National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: March 9, 1999

In reply refer to: A-99-16 through -18

Honorable Jane Garvey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On May 11, 1996, the crew of ValuJet flight 592, a DC-9-32, reported smoke and fire shortly after departing Miami, Florida. The flight recorders stopped about 40 to 50 seconds before the airplane crashed on its return to the airport, killing all 111 passengers and crew.

On July 7, 1996, TWA flight 800, a Boeing 747-100, on an international passenger flight from New York to Paris, exploded about 13 minutes after takeoff as it was climbing through 13,700 feet. Both flight recorders stopped at the time of the explosion, but the airplane did not hit the water off Long Island, New York, for another 40 to 50 seconds. All 230 people aboard the airplane were killed.

On December 19, 1997, SilkAir flight 185, a Boeing 737, entered a rapid descent from 35,000 feet, which ended with a high speed impact in the Sumatran River near Palembang, Indonesia. There were 104 fatalities. The Indonesian investigation, in which the Safety Board participated, determined that both flight recorders stopped prior to the airplane entering the rapid descent.

On September 2, 1998, Swissair flight 111, an MD-11, on a regularly scheduled passenger flight from New York to Geneva, Switzerland, 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. Thus far, the Canadian Transportation Safety Board's (TSB) investigation, which is being conducted in close cooperation and coordination with the National Transportation Safety Board and Swiss investigative authorities, has been severely hampered by the lack of data from the cockpit voice recorder (CVR) and digital flight data recorder (DFDR), which stopped nearly 6 minutes before the airplane hit the water.

These recent accidents are just the latest in a long history of accident and incident investigations that were hindered by the loss of flight recorder data due to the interruption of aircraft electrical power. The following list contains only some of the more notable accidents for which vital flight recorder information was not available because of a premature loss of electrical power:

- Overseas National Airways (ONA) flight 032, a DC-10-30; JFK Airport, New York; November 12, 1975. During the takeoff roll, the right engine ingested a large number of sea gulls and disintegrated causing the loss of electrical power to the flight data recorder. The airplane and CVR were destroyed by the postcrash fire. An ONA employee occupying the flight deck observer seat captured the takeoff roll on a movie camera with audio, which became the only record of the accident sequence. There were no fatalities among the 139 passengers and crew.

- Southern Airways flight 242, a DC-9-31; New Hope, Georgia; April 4, 1977. Following the airplane's penetration of a level 6 thunderstorm, both engines failed. The pilots attempted a dead-stick landing on a two-lane highway. Both recorders stopped following the engine failures and did not resume operation until 2 minutes 4 seconds later, when the auxiliary power unit was started. There were 62 fatalities and 23 survivors.

- American Airlines flight 191, a DC-10-10; Chicago O'Hare Airport; May 25, 1979. The pylon of engine No. 1 failed during takeoff rotation, after which the engine separated from the airplane, removing power to a portion of the DFDR sensors and the CVR. The airplane crashed 32 seconds later. There were no survivors among the 271 passengers and crew. Two people on the ground were also killed.

- United Airlines flight 811, a Boeing 747-122; Honolulu, Hawaii; February 24, 1989. Engines No. 3 and 4 were shut down because of foreign object damage from the right forward cargo door, which separated causing extensive damage to the fuselage and adjacent passenger cabin. The CVR was lost for 21.4 seconds during the emergency descent as a result of engine shutdown. There were nine fatalities.

Since 1983,[1] there have been 52 accidents and incidents, including the 4 recent accidents mentioned above, in which information from either a CVR or FDR or both were lost due to interruption of electrical power following an engine or generator failure or crew action. Until recently, recorder technology did not offer a practical solution to the problem of loss of electrical power to the on-board 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 assessing the feasibility of an independent power source, strong consideration must be given to reliability, complexity, maintainability, and cost. The independent power source must also automatically engage when power to the recorders is lost. Older model tape-based recorders require too much electrical power and are not easily adapted to a direct current (d.c.) battery or capacitor. However, the relatively low power requirements of solid-state flight recorders (about 10 to 12 watts from a 28-volt d.c. system) would permit the use of an independent power source. Thus, it is evident that the use of an independent power source would also require the use of solid-state flight recorders.

