A review on Ejectable Versus Non-Ejectable Flight Data Recorder

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Abstract

Flight recorders, often called "black box" are two devices designed to record data about flights. Flight Data Recorders (FDR) record various flight parameters. All aircraft's are required to have Flight Data Recorder (Black) systems installed in it. Depending on aircraft, manufacturer can either use Non-Ejectable Flight Data Recorder or Ejectable Flight Data Recorder. This requirement is implemented in all large air carrier aircraft operating under U.S Code Of Federal Regulations, Title 14, Aeronautics And Space, Part 121 [9]. The paper will discuss about the comparison between Ejecatable Flight Data Recorder and Non Ejectable Flight Data Recorder Systems. Ejectable Flight Data Recorder Systems are deployable with the help of sensors. Ejectable recorders were invented by the Canadian government's National Research Council in the 1960s and thousands are installed on fighter jets, including the US Navy's F/A-18 jets, and small aircraft, like helicopters. [3].
Non-Ejectable Flight Data Recorder Systems are usually placed in one fireproof, shock proof, and waterproof container. Usually Ejectable systems are more complex than nonejectable systems.

Keyword:

Flight Data Recorder (FDR), Ejectable FDR, Non-Ejectable FDR.

Introduction:

A flight data recorder is a small line-replaceable computer unit employed in aircraft. Its function is recording pilots' inputs, electronic inputs, sensor positions and instructions sent to any electronic systems on the aircraft.[4]. Flight data recorders are designed to be small and thoroughly fabricated to withstand the influence of high speed impacts and extreme temperatures.
State-of-the-art high density flash memory devices have permitted the solid state flight data recorder (SSFDR) to be implemented with much larger memory capacity. A large number of aircraft are now equipped with solid-state recorders and no longer use disk drives. In the past ten to fifteen years, the density of memory chips has greatly

increased and the ability to record thousands of parameters for hundreds of flight hours in flight data recorders or quick access recorders is now possible. Compression algorithms are used by the manufacturers and may become even more prevalent with the introduction of video recorders. New video compression schemes have a significant compression factor which is usually some hundreds of times; that is, the compressed file will be less than 1% of the size of original file (Horowitz et al., 2012). This means that the compression is still useful, even though the memory capacity is much larger. This work has been done relative to hard disks of flight data recorders, but flash memory developers can utilize the results, as well. Smaller aircraft, General aviation aircraft and on Military aircraft this requirement is partially implemented. [5]

Fig. Flight Data Recorder [1]

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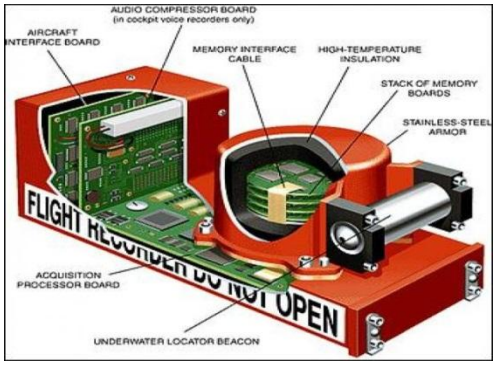

Fig. Inside Flight Data Recorder [5]

EJECTABLE FDR SYSTEMS

Ejectable FDR systems are usually contained in a module mounted in the aircraft skin or surface (vertical stabilizer or aft fuselage). Aircraft sensor and audio data are received and processed by internal avionics and transferred to the CSFDR for storage **(15** to 30 **min** first-in-first-out record time). The CPI consists of a radio beacon transmitter/antenna system that will transmit an omnidirectional emergency signal (121.5 and/or 243 MHz) and powered **by** either a nickel-cadmium or lithium battery. One new ejectable CPL will provide a visual marker (strobe light) that time-shares battery power with the radio beacon. The CPL is activated upon ejection from the aircraft and is required to transmit the emergency signal for 48 hr minimum. The ejectable CSFDR is deployed from the aircraft **by** one or more of the following switch devices: frangible switch (nose, wings, and belly); water activated switch; electromechanical switch (ejection seat); and manual electromechanical switch (test and maintenance). [6]

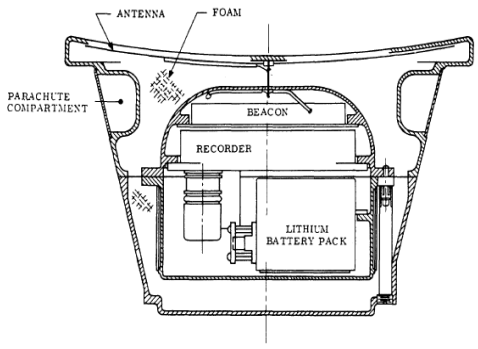

Fig. Ejectable Flight Data Recorder for Aircraft[6]

