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Research Article

Analysis of Black Box of International Airlines and its Future Scope

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Abstract

Any plane or flying jet is required essentially to be equipped with a Cockpit Voice Recorder (CVR) & a Flight Data Recorder (FDR). It is these two important items to which we refer as a 'Black Box.' While they do nothing functional in helping the plane during the flight, but both of this equipment's are crucially important in the case if plane crashes, as they hold down the history of each & every act going on inside the plane's cockpit area & later on help crash investigators in finding out what had actually happened just before the crash. Each usable recorder has a device fitted to it, known as an Underwater Locator Beacon (ULB), comes into use when plane's crashed parts falls into the sea or any water body after crash. The device is activated, as soon as the recorder comes into contact with the water & it starts transmitting signals from the depth as deep as 14,000 feet. Most important aspect of it is that, A Black Box is not black at all, but bright orange in colour. All recorders undergo countless tests before getting deployed in any plane or aircraft.

Keywords: *Beacon, EUROCAE, Flight Data Recorder, Cockpit voice recorder, Open VMS, Aviation Safety & Security, Cloud Computing*

1. Introduction

Black box is any electronic data recording device that is placed in ships, aircrafts, satellites, jets, or any other aero-model etc. It includes two components, a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR). It records data regarding the various aspects of flight, like elevation level, the distance travelled, the position of the wing flaps and rudder, fuel level etc. This device is usable only after an air crash. It helps the investigators to find out the reason behind the crash of an aircraft and the necessary measures are taken to avoid the reoccurrence of any such crashes in coming future. The internal construction of the black box consists of an aircraft interface board, audio compressor board, high temperature insulation, stainless steel shell, acquisition processor board, etc. The aircraft interface board interfaces data from DAS (data acquisition system) to the flight recorder. High temperature insulation and stainless-steel shell help in protecting the black box. But there have been several incidents where the black boxes have not been able to definitively identify the reasons for the crash, because either they are too damaged to be read or might have missing data due to power loss.

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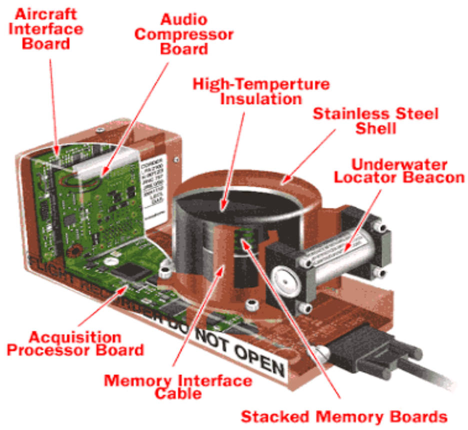


Fig.1 Construction of the black box

2. Specifications

The design of today's era black boxes is governed by the Internationally Recognized Standards and specially recommended practices related to flight recorders which are permanently included in ICAO, Annexure 6, which makes references to industries & fire protection specifications. In the United States of America, the Federal Aviation Administration (FAA) is a government authority that regulates all aspects of US aviation industry, and puts forward required design Specifications in their Technical Standard Order, based on the EUROCAE documents. Currently, EUROCAE has some certain specifications that are as follows:

- A recorder must be able to withstand an acceleration of 3400 g (ie 33 km/s^2) for 6.5 milliseconds.

This is roughly equivalent to an impact velocity of 270 knots (310 mph; 500 km/h)

- A deceleration or crushing distance of 450 cm.

Additionally, there are specific conditions for

- Penetration Resistance
- Static Crush
- High & Low Temperature Fires
- Deep Sea Pressure
- Sea Water Immersion
- Fluid Immersion

EUROCAE ED-112 defines the minimum required specifications to be met for all aircraft requiring flight recorders for recording of flight data for further use, cockpit audio, images etc are used for investigations of any unfortunate accidents or incidents. In order to facilitate recovery of the black box from an aircraft accident site they are coloured in bright yellow or orange colour with immense reflective surfaces. All are lettered Flight Recorder, Do Not Open in English language on one side and the same in French language on another side. To assist recovery from submerged sites they are equipped with a device named Underwater Locator Beacon which is automatically activated in the event of an accident or crash.

