National Transportation Safety Board
Washington, D.C. 20594
Safety Recommendation

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In reply to refer to: A-91-23 and -24

Honorable James B. Busey
Administrator
Federal Aviation Administration
Washington, DC 20591

A digital flight data recorder (DFDR) records values for parameters related to the operation of an airplane (for example, ALTITUDE, AIRSPEED, and HEADING). The values are recorded in a serial binary digital data stream that must be converted either to engineering units or to discrete states. The arrangement of the recorded values in the data stream (the configuration) often varies from one DFDR system to another; consequently, accurate conversion of the recorded values to their corresponding engineering units or discrete states can be accomplished only when the configuration of the data stream has been thoroughly documented.

In the first years after DFDRs were introduced, which occurred nearly 20 years ago, only three types of aircraft (the Boeing B-747, Lockheed L1011, and McDonnell Douglas DC-10) were required to be equipped with a DFDR. To perform readouts of DFDRs, the Safety Board acquired documentation for the DFDR systems used and established related computer files. Maintaining the necessary documentation was manageable for the Safety Board then even though the DFDR systems used in these three types of aircraft generated data streams in which the parameter characteristics were recorded in many unique configurations.[1] As the number of types and models of aircraft increased over subsequent years, however, so did the number of unique configurations. Consequently, the Safety Board adopted the practice of obtaining generic documentation from the aircraft manufacturers as new models of aircraft were introduced and requesting more detailed documentation from the operators of specific aircraft when needed (after an accident or incident). Aircraft manufacturers are not necessarily a reliable source of accurate documentation for the DFDR in a specific aircraft, however, because operators may modify the configuration of the DFDR data stream after the aircraft is delivered.

Title 14 of the Code of Federal Regulations (CFR) now requires all operators under Part 121 and some operators under Parts 125, 135, and 91 to equip their aircraft with a DFDR. The number of DFDR systems now in aircraft has resulted in so many unique configurations of data streams (more than 250) that it is impractical for any single agency or organization to maintain

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[1] The configuration of data recorded for a given make and model of aircraft often varies from airplane to airplane.

files for all configurations. In addition, the number of DFDR systems will continue to grow; for example, operators are to retrofit older B-727s, B-737s, DC-8s, and DC-9s and others with expanded DFDR systems by 1994. The Safety Board must therefore rely on the documentation maintained by operators. The Board has found, however, that many operators do not maintain their documentation of recorded parameters in sufficient detail to enable them to respond quickly to the Board's request for the material after an accident or incident.

The Safety Board is concerned about the lack of adequate documentation because (1) some operators and FAA inspectors appear to be unaware of the appropriate level of detail required by current regulations for DFDR records (documentation); (2) operators need detailed documentation to perform required periodic maintenance checks of a DFDR system; and (3) operators and accident investigators need detailed documentation to decipher the data recorded by the DFDR. Furthermore, because parameter documentation for different DFDR systems is not presented in a standard format, the exchange of DFDR information among government and industry personnel is difficult. These areas of concern are discussed below.

Federal Requirements for Records

Federal regulations (Title 14 CFR Parts 23, 25, 27, 29, 91, 121, 125, and 135) require operators to have records (documentation) that reflect the status of life-limited appliances, such as DFDR systems.[2] The experience of the Safety Board with DFDRs suggests that many operators believe that maintenance checks based on the generic information contained in the recorder service manual are sufficient to confirm the status of the system, to repair the system, and to comply with the operator's inspection and repair requirements. However, generic information in the service manual is not sufficient in all instances; consequently, the status of DFDR systems cannot be established. Furthermore, the specific data correlation requirements set forth in 14 CFR 25.1459 cannot be met.[3]

A flight recorder system comprises several components such as remote sensors, the flight data acquisition unit (FDAU),[4] and the recorder. The status of a DFDR system depends on the status of all its components. The failure of a remote sensor or the malfunction of a FDAU, for example, may become apparent only when the recorded values are examined. Consequently,

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[2] Status is the indication of whether or not a DFDR system is functioning.

[3] Paragraph (c) of 14 CFR 25.1459 states that "a correlation must be established between the flight recorder readings of airspeed, altitude, and heading and the corresponding readings (taking into account correction factors) of the first pilot's instruments."

[4] The FDAU provides the means for gathering, conditioning, and converting parameters in the data stream to digital data.

the only way to determine the status of a DFDR system is to examine the recorded values as engineering units or discrete states.

