (e) The transmitting antenna should be fitted at an appropriate place on the aircraft.
- (f) This proposed black box should be including reception of GPS parameters may be through GPS additional receiver on board the aircraft suitably integrated.
- (g) This black box also to transmit GPS parameters (aircraft positional parameters) along with flight performance parameters in real time.
- (h) Cock-pit video as an additional input.
- (i) Video recording of passenger location.
- (j) New black box must withstand vibrations.
- (k) New black box must withstand explosion if any.

- (l) The proposed FDR to have dual battery power systems so that the last data recorded parameters with GPS must be transmitted for a longer time, in case of accidents like Transatlantic France flight, MH570 and Air Asiaflight 8501.
- (m) Lastly, it switches over to work as locator beacon after exhausting all power sources.

The block diagram of the proposed futuristic black box is as shown in Fig. 1. The air traffic control centers ATCs) can be re designated as Air Traffic, Telemetry, Tracking and Control Centers (ATTTCCs). In addition to existing flight performance parameters cockpit video, GPS parameters, passenger cabin video and external video inputs can also be comprehensively designed. The external video cameras can be so located that engine intakes could also be monitored and viewed. All these signals have to be combined before giving it to modulator, transmitted for further transmission to ATTTCC in contact. From ATTTCC the data can be transmitted to master ATTTCC by conventional means either by fiber or through a satellite. The passenger video inputs can help monitor in case of any terrorist related activities in the passenger cabin.

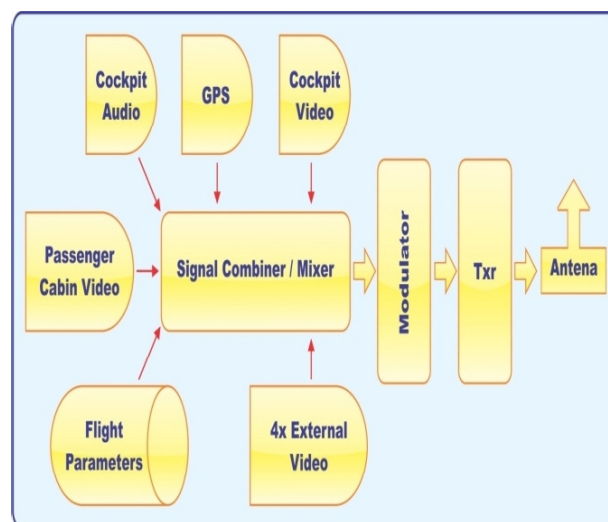


Fig. 1 Block Diagram of the Proposed Futuristic Black Box

B. Global Networking for Real Time Monitoring of Flight Parameters

The flight parameters received at the ground station can be uploaded to a satellite and from there the information can be sent to manufacturer, aircraft operating agency and flight safety (accident investigation agency) and so on. The networking technologies either satellite based, optical fiber based, or a combination of both networks is well established in the world. Hence, there is an easy scope for distribution of flight data as required. These global flight safety parameters on line network could have some regional reference stations and some master control centers across the global.

The block diagram of the proposed global networking for real time monitoring of flight performance parameters is as shown in Fig. 2. Once the data is received at any of the

ATTCC it can be transmitted to shareholders anywhere in the world. Manufacturer, Fleet owner, Govt-DGCA and ICAO authorities can view the data in near real time.

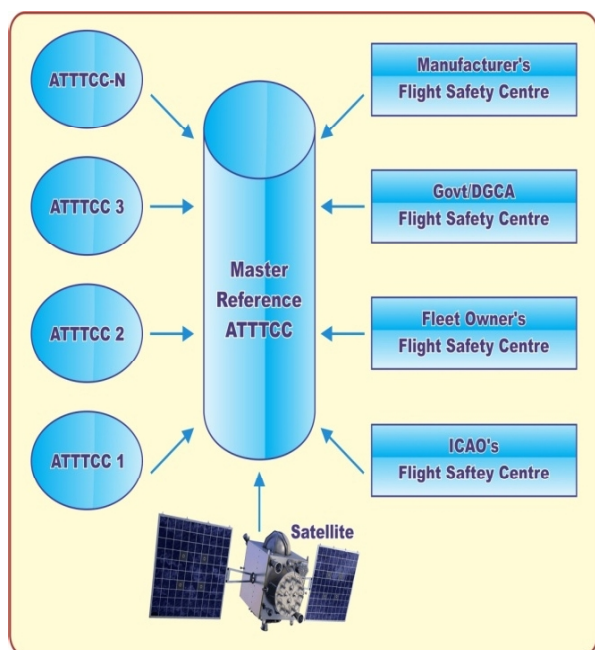


Fig. 2 Block Diagram of the Proposed Global networking for Real Time Monitoring

The technology for recording spacecraft orbital parameters and its health keeping parameters, down loading, monitoring and analysis already exists in spacecraft control operations. They are daily required for control and re-positioning of spacecraft in its designated position for its intended missions. This kind of global networking exists for spacecraft operations including over sea based ship control and monitoring. The concept proposed in this methodology is to tap the flight performance parameters being recorded by FDR and transmit live to one of the nearest controlling ground station, uplink to a satellite or through fiber optic network or by a combination of both networks. This data can be made available to flight operators, manufacturers, flight safety authorities IACO and user locations. ICAO can designate some reference ground stations and master control stations for distributions of real time downloaded flight performance data across the globe for near real time monitoring through this proposed global flight safety network.

