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FLIGHT DATA RECORDER READOUT EXPERIENCE IN AIRCRAFT ACCIDENT INVESTIGATIONS, 1960 - 1973

NATIONAL TRANSPORTATION SAFETY BOARD

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16. Abstract

This study evolved from a review of 509 accident and incident flight recorder readouts to provide information on the Safety Board's experience over a period of 14 years. The report covers their regulatory history, description and operation of recorders, readout of equipment and procedures, statistical review of occurrences related to phase of flight and types of operation, accident damage to recorders, malfunctions of recorders, foreign accident readouts, and recommendations related to this study.

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SPECIAL STUDY

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ADOPTED: MAY 14, 1975

NATIONAL TRANSPORTATION SAFETY BOARD
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SPECIAL STUDY

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INTRODUCTION

For many years aircraft accident investigators were constrained to the examination and analysis of physical evidence because of the lack of in-flight data from an aircraft flight data recorder. Although much information was gathered by examining the remains of an aircraft and by studying maintenance records, weather information, flight operations data, and human factors, it was difficult to reconstruct the circumstances of an accident. Ground witnesses were the primary source of information on aircraft flightpaths and maneuvers.

The flight data recorder added a new dimension to the investigation. It records data on altitude, airspeed, aircraft heading, and vertical acceleration. Now the progrees of an entire flight can be studied. In addition, since the recorder contains a permanent record of numerous flights, previous flights conducted by a flightcrew can be compared. When pertinent meteorological information is added to the recorded flight data, a geographical path of the aircraft can be developed. Also, recorded flight data can be used to study aircraft performance, to program flight stimulators, or to conduct special test flights in similar aircraft to duplicate portions of the accident flight.

The recorded flight data also permit a more detailed investigation of incidents and accidents which involve turbulence encounters, in-flight evasive actions, or midair collisions. Turbulence encounters can be analyzed to determine the type of turbulence encountered and to determine approximately the loads imposed on the aircraft. Information on the loads encountered during turbulence helps maintenance personnel to determine what part of the aircraft structure should be inspected. One air carrier has develcped a successful meteorological system for predicting areas of turbulence along its routes, and has used flight recorder readouts of turbulence encounters to gather data for this system.

The Safety Board has reviewed 509 accidents and incidents to provide information concerning its experience with flight data recorders over a period of 14 years, which ended June 30, 1973.

During those 14 years most U.S. air carriers have used electromechanical flight data recorders which employed metal foil as the recording medium. Permanent traces are scribed mechanically. Recording is continuous from the start of the takeoff roll to the end of the landing roll. The following parameters are recorded: Pressure altitude, indicated airspeed, magnetic heading, and vertical acceleration against a base of elapsed time.

The following report discusses a wide variety of accident and incident circumstances which required a readout of the flight recorder. The report discusses the more common malfunctions of the recorders and the information which can be gained from the readout despite these malfunctions.

REGULATORY HISTORY

The first Civil Air Regulation on flight recorders, Amendment 100, was effective April 1941. It required the installation of a device to record altitude and radio transmitter operation (on and off). The compliance date was subsequently revised three times, and finally, in June 1944, the Civil Aeronautics Board rescinded the requirement. The CAB action was brought about by maintenance difficulties and lack of replacement parts for the recorders.

A similar regulation was adopted in September 1947; it required a flight recorder in aircraft of 10,000 pounds or more, to record altitude and vertical accelerations. Again, on July 1, 1948, the CAB rescinded this requirement since there were no instruments readily available of proven reliability and fully adequate for the purpose intended. No flight recorders were installed during this period.

During the ensuing 9 years, the CAA and CAB studied the requirements, met with industry representatives, and proposed amendments which would define the flight recorder program. In August 1957, the CAB adopted amendments to Civil Air Regulations, Parts 40, 41, 42, and 43, to be effective in September 1957. These required flight recorders to be installed after July 1958 in all aircraft over 12,500 pounds that would be operated in air carrier service above 25,000 feet altitude. The functions to be recorded were: Airspeed, altitude, direction, vertical accelerations, and time. In September 1959, these regulations were revised to establish a retention period of 60 days for records and to clarify the time period that the flight recorder must be in operation, that is, continuously during flight, from the beginning of the takeoff roll until the end of the landing roll. These requirements, together with subsequent amendments to the Federal Aviation Regulations (FAR), resulted in the recording of flight records continuously during flight of all turbine-powered transport category aircraft operated by air carriers of United States registry. (See Appendix A.)

Although aircraft flight recorders have been required by FAR's aboard large aircraft since 1957, these have been of the oscillographic type that engraves altitude, airspeed, heading, and vertical acceleration traces on metal foil as a function of time. A digital flight data recorder (DFDR) has since been developed which encodes 64 12-bit words per second on magnetic tape using Harvard BiPhase code.

The DFDR is a multiparameter, magnetic tape flight recorder which was developed to allow recording of an increased number of flight data parameters, as required by 14 CFR 121. (See Appendix A.) The regulation requires that all large aircraft, which were certificated after September 30, 1969, and are turbine-engine powered or certificated for operation above 25,000 feet, be equipped with expanded parameter recorders. This includes the wide-bodied jets, such as the Boeing B-747, the Douglas DC-10, and the Lockheed L-1011.

The National Transportation Safety Board supported the regulations which required the expanded parameter recorder and recommended its application to new and existing type aircraft. The Board submitted information on specific cases to show how the proposed additional data might have increased the speed and accuracy of past accident investigations. The Board asserted that the additional data would enable the investigator, for the first time, to define the external or environmental forces exerted on the aircraft and the control forces exerted on the aircraft by the pilot, and would display the aircraft's responses to these forces. The Board further asserted that by using the additional data, the accident investigator could study and analyze the complex interactions between the man, the machine, and the environment, the capability for which, heretofore, had not been possible.

The amendment to 14 CFR 121 became effective on September 18, 1970. Appendix A gives a list of the new mandatory parameters, their range, minimum accuracy of recording and readout, and maximum sampling and recording intervals. The DFDR is capable of recording over 100 aircraft and flight parameters, although this number is well above that required by Part 121.

Amendment 135-9, "Air Taxi Operations with Large Aircraft," which requires air taxi operators using large aircraft to comply with certain rules of Part 121, became effective November 15, 1969. This rule, 14 CFR 135.2, requires the installation of a cockpit voice recorder and flight recorder for operators of turbojet-powered airplanes with maximum certificated takeoff weights of over 12,500 pounds but under 27,000 pounds with passenger-carrying capacities of not more than 12 persons, used in plane load charter flights. However, exemptions have been granted from this requirement and operators do not have to comply with the recorder requirements until May 15, 1975.

There have been four cases wherein the flight data recorder was not recovered because the wreckage was in deep water and could not be located. Loss of these data hampered the investigations considerably. A recommendation by the Safety Board resulted in an amendment to 14 CFR 121.343 which required that after March 18, 1974, each recorder had to be equipped with an approved device to assist in locating that recorder under water. This device, referred to as an underwater locator beacon, is a miniature battery-powered acoustic transmitter which is activated by fresh or salt water, and will emit an intermittent acoustic signal of specific frequency.

Such a device had been mounted on the flight recorder carried on board a large air carrier aircraft which went down recently in the Ionian Sea. According to the manufacturer of the device, this locator beacon had an operating depth of 20,000 feet, a detection range of 2,000 to 4,000 yards, and was capable of transmitting acoustic signals for 30 days after activation. During the first 13 days following the accident, air, surface, and subsurface units of the U. S. Sixth Fleet attempted to locate the recorder by conducting visual, radar, and acoustic searches with negative results. Then, 27 days after the accident, salvage experts, using a dipping hydrophone at a depth of approximately 2,500 feet, detected the beacon's acoustic signal in an area with a depth of 10,380 feet. A fresh locator beacon was dropped to mark the area while awaiting a decision on wreckage recovery.

The recorders are designed to comply with FAA Technical Standard Order TSO C51a. (See Appendix B.)

DESCRIPTION AND OPERATION OF FLIGHT RECORDERS

General

Two types of instruments are used by U. S. air carriers to record aircraft flight data. The most familiar of these is the flight data recorder (FDR) which uses metal foil as the recording medium and incorporates mechanically and electrically operated styli which scribe a permanent record of pressure altitude, indicated airspeed, magnetic heading, and vertical acceleration -- all against a base of time. The second type, in use only on wide-bodied, turbine-powered aircraft, is the DFDR, which uses magnetic tape as the recording medium and records a much wider range of aircraft flight data. A flight data acquisition unit (FDAU) installed on the DFDR-equipped aircraft is supplied with aircraft data in analog form from various sensors and transmitters on the aircraft. This information is converted to digital form and is transmitted to the DFDR and recorded.

The scribed traces on the metal foil media are read out by an optical reader. A computer is used to read out the DFDR magnetic tape.

Flight Data Recorder (FDR)

The FDR altitude and airspeed sensors sense ambient static air pressure from one of the aircraft's static pressure systems. Pitot or dynamic pressure is sensed from either the copilot's pitot system or from an independent source. The altitude and airspeed sensors then position the recording styli mechanically in response to changes in these pressures. An alternate source of altitude and airspeed information is the on-board central air data computer (CADC). This computer, which senses pitot and static pressures, sends appropriate electrical signals to servo amplifiers in the recorder which cause the recording styli to be positioned by servo motors.)

The magnetic heading source is the No. 2 aircraft compass system. Signals from an instrument in the cockpit are sent to a servo amplifier in the FDR which then positions the recording stylus by means of a servo motor. The vertical acceleration source is an accelerometer located away from the recorder at some point on aircraft structure close to the aircraft's center of gravity. This recording stylus is also positioned by a servo motor.

Digital Flight Data Recorder (DFDR)

Altitude and airspeed information is obtained from the onboard CADC through the FDAU. The recorder records a number of additional parameters. (See Appendix A.)

Description of Flight Recorders

Lockheed Aircraft Service Company -- The Model 109-C FDR is shaped like a sphere and is about 15 inches in diameter. The mounting flange is located where the top and bottom halves of the sphere fit together.

The upper half of the sphere is a removable cover which is secured to the lower half by a clamp-type retainer ring. The inner and outer shells which make up the recorder case are made of stainless steel with a 1-inch space between, which contains insulating material. The recording medium is aluminum foil, 2½ inches wide and .001 inch thick. A supply spool, which contains the foil, and a takeup spool are housed in a stainless steel cassette. The foil is fed from the supply spool, over a flat, teflon-coated platen which is part of the cassette wall, and onto the takeup spool. The various recording styli are mounted so that they contact the foil surface as it passes over the platen. One spool of the foil medium can record up to 200 hours of operation. The foil can be used only one time because the traces are embossed.

The Model 109-D FDR operates in essentially the same manner; however, the container is rectangular and suitable for installation in a typical radio rack.

The Model 209 DFDR uses six sequential tracks on a mylar magnetic recording tape. During operation, one track is recorded at a time in a predetermined bidirectional sequence. Old data are erased before new data are recorded. When a tape ends, motor rotation is reversed and the recording electronics are switched to the next track. The recording time for the six tracks is more than 25 hours. Tape speed is 0.46 inches per second, and the data density is 1,670 bits per inch.

Sundstrand Data Control -- The Model F-542 series FDR is rectangular and can be installed in a typical radio rack. The recording medium is a metal foil with a high nickel content and is about 5 inches wide and .001 inch thick. The foil is housed in a steel magazine with supply and takeup spools. The foil is fed from the supply spool to the takup spool at a constant rate by a motor-driven sprocket roller.

The recording styli are mounted so that they contact the foil as it passes over the scribe roller just before it is wound onto the takeup spool. The diamond-edged styli are held away from the foil surface and contact the foil at regular intervals. A cam-activated pressure bar presses against all styli to record the specific parameter data. One spool of foil can record about 400 hours of operation on one side and may be reversed to record an additional 400 hours on the other side.

The Model 573A DFDR utilizes four sequential tracks on a metal magnetic tape called Vicalloy. It switches tracks like the Lockheed DFDR. The four tracks record a total of 25 hours. Tape speed is 0.43 inch per second, and the data bit density is 1,786 bits per inch.

Fairchild Industrial Product -- The Model 5424 FDR is similar in every respect to the Sundstrand FDR. The same type of foil recording medium is used, and the operation of the recorder is essentially the same.

RADIO TRANSMISSION INDICATORS

Exact correlation between the flight recorder readout and the cockpit voice recorder transcript is essential to an investigation. The correlation helps the investigator relate crew activities to aircraft operation.

Radio transmissions recorded by the cockpit voice recorder can be related to real time by comparison to air traffic control recordings, whereas the flight recorder yields elapsed time only. Therefore, it was determined that radio transmissions would provide the most reliable commonality. Consequently, in response to a Safety Board recommendation, the FAR's were amended to require that, after September 18, 1972, all flight recorders record data from which the time of each radio transmission, either to or from air traffic control, could be determined. Radio transmissions from the aircraft to ground radio stations were selected as the ones to be recorded.

Recording of radio transmission indications is accomplished by use of a relay-operated binary (two-position) scriber in the flight recorder. The relay is energized by keying of the very high frequency (VHF) transmitters on board the aircraft and is de-energized when the transmitters are turned off. Keying of a transmitter by either the pilots or the flight engineer will energize the binary scriber and cause it to move across the surface of the recording medium to a new position. It will remain in that position until the transmitter is turned off, then return to its original position. Movement of the scriber, together with movement of the recording medium, produces a "square wave" pattern which can be measured to determine the length of the transmission while space between the indications is measured to determine the time between transmissions. Thus, the two recorder outputs can be correlated accurately. (See Figure 1.)