Personnel examining recorded values must know all the parameters recorded, the location of each parameter in the data stream, and the characteristics of the values; such knowledge is gained from documentation that adequately identifies all the parameters recorded, the sequence in which they are recorded, and the characteristics of data recorded.

The Need for Documentation to Decipher Data

Accurate, comprehensive, and timely data from a DFDR after an accident or incident help investigators identify malfunctions of aircraft equipment and operational systems, and help them determine proper corrective action. These data also allow investigators to focus their efforts on time-critical phases of an investigation, such as interviewing witnesses and crewmembers, documenting damage to the airplane, and surveying the accident site, before vital information is lost. Inaccurate or incomplete data from a DFDR could result in invalid or incomplete findings, which could lead an investigation in the wrong direction. The importance of accurate, timely data and of detailed documentation is illustrated in the following examples.

(1) On September 20, 1989, USAir flight 5050, a Boeing 737-400, crashed during a rejected takeoff from La Guardia Airport in New York City. The airplane ran off the end of the runway, struck the approach lights, and came to rest in a body of water. Two passengers were killed, and the aircraft was destroyed. The Safety Board requested from the operator a listing of parameters and the respective conversion algorithms for the DFDR. The operator performed its own DFDR readouts through an automated process developed by the recorder manufacturer (Loral Fairchild) and therefore did not have the necessary documentation readily available. The recorder manufacturer provided the Safety Board a partial list of key data parameters, which was corroborated by the FDAU manufacturer. The aircraft manufacturer also provided some information on key parameters.

Based on the information provided by the recorder manufacturer and corroborated by the FDAU manufacturer, the Safety Board produced preliminary data sets of the accident sequence and distributed them to the investigative parties. When the Safety Board received comprehensive documentation from the FDAU manufacturer, 5 days after the accident, laboratory personnel produced a revised data set based on the new documentation. A comparison of data sets indicated disparities affecting key parameters. The disparities were the result of differences between initial design specifications used by the recorder manufacturer and the actual engineering specification.

Nearly 5 weeks after the accident, Boeing determined and informed Safety Board personnel that parameters AUTOPILOT OFF and TAKEOFF GO AROUND (TOGA) were recorded; these parameters were significant to the investigation. Identifying this information was delayed because a complete list of all recorded parameters had not been readily available to the accident investigators at Boeing and at the Safety Board.

(2) During an ILS[5] approach to Metropolitan Airport in Detroit, Michigan, in icing conditions on December 18, 1986, the pilot lost control of an ATR-42 airplane operated by Simmons Airlines. The airplane rolled abruptly to the right and left then descended 600 feet before the flightcrew could regain control of the airplane.[6] On the same day, a second airplane of the same type and operated by the same carrier had a similar but less severe encounter. The Federal Aviation Administration (FAA) acted promptly to prohibit operation into forecast icing conditions until the airworthiness of the airplane could be further evaluated. Analysis of the DFDR data clearly identified the cause of the loss of control as operational in nature rather than airworthiness-related. The analysis was delayed by several days, however, while the aircraft manufacturer assembled the necessary documentation for the specific airplane and hand-carried it from France. Had the operator been able to provide the necessary documentation when it was initially requested by the Safety Board, the icing restriction might have been avoided and a serious operational deficiency could have been corrected sooner.

(3) On November 11, 1990, a Fokker F28 MK0100 operated by USAir was involved in an incident near Atlanta, Georgia. As a result of the incident, questions were raised about the airworthiness of this newly certificated aircraft. The nature of the incident, a jammed stabilizer, generated serious safety concerns. The operator was unable to provide the necessary documentation to decipher the recorded data; consequently, the investigation was delayed several days while the FDAU manufacturer prepared and shipped the documents.

The practice of leasing aircraft has also contributed to the difficulty of obtaining accurate and detailed documentation following an accident or incident. Some operators of leased aircraft have little knowledge of the exact parameters being recorded by the DFDR system. Philippine Airlines, for example, leased and operated a Boeing 737-300 that was involved in a fatal accident on May 11, 1990.[7] The Philippines government requested the Safety Board to perform a readout of the DFDR. The operator did not have the necessary documentation, so the Safety Board obtained information from the aircraft manufacturer. That information proved to be incorrect for the DFDR system installed in the airplane; consequently, the investigation was delayed several days while current documentation was assembled and its accuracy was verified.

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[5] Instrument landing system.

[6] Additional details are in Aircraft Accident/Incident Summary Investigation DCA-87-IA015.

[7] The airplane, operating as flight 143, exploded and burned after it was pushed back from the airport gate at Manila. Of the 113 persons on board, 8 were killed.