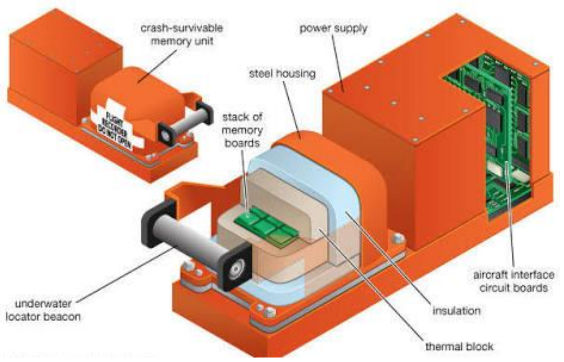


Fig.2 Important parts of Black Box

3. Hardware

The black box consists of two important parts:

- Flight Data Recorder (FDR)
- Cockpit Voice Recorder (CVR)

Flight Data Recorder records 3000 parameters in flight such as the air speed, altitude, position of flaps, stabilizers, engine performance etc. The Flight Data Recorder records 25 hours of flight data and 2 hours of digital data. The Flight Data Recorder has a solid-state memory unit which stores data. The memory board of the recorder is protected by a metallic casing capable of withstanding impacts equivalent of 3400 times the force of gravity and temperature up to 2000-degree Fahrenheit. The voice frequency of person and instrumental data ongoing processed by the flight recorder are stored in digital format on solid-state memory boards. One other important hardware component of the black box is the beacon that starts sending out ultrasound signals as it touches the sea level. It can send signals up to 14,000 feet deep below sea level. It sends signals for every 1 second for the next 30 days.

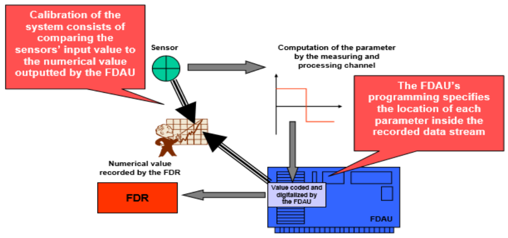


Fig 3 Calibration Process Diagram

4. Software

The operating system used in black box is the Open VMS system. Open VMS is a multiuser, multiprocessing virtual memory based operating system designed for use in time sharing, batch processing and transaction processing. Apart from Open VMS, the other software that can be used is the Linux software. There is a part in Open VMS systems called the ACMS or Application Control and Management System which is a transaction processing monitor software system for computers running the Open VMS operating system. In Open VMS when process priorities are properly adjusted, it may approach real time operations system characteristics. The system offers high availability through clustering and the ability to distribute the system over multiple physical machines. This allows the system to be tolerant against disasters that may disable individual data processing facilities.

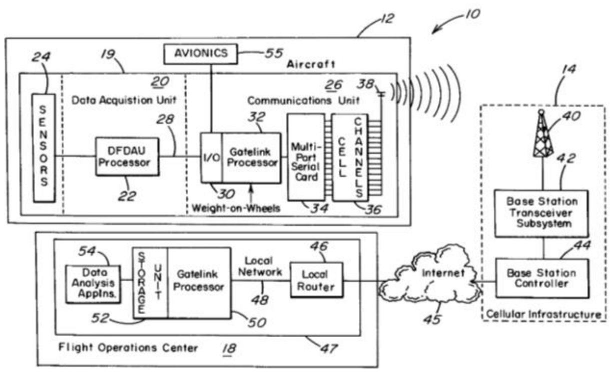


Fig 4 Aircraft data acquisition and transmission system

Table 1 Analysis report of different Aircrafts

S. No.	Aircraft Type	Introduced into Service	FDR Type	No. of Parameters	FDR Data Capacity
1	Boeing 707	1958	Analoge	5	Mechanical limit of about 10 parameters
2	Airbus 330	1993	Digital (Solid State / Tape Medium)	280	128 wps (Serial Data Input)
3	Embraer 170	2004	Digital (Solid State Combi Recorder)	774	256 wps (Serial Data Input)
4	Airbus 380	2007	Digital (Solid State)	>1000	1024 wps (Serial Data Input)
5	Boeing 787	2009	Digital (Solid State EAFR[9])	>1000	Ethernet System