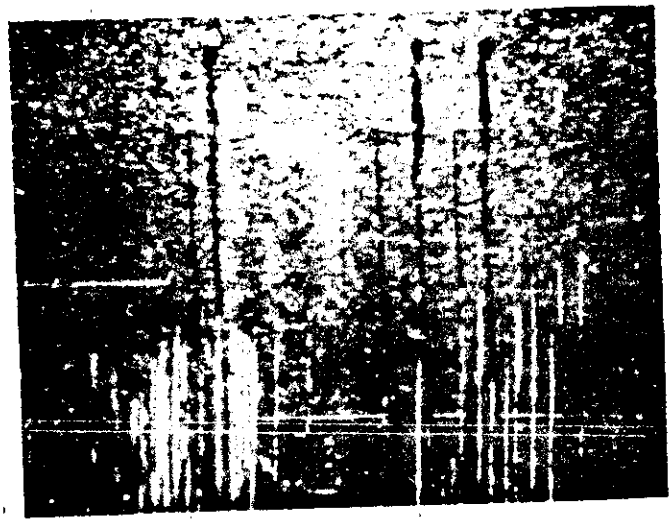


Figure 1. Example of radio transmission indications.

FLIGHT RECORDER READOUT EQUIPMENT

Flight recordings are read out by an optical readout machine of high accuracy. The readout machine was built to the Safety Board's specifications. (See Figure 2.) The machine contains a fixed platen for mounting the foil medium and a moving microscope for following the recorded traces. A fiber optics unit supplies the light source. The flexible light source is helpful when the foil surface has been discolored by heat since the scribed traces are not always plain. The microscope has a magnification range of 35-200 and can accommodate a Polaroid pack camera to photgraph segments of the traces through the microscope.

Side movements of the microscope -- The X dimension, and the in-and-out movement, the Y dimension -- are controlled through the use of two switches mounted on the machine console. These switches operate DC pulse-type motors which are connected through gear boxes to jackscrews. The

Figure 2. Flight recorder optical readout machine.

motors cause the microscope to move 0.0005 inch with each pulse. Electronic counters on the machine display the X and Y dimensions in inches of microscope movement from selected reference points.

The tape is read out by measuring the profile of each parameter trace for a selected time period. The measurements are made by following the traces with the microscope and logging the X and Y coordinates in inches of microscope movement at random intervals along the trace. More data points are taken where changes occur in the profile and fewer are taken where the traces are more constant. The X and Y coordinates in inches are then compared with the most recent recorder calibration record to determine values of each parameter and elapsed time. These values are then plotted on a graph with appropriate scales for analysis of aircraft operation. Radio transmission indications are also plotted as a parameter to be used in correlating the cockpit voice recorder transcript with the flight recorder readout.

The Safety Board has recently purchased a complete data reduction station to process data from digital flight recorders. (See Figure 3.)

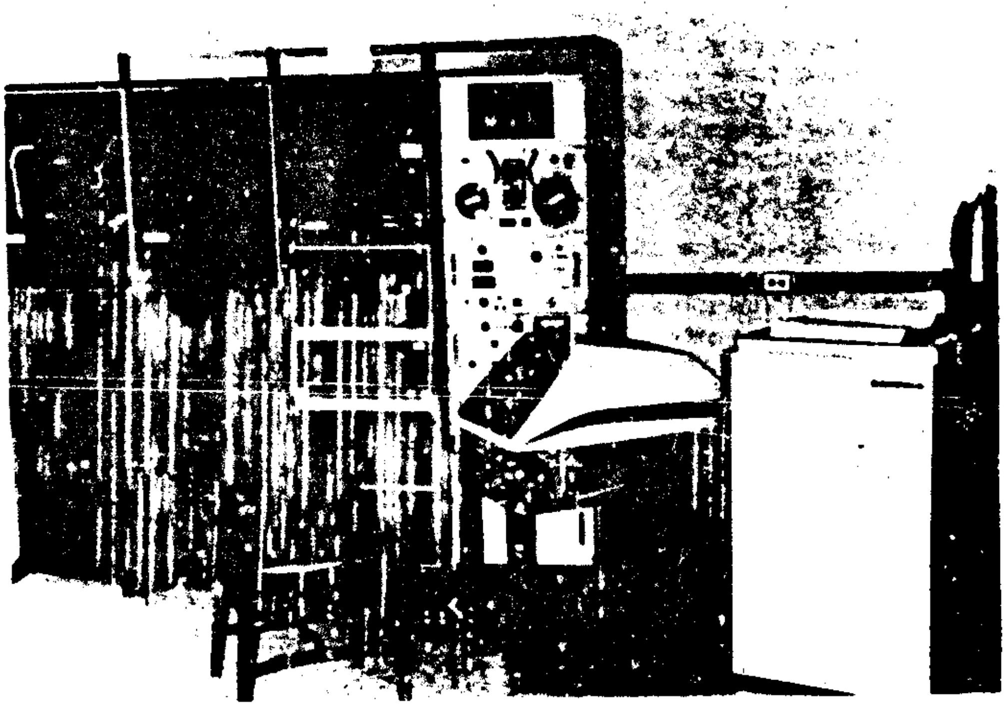


Figure 3. DFDR readout station.

The heart of the system is a minicomputer (PDP-11/40) with 24K parity core and disk operating system. Peripherals include an alpha-numeric cathode-ray-tube (CRT) terminal, two industry compatible, 9-channel magnetic tape units, a high-speed printer/plotter, and a paper tape reader and punch. The system contractor supplied specialized hardware and computer programs for our application. Specialized hardward includes: Two DFDR readers so that the ½-inch tapes can be transcribed to a 9-track tape without being removed from their crash-proof containers; a reel-to-reel tape deck so that ½-inch tapes can be played in the normal manner if it becomes necessary to remove them from a damaged DFDR; a computer interface to reformat the Harvard iPhase data stream from the preceding devices into computer-compatible format, i.e., NRZ; and an interface for getting X-Y coordinate data from the metal foil of the older type recorders into the computer.

The signal from the original DFDR tape is transcribed (reformatted and recorded) onto a 9-track computer tape. After a transcription tape is generated, it is played back on a 9-track tape machine which feeds the information to the computer. A program, based on the airline and type of aircraft, is called from the disk which converts the taped data from raw form into the parameter values originally transmitted to the recording system by the aircraft sensors.

The computer programs include a search routine for locating a specific flight among those recorded on the 25-hour tape, limit exceedance and max-min routines, plotter and print routines. Operator commands are entered via the terminal, in question-and-answer form. The computer asks questions which the operator reads on the CRT screen and answers via the keyboard.

The end result of a normal readout is a second-by-second listing of the data for as much of a given flight as desired, along with a plot of the data. This listing is called the "engineering units printout." The equipment can also generate a raw data (octal) printout. It can plot the data versus time in either strip-chart form (8 plots side-by-side, each 2 inches high) or in regular report style form.

STATISTICAL ANALYSIS OF 14 YEARS' EXPERIENCE WITH FDR READOUTS

General

From 1959 through 1973, the Safety Board received 509 FDR's and 4 DFDR's for readouts. The 4 DFDR's were read out at the recorder manufacturer's facilities since the Board did not have its DFDR readout station until November 1974. Therefore, the 4 DFDR cases were not included in the following statistical study.

The 509 cases reviewed demonstrated a high degree of recorder reliability and foil recording medium survivability. The main concern in recorder design, aside from the operational and recording accuracy requirements, is survivability of the recording medium in an accident. The recorder environmental tests for impact, crushing, penetration, exposure to fire, and immersion in sea water are set forth in Technical Standard Order C51a, issued by the FAA. (See Appendix B.) The recorder manufacturer must demonstrate that traces recorded on the medium remain legible and readable following exposure of the recorder to all of these tests in succession.

The following data attest to the reliability of the recorders and survivability of the foil recording media since readouts were precluded by either damage or malfunction in only 8 percent of the cases.

	No.	Percent
Readouts obtained despite damaged or malfunction recorders	409	81
Partial readouts obtained because of one or more malfunctioning parameters	33	6
No readout obtained because of recorder either damaged or malfunctioning	37	8
Readout request cancelled; records incomplete; no formal readout required	26	4
Recorders not recovered from deep water	4	1
	509	100

Recorder Readouts Related to Flight Regimes

The following tables present the number of readout cases as they relate to types of operation and the regime of flight in which the accidents/incidents occurred. Overall, these tables reflect that the greatest number of flight recorder readouts were performed for accidents/incidents which occurred during the landing regime, a total of 49 percent. The next highest number, 36 percent, involved the en route flight regimes. The takeoff regimes accounted for 14 percent.

Table 1

Regular Schedule/Charter Operations

Taxi Accidents/Incidents		
Taxiing to the runway	3	
Taxiing from the runway	1	
Total		4
Takeoff Accidents/Incidents		
Aborted, never became airborne	16	
Aborted just after liftoff	1	
Never became airborne	5	
Just after liftoff	23	
Initial climbout	11	
Total		56

En Route Accidents/Incidents

Climbing to cruise altitude	24	
During cruise	98	
Descending from cruise	38	
Total		160

Landing Accidents/Incidents

Aborted	3	
Initial approach	27	
Final approach	56	
Go-around/Missed approach	6	
At touchdown	55	
During landing rollout	63	
Total		210

Table 2

Training Operations

Takeoff Accidents/Incidents

Aborted	3	
Just after liftoff	1	
Total		4

En Route Accidents/Incidents

During cruise	7	
Descending from cruise	2	
Total		9

Landirz Accidents/Incidents

Initial approach	2	
Final approach	6	
Go-around/Missed approach	3	
At touchdown	2	
During larding rollout	3	
Total		16

Table 3

Other Operations

Takeoff Accidents/Incidents

Just after liftoff	3

En Route Accidents/Incidents

During cruise	3	

Landing Accidents/Incidents

Final approach	1	
At touchdown	5	
Total		12

Certain Occurences Related to Flight Phase

In-flight turbulence encounters, in-flight evasive action maneuvers, and midair collisions accounted for 26 percent of the cases reviewed. The following tables present these three areas in relation to the phase of flight in which they occurred. The 17 midair collisions accounted for 380 fatalities in the air carrier aircraft involved and approximately 25 fatalities in the other aircraft. The 114 cases involving turbulence and evasive action resulted in a large number of serious injuries to flight attendants and passengers. The tables for in-flight evasive action and midair collisions reflect that the majority of cases, 35 percent in each category, occurred while the aircraft was descending from cruise altitude.

Table 4

Turbulence Encounters

Climbing to cruise altitude	10	
During cruise	69	
Descending from cruise	12	
Landing final approach	3	
Total		94

Table 5

In-flight Evasive Action

Climbout after takeoff	1	
Climbing to cruise altitude	5	
During cruise	6	
Descending from cruise	7	
Landing initial approach	1	
Total		20

Table 6

Midair Collisions

Climbout after takeoff	2	
Climbing to cruise altitude	1	
During cruise	3	
Descending from cruise	6	
Landing initial approach	1	
Landing final approach	4	
Total		17

ACCIDENT DAMAGE TO FLIGHT RECORDERS

Experience during the early years of flight recorder operation showed that the damage incurred by the recorders and foil recording media could be attributed directly to the location of the recorder within the aircraft. Therefore, in response to a Safety Board recommendation, the FAR's were amended to require relocation of the recorders as far aft in the fuselage as practicable. The effectiveness of this relocation can be illustrated by the following statistics.

A total of 202 cases was processed before this relocation. Extensive damage to the recorder and foil medium precluded a readout in five of these cases. Readouts were possible, despite varying degrees of damage, in an additional 22 cases, 11 percent, with 10 of these cases, 46 percent, involving damage to the foil medium. Figures 4 through 7 are examples of damage to the recorder and foil medium before the relocation.

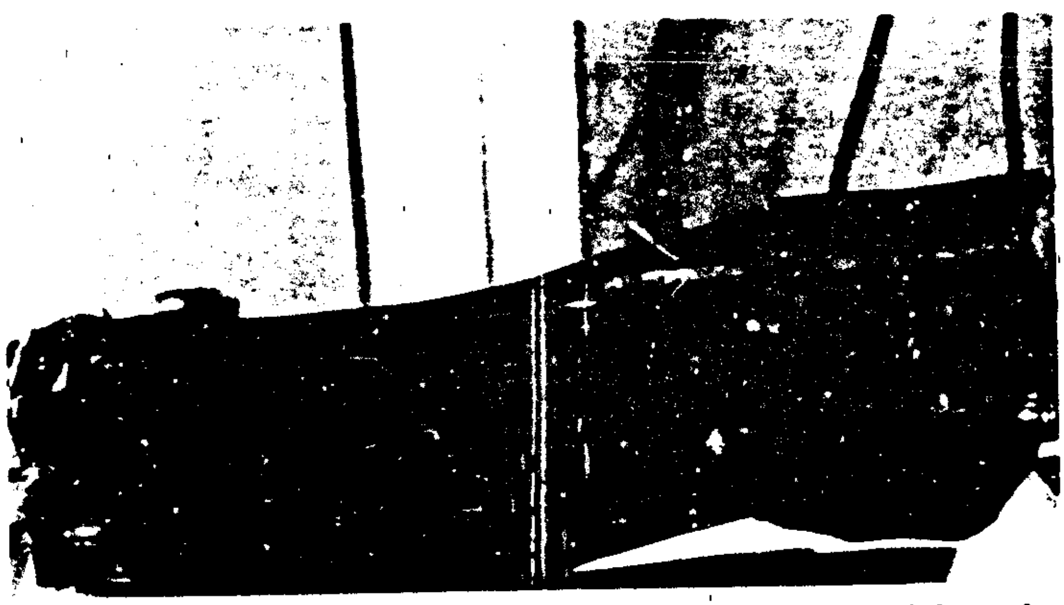


Figure 4. Typical flight recorder damage with recorder located forward in the aircraft

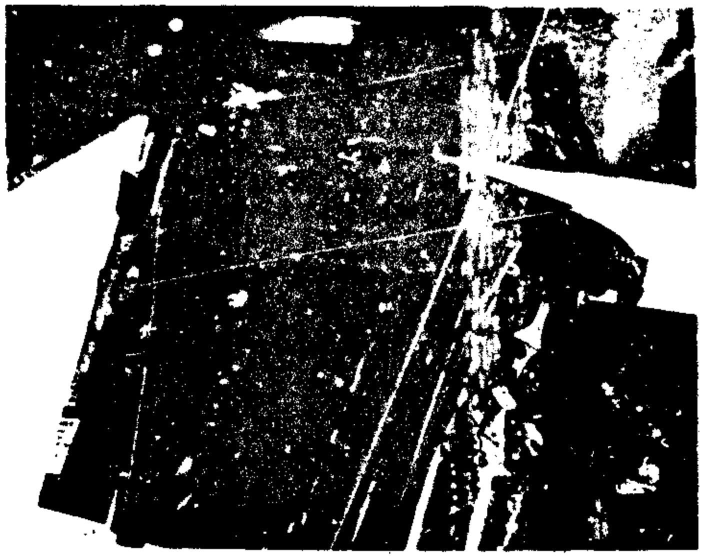


Figure 5. Damage to foil recording medium removed from flight recorder in Figure 4

Figure 6. Crushing damage to flight recorder located in leit main landing gear wheel well

Figure 7. Fragmented and reconstructed foil recording medium removed from flight recorder in figure 6

The study includes 301 cases which were processed after the recorders were relocated. Extensive damage to the recorder and foil medium precluded a readout in only one case. Readouts were possible, despite varying degrees of damage, in an additional 28 cases, 9 percent, with 6 of these cases, 12 percent, involving damage to the foil medium as well. Figure 9 is typical of the condition of a recorder removed from aircraft wreckage (Figure 8) since the relocation.

