# Loss of Pitch Control on Takeoff
# Emery Worldwide Airlines, Flight 17
# McDonnell Douglas DC-8-71F, N8079U
# Rancho Cordova, California
# February 16, 2000

## Aircraft Accident Report

**NTSB/AAR-03/02**

PB2003-910402
Notation 7299A

**National Transportation Safety Board**
Washington, D.C.

**THE CORRECTIONS BELOW ARE *INCLUDED***
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- Page 5, paragraph 3 has been updated with the correct time. (15 August 2005) The time originally printed as 1940:50.

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**Adopted August 5, 2003**

**National Transportation Safety Board**
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

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**Abstract:** This report explains the accident involving Emery Worldwide Airlines flight 17, a McDonnell Douglas DC-8-71F, which crashed in an automobile salvage yard shortly after takeoff, while attempting to return to Sacramento Mather Airport, Rancho Cordova, California, for an emergency landing. Safety issues discussed in this report include DC-8 elevator position indicator installation and usage, adequacy of DC-8 maintenance work cards (required inspection items), and DC-8 elevator control tab design. Safety recommendations are addressed to the Federal Aviation Administration.

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# Contents

**Figures** . . . v

**Abbreviations** . . . vi

**Executive Summary** . . . viii

**1. Factual Information** . . . 1
1.1 History of Flight . . . 1
1.2 Injuries to Persons. . . . 7
1.3 Damage to Aircraft . . . 8
1.4 Other Damage . . . 8
1.5 Personnel Information. . . . 8
1.5.1 The Captain . . . 8
1.5.2 The First Officer. . . . 9
1.5.3 The Flight Engineer . . . 9
1.6 Airplane Information . . . 9
1.6.1 Cargo Load Information. . . . 10
1.6.2 DC-8 Longitudinal Flight Control System. . . . 11
1.6.3 Maintenance Information . . . 17
1.7 Meteorological Information . . . 27
1.8 Aids to Navigation . . . 27
1.9 Communications . . . 27
1.10 Airport Information. . . . 27
1.11 Flight Recorders. . . . 28
1.11.1 Cockpit Voice Recorder . . . 28
1.11.2 Flight Data Recorder . . . 28
1.12 Wreckage Recovery and Documentation . . . 38
1.12.1 Longitudinal Flight Control Surfaces . . . 39
1.13 Medical and Pathological Information . . . 41
1.13.1 Flight Crew Information . . . 41
1.13.2 Cargo Handlers—Postaccident Drug and Alcohol Testing . . . 41
1.14 Fire/Explosion . . . 42
1.15 Survival Aspects . . . 42
1.16 Tests and Research. . . . 42
1.16.1 DC-8 Elevator Flight Control Tests . . . 42
1.16.2 Airplane Performance Studies . . . 47
1.17 Operational and Management Information . . . 50
1.17.1 Emery Worldwide Airlines, Inc. . . . 50
1.17.2 Tennessee Technical Services . . . 57
1.17.3 FAA Oversight of Emery Worldwide Airlines’ Certificate . . . 59
1.18 Additional Information . . . 62
1.18.1 Design and Certification of DC-8 Elevator System . . . 62
1.18.2 Party Submissions Regarding Contact/Possible Contact with the Bolt . . . 63

**2. Analysis** . . . . . 65
2.1 General . . . . . 65
2.2 The Accident Sequence . . . . . 65
2.2.1 Disconnection of the Right Elevator Control Tab . . . . . 66
2.3 Role of Aircraft Maintenance in the Accident . . . . . 68
2.4 Preflight Inspection and Flight Control/EPI Checks . . . . . 69
2.4.1 Preflight Inspection . . . . . 69
2.4.2 Elevator Checks/Use of the EPI Gauge . . . . . 70
2.5 Elevator Design Issues . . . . . 71
2.5.1 Elevator Geared Tab Crank Arm Fractures . . . . . 73
2.6 Emery's DC-8 Maintenance Documents and Guidance . . . . . 73
2.6.1 Required Inspection Items . . . . . 73
2.6.2 Emery's B-2 Inspection . . . . . 74
2.6.3 DC-8 MM Information . . . . . 75
2.7 FDR-Related Issues . . . . . 76
2.8 Drug and Alcohol Testing of Ground Personnel . . . . . 79

**3. Conclusions** . . . . . 81
3.1 Findings . . . . . 81
3.2 Probable Cause . . . . . 83

**4. Recommendations** . . . . . 84

**5. Appendixes**
**A:** Investigation and Hearing . . . . . 89
**B:** Cockpit Voice Recorder Transcript . . . . . 90

# Figures


**1.** The airplane's ground track, with selected CVR comments, during the accident flight . . . . . . . . . . . . 7

**2.** A diagram of the elevator control tab installation . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 12

**3.** A photograph of an EPI gauge similar to the gauge installed on the accident airplane . . . . . . . . . . . 14

**4.** EPI installation on the lower left side of the first officer's instrument panel (shown by the yellow arrow), similar to that on the accident airplane . . . . . . . . . . . . . . . . . . . . . . . . 15

**5.** Photograph showing the elevator damper's location on the right elevator of a DC-8 . . . . . . . . . . . . 24

**6.** Elevator, pitch, and control column plots recorded by the accident airplane's FDR during ground operations before the accident flight. The first 20 seconds of data were recorded while the gust lock was engaged . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 31

**7.** Pitch attitude, control column position, and (corrected) elevator position FDR data from the accident flight. About the first 20 seconds of data were recorded while the gust lock was engaged . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 32

