

# **Aviation Recorder Overview**

*Dennis R. Grossi*  
*National Transportation Safety Board*

## **KEYWORDS**

Aviation, Recordings, Overview, Investigation

## **INTRODUCTION**

There are a wide variety of airborne and ground-based aviation recording devices that can provide vital information for accident prevention purposes. The primary information sources include the mandatory crash-protected flight recorders, airborne quick access data recorders, and ground-based recordings of air traffic control (ATC) radar returns and radio communications. Other sources of recorded information, such as aircraft system internal memory devices and recordings of airline operational communications, have also provided vital information to accident investigators. These devices can range from nonvolatile memory chips to state-of-the-art solid-state flight recorders. With the exception of the mandatory flight recorders, these devices were designed primarily to provide recorded information for maintenance trouble-shooting or specific operational requirements. Regardless of their original purpose, they have all been used in one form or another to investigate aviation accidents. This paper will give an overview of the evolution of flight recorder technology and regulatory requirements, and describe the capabilities and limitations of the various types of recorded information available to the aviation community for accident prevention and, in particular, accident/incident investigation.

## **CRASH-PROTECTED FLIGHT RECORDERS**

### **Evolution of Regulatory Requirements**

#### **First Flight Data Recorder**

The need for a crash-survivable recording device became apparent following a series of airline crashes in the early 1940s. This spurred the Civil Aeronautics Board (CAB) to draft the first Civil Aviation Regulations calling for a flight recording device for accident investigation purposes. However, recorder development was delayed by shortages brought about by World War II. As a result, such a device was not available, and after extending the compliance date three times, the CAB rescinded the requirement in 1944. The CAB issued a similar flight recorder regulation in 1947, after the war, but a suitable recorder was still not available and the regulation was rescinded the following year.

During the 9 years following the rescission of the 1947 flight recorder rule, the Civil Aviation Authority (CAA), the CAB, and aviation industry representatives studied the capabilities of recorder technology in an effort to develop new recorder requirements. Finally in 1957, after determining that suitable recording devices were available, the CAA issued a third round of flight recorder regulations. These regulations called for all air carrier airplanes over 12,500 pounds that operate above 25,000 feet to be fitted with a crash-protected flight recorder by July 1, 1958, that records altitude, airspeed, heading, and vertical accelerations as a function of time. This marked the introduction of the, first true crash-protected flight data recorder.

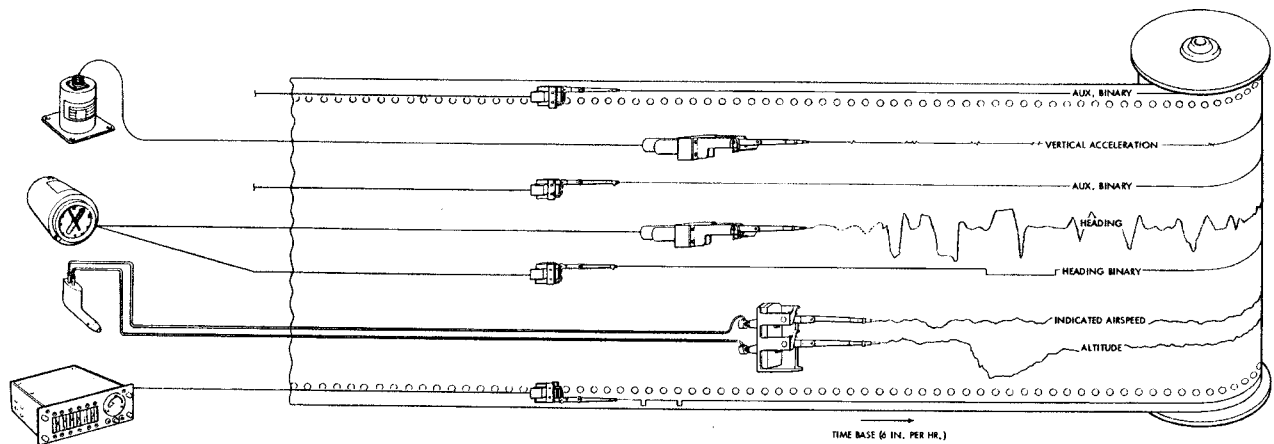


Figure 1 System schematic for a typical oscillographic foil recorder.

### ***First Cockpit Voice Recorder (CVR)***

As a result of a CAB recommendation to record flight crew conversation for accident investigation purposes, the Federal Aviation Administration (FAA) conducted a study in 1960 that established the feasibility of CVRs. The FAA produced airworthiness installation approval criteria and operating rules that called for the installation of a CVR in transport category aircraft operated in air carrier service. The compliance dates were July 1, 1966, for all turbine-powered aircraft, and January 1, 1967, for all pressurized aircraft with four reciprocating engines.