5. Data Collection: Flight Data Recorders

In case of any unfortunate crash, both Crash-Protected FDR's & Optional Quick Access Recorders (QAR's) began to be installed on every commercial aircraft by the 1960's. The evolution of these efficient data collection devices is shown by using the following examples:

5.1 Cockpit Voice Recorder (CVR)

It would be better named the Cockpit Audio Recorder as it provides a lot more information than just the voices of the pilots driving the plane. In fact, it creates a complete record of the total existed audio environment in the cockpit area of plane. This readily includes

- Crew Conversation
- Radio Transmissions
- Aural Alarms
- Control Movements
- Switch Activations
- Engine Noise
- Airflow Noise

Older CVRs could retain only the last 30 minutes of an aircraft's flight, but a modern CVR could retain the last 2 hours of information, being of greater source of information. A typical traditional CVR is 16 cm (6.3 inches) in height, 12.7 cm (5.0 inches) in width and 32 cm (12.6 inches) in depth. It weighs 4.5 kg (10 lbs). Around 80% of aircraft accidents involve typical human factors, which means that crews irresponsible performance may certainly have contributed to the following event. As a result, the CVR often provides accident investigators with valuable insights into why an accident would have occurred.

5.2 Flight Data Recorder (FDR)

The FDR records various important flight parameters. The data recorded varies widely, depending upon the age & size of the aircraft. The minimum requirements, however, is to record a basic group of 5 essential parameters:

- Pressure Altitude
- Indicated Airspeed
- Magnetic Heading
- Normal Acceleration
- Microphone Keying

Microphone keying is recorded to correlate FDR data with CVR information, that is the basic & crucial step of information retrieving. This basic requirement has existed in all types of aircrafts since the 1960s. Today, modern jet aircraft far exceed this, and are fitted with FDRs that can record thousands of parameters covering all aspects of the aircraft operation. The FDR retains the last 25 hours of aircraft operation and, like the CVR, operates on the endless-loop principle. As FDRs have a longer recording duration than CVRs, they are very useful for investigating incidents and accidents. A typical FDR is 16 cm (6.3 in) in height, 12.7 cm (5.0 in) in width and 50 cm (19.6 in) in depth. It weighs 4.8 kg (10.6 lbs). The FDR often tells accident investigators what happened during an accident sequence and the events leading up to it.

5.3 Data Storage

Older CVRs were analogue recorders which used magnetic tape as the recording medium. Modern solid-state CVRs, however, store the digitized audio information in memory chips. Older FDRs were mostly digital recorders using magnetic tape as the recording medium. As with CVRs, modern solid-state FDRs store the digitized data in memory chips.

5.4 Underwater Location Beacon

Each recorder is fitted with battery-powered Underwater Location Beacon (ULB) to aid underwater recovery. When the ULB is immersed in water, it will begin to radiate an acoustic signal which can be received and transformed into an audible signal by a receiver. The ULB is sometimes called a pinger due to the audible signal created by the receiver. The ULB must meet the following requirements:

- Nominal Operating Frequency: 37.5 kHz
- Size (typical): (9.95 cm long * 3.3 cm diameter)
- Operating Depth: 0 to 6,096 metres (20,000 feet)
- Automatic Activation by Both Fresh & Salt Water
- Minimum Operating life of 30 days.

The acoustic output will surely decrease as the battery voltage decreases. It may have a bit possibility to still detect the ULB after 60 or more days but the detection range would be decreased. It can only be detected by a receiver under the water surface. The maximum detection range of a ULB is typically up to 2 - 3 kilometres but is largely dependent on:

- ULB acoustic Output Level
- Receiver Sensitivity
- Whether the ULB is Buried by Debris
- The Ambient Noise levels
- Water Temperature Gradients
- Depth difference between the ULB & Receiver

6. The Flight Tracer System

Glass box is a system which would be transparent and it is a real-time system which provides the transfer of data stored in black box to the ground. The process is done with the help of network of servers and databases that covers ever more of the world every day. It tracks aviation data using software and offers omnipresence, impregnability, infinite storage and incomparable power of search.