[1] Origin date of the Safety Board's current aviation accident database. Data prior to 1983 are incomplete.

The replacement of magnetic tape flight recorders with solid-state flight recorders would not appear to be an undue burden on the industry. In fact, several major U.S. air carriers have recognized the economic benefits of solid-state recorders and are replacing the obsolete tape flight recorders in their fleets with solid-state units solely for economic reasons. Further, replacement units exist that meet the latest Technical Standard Order (TSO)[2] standards and that are capable of recording 2 hours of CVR audio.

Other factors have also influenced the industry's movement to solid-state flight recorders. The poor survivability and performance of magnetic tape flight recorders in recent years have raised concerns in the United States and abroad about the ability of that medium to provide data of sufficient quality for accident and incident investigations. In several recent accidents, the magnetic tape flight recording medium was destroyed or damaged due to postaccident fire or water immersion. These accidents were in addition to those that lead to the markedly improved crash/fire survivability standards in TSOs C123a and C124a.[3]

Another factor is that the future serviceability of magnetic tape recorders is also in doubt. Of the tape flight recorders received by the Safety Board for readout, laboratory staff have noted an increase in the number of tape units with unreliable data and units that are partially or completely unserviceable. The Bureau Enquetes-Accidents, the French accident investigation authority, has had similar experiences and is developing a recommendation that would ban the Fairchild F800[4] magnetic tape flight recorder because of its unreliability. The decline in serviceability is reminiscent of the serviceability problems experienced during the final years of the oscillographic foil flight recorders.

An additional consideration is the fact that magnetic tape flight recorders are no longer in production, and only a few manufacturers produce the precision instrumentation tape decks needed for playback of tapes recovered from accident-involved recorders. Some recorder manufacturers have also indicated a substantial decrease in the number of suppliers of tape recorder parts such as drive motors and magnetic heads. One manufacturer predicts that its stockpile of magnetic tape may be depleted by 2005.

Another significant factor that would warrant the industry to replace magnetic tape flight recorders with solid-state flight recorders involves the future requirement to record data link communications. In about 2004 to 2005, analog CVRs will no longer meet the requirements for aircraft using controller–pilot data link (CPDL) communications. It is anticipated that future regulatory changes will require that aircraft using CPDL communications be fitted with solid-state CVRs (SSCVRs) that can record data link messages.[5] To that end, the Safety Board encourages

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[2] TSOs detail the minimum performance standards for specified articles—such as materials, parts, and appliances—used on civil aircraft. TSOs are issued by the FAA Administrator.

[3] The TSOs were developed in response to the Safety Board's Safety Recommendations A-92-45 through -48.

[4] L-3 Communications, Inc., is the current manufacturer of Fairchild aviation recorders.

[5] The FAA has indicated that it will initiate rulemaking to clarify that the present requirement to record all voice messages be expanded to include cockpit data messages. According to the FAA, the rulemaking is expected to take effect about 2004.

the industry to consider for future CVR installations on airplanes using controller–pilot data link communications that the CVRs be capable of recording digital data link messages.

As the technology and application of data link communications evolve, the industry will also need to consider developing the capability that enables qualified ground personnel to perform real-time monitoring of the flight parameters to assist the flight crew when an in-flight problem or emergency occurs. Such monitoring will require a communications network that is capable of transmitting real-time flight data to qualified ground personnel.

Current regulations call for a CVR with a minimum 30-minute recording duration. This minimum requirement was based on the limitations of 1960s recorder technology, which was constrained by the amount of magnetic tape that could be impact/fire protected. In the years since CVRs became mandatory, the Safety Board has investigated many accidents and incidents for which the 30-minute CVR recording was not sufficient to retain key events. This prompted the Safety Board to recommend in 1996 that all newly manufactured CVRs be SSCVRs with a 2-hour recording duration (Safety Recommendation A-96-171).[6] Accident investigations in which the Safety Board has participated subsequent to the issuance of Safety Recommendation A-96-171 continue to demonstrate that a lack of recorded voice and other aural information can inhibit safety investigators and delay or prevent the identification of safety deficiencies.