### **1972 Flight Data Recorder Rule Change**

FDR requirements remained virtually unchanged until December 10, 1972, when the rules for transport category airplanes that received type certification after September 30, 1969, were amended to require an expanded parameter digital flight data recorder (DFDR) system. The expanded parameter requirements included existing parameters plus parameters for pitch and roll attitude; thrust for each engine; flap position; flight control input or control surface position; lateral acceleration; pitch trim; and thrust reverser position for each engine. Unfortunately, this rule change, which was retroactive to include the Boeing 747, did not affect airplanes such as the Boeing 707, 727, and 737, and the McDonnell Douglas DC-8 and DC-9, all of which had type certificates issued prior to 1969. Therefore, existing and newly manufactured versions of these older aircraft types could be operated under the same FDR rules established in 1957. The flight recorder requirements remained essentially unaltered until the issuance of rule changes in 1987 and 1988.

### ***1987 and 1988 Flight Recorder Rule Changes***

During the 30 years following the issuance of the original 1957 FDR regulations, the National Transportation Safety Board (NTSB) and its predecessor, the CAB, issued numerous safety recommendations to the FAA requesting upgraded recorder standards to meet the needs of accident investigators. The recommendations called for:

1. Replacement of original foil-type oscillographic recorder with digital recorders;
2. Retrofit of exiting transport category airplanes fitted with the five-parameter FDRs with six additional parameters;
3. Expanded parameter requirements for newly manufactured transport category airplanes;
4. Use of hot-microphones by the flight crew below 18,000 feet;

5. Recording of hot-microphone channels on CVR; and
6. CVR and FDR requirements for some air taxi and corporate executive aircraft.

The FAA repeatedly sighted cost as the primary reason for not adopting the recommendations.

Following a series of high visibility accidents in the early 1980s, the FAA issued flight recorder rule changes in 1987 and again in 1988. These rule changes called for:

1. Replacement of oscillographic foil-type FDRs digital recorders by May 26, 1989;
2. The number of mandatory parameter for airplanes type certificated before October 1969, would be increased to include pitch and roll attitude, longitudinal acceleration, thrust of each engine, and control column or pitch control surface position. The original compliance date, May 26, 1994, was extended by 1 year to May 26, 1995;
3. Transport category airplanes (20 or more passengers) manufactured after October 11, 1991, would be required to record 28 parameters in a digital format;
4. Existing transport category airplanes (20 or more passengers) fitted with a digital data bus would be required to record 28 parameters in a digital format;
5. All multiengine turbine-powered air taxi aircraft capable of carrying 10-19 passengers manufactured after October 11, 1991, would be required to have a 17-parameter FDR;
6. The CVR requirements were extended to multiengine turbine-powered aircraft capable of carrying 6 or more passengers and requiring two pilots; and
7. Flight crews would be required to use existing CVR hot-microphone systems below 18,000 feet.

#### ***1997 Flight Data Recorder Rule Changes***

Following two fatal Boeing 737 accidents (United Flight 585, Colorado Springs, CO, July 1989, and USAir Flight 427, Pittsburgh, PA, September 1994), the NTSB reexamined FDR parameter requirements.

As a result, the NTSB made safety recommendations to the FAA that called for:

1. Additional parameters for most existing air transports that focused on recording crew flight control inputs and the resulting control surface movements; parameter retrofits to be completed by January 1, 1998;
2. Increased parameter requirements for transport airplanes manufactured January 1, 1996;
3. Urgent retrofit of all Boeing 737 airplanes with FDR parameters to record lateral acceleration, and crew flight control inputs and the resulting control surface movements by the end of 1995.

The FAA responded with rulemaking action that issued a notice of proposed rulemaking in August 1996 and a final rule on August 18, 1997. Although the final rule generally met the requirements of the safety recommendations, the compliance dates were significantly relaxed from those recommended by the NTSB. In addition, the FAA did not agree with the urgent recommendation to retrofit Boeing 737 by the end of 1995. However, the final rule did include the requirement that air transports record flight control crew inputs and control surface position. The final rule calls for:

1. Transport airplanes type certificated before October 1, 1969, and manufactured before October 11, 1991, to record as a minimum the first 18 to 22 parameters listed in the rule by August 18, 2001;
2. Transport airplanes manufactured after October 11, 1991, and before August 18, 2001, to record as a minimum the first 34 parameters listed in the rule by August 18, 2001;
3. Transport airplanes manufactured after August 18, 2000, must record as a minimum the first 57 FDR parameter listed in the rule;
4. Transport airplanes manufactured after August 18, 2002, must record as a minimum all 88 FDR parameter listed in the rule.

The specific parameter requirements are contained in Table 1.

#### ***March 9, 1999, NTSB and TSB Flight Recorder Recommendations***

A recent set of flight recorder recommendations was a combined effort of the Transportation Safety Board of Canada (TSB) and the NTSB of the United States. These recommendations followed the September 2, 1998, accident of Swissair flight 111, an MD-11, on a regularly scheduled passenger flight from New York to Geneva, Switzerland. The flight diverted to Halifax after the crew reported smoke in the cockpit; the airplane crashed into the waters near Peggy's Cove, Nova Scotia, killing all 229 passengers and crew on board. The investigation has been severely hampered by the lack of data from the CVR and FDR, which stopped nearly 6 minutes before the airplane hit the water.