IV. ANALYSIS AND DISCUSSIONS

In case of flight data recorder (FDR) of aircraft, recording is already done but transmission is not carried out in real time. Thus in case of accidents especially across transatlantic, Southeast Asia and Australian flights the location of black box becomes very difficult. In some cases, it may not be feasible to retrieve the black box and the reasons for accident are inconclusive with many Ifs and BUTs. If FDR is redesigned and modified to transmit similar to spacecraft orbital and on board systems health keeping parameters, the FDR will

become a “wonderful black box”. Along with this continuous monitoring of down loaded flight safety parameters including flight position parameters (GPS Parameters) and its uploading through global network will save lot of time and costly retrieval efforts. The tale of Flight MH370 is the greatest unsolved mystery in aviation since Amelia Earhart disappeared with her Lockheed Electra in 1937. This solution could have given a clear path for speculations surrounding the mystery of MH370.

Present day FDRs receive inputs via specific frames from the FDAU units. They record significant flight parameters, including the control and actuator positions, engine performance and time of the day. A total of 29 parameters were recorded until 2002, but as of now a total of 88 parameters are required to be recorded as per US federal regulations. Here as per proposed system in this research paper FDR design may include recording of many parameters for flight data analysis such as optimum fuel consumption and dangerous flight crew habits. For real time monitoring the optimum parameters for flight performance, engine performance, time of the day, GPS positional parameters, control actuator positions are certainly required to be transmitted in addition to recording. This is to optimum usage of bandwidth available for down loading and monitoring in near real time. The proposed FDR can be designed with dual battery power systems so that they can transmit last recorded parameters with GPS for a longer time, in case of accidents like Transatlantic France flight, MH370 and Air Asiaflight 8501. This will also enhance capability to locate debris in a quicker time. The appropriate place for locating the transmitting antenna is very critical on the aircraft. FDRs are usually located in the rear of the aircraft, typically in the tail. Hence antenna integration on to the aircraft platform should be feasible, but with suitable capabilities for transmitting.

The proposed futuristic FDR design is that of modifying or redesigning the existing FDRs to transmit the recorded flight performance parameters along with GPS parameters. The advent of VVLSI, data processing and micro strip antenna array technologies along with digital communications, it would not be difficult to design the FDR for transmission purpose from the aircraft. The proposed global network for navigation and monitoring flight performance parameters is expected to cover every single moment of every flight along with continuous communication contact from departure to destination. It will be capable of controlling and monitoring all phases of all flights over continental and oceanic space on 24X7 basis. Hence, this monitoring network is ideally suitable as a diagnostic tool and monitoring system for accident investigation and debris location in real time. Once live recording and monitoring is ensured then flight parameters with GPS parameters are available to manufacturer to know the real causes of accidents. With existing data mining technologies availability, it will ensure the manufacturer’s responsibilities to user from womb to tomb. This is a great solution for coming out of black box recovery syndrome in case of accident. This solution is likely to enhance the flight safety and will help in preventing the aircraft accidents. Cost

of proposed black box design, manufacture, testing, installation, integration and maintenance is the major factor of economy and development. The passenger video inputs can help monitor in case of any terrorist related activities in the passenger cabin.

V.CONCLUSIONS

In this paper the existing process of FDR's capabilities studied, discussed and analyzed. After this, futuristic black box design considerations successfully elucidated with flight parameters along with GPS parameters transmitting capabilities. An attempt is made to propose a global network for controlling and monitoring of these parameters by down loading at some reference ground stations. After which they can be transmitted to various agencies for live monitoring through satellite based or optic fiber based or by both. The proposed live flight data recording and monitoring may not be feasible for all aircraft world over. For military flights, it would be size and space constraints since recording and retransmission is required.

The major contribution of this research paper is the availability of flight performance and GPS parameters in near real time at designated locations for monitoring continuously. Another major contribution is the futuristic design of FDR for transmission capability of the recorder parameters along with location (GPS) parameters. The existing process of accident investigation which requires the retrieval of FDR is not suitable for long haul military or civilian aircraft flying across continents. Through this proposed methodology the real time availability of the black box parameters along with GPS will be a great assistance and highly suitable for accident investigation and debris location. Satellite orbital and its health keeping parameters recorded on board are regularly monitored at ground stations. Similar technologies can be applied to FDRs of aircraft transmitting aircraft performance and GPS parameters to nearest air traffic control reference station and then to a master control for further distribution of FDR data.

In case of difficult in transmitting many flight performance parameters (88), the important parameters such as flight performance, engines performance, time of the day, GPS positional parameters, control actuator positions can be transmitted in addition to recording. The advantages of the proposed methodologies are

- (a) The flight performances with GPS parameters are available to users/manufacturers or as designated by ICAO in near real time.
- (b) Improved flight safety and will help prevent accident prevention.
- (c) Remotely monitoring aircraft performance and status in real time.
- (d) Detect and record the reliability of the aircraft performance.
- (e) On line aircraft performance data efficiency to improve guidance to aircraft during flight and overall system performance.

- (f) It will be a diagnostic tool for accident investigation and debris location in real time.
- (g) Highly suitable for twin or multiengine aircraft. For example, Taiwanese TransAsia flight GE 235 has two engines. Flight safety experts are suspecting that though one engine failed, the serviceable engine was switched off leading to accident. Such suspicions' will never arise if the proposed system in this paper is in place.
- (h) User, designer and manufacturer are greatly relieved to monitor and know the real causes of accident in real time and extend support from womb to tomb.
- (i) The passenger video inputs can help monitor in case of any terrorist related activities in the passenger cabin.
- (j) The engine intake/propeller video inputs can help monitor in case of any damage related information.

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