There is a need today for tracking aircrafts in real-time so that exact status can be known. Data can be recovered just after crash could help in preventing future accidents if the mispenning is occurred due to mechanical or technical fault of the plane. Glass box doesn't need any large equipment, only interfacing has to be providing in between main (plane) and distributed (ground) servers. Other advantages include product enhancement, log maintenance and fully automation.

6.1 Possible ways of communication

We know that the transmission of data could only takes place on suitable frequency ranges and a proper communication process must be there. The working of glass box is different when flight passes from land and when it passes from water bodies. When plane is over any large water body there is only one process of transmission i.e. satellite communication. The possible ways of communication are:

- HF- 3 kHz to 30 MHz
- VHF- 30 kHz to 300 MHz
- UHF- 300 MHz to 3GHz
- Radar, it offers higher bandwidth & security of the signal
- Satellite is available worldwide. It may be the only option when flying over ocean or desert.

These communication processes have one advantage over other and it can be possible to find the suitable communication as the area differs. The best method over both land and sea is found to be satellite communication.

6.2 Implementation Of Flight Tracer

The glass box system has a plane server which transmits data in real time. The plane server determines the flight parameters & forwards it to the transmitter & than to the black box at an instant. The flight tracer includes a concentrated Handshaking, communication protocol and header data formatting for communication between two links. The tracer system has been implemented on windows 7 for test and simulation purposes. In this the data from flight is transmitted to the ground server which is nearest area wise.

A shortest distance algorithm is needed to find which server has to transmit data if many servers are present at a time. The algorithm will find the server which has the minimum distance from the plane. And after that the data is sent to that ground server. Besides this, a set of algorithms is also being developed to encode the data, transmit it in real time, when the ground servers receive an informative data packets from an aircraft, it sends an acknowledgement to the plane server and checks the data packet sequence thoroughly to check any error. Each data packet carrying information is identified with the flight codes & the destination of the flight to be reached. The flight parameters are encoded at plane server by using embedded C language & its attributes. The decoding of flight parameters is done at ground station servers using functions of VB.NET language & its corresponding attributes.

6.3 Shortest Distance Algorithm

If two or more stations are present in any area then using shortest distance formula we find the shortest distance from the plane. The mathematical formula for shortest distance is:

$$D = \sqrt{[(x2 - x1)^2 + (y2 - y1)^2]}$$

Here d is the distance. x1, x2 are the latitude of plane and origin ground server while y1 and y2 are the longitudes of plane and ground server. The position of ground server gets varied with the flight according to area. If two or more servers are under coverage area of the plane then the one with shortest distance is transferred. This distance is most important in mechanism of the flight tracer system.

At the successful reaching of each flight the data from various servers are encoded and a text file is transmitted at the destination of the flight. Thus, the whole data is accumulated in the database of the flight. It is very uncluttered that, using this integrated system, the flight data recorder can be obtained at an instant after a crash, with which the exact cause of the crash can be determined undoubtedly.

6.4 Fault Tolerant Design

The on-flight plane tracker is designed keeping all aspects in mind to be fault tolerant to avoid any possible problems in working with numerous servers. The system works with

- 1 Air-Borne Server
- 1 Ground Based Control Server
- Several Ground Based Data Servers

Therefore, it is very imperative that the system should continue to work even if any faults are developed in any of the multiple functional servers. Fault tolerance is achieved by decoupling the lower level communication from the upper level communication programs. The system utilizes a separate module to test the connectivity strength of airborne server to the ground based server facilities. In case of any serious problem in communicating with the selected ground server, the system moves onto handshake process with the next server inline in order to continue the transmission to get effective results.