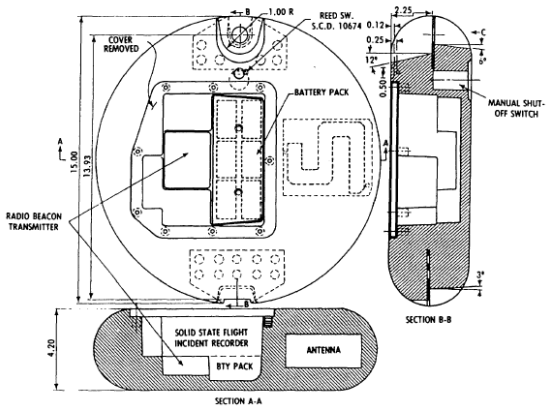

Fig. Ejectable Flight Data Recorder for Helicopters[6]

NON-EJECTABLE FDR SYSTEMS

Nonejectable CSFDR systems are usually contained within a crash hardened case and mounted inside the aircraft as other avionics equipment. The FDR systems are usually housed in separate crash hardened cases. CSFDR's store aircraft sensor parameter data **(30 min** to **25** hr first-in-first-out record time) and CSCVR's store aircrew audio data **(15** to **30 min** first-in-first-out record time). Nonejectable CSFDR systems function similar to ejectable systems except there is no ejection mechanism and the CPI does not have a strobe visual marker. Figure 4 depicts a nonejectable type CSFDR which includes both a Crash Survivable Memory Module **(CSMM)** with accompanying signal conditioning and memory controls in one package. Figure **5** depicts a cross section of the **CSMM.** Upon an aircraft crash, the nonejectable CSFDR will continue to record as long as power and signal inputs are supplied to the system. Although this has never happened during a major accident, it is a potential problem particularly during a minor accident or incident. Most nonejectable CSFDR systems are designed to operate using aircraft systems power; however, some are designed to operate using aircraft battery power.

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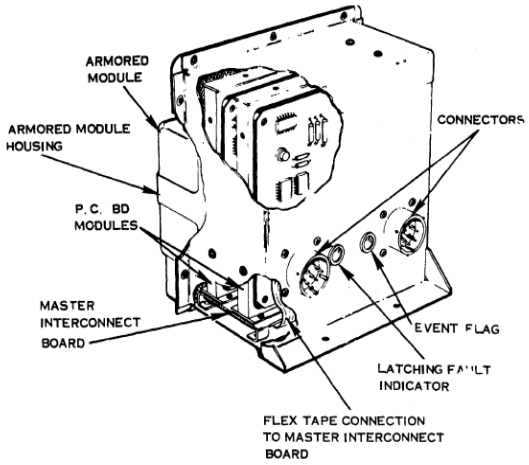

Fig. Non-Ejectable Flight Data Recorder for Aircraft[6]

EJECTABLE VERSUS NON- EJECTABLE FDR SYSTEM

a. **Complexity, Reliability, and Maintainability:-** As there are Different FDR System manufacturers it has considerable reliability differences also. The overall functional reliability of the system is equal to designed to be equal, as it is assumed for purpose of analysis. The ejectable system must function reliably as it has more equipment's in it i.e., the ejection system itself. peculiar to ejectable system one reliability problem has been inadvertent deployments. The U.S. Navy/Marine Corps aircraft with ejectable FDR systems (220 Total) experienced approximately 60% of these inadvertent ejections between 1979 and 1982[7].It was examined that approximately 60% of these inadvertent ejections were caused by inadvertent manual deploy switch operation, 35% by incorrect maintenance procedures, and 5% induced by component failures, which results 95% inadvertent ejections were human operational errors while 5% were truly reliability errors. Whereas, In non ejectable system do not face any of these ejection problems in any case. A sample of 361 incidents of ETL's or General Aviation aircraft between 1979 and 1981 indicated 99 (27.2 %) false alarms. [8] It was studied that accidental operation of control or remote switch, inadequate installation/handling, and switch malfunction are most general causes of these false alarm. Non ejectable FDR's faces an over reliability problem in that case after the incident of accident or crash, the system will continues recording until and unless the engine get stop or a special sensor fitted in it stops operation of recording. After the incident of crash or accident if system continues recording it may erase the critical and important data required for crash analysis.

b. **Survivability:-** In both Ejectable and non ejectable FDR system overall survivability requirements are the same. After accident or crash all the data stored in FDR are recoverable for analysis when CPI radio beacon transmits after accident or crash. The basic difference between ejectable and non ejectable FDR system is the test requirements and consequent design requirements for survivability. The survivability test requirements established by the U.S. Federal Aviation Administration (FAA) for air carrier aircraft, as contained in TSO-C51a [9], have been the U.S. standard for private, air carrier, and military systems. The survivability test requirements for non ejectable systems are generally more severe than those for ejectable system in area of penetration resistance, static crush, and fire protection. The difference between non ejectable and ejectable FDR system is that non ejectable systems remain with the crashed aircraft and are subjected to more severe mechanical and thermal environment than do ejectable systems that depart the aircraft and clear the crash fire. Non ejectable systems must be designed with crash hardend armor, as a result of more stringent survivability test requirements. Thus, increasing weight, volume, power requirements and cost. Subsequent testing, evaluation and analysis realistic. Consequently, revisions to TSO-C51aas drafted in reference 10, has been proposed. This revision more logically defines the survivability requirements as related to the real crash environment and in terms of testability. The primary reason for non operation of the non ejectable CPI/ELT systems was determined to be caused by mechanical/thermal destruction/damage. It should be noted that a non ejectable PI/ELT/ULB on an aircraft submerged in water is virtually useless for SAR aircraft location; i.e., /VHF/UHF radio beacon signals transmitted through water cannot be received by SAR aircraft radio equipment. Empirical crash survivability data for SFDR systems are even more limited than that for CPI systems. Media survivability is increased considerably if the CSFDR is located as far aft in the aircraft as possible. There are no known cases of an ejectable SFDR not surviving a crash.