The single case, mentioned above, which involved loss of readout capabilities, concerned an aborted takeoff accident with postcrash fire. The recorder had been installed close to the passenger oxygen cylinders which released a stream of oxygen directed at the recorder after the fire had disrupted the oxygen system plumbing. The resultant oxygen-fed fire consumed most of the flight recorder and destroyed the portion of the foil medium which contained the pertinent flight record. (See Figures 10 and 11.)

Figure 8. Remains of aircraft tail section where flight recorder was located

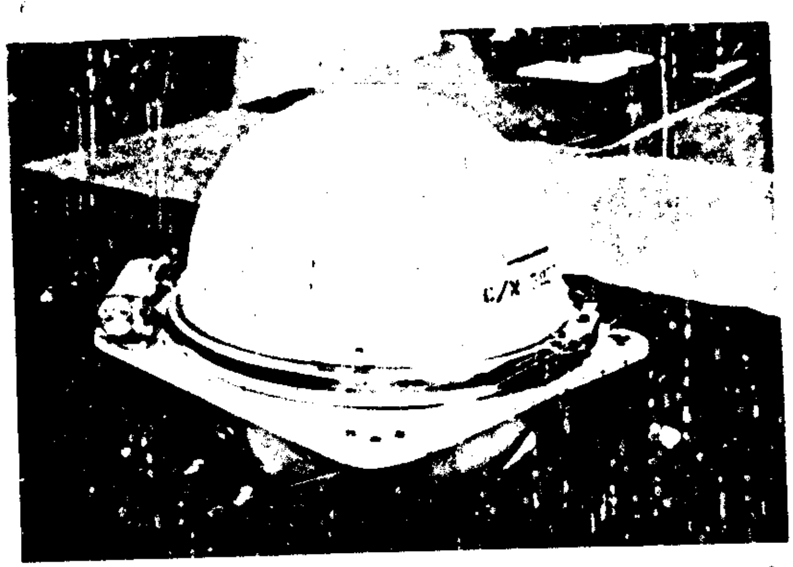


Figure 9. Flight recorder removed from tail section in Figure 8

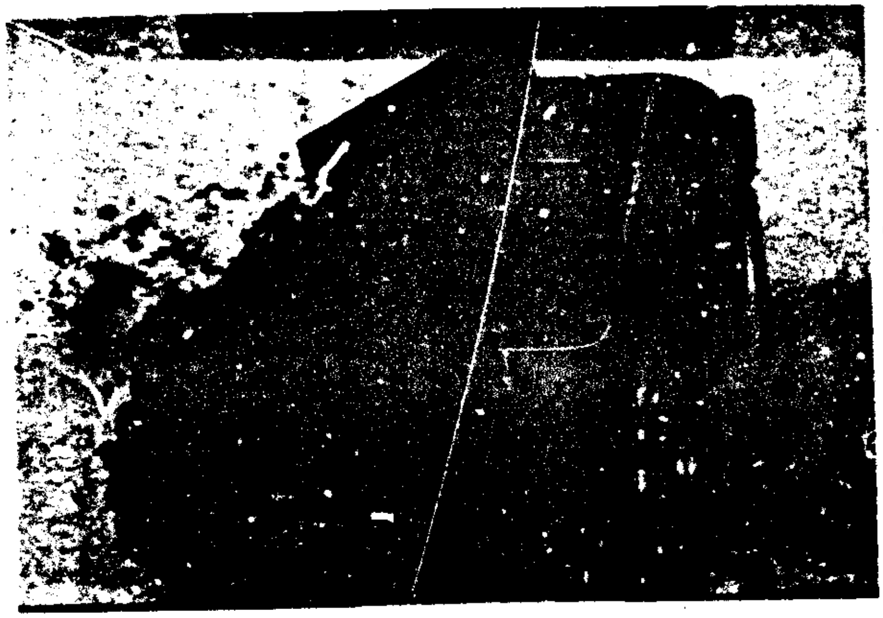


Figure 10. Remains of flight recorder with extreme fire damage

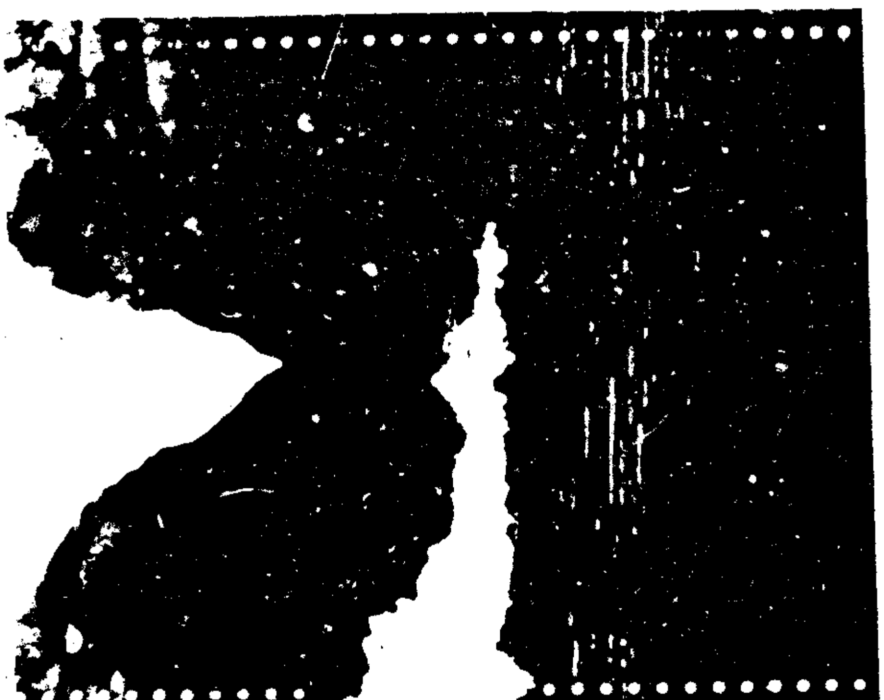


Figure 11. Foil recording medium with extreme fire damage removed from flight recorder in Figure 10

The following table shows the number and types of foil recording medium damage incurred before and after the relocation of the flight recorders.

Table 7

Type of Damage	Before Relocation	After Relocation
Mechanical only	6	5
Fire only	2	0
Mechanical/fire	2	1
Total	10	6

Figure 12 is an example of damage to the foil medium as the result of exposure to sand and sea water over a period of three weeks before recovery of the recorder. Figure 13 is an example of the surface damage from prolonged exposure to heat on an aluminum foil medium. The line visible in the photograph is a recorded parameter trace which was still visible in oxides formed by heat.

Figure 12. Example of foil recording medium after three weeks' immersion in sea water following an accident

Figure 13. Example of burned foil recording medium with visible recorded trace

MALFUNCTIONS OF THE FLIGHT RECORDER

The types of malfunctions found in flight recorders over the years have varied and some have been repeated. Records of the early years are incomplete with regard to some of these malfunctions and their causes. The following, however, represent typical malfunctions.

Recorder Not Operating

There were three cases during the early years during which the flight recorder was not operating at the time of the accident; however, the reasons were undetermined because of incomplete records. A fourth case in recent years concerned a recorder which stopped recording just 14 minutes before the accident. The recorder survived sufficiently to be tested and it was found that a single gear operated by the recorder drive motor was slipping on its shaft because the setscrews were not tightened. The gear turned a shaft, which operated both the foil medium takeup drive, and the cam shaft, which activated the scriber pressure bar. There was evidence, however, to indicate that the drive motor was operating and the recording styli were moving in response to inputs up to the time of impact.

Foil Medium Expended

There were four cases in which the foil medium was expended before the accident -- a condition that had gone unnoticed by the operator in each case.

Reversed Pitot/Static Lines

In one case, the pitot and static pressure lines were attached to the recorder in reverse. As a result, the recording fitting was modified to prevent recurrence of the malfunction.

Altitude and Airspeed Malfunctions

In two cases, the airspeed trace was being scribed in a reversed direction and the altitude trace seldom rose above airport elevations. The malfunction was caused by a gross leak in the static pressure line which supplied the recorder altitude and airspeed sensors. The leak had occurred at some point where the static lines passed through a pressurized portion of the fuselage on their way to the recorders.

A similar case occurred in which, again, the airspeed trace was being scribed in reverse; however, the altitude trace was static at all times. The malfunction occurred because the static pressure line was disconnected from the recorder, and, therefore, the ambient pressure in the altitude and airspeed sensor was trapped from a takeoff point about 75 flights earlier. Such a condition as described in both cases would have no effect on pneumatic instruments in the cockpit because the flight recorder static line is separate from the flight instrument static system.

Gaps in Recorded Traces

Gaps in recorded traces have occurred in 14 cases. The malfunction is associated with irregular foil movement through the magazine in the recorder and all parameters are affected. The frequency of the gaps may range from sporadic to continuous. Readouts were performed in 10 cases; however, this condition was so extensive in the other four cases that readouts could not be made. This malfunction may be the result of several conditions or combinations of these conditions:

- High clutch torque on the magazine
- Dirty scribe roller in the magazine
- Incorrect threading of foil in the magazine
- Excessive differential torque setting of the takeup drive
- Low torque setting of the takeup drive
- Takeup drive switch out of adjustment

Figures 14 and 15 provide a comparison of typical recorded traces with traces containing gaps.

Other Malfunctions

Other cases have been processed where malfunctions created difficulties in making complete readouts and providing sufficient information for analysis of aircraft activity before accidents:

- Inadequate stylus pressure has produced either faint traces or no visible traces at all.

- Improper alignment of recording stylus movement with the foil surface resulted in traces which faded out in the upper half of their operating range, causing loss of data.

- Investigations have been hampered in 11 instances where data were lost because of either inoperative magnetic heading or vertical acceleration parameters which produced static traces, or both. Loss of the vertical acceleration parameter caused great difficulty in the investigation of one accident involving structural failure of a wing in turbulence.

Information regarding aircraft activities can often be developed from the flight recorder readout despite malfunctions in one or more parameters.

For example, in the case of the structural failure just mentioned, the aircraft sustained a catastrophic failure of the right wing during descent from cruising altitude. A turbulence encounter was suspected; however, the investigation also developed evidence of preexisting fatigue cracks in the area of the failure. Determination of cause was complicated further when the flight recorder readout disclosed that the vertical acceleration (g force) parameter was inoperative and, therefore, could not provide information relating to turbulence.