The sale of used aircraft also contributes to the difficulty of obtaining accurate and detailed documentation on DFDR systems. Operators often modify the configuration of the DFDR system on an aircraft, which invalidates the documentation provided by the aircraft and FDAU manufacturers. The operator performing such modification must establish and maintain adequate documentation and make this documentation available to the new owner when the aircraft is sold. Consequently, the records maintained by the operator of an aircraft with a modified DFDR system are the only source of documentation. Although the FAA does require operators to maintain this documentation, the Safety Board's experience demonstrates that some operators are not complying with the requirement. Aircraft and FDAU manufacturers cannot be expected to keep track of changes in documentation after an aircraft is delivered.

The difficulty of obtaining detailed documentation of recorded parameters has been a problem for government and industry personnel since DFDRs were introduced. So that accurate information is available when needed, the Safety Board believes that the FAA should also require operators to retain documentation that shows the relationship between parameter activity and the corresponding recorded values for each parameter. The operators should be required to retain such documentation for each aircraft it operates. For identical DFDR installations on the same make and model of aircraft, a single documentation package will meet current requirements. However, operators should be required to revise and to maintain the documentation on any aircraft for which a change has been made to the characteristics of the parameters that will affect the configuration of the DFDR data stream.

The Need for Standard Format in DFDR Documentation

Because there is no standardization in the format of DFDR documentation, identifying the actual configuration of recorded data can be difficult and, as a result, can introduce delays and possible errors. For example, documentation for each parameter should include the following: word slot (1-64), number of bits (1-12), subframe (1-4), and conversion equation. If any of these parameter characteristics or elements of configuration is not present or is not clearly documented, the data cannot be recovered properly. Furthermore, DFDRs in some aircraft record over 200 parameters; a standard format for documenting parameter characteristics and the configuration of the data stream would allow readouts to be performed in a more timely manner.

Some recorder manufacturers and air carriers have also experienced difficulties in interpreting DFDR documentation and share the Safety Board's concern about the lack of standardized documentation. A common format would make it easier for government and industry personnel to retain and disseminate the detailed documentation necessary to decipher the data recorded by DFDRs.

On August 28, 1990, representatives of the major domestic and international air carriers and flight recorder manufacturers discussed issues related to DFDRs at a meeting conducted by Aeronautical Radio, Inc. (ARINC).

At the meeting, the Safety Board introduced a proposal for developing standardized DFDR documentation; the proposal was supported by the participants. Draft standardized documentation is now being circulated among air carriers and accident investigation authorities for review and comment. When completed, the standard will become an appendix to ARINC standards 542, 573, 717, and 747, which address flight recorder characteristics. Because the standard will reflect the needs of accident investigators and the aviation industry, the Safety Board believes that the FAA should require operators to maintain DFDR documentation in the format described in this standard or an equivalent.

Recommendations

Based on the deficiencies in DFDR documentation described above, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Issue permanent policy and guidance material for the continued airworthiness of digital flight data recorder (DFDR) systems stating that the make and model of the flight data recorder, and the make and model of the flight data acquisition unit, if installed, must be maintained as part of each aircraft's records, as well as at least the following information for each parameter recorded:
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> Location of parameter word (2 through 64 or 128).
> Assigned bits (1 through 12).
> Range (in engineering units when applicable).
> Sign convention (for example, trailing edge up = +).
> Type sensor (for example, synchro or low level DC).
> Accuracy limits (sensor input).
> FAA requirement (that is, mandatory or not mandatory).
> Subframe/superframe assignment--
> Documentation for engineering unit conversion.
> General Equation: Provide A_0, A_1, A_2, and A_3 for the equation $Y = A_0 + A_1X + A_2X^2 + A_3X^3$
> where Y = output in engineering units and
> X = input in decimal or converted counts.
> Nonlinear parameters: Provide a sufficient number of data samples (engineering units versus recorded decimal counts) to develop a conversion algorithm that will accurately define the full range of the parameter.
> Discrete parameters: Status (that is, 1 = on, 0 = off).
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> (Class II, Priority Action) (A-91-23)

Require operators to maintain current information for each unique digital flight data recorder configuration in its inventory using a single, universally adopted format, such as that described in the standard being developed by Aeronautical Radio, Inc. (ARINC). (Class II, Priority Action) (A-91-24)

Chairman KOLSTAD, Vice Chairman COUGHLIN, and Members LAUBER, BURNETT and HART concurred in these recommendations.

By: James L. Kolstad
Chairman