The CVR installed on Swissair flight 111 used a continuous-loop magnetic tape with a 30-minute duration. The earliest information on the CVR tape was recorded about 15 minutes before the crew noted an unusual odor. Crew conversations and cockpit sounds prior to the beginning of this 30-minute recording might have provided insight into any initiating or precursory events that led to the accident.

About 38 minutes prior to the crew noting an unusual odor, Boston Center[7] issued flight 111 a radio frequency change. During the following 13 minutes, Boston Center made repeated attempts to contact flight 111 but did not establish contact. Any cockpit conversations, flight deck noises, or attempted crew transmissions that occurred during this period were subsequently overwritten on the CVR, and thus were not available to the accident investigators.

Although 30-minute magnetic tape CVRs are no longer being manufactured, units still exist and could be installed on aircraft today. Given the continued need for longer periods of recorded sound to capture the initiating events of aviation accidents, and the availability of and trend toward 2-hour CVRs, the Safety Board believes that a retrofit program is warranted. Therefore, the Safety Board believes that the Federal Aviation Administration (FAA) should require the retrofit after January 1, 2005, of all CVRs on all airplanes required to carry both a CVR and a FDR with a CVR that meets TSO C123a and is capable of recording the last 2 hours of audio.

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[6] The current status of Safety Recommendation A-96-171 is "Open—Acceptable Response."

[7] Boston Center is an FAA Air Route Traffic Control Center (ARTCC).

Although a number of options were identified for assessing the feasibility of an independent power source, a capacitor appears to be the most effective means of providing an independent power source. The capacitor method would provide a power source that requires very little maintenance, and, unlike a rechargeable battery, the capacitor method would not require any power sensing circuitry for normal operation. To maximize recorder reliability and to minimize any crew intervention, the independent power source should automatically engage whenever the normal electrical power to the recorder ceases, even when the aircraft is powered down normally. To increase the probability of recording accident data, the independent power source should be capable of powering the recorder for 10 minutes after main power to the recorder shuts off.

For a DFDR, an independent power source would not necessarily enable the recording of any additional information. Backup power to a DFDR would result only in the recording of data from sensors that are still powered and can relay that information to the DFDR. If aircraft power is lost, the probability is small that the sensors and data acquisition unit would still be receiving power or be able to relay that data to the DFDR. However, in the case of a CVR, the area microphone is powered by the CVR; as long as the CVR receives power, the area microphone will continue to operate and the CVR will continue to record sounds from the area microphone, provided that the connection between the microphone and the recorder is not compromised. In the case of the SilkAir accident, the 2-hour SSCVR stopped recording 5 minutes 58 seconds prior to the DFDR stopping, which stopped 1 minute 54 seconds prior to impact. Thus, any valuable dialog in the cockpit regarding the airplane status for those 7 minutes 52 seconds was lost.

However, providing a 30-minute CVR with 10 minutes of independent power after main power ceases would result in about one-third of the in-flight audio being recorded over. Thus, it would not be acceptable to fit 30-minute CVRs with an independent power supply that automatically engages when aircraft electrical power is terminated for any reason.

With maintenance-free independent power sources, it is now feasible to provide an independent power source for new-technology CVRs for a specific period of time, in the event that aircraft power sources to the CVR are interrupted or lost. Therefore, the Safety Board believes that for the CVR retrofit after January 1, 2005, the FAA should also require the CVR to be provided with an independent power source that is located with the CVR and that automatically engages and provides 10 minutes of operation whenever aircraft power to the recorder ceases, either by normal shutdown or by a loss of power to the bus.

The Canadian TSB shares the view that a CVR retrofit is warranted and has developed a similar recommendation, which was issued to the Canadian and European regulators in early March 1999. The Safety Board and the TSB hope that the actions recommended by the two investigative authorities are adopted by civil aviation regulators worldwide.

The Safety Board recognizes that in the case of ValuJet flight 592 and TWA flight 800, the microphone wiring may, in fact, have been compromised and, consequently, the implementation of this retrofit would probably not have materially benefited the investigation of those accidents. However, other changes that are discussed in the following paragraphs—such as dual combination recording systems, with one being placed as close to the cockpit as possible—could have resulted in obtaining additional critical information.