7. Black box useful or not

There have been several incidents where black boxes have not been able to supply information regarding the crash, either due to their debilitated condition or if they go missing, thus, taking away all the data with them. Here is the list of aircraft accidents where the information regarding the crash could not be retrieved by the black box.

Table 2 List of aircraft accidents that remains unresolved

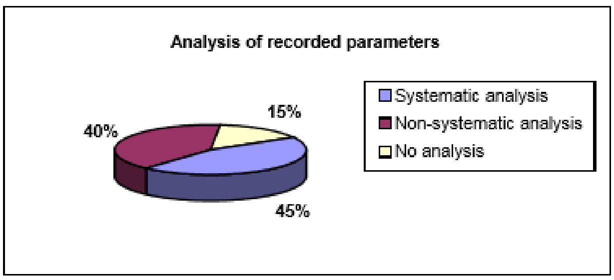
Sr. No.	Date of Crash	Flight No.	Airlines	Plane Type	Presumed Location	Remarks
1.	04/10/2001	1812	Siberia Airlines	Tupolev Tu-154	Black Sea	FDR not found, Main fuselage of the aircraft believed to contain the recorder, was believed to be at depth of 1000 m
2.	14/10/2004	1602	MK Airlines	Boeing 747-244 (SF)	Halifax, Nova, Scotia	FDR recovered, CVR mutilated in post-crash fire
3.	22/10/2005	210	Bellview Airlines	Boeing 737-200	Lisa Village, Ogun	FDR was never found
4.	03/06/2012	992	Dana Airlines	McDonnell Douglas MD-83	Lagos, Nigeria	CVR recovered, FDR mutilated in post-crash fire
5.	09/12/2012	N345MC	Private	Learjet 25	Iturbide, Mexico	CVR & FDR destroyed upon high speed impact
6.	08/03/2014	370	Malaysia Airlines	Boeing 777-2H6ER	South Indian Ocean	CVR missing, FDR missing search for debris & recorders underway

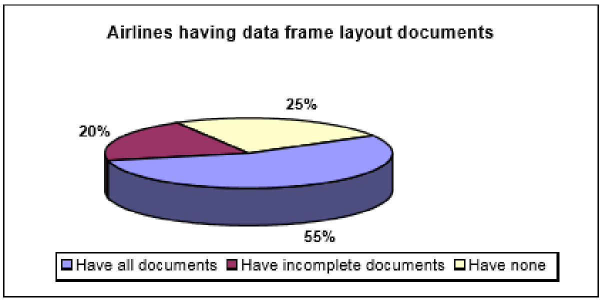
After performing an in-depth analysis of the above accidents and especially the Air France flight which crashed into the Atlantic Ocean in year 2009, there are few problems that are encountered with the black box:

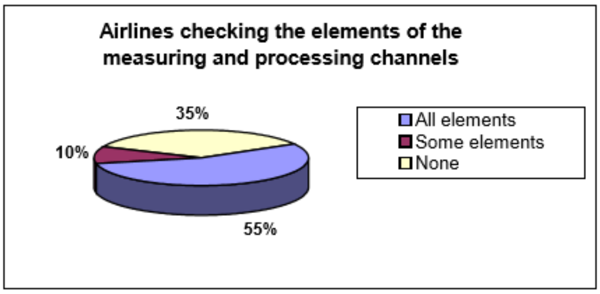
- The voice recorder in plane only captures the final 2 hours of the flight.
- Battery life is too short - The black box sends a ping (signal) activated on immersion in water, that is picked up by the microphone and fatherly by a signal analyser, but the battery lives only for 30 days generally.
- Black box is not easy to find in the middle of the ocean even though it is marked orange in colour.
- It does not float. - The box is made up of aluminium which helps in withstanding high pressure, fire etc. as a result of which the black box becomes very heavy.