## Part 121.344, Flight Data Recorders for Transport Airplanes

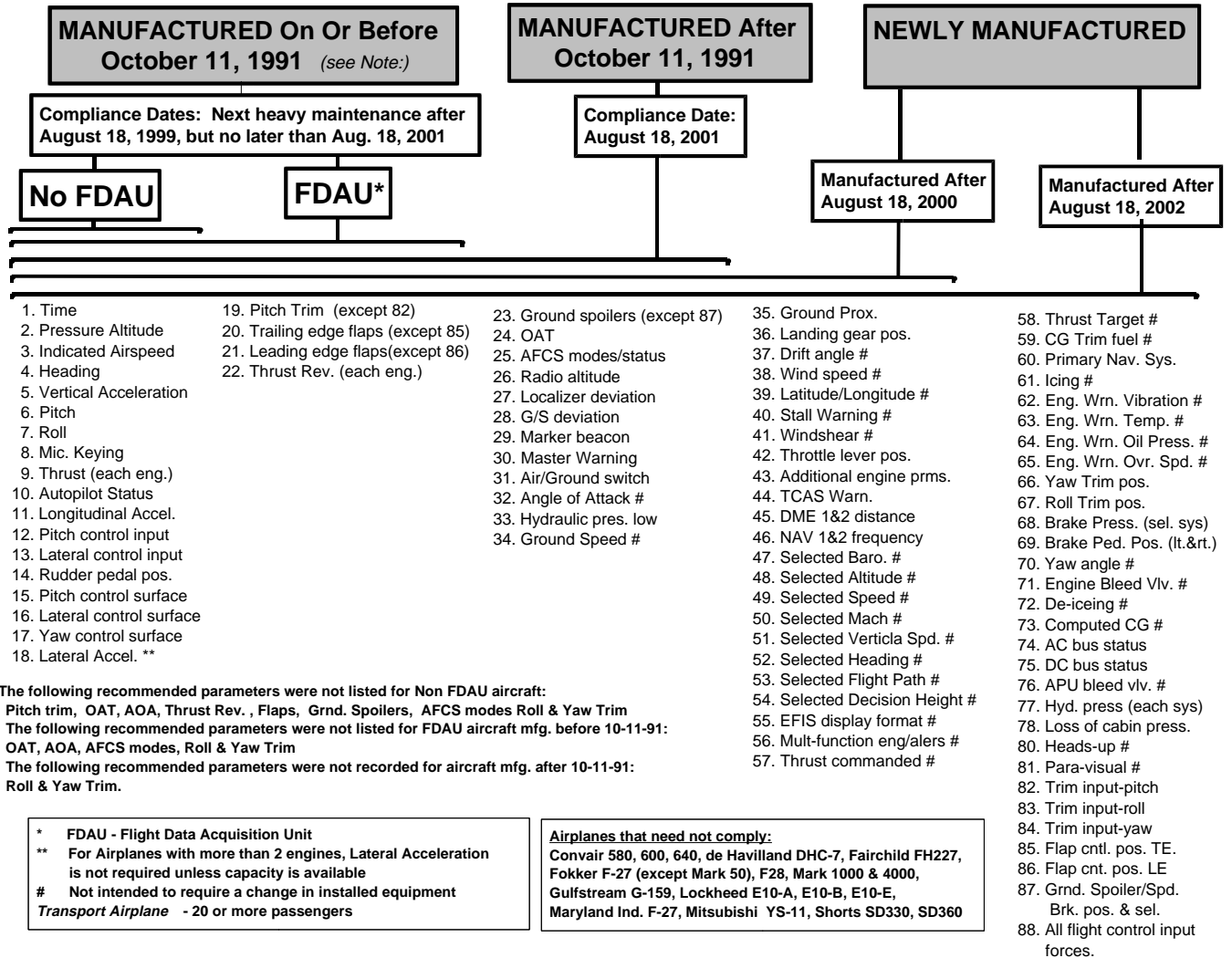


Table 1 Parameter Requirements for Air Carrier Flight Data Recorders.

The Swissair accident was just the latest in a long history of accident and incident investigations that were hindered by the loss of flight recorder information due to the interruption of the aircraft electrical power to the flight recorders. However, recent innovations in recorder and power supply technologies have made it possible to provide an independent power source that would provide sufficient power to operate a solid-state flight recorder for 10 minutes. In addition, the availability of combined voice and data recorders has introduced the possibility of fitting

two combined recorders on newly manufactured airplanes, placing one recorder near the cockpit to reduce the probability of a mechanical or electrical interruption of the signals and power supply, and the second recorder as far aft as practical to enhance survivability.