This recorder contained three auxiliary traces made by binary scribers. These were the trip and date reference line binary, the heading north-south binary, and the timing binary. These scribers, unlike the parameter scribers, are in constant contact with the foil surface and scribe a straight line trace only. Examination of these traces disclosed the presence of small identical deviations at two points, 18 seconds apart, on each trace during the final seconds of recording. The earliest deviation, an up-and-down movement of 0.001 inch, was coincident with a sudden change in both altitude and airspeed. The second deviation in each trace was a sudden downward movement of 0.003 inch and the traces became aberrant thereafter. These deviations, which affected all three traces simultaneously, could only have resulted from shifting the foil magazine up and down within the recorder while the binary scribers

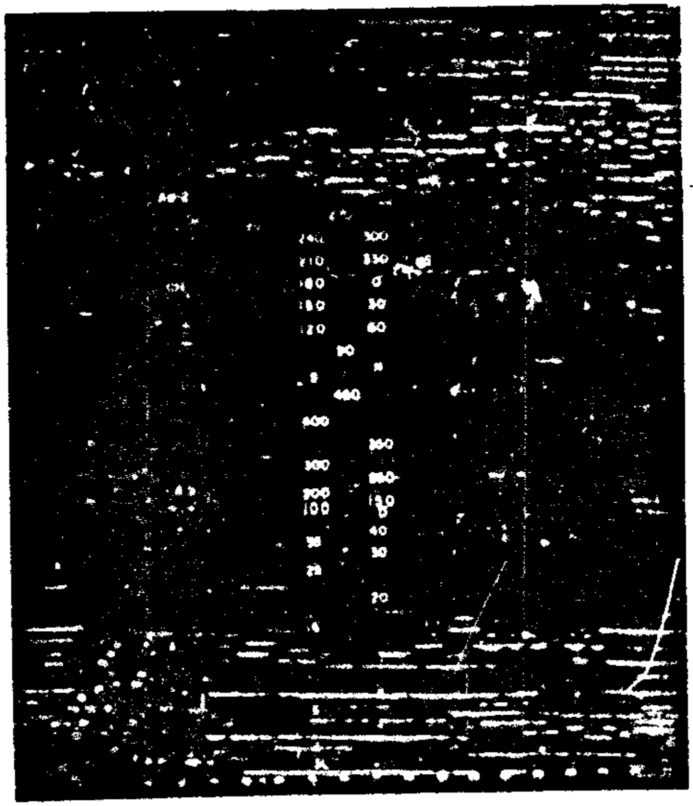
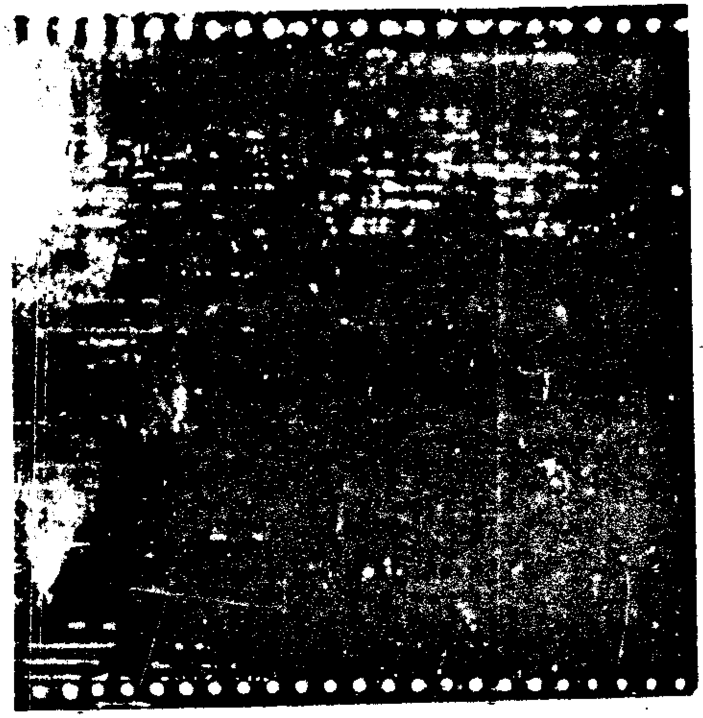


Figure 14



Reproduced from best available copy.

Figure 15

Comparison between typical recorded parameter traces (Figure 14) and a malfunctioning recorder with gaps in all parameter traces (Figure 15) remained in place. These dimensions were given to the recorder manufacturer to determine their possible significance.

Calculations and actual tests showed that the small deviation represented a downward movement of the magazine as the result of an +8g load on the recorder. The second and larger deviation was calculated to represent a load of -20 g which caused the magazine to move upward.

This information was sufficient to demonstrate that the wing failed because of turbulence-induced loads in an area of the wing which had been weakened to some degree by preexisting fatigue cracks.

RECORDER READOUT SERVICE TO FOREIGN GOVERNMENTS AND OTHERS

During the period covered by this study, the Safety Board provided flight recorder readout service to 25 foreign governments to aid their investigation of accidents under International Civil Aviation Organization (ICAO) agreements. The service was also extended to the U. S. Air Force and the National Aeronautics and Space Administration, both of which operate aircraft equipped with commercial-type flight recorders. See Table 8 for the percentage of these requests compared to the total case workload in each fiscal year.

Table 8

Fiscal Year	Total Cases	Foreign And Other	Percent of Total
1960	4	0	0
1961	10	0	0
1962	14	2	14
1963	18	0	0
1964	25	4	16
1965	36	4	11
1966	40	4	10
1967	50	7	14
1968	55	10	18
1969	64	8	12
1970	53	8	15
1971	59	5	8
1972	46	13	28
1973	35	11	31

DISCUSSION

The flight data recorder as an accident investigation tool has contributed significantly in improving the quality of the Board's investigations and safety recommendations.

Following are a few examples of how the use of this data has improved the accident findings and obviously, if the data had not been available, their findings would have been much less definitive.

Takeoff, Takeoff/Abort, Landing/Abort, and Overrun Accidents -- The FDR data have been used extensively in these accidents to calculate runway distances, accelerations, decelerations, and speeds to arrive at definitive causes in these accidents.

Midair Collisions -- FDR data have been utilized for ground track plots and three dimensional plots to define collision angles and also to establish visibility capabilities for both aircraft.

Approach and Landing Accidents -- The FDR has disclosed errors in descent profiles, unauthorized approach procedures, misreading of altimeters, high descent rates and stalls, and has been utilized to program simulators or test aircraft for accident flight simulations and reconstruction.

The FDR has been utilized to analyze abnormal maneuvers, loss of control in turbulence, control system failures, and has also proven to be of great assistance in the analysis of vortex turbulence accidents.

CONCLUSIONS

From the statistical evidence presented, the Board believes that the flight recorder design has proven to be adequate and that impact damage to the recorders has been minimized since their relocation in the rear of the aircraft. It is also evident that recorder malfunctions have primarily resulted from personnel error and inadequate maintenance.

The flight data recorder has provided a new dimension in aircraft accident investigation and, over the years, has provided technical data which enabled the Safety Board to arrive at more precise causes and causal factors. The flight data recorders have been a valuable source of data which clearly delineated safety problems and provided technical substantiation which enabled the Board to make specific safety recommendations for the resolution of these problems.

The Safety Board believes it absolutely necessary, however, to expand the present flight data recorder capability to provide additional needed parameters to assess fully all aspects of an accident. Investigation of recent complex accidents involving wide-bodied transport aircraft and other large transport aircraft has shown that additional parameters would have provided a more complete understanding of the underlying causal factors, and would have produced more effective measures to prevent future accidents.

The Safety Board believes that the flight data recorder has contributed significantly in providing the airline industry and traveling public with its present high level of safety.

RECOMMENDATIONS

During the preparation of this report, the Board has made eight recommendations to the Administrator, Federal Aviation Administration. (See Appendix D.)

The major aspects and intent of these recommendations were included as agenda items in the Federal Aviation Administration's First Biennial Airworthiness Review Conference held on December 2, 1974, in Washington, D.C.

Summaries of the discussions on these items are contained in Appendix D.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

May 14, 1975

APPENDIX A

PERTINENT FEDERAL AIR REGULATIONS

§ 25.149 Flight recorders.

(a) Each flight recorder required by the operating rules of this chapter must be installed so that --

(1) It is supplied with airspeed and altitude data obtained from sources that meet the accuracy requirements of § § 25.1323, 25.1325, and 25.1327, as appropriate;

(2) The vertical acceleration sensor is rigidly attached, and located longitudinally either within the approved center of gravity limits of the airplane, or at a distance forward or aft of these limits that does not exceed 25 percent of the airplane's mean aerodynamic chord;

(3) It receives its electrical power from the bus that provides the maximum reliability for operation of the flight recorder without jeopardizing service to essential or emergency loads; and

(4) There is an aural or visual means for preflight checking of the recorder for proper recorder tape movement.

(5) Except for recorders powered solely by the engine-driven electrical generator system, there is an automatic means to simultaneously stop a recorder that has a data erasure feature and prevent each erasure feature from functioning, within 10 minutes after crash impact.

(6) There is a means to record data from which the time of each radio transmission either to or from ATC can be determined.

(7) The underwater locating device, when required by the operating rules of this chapter, is on or adjacent to the container that records time, altitude, airspeed, vertical acceleration, and heading and is secured in such a manner that they are not likely to be separated during crash impact.

(b) Each nonejectable record container must be located and mounted so as to minimize the _ obability of container rupture resulting from crash impact and subsequent damage to the record from fire. In meeting this requirement the record container must be located as far aft as practicable, but need not be aft of the pressurized compartment, and may not be where aft-mounted engines may crush the container upon impact.

APPENDIX A

(c) 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. The correlation must cover the airspeed range over which the airplane is to be operated, the range of altitude to which the airplane is limited, and 360 degrees of heading. Correlation may be established on the ground as appropriate.

(d) Each recorder container must be either bright orange or bright yellow. (Amdt. 25-8, 31 F.R. 127, Jan. 6, 1966, as amended by Amdt. 25-25, 35 F.R. 13192, Aug. 19, 1970; Amdt. 25-31, 36 F.R. 23549, Dec. 10, 1971)

§ 121.343 Flight recorders.

(a) No person may operate a large airplane that is certificated for operations above 25,000 feet altitude or is turbine engine powered, unless it is equipped with one or more approved flight recorders that record data from which the following information may be determined within the ranges, accuracies, and recording intervals specified in Appendix B of this part --

(1) Time, altitude, airspeed, vertical acceleration, and heading; and

(2) After September 18, 1973, for airplanes having an original type certificate issued after September 30, 1969, pitch attitude, roll attitude, sideslip angle or lateral acceleration, pitch trim position, control column or pitch trim control surface position, control wheel or lateral control surface position, rudder pedal or yaw control surface position, thrust of each engine, position of each engine, position of each thrust reverser, trailing edge flap or cockpit flap control position, and leading edge flap or cockpit flap control position.

(b) Whenever a flight recorder required by this section is installed, it must be operated continuously from the instant the airplane begins the takeoff roll until it has completed the landing roll at an airport.

(c) Except as provided in paragraph (d) of this section, and except for recorded data erased as authorized in this paragraph, each certificate holder shall keep the recorded data prescribed in paragraph (a) of this section until the airplane has been operated for at least 25 hours of the operating time specified in § 121.359(a). A total of 1 hour of recorded data may be erased for the purpose of testing the flight recorder or the flight recorder system. Any erasure made in accordance with this paragraph must be of the oldest recorded data accumulated at the time of testing.

Except as provided in paragraph (d) of this section, no record need be kept more than 60 days.

(d) In the event of an accident or occurrence that requires immediate notification of the National Transportation Safety Board under Part 430 of its regulations and that results in termination of the flight, the certificate holder shall remove the recording media from the airplane and keep the recorded data required by paragraph (a) of this section for at least 60 days and for a longer period upon the request of the Board or the Administrator.

(e) Each flight recorder required by this section must be installed in accordance with the requirements of § 25.1459 of this chapter. The correlation required by paragraph (c) of § 25.1459 need be established only on one airplane of any group of airplanes --

(1) That are of the same type;

(2) On which the model flight recorder and its installation are the same; and

(3) On which there is no difference in type design with respect to the installation of those first pilot's instruments associated with the flight recorder. The most recent instrument calibration, including the recording medium from which this calibration is derived, and the recorder correlation, must be retained by each certificate holder.

(f) After March 18, 1974, each flight recorder required by this section that records the data specified in subparagraph (a)(1) of this section must have an approved device to assist in locating that recorder under water.

(g) After September 18, 1972, each flight recorder required by this section must record data from which the time of each radio transmission either to or from ATC can be determined. (Amdt. 121-66, 35 F.R. 13192, Aug. 19, 1970, as amended by Amdt. 121-82, 36 F.R. 23552, Dec. 10, 1971)

APPENDIX A

AIRCRAFT FLIGHT RECORDER SPECIFICATIONS

Information	Range	Accuracy, minimum (recorder and readout)	Recording interval, maximum seconds)
Time		±0.125 percent per hour, except accuracy need not exceed ±4 seconds.	60.
Altitude	-1,000 ft. to maximum certificated altitude of aircraft.	±100 to ±700 ft. (see table I TSO-C51a; FAR 37.150).	1.
Airspeed	100 to 450 KIAS or 100 KIAS to 1.0_{vd} whichever is greater.	±10 knots at room temp. ±12 knots at low temp. (see table III, TSO-C51a; FAR section 37.150).	1.
Vertical acceleration	-3 to 6g	±0.2g stabilized, ±10 percent transient (see TSO-C51a).	0.25 (or 1 second in which ± peaks are recorded).
Heading	360°	±2°	1.
Pitch attitude	±75°	±2°	1.
Roll attitude	±180°	±2°	1.
Lateral acceleration (in lieu of sideslip angle)	±1.0g	±.05g stabilized. ± 10 percent transient.	0.25 (or 1 second in which ± peaks are recorded).
Sideslip angle (in lieu of lateral acceleration)	±30°	±2°	0.5.
Pitch trim position	Full range	±1° or ±5 percent whichever is greater.	2.
Control column or pitch control surface position	Full range	±2°	1.

AIRCRAFT FLIGHT RECORDER SPECIFICATIONS

Information	Range	Accuracy, minimum (recorder and readout)	Recording interval, maximum seconds)
Control wheel or lateral control surface position	Full range	±2°	1.
Rudder pedal or yaw control surface position	Full range	±2°	0.5.
Thrust of each engine	Full range forward	±2 percent	4.
Position of each thrust reverser	Stowed and full reverse		4.
Trailing edge flap or cockpit flap control position	Full range (or each discrete position).	±3°	2.
Leading edge flap or cockpit flap control position	Each discrete position		2.
Angle of attack (if recorded directly)	-20° to +40°	±1°	0.5.

(Amdt. 121-66, 35 F.R. 13193, Aug. 19, 1970)

APPENDIX B

§ 37.150 Aircraft flight recorder -- TSO-C51a.

(a) Applicability. This technical standard order prescribes minimum performance standards that aircraft flight recorders must meet in order to be identified with the applicable TSO marking. New models of flight recorders that are to be identified and that are manufactured on or after the effective date of this section must meet the Minimum Performance Standard for Aircraft Flight Recorders set forth at the end of this section.

(b) Marking. In addition to the markings required by § 37.7, the rating (nominal voltage and wattage) must also be marked on the recorder.