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c. **SAR:-** The SAR requirements for both ejectable and non ejectable CSFDR systems are the same. Successful SAR operations are highly dependent on proper CPI radio beacon activation/transmission and the ability of the
SAR aircraft to receive the radio signal find and visually locate the downed aircraft, and recover survivors and the CSFDR systems.The difference between ejectable and nonejectable system capability to adequately accomplish the SAR mission. Ejectable CPI systems have an excellent activation/survivability/transmission record. The problem with ejectable systems has been the inadvertent deployments that require unnecessary recovery, sometimes repair, and reinstallation of the ejected package. Non ejectable **CPI** systems, on the other hand, have a poor activation / survivability/transmission record. The primary reasons for this poor record are inadequate actuation sensors (usually acceleration switches), poor crash survivability, and inability to transmit VHF/UHF emergency signal through wreckage obstruction or through water (into water crash). Therefore, ejectable systems have a clear advantage over non ejectable systems for SAR operations.

d. Weight, Volume, and Power Requirements:- It is a design and operational objective to minimize weight, volume, and power requirements of CSFDR systems. Commercial non ejectable magnetic tape systems are relatively heavy **(30** to **50 lb),** voluminous (1,600 to Z,400 in.5), drawing **60** to 100 W power. Existing ejectable systems tend to weigh less **(20** to **35 lb),** be less voluminous (1,200 to 1,800 in. 3), and require less power (40 to 70 W). New ejectable and non ejectable systems using digital solid state technology and new lightweight crash protection materials have reduced system weight, volume, and power requirements considerably, i.e., weight(10 to **20** lb), volume (600 to 1,000 in. 3), and power **(15** to **30** W).

e. System Safety:- The only safety considerations for CSFDR systems are batteries (CPI operation) and ejection systems. Many CPI systems use lithium batteries because of their long storage life (up to **5** years) and their lightweight and small volume. Some lithium batteries (not currently in CPI systems) have proven to be hazardous by exploding under high temperature conditions. All lithium batteries currently used in military CPI systems have been qualified under TSO-C97 or similar military specifications. Another perceived hazardous component is the explosive squib release mechanism used on some ejectable systems. The squibs used on ejectable systems are completely enclosed devices of the type that have been used on aircraft for years and, in fact, pose no hazard to aircraft or personnel. One real hazard does exist, however, with the mortar type ejectable system. When fired or ejected, the deployable package departs the aircraft at about 100 ft/sec. Therefore, if ejected inadvertently while the aircraft is on the ground, the package could be hazardous or fatal to nearby personnel. For this reason alone, the **U.S.** Navy does not use the mortar type CSFDR ejectable systems.

f. Cost:- Acquisition costs (including DT&E and installation) tend to be higher for ejectable CSFDR systems due to their additional complexity. Cursory cost analysis indicates that the acquisition cost of a nonejectable magnetic tape system should be less than $20,000 per system while an ejectable magnetic tape system should be less than $30,000 per system. Digital solid state memory technology has initially increased these acquisition costs because of their state-ofthe- art development; however, costs should decrease as more semiconductors and systems are produced. It should be noted that solid state technology has increased reliability, maintainability, survivability, and operability while reducing weight, volume, and power requirements.

g. Cost/Benefits:- Several cost/benefit analysis of CSFDR systems on U.S. Navy aircraft have established very high net results. These positive net cost/benefits are derived primarily from projected reductions of aircraft and aircrew losses, SAR missions, and recovery operations through the use of recorded flight data. Obtaining information immediately after an aircraft accident or incident permits rapid determination of cause and immediate implementation of ppropriate corrective action to prevent recurrence.CPI/ELT radio beacon transmissions from a downed aircraft can reduce SAR flying hours. In cases where the approximate location of a downed aircraft is unknown and even when a wide area must be searched, fewer SAR flying hours are required through the use of CPI/ELT locating. CPI/ELT transmission and SAR aircraft receiving provide rapid location of surviving aircrew. The ejectable CSFDR provides more cost effective benefits to the SAR operation due to its high reliability, survivability, and water recovery capabilities. Further quantifying of the cost/benefits resulting from CSFDR systems on aircraft should be conducted.

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