As discussed earlier, it would not be practical to provide FDRs with an independent power source. However, if the FDR were part of a dual combination voice and data recorder system, an independent power source should be installed. Combination recorders are now available and provide the functions of both a DFDR and a CVR in a solid-state format; they do not require more space than the current DFDR models; they weigh less than the combined weights of a DFDR and a CVR; and they cost less than the combined costs of a DFDR and a CVR. In addition, combination recorders will allow for the use of dual redundant recorders, with one recorder located in close proximity to the cockpit to reduce the possibility of signal loss, and one as far aft as practicable to enhance survivability.

One particular problem that has occurred in several accidents, such as ValuJet flight 592 and TWA flight 800, is that either the aircraft's electrical power bus had been severed or the signal wires connecting the CVR/DFDR to the aircraft's sensors had been compromised. The CVR and DFDR are intentionally located in the rear of the aircraft for greater survivability. This rear mounting usually results in long cable runs from the forward cockpit areas to the recorders. One option for mitigating the risks to both recorder and cable survivability would be to locate one combination recorder in the rear of the aircraft and another combination recorder near or in the cockpit of the aircraft. This installation would virtually eliminate the vulnerability of the signal wires to external damage. As a result, the probability of the loss of power to the combination recorder due to an in-flight fire or breakup would decrease. The additional, forward-mounted combination recorder would also be fitted with an independent power source; consequently, if primary aircraft power were lost, the independent power source would further ensure that the combination recorder continued to record via the cockpit area microphone.

Therefore, the Safety Board believes that the FAA should require all aircraft manufactured after January 1, 2003, that must carry both a CVR and a DFDR to be equipped with two combination (CVR/DFDR) recording systems. One system should be located as close to the cockpit as practicable and the other as far aft as practicable. Both recording systems should be capable of recording all mandatory data parameters covering the previous 25 hours of operation and all cockpit audio including CPDL messages for the previous 2 hours of operation. The system located near the cockpit should be provided with an independent power source that is located with the combination recorder, and that automatically engages and provides 10 minutes of operation whenever normal aircraft power ceases, either by normal shutdown or by a loss of power to the bus. The aft system should be powered by the bus that provides the maximum reliability for operation without jeopardizing service to essential or emergency loads, whereas the system near the cockpit should be powered by the bus that provides the second highest reliability for operation without jeopardizing service to essential or emergency loads.

Until recently, it has been the general practice of aircraft manufacturers to use different aircraft electrical buses to provide power to the CVR and FDR; however, there has never been a requirement to do so. Current regulations call for power only from an electrical bus that provides the maximum reliability for operation without jeopardizing service to essential or emergency loads. As a result, MD-11 airplanes, which are currently configured with the CVR and FDR on the same generator bus, meet all regulatory requirements. However, with this configuration on MD-11 airplanes, such as Swissair flight 111, the failure or disabling of that bus would cause the loss of both flight recorders. Consequently, the Safety Board believes that CVRs, FDRs, and redundant combination flight recorders should be powered from separate generator buses. Therefore, the Board believes that the FAA should amend Title 14 *Code of Federal Regulations* Parts 25.1457 (cockpit voice recorders) and 25.1459 (flight data recorders) to require that CVRs, FDRs, and redundant combination flight recorders be powered from separate generator buses with the highest reliability. The Canadian TSB has developed a similar recommendation, which was issued to the Canadian and European regulators in early March 1999.

In its report on a September 8, 1989, incident involving USAir flight 105, a Boeing 737, at Kansas City, Missouri, the Safety Board cited the need for a video recording of the cockpit environment.[8] The report pointed out the limitations of existing flight recorders to fully document the range of the flight crew actions and communications. It also noted that the introduction of aircraft with electronic "glass" cockpits and the future use of CPDL communications would enable the flight crew to make display and data retrieval selections that will be transparent to the CVR and FDR. The Safety Board indicated that it would monitor and evaluate progress in the application of video technology to the cockpits of air transports. In the 9 years since that incident, considerable progress has been made in video and flight recorder technologies, and the need for video recording is becoming more evident. Video recording of the cockpit environment on newly manufactured airplanes is now technologically and economically feasible, and interest in video recording is growing.