(c) Data requirements. The manufacturer must furnish the Chief, Engineering and Manufacturing Branch (in the case of the Western Region, the Chief, Aircraft Engineering Division), Flight Standards Division, Federal Aviation Administration, in the region where the manufacturer is located, the following technical data:

(1) Six copies of the manufacturer's operating instructions, equipment limitations, and installation procedures.

(2) One copy of the manufacturer's test report.

MINIMUM PERFORMANCE STANDARD FOR AIRCRAFT FLIGHT RECORDER

1. Purpose. To establish minimum requirements for approved Aircraft Flight Recorders to be used in aircraft primarily for accident analysis, the operation of which may subject the recorder to environmental conditions specified in section 3.

2. Scope. This standard covers three basic types of aircraft flight recorders for recording time, airspeed, altitude, vertical acceleration, and heading. The intelligence received by the record medium can be from direct and/or remote sensors.

2.1 Definition of the types. Type I - Nonejectable; Type II - Nonejectable, restricted to any location more than one-half of the wing root chord from the main wing structure through the fuselage and from any fuel tanks; Type III - Ejectable, unrestricted location.

3. General requirements.

APPENDIX B

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3. General requirements.

3.1 Environmental conditions. The following conditions have been established as design requirements only. Tests shall be conducted as specified in sections 5, 6, and 7.

3.1.1 Temperature. When installed in accordance with the instrument manufacturer's instructions, the recorder shall function over the range of ambient temperature shown in column A below and shall not be adversely affected by exposure to the range of temperature shown in column B below:

Instrument location	A	B
Heat areas (temperature controlled)	-39 to 50C	-65 to 70C
Unheated areas (temperature uncontrolled)	-55 to 70C	-65 to 70C

3.1.2 Humidity. The recorder shall function and shall not be adversely affected when exposed to any relative humidity in the range from 0 to 95 percent at a temperature of approximately 32°C.

3.1.3 Vibration. When installed in accordance with the instrument manufacturer's instructions, the recorder shall function properly and shall not be adversely affected when subjected to vibrations of the following characteristics:

Recorder location in airframe	Cycles per sec.	Max. double amplitude (inches)	Max. acceleration
Airframe structure mounted	5-500	0.036	10g

APPENDIX B

3.1.4 Altitude. The recorder shall function and shall not be adversely affected when subjected to a pressure and temperature range equivalent to -1,000 to 50,000 feet standard altitude, per NACA Report No. 1235, except as limited by the application of paragraph 3.1.1. The recorder shall not be adversely affected following exposure to extremes in ambient pressures of 50 and 3 in. Hg. absolute.

3.1.5 Radio interference. The recorder shall not be the source of objectionable interference, under operating conditions at any frequencies used on aircraft, either by radiation or feedback, in electronic equipment installed in the same aircraft as the recorder.

3.1.6 Magnetic effect. The magnetic effect of the recorder shall not adversely affect the operation of the other instruments installed in the same aircraft.

4. Detail requirements.

4.1 Recording medium. The record medium shall conform to the following requirements:

a. The recording medium of recorders employing mechanical inscribed markings shall advance at a rate of not less than 6 inches per hour, and that of recorders employing other means of recording shall advance at a rate sufficient to permit resolution within the accuracy prescribed in section 4.3.

b. The recording medium shall provide a recording of the required data for at least the total elapsed operating time of a flight for which the aircraft might be used.

c. The recording medium shall not be subject to deterioration or distortion of the recorded data within the limits specified herein.

4.2 Recording intervals and ranges.

a. Time: The time lapse shall be recorded at intervals of not more than 1 minute.

b. Pressure altitude: -1,000 to 50,000 feet of standard atmosphere pressures, and shall be recorded at intervals of not more than one second.

c. Vertical acceleration: +6 to -3g, and shall be recorded at intervals of not more than 1/10 of 1 second, or at intervals of 1 second in which peak accelerations are recorded.

d. Airspeed: 100 to 450 knots IAS, and shall be recorded at intervals of not more than one second.

e. Heading: 360 degrees azimuth, and shall be recorded at intervals of not more than one second.

4.3 Record resolution. The record resolution shall be such that the data can be analyzed with the accuracy specified in section 6.

4.4 Record protection. The recorder shall be of such design that the recorded data will be protected against damage by fire, impact, and water within the limits specified herein.

4.5 Pressure altitude. The terms of pressure altitude shall conform to tables I and II.

4.6 Airspeed. The terms of airspeed shall conform to table III.

4.7 Power variations. All units shall properly function with +10 percent to -20 percent variation in DC voltage and/or ±10 percent variation in a.c voltage and ±5 percent in frequency, provided the a.c. voltage and frequency vary in the same direction. The recorder shall not be damaged when subjected to lower voltages.

4.8 Power malfunction indication. A means shall be provided for indicating when adequate power is not being received by the recorder for proper operation.

4.9 Automatic ejection. The automatic ejection provision of Type III recorders, including the structure holding the ejectable portion, shall be capable of operating when subjected to inertia loads corresponding to an acceleration of 6 g's acting in any direction.

5. Test conditions.

5.1 Atmospheric conditions. Unless otherwise specified all tests required by this standard shall be conducted at an atmospheric pressure of approximately 29.92 inches of mercury and at an ambient temperature of approximately 25° C. When tests are conducted with the atmospheric pressure or the temperature substantially different from these values, allowance shall be made for the variation from the specified conditions.

5.2 Vibration (to minimize friction). Unless otherwise specified all tests for performance may be made with the recorder subjected to a vibration of 0.002 to 0.005 inch double amplitude at a frequency of 1,500 to 2,000 cycles per minute. The term double amplitude as used herein indicates total displacement from positive maximum to negative maximum.

APPENDIX B

5.3 Vibration equipment. Vibration equipment shall be used which will provide frequencies and amplitudes consistent with the requirements of section 3.1.3 with the following characteristics:

5.3.1 Linear motion vibration. Vibration equipment for testing air-frame structure-mounted recorders of portions thereof shall be such as to allow vibration to be applied along each of three mutually perpendicular axes of the test specimen.

5.3.2 Circular motion vibration. Vibration equipment for testing shock-mounted recorders of portions thereof shall be such that a point on the case will describe, in a plane inclined 45 degrees to the horizontal plane, a circle, the diameter of which is equal to the double ampltidde.

5.4 Position. All tests shall be conducted with the recorder mounted in its normal operation position.

5.5 Test voltage. All tests for performance shall be conducted at the voltage rating recommended by the manufacturer.

5.6 Power conditions. All tests for performance shall be conducted at the power rating recommended by the manufacturer.

6. Allowable record errors.

6.1 Altitude record error. The recorder shall be tested for allowable error at the test points specified in table I on decreasing and increasing pressure. The rate of change in pressure during this test shall not be less than 3,000 feet per minute. On decreasing pressure, the pressure shall be brought down to, but shall not exceed, the specified test point. On increasing pressure, the pressure shall be brought up to, but shall not exceed, the specified test point. Within 1 minute after applying the specified pressure, the error in the record shall not exceed the tolerance values indicated in table I for each test point.

6.2 Acceleration record error. The acceleration error shall not exceed plus or minus 0.2G in a stabilized condition, and the total error in following a single, triangular, acceleration pulse of one-half second duration or greater, shall be no more than 10 percent of the acceleration. (An analytical evaluation is considered acceptable.)

6.3 Time scale record error. The time lapse error shall not exceed plus or minus 1.0 percent during an 8-hour period.

6.4 Airspeed record error. The recorder shall be tested for allowable error at the test points specified in table III on increasing and decreasing speeds. The allowable error shall not exceed the tolerance value specified in table III.

6.5 Heading record error. The heading record error shall not exceed plus or minus 2 degrees when measured at 15 degree intervals over 360 degrees in azimuth. The error is the difference between the sensor and the recorder.

7. Performance tests. The following tests, in addition to any others deemed necessary by the manufacturer, shall be the basis for determining compliance with the peformance requirements of this standard.

7.1 Room temperature. The recorder shall be tested at room temperature to determine compliance with the requirements under section 6.

7.2 Low temperature. The recorder shall be subjected to an ambient temperature of minus 55° C. for 5 hours and while still exposed to this temperature it shall be tested to determine compliance with the requirements under section 6.

7.3 High temperature. The recorder shall be subjected to an ambient temperature of 50° C. for 5 hours and while still exposed to this temperature it shall be tested to determine compliance with the room temperature accuracies under section 6.

7.4 Extreme temperature exposure. The recorder, after exposure to an ambient temperature of 70° C. for 24 hours followed by exposure to -65° C. for 24 hours followed immediately by exposure to room temperature for not more than 3 hours, shall meet the requirements of section 7.1. There shall be no evidence of damage as a result of exposure to the extreme temperatures.

7.5 Hysteresis. Not more than 15 minutes after the altitude sensor has been first subjected to the pressure corresponding to standard altitude of 50,000 feet, the pressure shall be increased at a rate corresponding to a decrease in altitude of not less than 3,000 feet per minute until the pressure corresponding to 25,000 is reached. Within 10 seconds the error shall not exceed the room temperature error at this test point by more than 100 feet. The altitude sensor shall remain at this pressure for not more than 15 minutes before the test to determine compliance with table II is made, after which the pressure shall be further increased at the above rate until the pressure corresponding to 20,000 feet is reached. The altitude sensor shall remain at this pressure for not more than 10 minutes before the test to determine compliance with table II is made. The pressure shall be further increased at the above rate until atmospheric pressure is reached.

APPENDIX B

7.6 After effect. Not more than 5 minutes after the completion of the hysteresis test, the altitude record shall have returned to its original recording, corrected for any change in atmospheric pressure, within the tolerance shown in table II.

7.7 Vibration.

7.7.1 Resonance. The recorder, while operating, shall be subjected to a resonant frequency survey of the appropriate range specified in section 3.1.3 in order to determine if there exists any resonant frequencies of the parts. The amplitude used may be any convenient value that does not exceed the maximum double amplitude and the maximum acceleration specified in section 3.1.3.

The recorder shall then be subjected to a vibration at the appropriate maximum double amplitude or maximum acceleration specified in section 3.1.3 at the resonant frequency for a period of 1 hour in each axis or with circular motion vibration, whichever is applicable. When more than one resonant frequency is encountered with vibration applied along any one axis, a test period may be accomplished at the most severe resonance, or the period may be divided among the resonant frequencies, whichever shall be considered most likely to produce failure. The test period shall not be less than one-half hour at any resonant mode. When resonant frequencies are not apparent within the specified frequency range, the recorder shall be vibrated for 2 hours in accordance with the vibration requirements of section 3.1.3 at the maximum double amplitude and the frequency to provide the maximum acceleration.

7.7.2 Cycling. The recorder, while operating, shall be tested with the frequency cycled between limits specified in section 3.1.3 in 15-minute cycles for a period of 1 hour in each axis at an applied double amplitude specified in section 3.1.3 or an acceleration specified in section 3.1.3, whichever is the limiting value. After the completion of this vibration test, no damage shall be evident and the recorder shall meet the requirements of section 6.

7.8 Humidity, water, impact, penetration resistance, static crush, and fire protection tests. The humidity, impact, penetration resistance, static crush, and fire protection tests shall be made in the following sequence on the same recorder without the need for repairs.

7.8.1 Humidity. The recorder shall be mounted in a chamber maintained at a temperature of 70±2° C. and a relative humidity of 95±5 percent for a period of 6 hours. After this period the heat should be shut off and the recorder should be allowed to cool for a period of 18 hours in this atmosphere in which the humidity rises to 100 percent as the temperature decreases to not more than 38° C. This complete cycle should be conducted fifteen (15) times. Immediately after cycling, the recorder shall be subjected to the Record Error Tests of section 6.

7.8.2 Impact. The intelligence on the record medium shall be capable of being analyzed after the recorder has been subjected to the following impact shock: Types I and II - Half sine wave impact shocks applied to each of the three main orthogonal axes and having a peak acceleration magnitude of 1,000 g with a time duration of at least 5 milliseconds. Type III - Acceleration not less than the shocks developed on contract with a horizontal rock surface, considering the direction of ejection and any provisions for alleviation of shock. With regard to the former, the aircraft shall be assumed to be tilted at least 30 degrees from horizontal in the most critical direction.

7.8.3 Penetration resistance (Type I and II recorders only). The intelligence on the record medium shall be capable of being analyzed after the recorder has been subjected to an impact force equal to a 500-pound steel bar which is dropped from a height of 10 feet to strike each side of the enclosure in the most critical plane. The point of contact of the bar shall have an area that is no greater than 0.05 square inches. The longitudinal axis of the bar shall be vertical at the time of impact. NOTE: The objective of this test is to achieve protection of the record medium from possible damage caused by airframe structural members striking the recorder case during crash impact.

7.8.4 Static crush (Type I and II recorders only). The intelligence on the record medium shall be capable of being analyzed after the recorder has been subjected to a static crush force of 5,000 pounds applied continuously, but not simultaneously to each of the three main orthogonal axes for a test period of 5 minutes.

7.8.5 Fire protection. The record medium shall remain intact so that the intelligence can be analyzed after the recorder is exposed to flames of 1100° C. enveloping at least 50 percent of the outside area of the case for the following periods of time: Type I - 30 minutes; Type II - 15 minutes; Type III - 1.5 minutes.

APPENDIX B

7.8.6 Water protection. The intelligence on the record medium shall be capable of remaining permanent and reproducible after the record medium has been immersed in sea water for 36 hours.

7.9 Position error. The recorder shall meet the following requirements when turned from its normal operating position through 90° forward and back, and left and right where applicable:

a. Time: Section 6.3.

b. Altitude: Section 6.1, except that the tolerance may be increased by 25 feet.

c. Acceleration: Section 6.2.

d. Airspeed: Section 6.4.

e. Heading: Section 6.5.