As a result, the U.S. NTSB and TSB of Canada issued safety recommendations on March 9, 1999, to require:

1. By January 1, 2005, the retrofit of a 2 hour solid-state CVR that is fitted with an independent power supply capable of operating the CVR and area microphone for 10 minutes when aircraft power to the CVR is lost;
2. By January 1, 2003, all newly manufactured airplanes required to carry both a CVR and FDR be fitted with two combined voice and data recorders, one recorder located as close to the cockpit as practical and the other as far aft as practical;
3. Amend Title 14 U.S. *Code of Federal Regulations* to require that CVRs, FDRs, and combination flight recorders be powered from separate generators busses with the highest reliability.

In a March 19, 1999 letter, the FAA agreed to the recommendations without revision and promised to issue a notice of proposed rulemaking by the end of the summer.

## EVOLUTION OF FLIGHT RECORDERS

Flight data recorders can be traced back to the origins of power flight. Wilbur and Orville Wright's historic first flight was documented by the first flight data recorder. This rudimentary device recorded propeller rotation, distance traveled through the air, and flight duration. Charles Lindbergh's airplane the *Spirit of St. Louis* was also fitted with a flight-recording device. Lindbergh's recorder was a bit more sophisticated, employing a barograph that marked changes in barometric pressure or altitude on a rotating paper cylinder (see Figure 2).



Figure 2 *Spirit of St. Louis* flight recorder.

These early recordings survived because they were designed to record historical events, not mishaps. The first practical crash-protected flight data recorder was not introduced until 1953. This recorder used styli to produce individual oscillographic tracings for each parameter on metallic foil. Time was determined by foil movement, which typically advanced at a rate of 6 inches per hour. This often resulted in an entire accident sequence being recorded within a 0.1 inch of foil movement. Investigators recovered the recorded information by optically reading the scribed markings through a microscope, and then converting the displacement of the scribed marks from the reference line to engineering units. This process was very time consuming and required a significant amount of reader interpretation.

The 1957 regulations that mandated the installation of FDRs by July 1958 created a market for FDRs that attracted other manufacturers who also use the metal foil oscillographic technique (see Figure 3 and 4). The regulations also required compliance with Technical Standards Order TSO C-51. This TSO defined the range accuracy, sampling interval, and type parameters to be recorded (altitude, airspeed, heading, vertical acceleration and time) and specified the requirement to survive a crash shock of 100 Gs and being enveloped in a 1100°C flame for 30 minutes. The TSO also defined three basic types of flight recorders:

**Type I:** Non-ejectable recorder, unrestricted location.

**Type II:** A non-ejectable recorder, minimum 15 minutes fire test, restricted to any location more than 1/2 of the wing root chord from the main wing structure through the fuselage and from any fuel tanks.

**Type III:** An ejectable recorder, minimum 1.5 minutes fire test, unrestricted location.

The early recorders were all of the Type I design and most were mounted in the cockpit area or in the main gear wheel well. Unfortunately, these locations subjected the recorders to fire and impact forces that destroyed or severely damaged the recording medium. Type II and III recorders were never fitted to commercial air carriers; however, ejectable recorders are currently in use on some military aircraft.

In the early 1960s, the CAB made a series of recommendations to the FAA that called for additional protection for FDRs against impact force and fire damage, and also recommended the relocation of the recorders to the aft area of the fuselage to provide maximum protection of the recording media. As a result, the FAA issued rule changes that specified the location of the recorder as far aft as practical and upgraded the performance standards in TSO C-51 and reissued it as C-51a. The upgraded TSO specifications increased the impact shock test from 100 Gs to 1,000 Gs and introduced static crush, impact penetration, and aircraft fluid immersion tests. The fire test was not changed. Unfortunately, neither TSO contained an adequate test protocol to ensure uniform and repeatable test conditions.



Figure 3 Early Lockheed model 109.

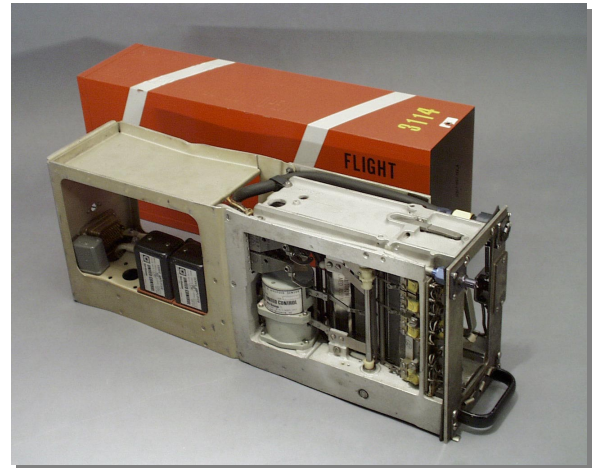


Figure 4 Sundstrand Model 542 FDR, 1/2 ATR long format.