The international aviation community is aware of the safety benefits of crash-protected video recorders. Agenda item 3 of ICAO's FLIRECP/2[9] specifically dealt with the need for standards and recommended practices (SARPs) concerning video recordings. The panel agreed that the use of video recordings in the aircraft cockpits would be very useful and noted that EUROCAE[10] was developing minimum operational performance specifications (MOPs). The panel agreed that video technology was maturing to the point where specific technical aspects (for example, video frame rate, number of cameras, and resolution per frame) must be determined, and that the ongoing work of EUROCAE and ARINC[11] should be considered when developing video recorder SARPs. The panel concluded that it was "strongly committed to the introduction of video recordings in an appropriate and agreed format, and that this should form part of the future work of the panel."

EUROCAE Working Group 50 (WG50) began drafting the fundamental needs for video recorders at its February 1999 meeting, which was attended by recorder manufacturers,

[8] National Transportation Safety Board. 1990. *USAir Flight 105; Boeing 737-200, N283AU; Kansas City International Airport, Missouri; September 8, 1989.* Aircraft Incident Report NTSB/AAR-90/04.

[9] International Civil Aviation Organization (ICAO), Flight Recorder Panel second meeting (FLIRECP/2).

[10] European Organisation for Civil Aviation Equipment (EUROCAE).

[11] ARINC, located in Annapolis, Maryland, is a private corporation whose principal stockholders are international air carriers. ARINC provides the aviation industry with communications and information processing systems and services, system engineering, and standards.

regulatory authorities, and accident investigators from around the world, including the Safety Board and the FAA. The fundamental needs for video recording are expected to be completed at the next meeting of WG50 in June 1999. Although WG50 remains committed to the task of defining standards for video flight recorders, it has not yet projected a completion date for a MOP.

The Safety Board believes that recorder systems and standard-setting processes should be flexible enough to incorporate new technology as it is developed. To that end, the Safety Board encourages the FAA and the aviation industry to take steps such as prewiring aircraft, developing system interfaces, and developing technical standards to facilitate the eventual introduction of new technology, such as video recorders.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require retrofit after January 1, 2005, of all cockpit voice recorders (CVRs) on all airplanes required to carry both a CVR and a flight data recorder (FDR) with a CVR that (a) meets Technical Standard Order (TSO) C123a, (b) is capable of recording the last 2 hours of audio, and (c) is fitted with an independent power source that is located with the digital CVR and that automatically engages and provides 10 minutes of operation whenever aircraft power to the recorder ceases, either by normal shutdown or by a loss of power to the bus. (A-99-16)

> Require all aircraft manufactured after January 1, 2003, that must carry both a cockpit voice recorder (CVR) and a digital flight data recorder (DFDR) to be equipped with two combination (CVR/DFDR) recording systems. One system should be located as close to the cockpit as practicable and the other as far aft as practicable. Both recording systems should be capable of recording all mandatory data parameters covering the previous 25 hours of operation and all cockpit audio including controller–pilot data link messages for the previous 2 hours of operation. The system located near the cockpit should be provided with an independent power source that is located with the combination recorder, and that automatically engages and provides 10 minutes of operation whenever normal aircraft power ceases, either by normal shutdown or by a loss of power to the bus. The aft system should be powered by the bus that provides the maximum reliability for operation without jeopardizing service to essential or emergency loads, whereas the system near the cockpit should be powered by the bus that provides the second highest reliability for operation without jeopardizing service to essential or emergency loads. (A-99-17)

> Amend Title 14 *Code of Federal Regulations* Parts 25.1457 (cockpit voice recorders) and 25.1459 (flight data recorders) to require that CVRs, FDRs, and redundant combination flight recorders be powered from separate generator buses with the highest reliability. (A-99-18)

If you have any questions about the recommendations, you may call (202) 314-6522.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

[Original Signed]

By: Jim Hall
Chairman