7.10 Dielectric. The insulation shall be subjected to a dielectric test with an RMS voltage at a commercial frequency applied for a period of 5 seconds, equivalent to five times normal circuit operating voltage, except where circuits include components for which such a test would be inappropriate, the test voltage shall be 1.25 times normal circuit operating voltage. The insulation resistance shall not be less than 20 megohms at that voltage.

7.11 Automatic ejection means. The automatic ejection means for Type III recorders shall be tested to demonstrate that it is capable of ejecting the recorder from its mounting when subjected to forward acting inertia loads of 5g's to 6g's.

8.0 Recorder color. The exterior surface of the recorder must be finished in either a bright orange or a bright yellow color.

TABLE I - ALTITUDE RECORD ERROR TABLE

Standard altitude (feet)	Equivalent pressure mercury		Tolerance, feet plus or minue	
	MM	IN.HG	Room temp. sec. 6.1	Low temp. sec. 7.1
-1,000	787.9	31.02	100	150
-500	773.8	30.47	100	------
0	760.0	29.92	100	150
500	746.4	29.39	100	------
1,000	732.9	28.86	100	------
1,500	719.7	28.33	100	------
2,000	706.6	27.82	100	------
3,000	681.1	26.81	125	------
4,000	656.3	25.84	150	210
6,000	609.0	23.98	150	250
8,000	564.4	22.22	150	------
10,000	522.6	20.58	150	------
12,000	483.3	19.03	180	350
14,000	446.4	17.57	210	------
16,000	411.8	16.21	240	------
18,000	379.1	14.94	270	450
20,000	349.1	13.75	300	------
22,000	320.8	12.63	335	------
25,000	281.9	11.10	375	560
30,000	225.6	8.83	450	600
35,000	178.7	7.04	525	730
40,000	140.7	5.54	600	800
50,000	87.3	3.44	700	------

TABLE II - ALTITUDE TEST TABLE

Tests	Reference section	Tolerance in feet
Hysteresis:	7.4	-----------
First test point 25,000 ----------	----------------	*90
Second test point 20,000 ---------	----------------	*90
After effect test -----------------	7.5	50

*In excess of the room temperature error.

APPENDIX B

TABLE III - AIRSPEED RECORD ERROR TABLE

Standard airspeed (knots)	Tolerance, knots plus or minus	
	Room temp. sec. 6.1	Low temp. sec. 7.1
100	10	12
150	10	12
200	10	12
250	10	12
300	10	12
350	10	12
400	10	12
450	10	12

(Amdt. 37-5, 31 F.R. 127, Jan. 6, 1966, as amended by Doc. No. 8084, 39 F.R. 5769, Apr. 11, 1967)

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

APPENDIX C

ISSUED: November 1, 1974

Forwarded to:

Honorable Alexander P. Butterfield
Administrator
Federal Aviation Administration
Washington, D. C. 20591

SAFETY RECOMMENDATION(S)
A-74-89 and 90

On July 8, 1974, a National Airlines, Inc., DC-10, N60NA, was involved in an accident near Tampa, Florida. The National Transportation Safety Board's investigation of the accident has revealed a need for corrective action on the digital flight data recorder (DFDR) system. The aft cowling on the No. 1 engine separated in flight and part of it was ingested by the No. 2 engine. Heavy engine damage, vibration, and fire resulted.

The DFDR readout showed that much data were lost during the flight, because of data dropouts or loss of synchronization during periods when the flight recorder was evidently subjected to airframe vibration. The Safety Board is concerned because immediately after the cowling separated 3 1/2 minutes of the data were lost and in the next 7 minutes about 70 percent of data were lost. In addition to these losses of vital data, 8.2 seconds of data were lost during take-off and 7.7 seconds after touchdown.

A Lockheed Aircraft Service Model 209 digital flight data recorder was installed in the aircraft. It had been certificated to operate properly during vibrations up to 10g. There is no evidence that the vibrations during this flight approached 10g.

The Safety Board is aware that an Airworthiness Directive is being considered to correct this and other problems with the recorder. We urge prompt action in this regard. We do believe, however, that intervals between maintenance checks on the modified recording system should be shortened until the system's reliability is established.

APPENDIX C

Honorable Alexander P. Butterfield (2)

In addition to the above-mentioned Airworthiness Directive, the Safety Board also believes that further corrective actions are needed to improve the reliability of the Lockheed Aircraft Service digital flight recorder systems. The maintenance checks on these recording systems should include either a readout by computer so that engineering unit printouts or plots of all parameters are obtained, or a readout by analog methods so that strip-chart records of all parameters are obtained. These data should be extracted from a previous flight of the aircraft and should include data from the various regimes of flight (takeoff, climb, cruise, descent, and landing). Several carriers, as you know, are currently conducting their maintenance checks with an electronic test unit, which can only sense data recorded a few seconds earlier and, therefore, actual flight data are not read out. Many malfunctions of the recording system caused by in-flight vibration, high temperatures, humidity, intermittent system failures, and tape track problems may go undetected and also are not likely to be sensed by the system's built-in test equipment.

The Safety Board has found loss of data as a result of a single electrical component (transducer, synchro, pot, etc.,) failure, and from recorders with contaminated tape heads. The maintenance check should require that all parameters be read out and that the tape heads are cleaned.

The Safety Board has previously recommended certain similar corrective actions in its Safety Recommendations A-73-116 through 118 concerning a complete loss of data following an in-flight engine disintegration.

Therefore, to insure that digital flight data recorder systems in the current fleet of wide-bodied jets are operating as specified in 14 CFR 121.343(a)(1)(2) and Appendix B, the National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Issue as soon as practicable an Airworthiness Directive on the Lockheed Aircraft Service Company Model 209 to prevent DFDR data dropouts caused by airframe vibrations.

2. Modify the periodic maintenance check procedures for all digital flight data recording systems which use Lockheed Aircraft Service Company recorders, as follows:

   a. Revise the maintenance check intervals so that they are commensurate with each operator's mean-time-between-failure rate, but do not exceed 3,000 hours.

Honorable Alexander P. Butterfield (3)

b. Require at each prescribed maintenance check a readout of actual flight data for all parameters either by computer or by analog methods for proper recorder performance.

c. Require that the tape heads in the recorders be cleaned every 2,000 hours or at every maintenance check period, whichever is later (not to exceed 3,000 hours).

d. Require maintenance checks every 500 hours on DFDR systems whenever a major modification is made as a result of service difficulties until a longer check period can be justified by the operator's new mean-time-between-failure rate for the system.

Personnel from our Bureau of Aviation Safety office will be made available if any further information or assistance is desired.

REED, Chairman, THAYER, BURGESS, and HALEY, Members, concurred in the above recommendations. McADAMS, Member, did not participate.

By John H. Reed
Chairman

APPENDIX C

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

November 7, 1974

Honorable John H. Reed
Chairman, National Transportation Safety Board
Department of Transportation
Washington, D.C. 20591

Dear Mr. Chairman:

This is to acknowledge receipt of your letter dated October 21, enclosing a copy of NTSB Safety Recommendations A-74-89 and 90. We are already processing an airworthiness directive which will be in accordance with your recommendations and will reply further when it is completed.

Sincerely,

Deputy Administrator for
Alexander P. Butterfield
Administrator

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

APPENDIX C

ISSUED: March 1, 1974

Forwarded to:

Honorable Alexander P. Butterfield
Administrator
Federal Aviation Administration
Washington, D. C. 20591

SAFETY RECOMMENDATION(S)

A-74-15 thru 17

The National Transportation Safety Board is concerned about the adequacy of information obtainable from aircraft flight data recorders which is applicable to accident investigations. Continuing sophistication of aircraft design, of ground-based navigation equipment, and of approach guidance equipment presents an extremely difficult challenge to the task of determining accident cause. Wreckage examination in many cases no longer produces sufficient information to assess the interrelationship of man, machine, and environment, particularly as they interact during a Category II- or Category III-landing approach. Reliance on avionics and electro-hydraulic servo hardware, which are contained in automatic flight control systems, airborne navigation receivers, and ground guidance signals, makes it especially imperative that all the facts relating to the operational status of this equipment be considered in the analysis of an accident situation. Necessary facts generally cannot be obtained from complex hardware and avionic circuits whose electrical power has been removed.

Consequently, the information that is recorded on the aircraft's flight data recorder has become increasingly important. As a result, the Board has reevaluated the requirements for these recorders, as specified in 14 CFR 121.343. The requirement for the minimum information which must be obtainable from the expanded parameter digital flight data recorder is described in paragraph (a)(2) of that regulation, which was adopted in September 1970. After considering the economic impact on the airline industry, the Board agreed to this compromise regulation.

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Honorable Alexander P. Butterfield - 2 -

Although the Board still believes that economic impact is a primary consideration, it, nevertheless, believes that the scope of the regulation is too narrow to serve the determination of cause and the prevention of similar accidents. This fact has been emphasized during several past accident investigations. The Eastern Air Lines L-1011 accident in Miami in December 1972, the Pan American B-707 accident in Boston in November 1973, the Northwest Airlines B-747 accident in Miami in December 1972, the Eastern Air Lines B-727 accident in Atlanta in December 1971, and the Alaska Airlines B-727 accident near Juneau in September 1971, are particularly good examples of accidents in which the investigation would have been more effective by information which can be readily recorded on a flight data recorder. In each of these accidents, a clearer understanding of the underlying causal factors might have produced more effective measures to prevent future accidents.

The Board believes it absolutely necessary to expand the flight data recorder capability so that those parameters described in Enclosure 1 are provided.

The advance in digital flight data recorder technology, particularly in those designed to the ARINC characteristic 573, makes the recording of additional data technically and economically feasible. Wide-bodied aircraft manufactured domestically are being delivered to foreign carriers with flight recorder installations which essentially provide the data proposed in Enclosure 1. In fact, such requirements will be imposed by the United Kingdom in 1975.

Moreover, the regulation, as adopted in September 1970, requires the installation of expanded parameter recorders only on aircraft whose type certificates were issued after September 1969. This compromise in the requirement was made because it was assumed that experience with those aircraft manufactured under type certificates issued before that date was sufficient to warrant lesser concern about accident investigation. Further, it was assumed that such aircraft would soon reach the end of their service lives. History now clearly indicates that these assumptions were not valid. New versions of the Boeing 727 and the Douglas DC-9 aircraft, which are still being manufactured, will continue to be used for many years. Also, the new aircraft will be operated in complex, all-weather approach environments.

The Board recognizes the difficulty of subjecting the expanded parameter flight data recorder to a cost-benefit analysis, since such a device is used primarily for accident investigation. The Board believes, however, that a catastrophic accident, which involves a wide-bodied aircraft with a large number of passengers, would create a high level of public concern. Both the Government and the aviation industry would certainly draw justifiable criticism if the facts related to such an accident cannot be determined precisely and rapidly. If the factors causing or contributing to the

Honorable Alexander P. Butterfield - 3 -

accident were proved later to be recurring factors, loss of lives as the result would be all the more needless and tragic.

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

1. Amend 14 CFR 121.343 so that the requirements of paragraph (a)(2) apply to all aircraft manufactured after a specified date, regardless of the date of original type certification.

2. Amend 14 CFR 121.343 to require that all aircraft manufactured after a specified date, regardless of the date of original type certification, be equipped with one or more approved flight recorders that record data from which the information listed in Enclosure 1, in addition to the information presently specified in 14 CFR 121.343 paragraph (a)(2), can be determined. The implementation of this action obviates the need for compliance with recommendation number 1 above.

3. Amend 14 CFR 121.343 to require that all aircraft, issued an original type certificate after September 30, 1969, be equipped at the earliest practical specified date with one or more approved flight recorders that record data from which the information listed in Enclosure 1 can be determined, in addition to the requirements already imposed by paragraph (a)(2) of that regulation.

Personnel from our Bureau of Aviation Safety are available if any further information or assistance is desired.

McADAMS, THAYER, BURGESS, and HALEY, Members, concurred in the above recommendations. REED, Chairman, was absent, not voting.

By: John H. Reed
Chairman

Enclosure 1

RECOMMENDED ADDITIONS TO THE EXPANDED PARAMETER FLIGHT DATA RECORDER

The National Transportation Safety Board believes that the following additional information is essential to the conduct of thorough and expeditious investigations of accidents involving modern, complex aircraft. We recommend that a requirement for data from which such information can be determined within reasonable ranges, accuracies, and recording intervals be added to the requirements for flight data recorders specified in 14 CFR 121.343.

1. Time (G.m.t.)

Time is an important and critical parameter in the evaluation of other recorded data, the derivation of dynamic changes and the correlation with other investigation data sources. As such, G.m.t. should be directly encoded in the DFDR tape. The current regulations require that time be controlled only to the extent that tape drive speed is maintained within specified accuracies. On some equipment, data loss is not reflected in DFDR-processed data printouts, and thus there is no correlation between lapsed time and actual time.

2. Automatic Flight Control System Status

Knowledge of the operating status of autopilot/autothrottle systems is essential in an investigation to determine the man-machine relationship during the accident. Since most of the avionic equipment has no memory, its status usually cannot be determined after power is interrupted. The role of such equipment during Category II and Category III approaches increases the importance of such knowledge. Engagement status and selected operating mode should be determinable.

3. Pilot Input/Control Surface Position - Three Axes

The current regulation requires that either control position or surface position be recorded. On those aircraft having aerodynamically boosted or electro-hydraulic servo-actuator-powered control systems, there is no positive relationship between control input and surface position. In fact, it is this relationship which might provide the only indication of flight control system malfunction. The control loops often mix a mechanical input from the pilot's control with an electrical input from an autopilot or stability augmentation system. System gains and positional relationships are often dependent upon control mode selection and operational conditions. Both parameters must, therefore, be measured to provide for an effective investigation.