	<b>TSO C84 CVR Requirements</b>	<b>TSO C-51 FDR Requirements</b>	<b>TSO C-51a FDR Requirements</b>
Fire	1100°C flame covering 50% of recorder for 30 minutes	1100°C flame covering 50% of recorder for 30 minutes	1100°C flame covering 50% of recorder for 30 minutes
Impact Shock	100 Gs	100 Gs	1000 Gs for 5 ms
Static Crush	None	None	5,000 pounds for 5 minutes on each axis
Fluid Immersion	None	None	Immersion in aircraft fluids (fuel, oil, etc.) for 24 hours
Water Immersion	Immersion in sea water for 48 hours	Immersion in sea water for 36 hours	Immersion in sea water for 30 days
Penetration Resistance	None	None	500 lb. dropped from 10 ft. with a 1/4-inch-diameter contact point

Table 2 Early flight recorder crash/fire survivability standards.

At about the same time as the foil recorders were being developed in the United States, recorders that used magnetic steel wire as a recording medium were being developed in the United Kingdom. The wire recorders were the first to use digital pulse coding as a recording method. The robust design of the wire recorder made it a fairly reliable recorder for its time. Although the wire recording medium was fairly impervious to post impact fires it did not fair as well with impact shock. The wire would often brake into several sections and become entangled making it difficult and tedious to reassemble in the proper sequence.

In the late 1940s, the French developed an FDR that used a photographic system that recorded data on light- sensitive paper. It had obvious disadvantages: inflammability and the tendency of the recording to disappear when subjected to light. The French later adopted the metal foil oscillographic recorder.

### ***Cockpit Voice Recorder***

In response to CAB recommendations, the FAA conducted a study in 1960 to determine the feasibility of recording the spoken words of the flight crew for accident investigation purposes. Although cockpit ambient noise levels posed a significant obstacle to 1960 recording technology, it was determined that recording crew conversation was feasible. The following equipment capabilities were initially proposed:

1. Record each crewmember's conversation, both transmitted and received, with ground facilities and on the airplane's intercommunication system. Also, other conversation in the cockpit not conducted over those media should be recorded. Sufficient channels should be provided so that there will be no possibility of more than one crewmember recording on a channel at one time.
2. Retain the last 30 minutes of the crew's conversation.
3. Contain provisions for stopping the recorder in the case of a crash so that the last 30 minutes of conversation is not erased or overwritten.
4. Recorder should withstand the crash conditions required in TSO-C51.
5. Recording should be intelligible over the ambient noise of the cockpit or it should be possible to filter out the unwanted noise from the record with appropriate ground equipment.
6. Recorder should be capable of recording crew voices, other than on the communication and intercommunication systems, without the use of lip or throat microphones.
7. It should contain indicating provisions to inform the crew when it is operating properly.

As a result, the FAA issued rules that mandated the use of CVRs on all transport category aircraft and issued TSO C-84, which established crash fire survivability and equipment approval standards.

### ***Magnetic Tape Flight Recorders***

The introduction of the CVR in the late 1960s and DFDRs in the early 1970s made magnetic tape the recording medium of choice until the introduction of solid-state flight recorders in the late 1980s. There were a variety of tapes and tape transports used by the various recorder manufacturers. The most widely used tapes were mylar, kapton, and metallic. The tape transports were even more varied, using designs such as coplaner reel to reel, coaxial reel-to-reel, endless loop reel packs and endless loop random storage.

Tape CVRs record four channels of audio for 30 minutes, and the DFDR records 25 hours of data. CVRs and FDRs record over the oldest data with the newest data in an endless loop-recording recording pattern. The DFDR tape transport and protective enclosure shown in Figure 5 is an endless loop real pack design adapted from a 1960s CVR.

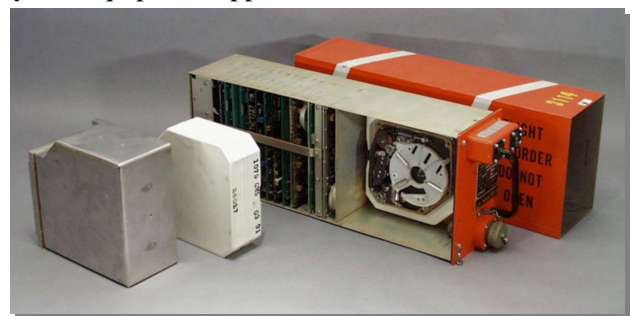


Figure 5 Fairchild model F800 DFDR, 1/2 ATR long format.

All of the magnetic tape flight recorders, including the units that used metallic tape, were found to be susceptible to thermal damage during postcrash fires. Although the TSOs called for a high intensity fire test, the lack of a detailed test protocol allowed for a less-than-adequate design to be approved. In addition, the real world experience would show magnetic tape flight recorders to be most vulnerable when exposed to long duration fires, a test condition not required at the time tape flight recorders received TSO approval. In addition, metallic tapes were found to be vulnerable to impact shock, which had a tendency to snap the tape releasing the spring tension and unwinding the tape, causing further tape damage and loss of data.