8. Survey report of 20 French airlines

- 55% of airlines had a comprehensive set of data frame layout documents
- 35% of airlines had filed their data frame layout documents & completed other required formalities with the local Civil Aviation Authorities
- None of the aircrafts calibrated the essentially required measuring & processing channels
- 55% of airlines only checked the various elements of the measuring & processing channels of mandatory parameters
- 85% of airlines performed a rigorous analysis of the parameters, including 45% systematically and 40% not systematically
- Of the 11 airlines that had data frame layout documents, 90% of it performed complete parameter analyses.







9. Combining black boxes with cloud computing technology: a recent proposal

Invented in the 1950s, Black Boxes (CVR & FDR) are still being used widely as the primary source of forensic information for aviation safety and security principally. Since the unfortunate MH370 tragedy, the International Telecommunication Union (ITU) adopted a live streaming proposal for future aviation communications. With widely used remote controlled communication capabilities, smart-phone owners can now already detect the location of their phone and wipe data out if they are lost somewhere, it is less imaginable that engineers can't do the same for flights using more advanced & sophisticated technologies. Tracking one smart-phone seems to be very easy but really, it's not. To be able to fulfil this simple requirement it requires to invest significantly in cloud computing technique, the on-demand technology to employ large amount of computational resources as required. Each aircraft produces both digital & analogue data from thousands of on-board sensors, multiplied by millions of flights around the globe, a full-scale tracking of every aircraft using only satellite communication alone could be very expensive, but it is not entirely unfeasible. In fact, we have already seen several good signs towards solving this problem. Hopefully, the better results would emerge out in near future.

10. Future scope

- Transmission–Top mounted antennas communicate with satellites at higher altitudes, at lower altitudes, data can be sent directly to the ground receivers.
- Bandwidth – To save money, aircrafts could flash data intermittently, switching to streaming ways in an emergency.
- Satellites – By 2015, a constellation of dedicated search towards technology, rescue satellites will track aeroplanes exact location more quickly globally.
- Storage Servers – Today, uncountable servers around the world stores & send real time flights recorded data. Eventually, in coming future every airline would have its own server.

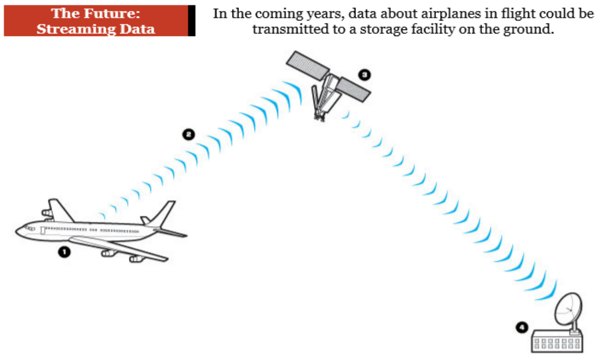


Fig 5 Future Streaming of Data

Conclusion

The Black box is currently widely used in the airplanes, ships and satellites but the current Black Box cannot be used for real time operations, since there is no bandwidth that can carry such huge amount of data. A technology needs to be invented that can carry a subset of data, Real time and Boeing has claimed to create such a technology and has patented for the same. Along with the above demands, the Black Box should be able to transmit signals for 90 days when submerged in deep waters which can increase the chances of success of recovering the black box. The signal from the Black box should be able to reach the surface of the sea or ocean so that it can be picked up by floating receivers/transmitters.

The floating device should be able to transmit data to SAR planes, ships or submarines or to the satellites sent into the zone or area to locate down the aircraft. Lastly, the Black box should have its own power source to transmit signals so it is not dependent on the power of the plane and hence, can result in a secure collection and retrieval of data.

In this paper, the real-time flight & its data tracking system is discussed to fulfil the need to find the black box easily after any unfortunate accident. The glass box system is eventually distributed, ascendable, trustable and representation are given with the bandwidths which are available today. The rules determining the format & transmission of data and types of packet are defined particularly to make fit for all 88 parameters that are recorded using flight data recorders & cockpit voice data recorders. Future work includes adding data encryption and routing specific modules in the system for better security & efficient data retrieval system. Data mining of data which is received on flight completion may be analysed for complete fuel efficiency and other operational efficiencies of an aircraft.

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