Additionally, the resolution of the measurement must be small enough to provide meaningful data. The currently specified ±2° accuracy/minimum resolution is broad and masks normal control surface motions during many flight conditions.

4. Spoiler/Speedbrake Position

Intentional or inadvertent spoiler/speedbrake extension is an important factor which must be considered in the investigation of hard landing accidents. Conversely, the failure of ground spoilers to extend can be a causal factor in landing overrun accidents. Spoiler position cannot be determined accurately unless it is recorded by a flight data recorder.

5. Flight Director Mode Selection

The selected operating mode of the captain's and first officer's flight director system is a significant factor in the investigation of Category I approach accidents. The inadvertent selection of an improper mode might have been a contributing factor in at least one accident which the Board investigated. However, the absence of firm evidence precluded positive determination of cause.

6. Localizer/Glide Slope Deviation

The deviation or error signal which is generated by the localizer and glide slope facility should be recorded. These data would provide valuable clues regarding aircraft position, cockpit workload, automatic tracking accuracy, and performance or involvement of both airborne and ground-based equipment.

7. Hydraulic System Status

Many of the new generation aircraft depend upon hydraulic power for flight control. Even with the redundancy provided, the failure of one or more hydraulic systems can be a significant factor in accident investigations. There are cases on record in which three of four systems were lost. A signal input to the DFDR actuated by the low pressure warning light circuitry could be used to record this information.

8. Electrical Bus Status

The energized/deenergized status of those electrical buses which are essential for primary flight control, primary flight instrumentation, or actuation of emergency equipment, should be recorded, if not evident by other means such as loss of specific signal inputs to the FDR, or to the cockpit voice recorder.

9. Fire Warning/Pressurization System Failure

Discrete signals should be recorded when those cockpit warning lights illuminate which indicate an in-flight fire or a failure in the cabin pressurization system that would reduce the design performance capability of the aircraft.

10. Vertical Acceleration Recording Interval

14 CFR 121.343 specifies that vertical acceleration is to be sampled and recorded at maximum intervals of 0.25 second. The older metal foil recorders provide vertical acceleration data points at maximum intervals of 0.1 second. This shorter interval is extremely useful in the investigation of in-flight turbulence encounters and hard landing accidents.

Since the natural frequency of the fuselage of a large aircraft is generally between 3-4 Hz., an in-flight turbulence encounter is likely to be evidenced by a large amplitude load within this frequency range. A minimum recording frequency of 2.5 times the structural frequency is necessary to detect and to analyze such conditions.

11. Longitudinal Acceleration

Longitudinal acceleration is an important factor in aircraft performance analysis. Although it is derivable from airspeed values, the direct recording of longitudinal acceleration would enhance the accuracy of such analyses. Furthermore, the availability of data regarding positive and negative accelerations, in a region below the minimum recording threshold of the airspeed parameter, is particularly significant in the investigation of takeoff and landing accidents.

12. Outside Ambient or Total Air Temperature

Temperature data are extremely significant in the determination of airspeed, engine thrust, and other related performance data. Since reported meteorological data are not entirely accurate, actual values should be measured. Temperature data are also important to fix acurately the penetration of frontal systems, so that wind shifts can be determined and the ground track established more accurately. Temperature data can establish the presence of icing conditions in an accident.

13. Strut Extension/Retraction Switch

In investigating an accident occurring during the takeoff or landing phase, it is important to correlate the liftoff or touchdown time with the flight recorder data. A discrete signal to indicate liftoff or touchdown should be recorded. This signal could be actuated by the strut scissors switch.

14. Outer, Middle, and Inner Marker Passage

This parameter would make it possible to establish a correlation between aircraft position and a fixed point over the ground and flight recorder time. Such a correlation is significant in establishing cockpit activities and deviation from prescribed approach procedures. Although these data are sometimes available from the aircraft's voice recorder, cross-correlation is difficult.

15. Radio Altitude

The radio altimeter is an essential instrument during Category II and Category III approaches. Its operating status and indication could be essential to an investigation of an approach accident. Therefore, its operating status and indication should be a recorded parameter.

APPENDIX C

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

MAY 9 1974

Honorable John H. Reed
Chairman, National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

Notation 1204B

Dear Mr. Chairman:

This replies to your Safety Recommendations A-74-15 thru 17 issued March 1, 1974. They have been reviewed carefully and we agree with your suggestion that additional recorded information listed in Enclosure 1 would assist in the accident investigative processes for certain aircraft. While these changes are currently feasible, using available hardware, adequate justification will have to be developed.

The present generation digital flight data recorder was first discussed between your technical personnel and representatives of the Federal Aviation Administration in late 1965, and Notice 67-6 was issued in February 1967. This was followed by a number of meetings involving National Transportation Safety Board, FAA, airline, aircraft manufacturers, and equipment manufacturers personnel. The main purpose of these sessions was to determine exactly what recorded information was essential. The wide-body aircraft were being built, all weather landing systems were being developed, and, in addition, the U.S. supersonic transport program was also in process. The recorder specifications developed during those meetings were intended to be fully applicable to the supersonic transport.

The effectivity of the new recorder rules was keyed to the first wide-body aircraft because it was believed that adequate experience had been obtained with earlier aircraft models to permit effective accident investigations even though only the older recorders were installed.

In summary, we find your current recommendations go beyond the arguments used during the formulation of the present rules. Therefore, to proceed with rulemaking adequate justification must be provided to substantiate the basis for the requested action.

We will introduce your recommendations as an agenda item to be discussed at the Airworthiness Review Conference to be held in December 1974. In preparation for that conference, we need information from you that will:

2

(1) Show a need for the new recorders to be installed in earlier aircraft (pre-wide-body models), and

(2) Show a need for each of the additional parameters outlined in your Enclosure 1.

Examples of accident investigations in which each specific type of information requested in your Enclosure 1 would have appreciably assisted your investigation would be most helpful.

A copy of the announcement regarding the Airworthiness Review Conference is enclosed to acquaint you with the procedure.

Sincerely,

Alexander P. Butterfield
Administrator

Enclosure

APPENDIX C

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

AIRWORTHINESS REVIEW PROGRAM

FAA Adopts Biennial Airworthiness Review Policy

In view of the rapid growth and technological advances of the aviation industry in the United States and abroad, the FAA has determined that it is appropriate to adopt a systematic method providing for the review of existing airworthiness standards and the promulgation of new and revised airworthiness standards on a periodic basis.

Accordingly an Airworthiness Review Program has been established. The program will be implemented through biennial Airworthiness Reviews which are to be administered by Flight Standards Service. The Airworthiness Reviews will be carried out with full opportunity for the participation of industry, other Government agencies, foreign governments, and the aviation public. All elements of the FAA will provide support to Flight Standards Service as necessary to ensure timely completion of the periodic airworthiness review process.

Pursuant to the policy announced herein, the Director of Flight Standards Service is issuing a Notice regarding the first biennial review, the 1974-75 Airworthiness Review. The Notice sets forth detailed information concerning the scope and schedule and invites submission of proposed amendments to the airworthiness standards, and it is published concurrently with this Notice.

Issued in Washington, D.C., on February 12, 1974.

ALEXANDER P. BUTTERFIELD,
Administrator.

(As published in the Federal Register /39 F.R. 5813/ on February 15, 1974)

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

[14 CFR Ch. I]

[Docket No. 13542; Notice No. 74-5]

AIRWORTHINESS REVIEW PROGRAM

Notice of Invitation To Submit Proposals for Consideration During the 1974–75 Airworthiness Regulations Review

The Federal Aviation Administration hereby gives public notice of the 1974-75 airworthiness review program. The airworthiness review encompasses the certification and operating regulations containing airworthiness standards and related procedural requirements. The program will be administerd by the Airworthiness Review Staff, a new office created for that purpose and reporting directly to the Director of Flight Standards Service. The airworthiness review will proceed according to the schedule contained in Appendix A to this notice.

Interested persons, including manufacturers and users of aircraft and their components, and the general public, both foreign and domestic, and foreign airworthiness authorities are invited to submit any proposals they deem appropriate for amendments of the airworthiness regulations. All proposals should be submitted in duplicate to the Federal Aviation Administration, Flight Standards Service, Attention: Airworthiness Review Staff, AFS-77, 800 Independence Avenue SW., Washington, D.C. 20591. In order to receive proper consideration, proposals must be within the scope of the 1974-75 airworthiness review as set forth in this Notice and must be received not later than April 15, 1974. Proposals that are received after that date may be deferred for consideration during a future airworthiness review.

The scope of the 1974-75 airworthiness review includes the following Federal Aviation Regulations (FARs) contained in Title 14 of the Code of Federal Regulations (14 CFR):

(1)

Part 21—Certification procedures for products and parts.
Part 23—Airworthiness standards: normal, utility, and acrobatic category airplanes.
Part 25—Airworthiness standards: transport category airplanes.
Part 27—Airworthiness standards: normal category rotorcraft.
Part 29—Airworthiness standards: transport category rotorcraft.
Part 31—Airworthiness standards: manned free balloons.
Part 33—Airworthiness standards: aircraft engines.
Part 35—Airworthiness standards: propellers.

(2) Those sections of the following FAR Parts that contain airworthiness requirements or that contain performance operating limitations that are related to type certification performance requirements:

Part 91—General operating and flight rules.
Part 121—Certification and operations: domestic, flag, and supplemental air carriers and commercial operators of large aircraft.
Part 133—Rotorcraft external-load operations.
Part 135—Air taxi operators and commercial operators of small aircraft.

(3) Those sections of the following FAR Parts which may be related to proposals dealing with the above mentioned parts:

Part 36—Noise standards: aircraft certification.
Part 37—Technical standard order authorizations.
Part 43—Maintenance, preventive maintenance, rebuilding, and alteration.

In order to facilitate evaluation of the large number of proposals expected in response to this Notice, it is essential that each proposal be clearly stated and accompanied by adequate justification. The following format should be followed:

TITLE—(Indicate subject matter and affected regulations, if applicable.)

PROPOSAL—(Give specific FAR section, if applicable and suggested language and/or indicate the precise objective being sought.)

JUSTIFICATION—(Give background of problem and reasons for proposal. Include or refer to any available supporting data.)

Proposals received by April 15, 1974, will be processed by the FAA, and a compilation of the proposals, together with identification of their proponents and the supporting data offered as justification will be distributed, not later than May 30, 1974, to known interested persons, for comment. At the time of that distribution a notice of the availability of the compilation will be published in the Federal Register to give all other interested persons the opportunity to comment upon them. In addition to proposals received from the public, the FAA may include in the compilation of proposals others that it considers appropriate for consideration during the review.

All comments on the compilation of proposals that are received before August 1, 1974, will be considered in preparing the final Agenda for the 1974-75 Airworthiness Review Conference, to be held at the Shoreham Hotel, 2500 Calvert St., NW., Washington, D.C. 20008, beginning at 9:00 a.m. EDT, December 2, 1974.

The conference, which will be open to the public, is scheduled for 8 full working days, December 2, 1974, through December 11, 1974, but may be extended, if necessary, for completion of the Agenda.

The conference record will be used in developing a Notice of Proposed Rule Making (NPRM), scheduled for publication in the FEDERAL REGISTER by May 30, 1975. The NPRM will provide the opportunity for further public comment on

(As published in the Federal Register /39 F.R. 5785/ on February 15, 1974) specific proposed amendments to the FARs, with the comment period open until September 1, 1975. Final rules to be adopted as a result of the airworthiness review will be published in the form of amendments to the FARs after consideration of the comments received in response to the NPRM. The publication of such amendments will be made in the FEDERAL REGISTER by February 13, 1976.

It should be noted that not all the proposals received in response to this Notice would necessarily be included in the compilation of proposals scheduled for distribution on May 30, 1974. Nor would all proposals included in that document necessarily be included in the Final Agenda for the Airworthiness Review Conference. Some proposals may be straight forward, noncontroversial, and adequately justified. Since no useful purpose would be served by including such items on the agenda, they will be held for inclusion in the NPRM. On the other hand, proposals which are not adequately justified, which require further research, or which the FAA believes could not result in fruitful discussion at the conference will be dropped or deferred for further study and possible consideration during future airworthiness reviews.

Appendix B to this Notice contains information as of February 1, 1974, on the status of the principal FARs involved in this review and a list of regulatory dockets concerning the airworthiness regulations. Some of those projects may be included for consideration in this airworthiness review; those that are at an advanced stage of processing may be completed independently of the airworthiness review.

Issued in Washington, D.C., on February 12, 1974.

JAMES F. RUDOLPH,
Director,
Flight Standards Service.

APPENDIX A—SCHEDULE OF 1974–75 AIRWORTHINESS REVIEW

February 15, 1974—Notice initiating 1974–75 Airworthiness Review and requesting proposals for amendments to the FARs.
April 15, 1974—End date for submittal of proposals.
May 30, 1974—Distribution of the compilation of proposals.
August 1, 1974—End date for submittal of comments on the proposals.
October 15, 1974—Distribution of Final Agenda for Conference.
December 2–11, 1974—Conference.
May 30, 1975—Issue Notice of Proposed Rule Making.
September 1, 1975—End date for comments on NPRM.
February 13, 1976—Issue Amendments to FARs.

APPENDIX B—STATUS OF PRINCIPAL AIRWORTHINESS PARTS AND A LIST OF REGULATORY DOCKETS CONCERNING AIRWORTHINESS

GENERAL AND MISCELLANEOUS

1. *Engine Airworthiness Review.* The intent of this project is to update and improve the engine airworthiness standards in FAR 33 and related aircraft airworthiness rules in FAR's 1, 21, 23, 25, 27, and 29. Proposed changes were published in Notice 71–12 (36 FR 8368, May 5, 1971; Regulatory Docket No. 11010). Issuance of final amendments is anticipated in the near future.