### ***Digital Recording Method***

The DFDR and its companion recorder, the quick access recorder (QAR), were introduced about the same time. DFDRs and QARs use the same recording techniques, but as the name implies, the QAR can be quickly accessed and downloaded. Most early model QAR systems recorded far more parameters than the mandatory DFDR systems. As nonmandatory recorders, QARs were not designed to survive a crash impact and postimpact fire, although a number have survived fairly significant crashes.

Most DFDRs and QARs require a flight data acquisition unit (FDAU) to provide an interface between the various sensors and the DFDR. The FDAU converts analog signals from the sensors to digital signals that are then multiplexed into a serial data stream suitable for recording by the DFDR. Industry standards dictated the format of the data stream, which for the vast majority of tape-based DFDRs is 64 12-bit data words per second. The recording capacity of the tape DFDR is limited by the length of tape that can be crash-protected and the data frame format. The capacity of the tape DFDRs was adequate for the first generation of wide-body transports, but was quickly exceeded when aircraft like the Boeing 767 and Airbus A320 with digital avionics were introduced.

### ***Digital Avionics Systems***

The introduction of digital avionics systems into commercial aviation in the early 1980s significantly increased the amount of information available to DFDRs and QARs. Digital avionics also brought about digital data buses, which carry digital data between systems. This made vast amounts of critical flight and aircraft system information available to the DFDR and QAR simply by tapping into the buses. The introduction of digital data buses also brought about digital FDAUs (DFDAU). The FDAU and DFDAU perform the same function except that DFDAUs can interface with the data buses and analog sensors.

### ***Solid-State Flight Recorders***

The introduction of solid-state flight recorders in the late 1980s marked the most significant advance in evolution of flight recorder technology. The use of solid-state memory devices in flight recorders has expanded recording capacity, enhanced crash/fire survivability, and improved recorder reliability. It is now possible to have 2-hour CVRs and DFDRs that can record up to 256 12-bit data words per second, or 4 times the capacity of magnetic tape DFDRs. Survivability issues identified during over the years have been addressed with new crash/fire survivability standards developed in close cooperation between accident investigators and the recorder industry (see Table 3). The lack of moving parts in solid-state recorders has greatly improved recorder reliability.

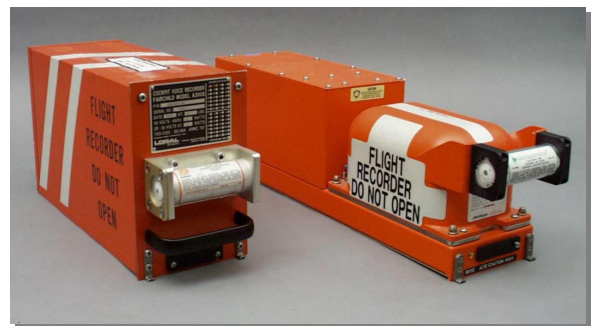


Figure 6 Typical solid -state CVR and DFDR.



<b>TSO C123a (CVR) and C124a (DFDR)</b>	
<b>Fire (High Intensity)</b>	1100°C flame covering 100% of recorder for 30 minutes. (60 minutes if ED56 test protocol is used)
<b>Fire (Low Intensity)</b>	260°C Oven test for 10 hours
<b>Impact Shock</b>	3,400 Gs for 6.5 ms
<b>Static Crush</b>	5,000 pounds for 5 minutes on each axis
<b>Fluid Immersion</b>	Immersion in aircraft fluids (fuel, oil etc.) for 24 hours
<b>Water Immersion</b>	Immersion in sea water for 30 days
<b>Penetration Resistance</b>	500 lb. Dropped from 10 ft. with a ¼-inch-diameter contact point
<b>Hydrostatic Pressure</b>	Pressure equivalent to depth of 20,000 ft.

Table 3 Current flight recorder crash/fire survivability standards.

### **Future Flight Recorder Capabilities Requirements**

As proposed in the Safety Board's March 9, 1999, recommendation letter to the FAA, two combination voice-data recorders built to TSO C123a and C124a standards will provide the redundant recording capabilities that separate CVRs and DFDRs cannot. Locating one recorder in the nose of the aircraft and the other in the tail will further enhance the probability of capturing catastrophic events that would otherwise compromise the CVR and DFDR when they are colocated. The forward-mounted flight recorder will be in close proximity to the cockpit and the avionics compartment, which reduces the possibility of signal loss. The addition of a 10-minute, independent alternate power supply adjacent to the flight recorder will further enhance the possibility that the recorder will be powered and critical data will be recorded until the end of the flight.

The next-generation combination flight recorders will be required to record more than the traditional voice and data parameters. The FAA anticipates that by 2004, the use of Controller Pilot Data Link (CPDL) messages will reach a level that will mandate recording of data link messages by a flight recorder. Recent advancements in video technology have made video recording a distinct possibility in the not-too-distant future. The International Civil Aviation Organization (ICAO) Flight Recorder Panel has concluded that video technology has matured to the point where specific technical aspects must be determined, and that the ongoing work of European Organisation for Civil Aviation Equipment (EUROCAE) and Aeronautical Radio Inc. (ARINC) should be considered when developing video recorder standards and recommended practices.