2. *Flight Systems, Inc., Petition to Amend FAR's 21, 61, 91. (Regulatory Docket No. 12492).* Petitioner requests, insofar as pertinent, amendment of FAR 21 to permit issuance of experimental certificates for aircraft used as test beds to conduct research and development and for amendment of FAR 91 to permit such aircraft to carry persons and cargo for compensation and hire.

3. *ALPA Petition on Xenon Strobe Anti-Collision Lights (Regulatory Docket No. 13126).* This project involves a petition to change FAR's 23, 25, 27, 29, and 91 to require white strobe anticollision lights on all aircraft.

4. *Bronson Engineering Company, Inc., Petition on Oxygen Supply (Regulatory Docket No. 13417).* This petition seeks to amend the oxygen supply requirements of section 121.333(e)(2) and 135.165(b)(3).

PART 21—CERTIFICATION PROCEDURES FOR PRODUCTS AND PARTS

The latest amendment to Part 21 is Amendment 21–39 (Published in 38 FR 29596, October 26, 1973), effective December 1, 1973. This amendment prescribes compliance with Part 36 noise standards for newly produced airplanes of older type designs. Regulatory projects in process that may affect Part 21 and their current status are given in items 1 and 2 under General and Miscellaneous.

PART 23—AIRWORTHINESS STANDARDS: NORMAL, UTILITY, AND ACROBATIC CATEGORY AIRPLANES

The latest amendment to Part 23 is Amendment 23–14 (Published in 38 FR 31816, November 19, 1973), effective December 20, 1973. This amendment updated the airworthiness standards applicable to airplanes certificated under FAR 23. A regulatory project in process that may affect Part 23 and its current status is as follows (see also items 1 and 3 under General and Miscellaneous):

Crashworthiness for Small Airplanes (Regulatory Docket No. 10162). The purpose of this project is to consider improvement in the crashworthiness of small airplanes, including the installation of shoulder harnesses. Proposals were published in Notice 73–1 (Published in 38 FR 2965, January 31, 1973).

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

The latest amendment to Part 25 is Amendment 25–34 (Published in 37 FR 25354, November 30, 1972), effective December 31, 1972. This amendment prescribes additional security requirements for certain large passenger-carrying turbojet airplanes operated under FAR's 121, 123, and 135. Regulatory projects in process that may affect this part and their status are as follows (also see items 1 and 3 under General and Miscellaneous):

1. *Smoke Emission (Regulatory Docket No. 9611).* The purpose of this project is to establish smoke emission standards for transport category airplane cabin interior materials. An Advance NPRM was issued on July 25, 1969. (Notice 69–30, published in 34 FR 12450, July 30, 1969).

2. *ALPA Petition on Ta -off Flap Setting (Regulatory Docket No. 9612).* This involves a petition to require means to prevent incorrect flap settings on transport category airplanes during takeoff.

3. *Cockpit Vision (Regulatory Docket No. 10709).* The purpose of this project is to establish specific standards for cockpit vision. Proposed cockpit vision standards were promulgated in Notice 71–28 (Published in 37 FR 23574, November 4, 1972).

4. *Aerospace Industries Association of America, Inc. (AIA) Petition for Miscellaneous Changes to FAR 25 (Regulatory Docket No. 11671).* This petition seeks to change FAR's 25.251, 25.303, 25.305(b), 25.571(e)(2), 25.683, 25.934, 25.959, 25.1103(d), 25.1333(b), and 25.1435(a)(4).

5. *Aviation Consumer Action Project Petition for Fuel System Inerting (Regulatory Docket No. 12274).* This petition seeks to require fuel system inerting for turbine-powered transport airplanes.

6. *ALPA Petition on Shoulder Harnesses (Regulatory Docket No. 13269).* This petition seeks to require shoulder harnesses for all crewmembers of transport airplanes.

7. *AIA Petition on Equipment, Systems, and Installations (Regulatory Docket No. 13333).* This petition seeks to amend section 25.1309.

PART 27—AIRWORTHINESS STANDARDS: NORMAL CATEGORY ROTORCRAFT

The latest amendment to this part is Amendment 27–8 (Published in 37 FR 20028, September 29, 1972), effective October 23, 1972. This amendment clarifies the requirements for rotorcraft manuals, markings, and placards. Regulatory projects in process that may affect this part and their status are given in items 1 and 3 under General and Miscellaneous.

PART 29—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY ROTORCRAFT

The latest amendment to this part is Amendment 29–8 (Published in 36 FR 21278, November 5, 1971), effective November 5, 1971. This amendment provides for the installation of rear position lights with minor obstructions in the field of coverage. Regulatory projects in process that may affect this part, and their status, are given in items 1 and 3 under General and Miscellaneous.

PART 31—AIRWORTHINESS STANDARDS: MANNED FREE BALLOONS

The latest amendment to this part is Amendment 31–2 (Published in 30 FR 3376, March 13, 1965), effective April 12, 1965. This amendment prescribes additional airworthiness requirements.

PART 33—AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES

The latest amendment to this part is Amendment 33–4 (Published in 36 FR 3490, March 21, 1971), effective on April 23, 1971. This amendment revised the fire detector and engine power response requirements. A project in process which affects this part is described in item 1 under General and Miscellaneous.

PART 35—AIRWORTHINESS STANDARDS: PROPELLERS

The latest amendment to this part is Amendment 35–2 (Published in 32 FR 3735, March 4, 1967), effective on April 3, 1967. This amendment resulted in clarification and updating of the requirements of FAR 35.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

APPENDIX C

ISSUED: January 22, 1974

Forwarded to:
Honorable Alexander P. Butterfield
Administrator
Federal Aviation Administration
Washington, D. C. 20590

SAFETY RECOMMENDATION(S)

A-73-116 thru 118

(revised)

The National Transportation Safety Board's investigation of a National Airlines Douglas DC-10 accident, which occurred in flight near Albuquerque, New Mexico, on November 3, 1973, disclosed a malfunction in the digital flight data recorder (DFDR). This malfunction precluded recovery of any data related to the accident. The Board is very much concerned about this type of failure, because it is not detectable by the test equipment aboard the aircraft and, therefore, might exist on a large number of aircraft equipped with the new DFDR.

National Airlines subsequently performed readouts of the DFDR throughout their entire fleet of wide-bodied aircraft to assess the extent of similar undetected malfunctions. Testimony at the Safety Board's public hearing held in Miami, Florida, on December 10-12, 1973, and subsequent readout examinations disclosed that, of 13 wide-bodied jets in the fleet, 7 had been operating with undetected malfunctions which would have precluded recovery of acceptable data for some parameters required under 14 CFR 121.343(a)(2).

In meetings with your staff, the Board's staff has discussed the preliminary findings of the survey of DFDR's conducted under GENOT 8000.92. In the Board's opinion, these preliminary findings also indicate that the current 2,000- to 3,000-hour inspection intervals are unrealistic and should be adjusted to be commensurate with the mean-time-between-failure (MTBF) rates that these recording systems have been experiencing during this early period of operation.

Therefore, to insure that recorders in the current fleet of wide-bodied jets are operating in an approved manner, as specified under 14 CFR 121.343 (a)(1), (2), and Appendix B, the National Transportation Safety Board recommends that the Federal Aviation Administration:

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Honorable Alexander P. Butterfield - 2 -

1. Require, within the next 100 flight hours, a readout of data recorded in flight on the digital flight data recorders, as required under 14 CFR 121.343(a)(2), and take action to insure that the parameters required are being recorded within the ranges, accuracies, and recording intervals specified in Appendix B thereof.

2. Require repetitive readout inspections, as specified above, at 500-hour intervals, until the reliability of these recorder systems improves.

3. Require retention by the operators of the data received in the two most recent readout inspections.

Personnel from our Bureau of Aviation Safety offices will be made available if any further information or assistance is desired.

REED, Chairman, McADAMS, BURGESS, and HALEY, Members, concurred in the above recommendations. THAYER, Member, was absent, not voting.

By John H. Reed
Chairman

nds

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DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

OFFICE OF THE ADMINISTRATOR

FEB 8 1974

Honorable John H. Reed
Chairman, National Transportation Safety Board
Department of Transportation
Washington, D.C. 20591

Dear Mr. Chairman:

Notation 1230

This is in reply to your Safety Recommendations A-73-116 thru 118 issued January 22, 1974, concerning your recommendations on digital flight data recorders relative to the National Airlines DC-10 accident of November 3, 1973. In addition, your release identified National Airlines operating with seven of 13 digital flight data recorders with undetected malfunctions.

The FAA has already initiated appropriate corrective action with regard to the National Airlines readout deficiencies which were cited in your letter.

Several other actions have been taken by the FAA. Immediately following the accident we initiated a national survey regarding the performance of all installed digital flight data recorders. Our accumulated data is sufficiently conclusive that a rule or regulation change at this time is not necessary. We have determined that the present maintenance programs with certain adjustments are adequate. We have also initiated a related maintenance bulletin to be released soon to all maintenance personnel which recommends corrective action in those cases where mean-time-between-failure (MTBF) and inspection frequencies are not deemed sufficient to properly service and maintain the digital flight data recorder.

The equipment combination involved in the National Airlines DC-10 accident is peculiar only to National Airlines. We believe the actions taken are appropriate and that our present rules are adequate. To apply your stringent recommendations based on a single accident would be inappropriate and would not serve the best interests of the aviation industry.

Sincerely,

Alexander P. Butterfield
Administrator

APPENDIX D

FEDERAL AVIATION ADMINISTRATION

FIRST BIENNIAL AIRWORTHINESS REVIEW CONFERENCE

SUMMARY

I-52 Improvement of flight recorders

Proposals 534, 535

NTSB representative indicated they felt the most important aspect of their proposal is the requirement for the expanded parameter data recorder in newly manufactured aircraft intended for 121 operations. This information, on the new airplanes intended for CAT II, CAT III, and auto-land is very, very useful. He pointed out that many other countries have similar type regulations, or plan to adopt similar type regulations. The technology is available for such expanded parameter data recorders, and it was further pointed out that aircraft being exported to some other countries, already have these installed. The NTSB representative then pointed out that in a recent accident investigation involving a landing approach, the airplane involved had a flight data recorder that recorded 96 parameters, and key information in the investigation was obtained. The ATA representative indicated that the entire subject of flight recorders has been subject to a series of detailed regulations over the years, which has subjected industry to millions of dollars in cost, and they can see that more will be required to be spent. This also tends to cause flight delays and cancellation of flights due to malfunctioning equipment. He pointed out that the basic philosophy of accident/incident investigations has led to requirements for flight records which have caused the economic burden on industry. They felt that NTSB was missing a basic point; that different accidents would require different data to determine the probable cause and it is impossible to provide all the data, and if expanded parameter recorders are required, an accident will occur where required data was not present, which will again lead to an escalation of the requirements. Pointed out the low level of reliability these recorders have experienced, and the expansion of data will tend to cause even lower reliability. The ATA representative finished by indicating strong opposition to the proposal, stating that it could not be technically justified. AIA representative indicated that they wish to modify their comments. They stated the proposal was unacceptable; that the needed parameters depend on the basic design of the airplane, that the proposal requires more study by the industry, and they are deferring specific recommendation. Representative from DOT in Ireland, spoke of the escalating cost of accident investigation, and any requirement that would tend to reduce this cost would certainly be desirable. ALPA representative indicated good accident investigation would hopefully prevent future accidents and save lives, and that the cost of the proposed equipment is outweighed by the potential future savings. They supported the recorders from the first, and then indicated their support for the requirement for increased parameters. FAA representative indicated that while FAA recognized the validity of all comments submitted, NTSB does need all of the available data to perform their accident investigation. He stated that the accident/incident investigation benefits the entire industry, pointing out that the requirement for flight data recorders is not an airworthiness requirement but that the requirement comes basically from the NTSB; that FAA recognizes the potential of the recorder in accident/incident investigations, and that it should be considered a continuous airworthiness item, and therefore FAA concurs with NTSB. AIA Representative indicated they wish to endorse the ATA position on Item 534. ALPA indicated that their proposal 534, was basically the same as proposal 535, except that 534 would require retrofit on older aircraft. They recognize the expense of such a retrofit, but believe the potential savings far outweigh the cost, and you cannot place a cost on human life. A representative from NTSB spoke to the AIA and ATA position on the subject. He stated that they recognize the background on the development of the requirements for flight data recorders indicates a lack of foresight at that time for new aircraft; that some of the foreign parameters required are useless for accident investigation, and gave, as an example, the requirement for control wheel and control surface position, which does not give a good indication of what actually happens on aircraft with advanced electrical/mechanical/hydraulic control system. Again, they reiterated the position that, although the proposed rule had additional cost, it is far offset by the benefits of accident investigation.

I-53 - Preflight checking of flight recorders

Proposal 818

FAA representative indicated that the purpose of the proposal is to improve the reliability of flight recorders, stating that means are available whereby the various parameters can be checked. He stated that this can be accomplished easily in many cases, and that some operators have already done this. NTSB representative indicated their support of the proposal, and stated that on many flights they have found that the tape does not record. AIA representative stated they wish to modify their comment; that it was impractical to check every parameter, and that the use of the word "power" in the proposal was too broad. They suggest that a revision to the proposal to read, essentially, "preflight means to check that data is being recorded." An ALPA representative indicated that in the past, and on some equipment, the crews cannot determine that the recorder is working, much less working properly, and support the proposal that means be available to determine that the recorder is working and that proper indications are being read. FAA representative indicated that although FAA recognizes that it may be very difficult to determine that the recorder is performing accurately, it is easy to accomplish the intent of the proposal to determine that the various parameters within the recorder are working and are within some limits; that crews can be advised that information is being recorded; and he used flap position as an example. The FAA representative indicated that there are presently devices available that can check on the various parameters and this can be accomplished without much additional wiring.

END

DATE

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