### **AIR TRAFFIC CONTROL RADAR AND AUDIO RECORDINGS**

Ground-based recordings of the air traffic control (ATC) radar and radio transmissions provide aircraft communication and position time history information. The FAA records all radio communications between controllers and pilots, and also landline communications between controllers. Air Route Traffic Control Centers (ARTCC) provide complete radar coverage of the United States and parts of Canada and Mexico. In addition, most ATC airport approach radar facilities also record.

#### **ATC Communication Recordings**

Recordings of the two-way radio communications between controllers and pilots and inter-controller communications via landlines are maintained for 30 days. In the event of an accident or incident, the original recording of the event can be set aside and retained for investigators, otherwise the recording medium will be reused and the information lost.

The ATC communications recordings have provided vital information to investigators. In instances where the aircraft are not fitted with a CVR these recordings provide the only record of flight crew communications and have at times provided background sounds (e.g., wind noise, rotor speed, sounds of

cockpit warnings, etc.) that have proven to be vital to the investigations. A time code is also recorded with the audio communications to provide a time reference independent of any subtle recording anomalies.

### **ATC and Other Radar Recordings**

Recorded radar data can provide aircraft position time history information. This is accomplished by recording the position coordinates of individual radar returns, time, and when available, altitude and identification information transmitted from the aircraft. The altitude and identification data are produced by a transponder fitted to the aircraft that also reinforces the radar return. A transponder is a receiver/transmitter, which will generate a reply signal upon proper interrogation from a radar facility.

The rate at which the radar antenna rotates will determine the sampling interval between returns. ARTCC rotate at between 5 to 6 revolutions per minute (i.e., generating radar returns every 10 to 12 seconds), whereas airport approach radar antennas do a complete rotation every 4.8 seconds. The most accurate position coordinates recorded by the ARTCC are in latitude and longitude, whereas approach radar records position coordinates as range and azimuth values, and both record the transponder-generated altitude values.

Military and private radar facilities can provide similar position time history information. Military aircraft (AWAC) and naval vessel radar data are also recorded and are available to investigators upon request.

### **Utilization of ATC Recordings by Accident Investigators**

The importance of ATC recorded data will be determined by the circumstances surrounding an accident or incident. Accidents or incidents involving very dynamic conditions, such as aerodynamic stall and loss of control, are difficult to evaluate with ATC data alone. ATC data are more significant for less dynamic accidents, such as controlled flight into terrain, or when used in conjunction with FDR and CVR data.

The correlation of events common to the ATC recordings and the FDR and CVR recordings can provide a very accurate local time reference. This can become critical because the FDR and CVR are only required to record relative time and the local time reference may vary from one ATC facility to the next. ATC radar and FDR data can be correlated by comparing the altitude time histories whereas ATC communication recordings can be correlated by the radio transmission time histories recorded by the various ATC facilities and the CVR and FDR.

In addition to a time reference, ATC-recorded information will also provide ground track reference, which is essential in performance-related accidents. A wind model can be developed when radar flight path data are combined with FDR parameters such as altitude, airspeed and heading and airplane acceleration parameters. This is particularly useful in accidents or incidents involving dynamic meteorological conditions such as wind shears or crosswind and turbulence conditions.

ATC radar data are particularly useful in evaluating the relative position of aircraft when multiple aircraft are involved. Investigations of mid-air collisions and wake turbulence encounters rely heavily on this information.

There are significant accuracy and resolution limitations that must be taken into consideration when using recorded radar data. The accuracy limitations are known and should be factored into the ground track calculations. The sampling intervals of 4.7 to 12 seconds, presents a significant limitation on usefulness of recorded radar data.

## NONVOLATILE MEMORY DEVICES

Modern aircraft utilize an increasing number of microprocessor-based electronic devices for operational and maintenance purposes. As a result, aircraft are fitted with nonvolatile memory (NVM) to store information such as flight crew entries to the navigation data base, system fault messages generated by electronic control devices and system status messages. These devices, generally known as electronically erasable read-only memory (EEROM) provide temporary storage of transitional information during power interruptions. The term “nonvolatile” implies that the stored information will be available regardless of whether the system is electrically powered or not.

Accident investigators have found NVM to be a valuable source of information. However, because NVM is not crash- or fire-protected, there is no assurance that it will be available following a catastrophic accident. With that said, there have been a significant number of cases where NVM has survived severe impacts and postimpact fires.

The recovery of information from NVM undamaged systems can be as simple as powering the system and reading or downloading the information. Damaged units may require a trip to the manufacturer’s facility where system experts can disassemble the unit to recover the information using specialized equipment and software.

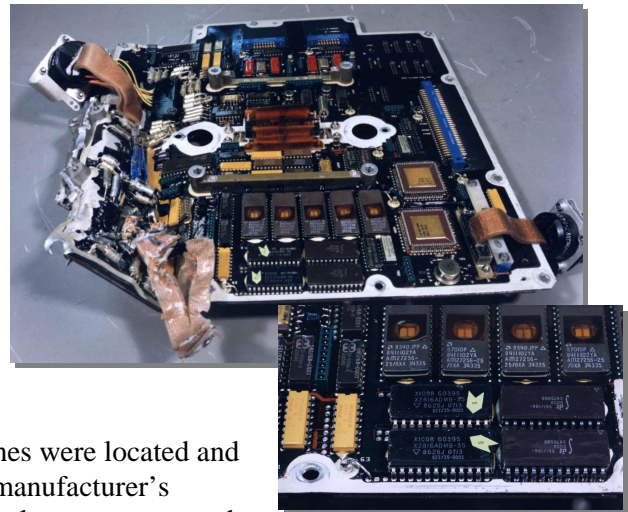
The amount of effort and technical expertise needed to recover information from NVM will generally be determined by the amount of damage and system complexity. The first step in the recovery process is a visual inspection of the disassembled unit to determine the amount of damage. It may be possible to simply replace a damaged connector or place the circuit board containing the memory device in a serviceable unit to recover the data. However, extreme caution must be taken when applying power to units that are suspected of receiving impact shocks that exceed the normal design requirements: an undetected short or open circuit might result in the loss of the stored data.

**Example: Lauda Air, Flight NG004, May 26, 1991**  
The May 26, 1991, fatal accident of Lauda Air flight

NG004, a Boeing 767 that crashed in Suphan-Buri Province, Thailand, demonstrated the importance of NVM. The aircraft departed controlled flight while climbing through 24,000 feet and experienced an in-flight breakup during the recovery maneuver and subsequently crashed into the jungle. The FDR magnetic tape recording medium was destroyed by the postcrash fire and provided no data. However, the crew comments recorded by the CVR indicated a problem with an engine thrust reverser just prior to the loss of control.

The electronic engine control (EEC) units for both engines were located and removed from the aircraft wreckage and brought to the manufacturer’s facility in Windsor Locks, Connecticut, to recover the fault messages stored in its NVM (see Figure 7). The EECs showed signs of severe impact shock. As a result, the EEROMs (identified in Figure 7 by the chevron symbols) containing the NVM were removed from the circuit

Figure 7 Damaged electronic engine control (EEC).



board and mounted on an identical laboratory test unit. A normal fault message download was performed and the data were subsequently processed using the manufacturer's proprietary software.

Each time an EEC fault message was generated, the following information was captured and stored in NVM:

- Diagnostic fault messages codes;
- Values for  $N_1$  (high pressure compressor rotation speed),  $P_2$  (fan inlet total pressure), mach number, temperature (cold junction compensation);
- Fault time in elapsed hours;
- Logging of flight and leg cycles.

The recovered data contained diagnostic messages from the last 390 hours of operation, which spanned 95 flights. The EECs from the left engine, which experienced the uncommanded thrust reverser deployment, provided a significant amount of information specifically relating to the faulty thrust reverser and ancillary altitude, airspeed, and engine thrust values provided key reference values, which gained added significance in light of the loss of the FDR data. The EEC from the right engine, which did not record any faults during the accident flight, yielded little additional information.

## CONCLUSIONS

As far back as the early 1940s, it became apparent to the aviation community that public confidence must be gained and maintained if commercial aviation were to prosper. It was also recognized that to do this would require a quick and accurate determination of probable cause of any aviation mishap. It was also obvious that the nature of aviation accidents would make it necessary to fit air transports with recording devices to provide accident investigators with the information needed to determine the cause of a mishap and take the proper corrective action to prevent it from recurring.

The first flight recorders introduced over 40 years ago gave accident investigators their first appreciation of the recorder's safety potential. However, the data provided by these early recorders was limited and often of such poor quality that the investigators could only determine, at best, what happened but could not determine with a high degree of certainty why it happened.

Flight recording technology has had to adapt to a rapidly evolving commercial aviation industry, and the corresponding needs of accident investigators. One of the most significant changes in recorder technology occurred in the early 1970s, with the introduction of digital data recorders. The amount and quality of data provided by DFDRs, CVRs, other recorded data such as ATC radar, gave accident investigators the first real opportunity to pursue an in-depth evaluation of the facts, conditions, and circumstances surrounding an occurrence. The introduction of digital recordings also made it practical to use flight recorder data proactively.

The introduction of digital avionics and fly-by-wire technologies in the 1980s provided investigators with challenges and opportunities. This new technology eliminated some well-established investigative techniques while offering an opportunity to record and recover vast amounts of previously unattainable information. Indeed, the amount of available information overwhelmed early model DFDRs. However, the advent of solid-state recorders has solved the recorder capacity problem while improving survivability and reliability.

The future of flight recording is promising. Advances in recorder and aircraft systems will allow for the introduction of recording techniques to record video images of the cockpit and data link messages, as well as providing more opportunities for the proactive use of flight data to prevent accidents.