**8.** Pitch attitude, control column position, and (corrected) elevator position FDR data for the previous takeoff from RNO. About the first 1 minute 20 seconds of data were recorded while the gust lock was engaged . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 32

**9.** A photograph of the accident airplane's right elevator control tab crank fitting. Note damage on forward face of control tab crank fitting lugs . . . . . . . . . . . . . . . . . . . . . . . 40

**10.** Photograph of the test airplane's right elevator control tab pushrod contacting the crank fitting . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 43

**11.** Photograph of the test airplane's disconnected right elevator control tab pushrod centered between the lugs of the crank fitting with the control tab rotated 3º to 4º in the TEU direction after the attachment bolt was removed . . . . . . . . . . . . . . . . 45

**12.** The control column position required for the left elevator control tab to reach its TEU physical stop (for the recorded elevator position) and the actual recorded control column position for the accident flight . . . . . . . . . . . . . . . . . . . . . . . . . . . . 49

**13.** Plots of the control column and corrected elevator position recorded by the accident FDR during the accident takeoff roll and the previous takeoff roll (from RNO) . . . 50

# Abbreviations

| | |
|---|---|
| **AC** | advisory circular |
| **AD** | airworthiness directive |
| **ALPA** | Air Line Pilots Association |
| **AND** | airplane nose down |
| **ANU** | airplane nose up |
| **AOM** | aircraft operating manual |
| **ASB** | alert service bulletin |
| **ASOS** | automated surface observation system |
| **ATC** | air traffic control |
| **ATP** | airline transport pilot |
| **c.g.** | center of gravity |
| **CAR** | Civil Aviation Regulations |
| **CFR** | Code of Federal Regulations |
| **CVR** | cockpit voice recorder |
| **DAY** | James M. Cox Dayton International Airport |
| **DFR** | digital flight recorder |
| **EPI** | elevator position indicator |
| **FAA** | Federal Aviation Administration |
| **FAR** | Federal Aviation Regulations |
| **FCD** | fleet campaign directive |
| **FDR** | flight data recorder |
| **FOB** | flight operations bulletin |
| **FSB** | field service bulletins |
| **FSDO** | flight standards district office |
| **GPWS** | ground proximity warning system |

| | |
|---|---|
| **HBAW** | flight standards handbook bulletin for airworthiness |
| **IFR** | instrument flight rules |
| **IPC** | Illustrated Parts Catalog |
| **MAC** | mean aerodynamic chord |
| **MEL** | minimum equipment list |
| **MHR** | Sacramento Mather Airport |
| **MM** | maintenance manual |
| **MPPM** | maintenance policies and procedures manual |
| **msl** | mean sea level |
| **NASIP** | National Aviation Safety Inspection Program |
| **OHM** | overhaul manual |
| **P/N** | part number |
| **PMI** | principal maintenance inspector |
| **POI** | principal operations inspector |
| **PTC** | pitch trim compensator |
| **RASIP** | Regional Aviation Safety Inspection Program |
| **RNO** | Reno/Tahoe International Airport |
| **S/N** | serial number |
| **SB** | service bulletin |
| **SDR** | service difficulty reports |
| **STC** | supplemental type certificate |
| **TED** | trailing edge down |
| **TEU** | trailing edge up |
| **TRACON** | terminal radar approach control |
| **TTS** | Tennessee Technical Services |
| **ULD** | unit loading device |

# Executive Summary

On February 16, 2000, about 1951 Pacific standard time, Emery Worldwide Airlines, Inc., (Emery) flight 17, a McDonnell Douglas DC-8-71F (DC-8), N8079U, crashed in an automobile salvage yard shortly after takeoff, while attempting to return to Sacramento Mather Airport (MHR), Rancho Cordova, California, for an emergency landing. Emery flight 17 was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 as a scheduled cargo flight from MHR to James M. Cox Dayton International Airport (DAY), Dayton, Ohio. The flight departed MHR about 1949, with two pilots and a flight engineer on board. The three flight crewmembers were killed, and the airplane was destroyed. Night visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules flight plan.

The National Transportation Safety Board determined that the probable cause of the accident was a loss of pitch control resulting from the disconnection of the right elevator control tab. The disconnection was caused by the failure to properly secure and inspect the attachment bolt.

The safety issues discussed in this report include DC-8 elevator position indicator installation and usage, adequacy of DC-8 maintenance work cards (required inspection items), and DC-8 elevator control tab design. Safety recommendations are addressed to the Federal Aviation Administration.

# 1. Factual Information

## 1.1 History of Flight

On February 16, 2000, about 1951 Pacific standard time,[1] Emery Worldwide Airlines, Inc., (Emery) flight 17, a McDonnell Douglas[2] DC-8-71F (DC-8), N8079U, crashed in an automobile salvage yard shortly after takeoff, while attempting to return to Sacramento Mather Airport (MHR), Rancho Cordova, California, for an emergency landing. Emery flight 17 was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 as a scheduled cargo flight from MHR to James M. Cox Dayton International Airport (DAY), Dayton, Ohio. The flight departed MHR about 1949, with two pilots and a flight engineer on board. The three flight crewmembers were killed, and the airplane was destroyed. Night visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules (IFR) flight plan.

On the day of the accident, Emery had operated the accident airplane on two cargo-carrying flight segments before the accident flight. The first was flight 18 from DAY to Reno/Tahoe International Airport (RNO), Reno, Nevada, which arrived at RNO about 1642, and the second flight segment was the first leg of flight 17, from RNO to MHR. Emery flight 17 departed RNO for MHR about 1755. The accident captain was aboard the airplane for both previous flight segments. He rode the jumpseat as he commuted from DAY to RNO to begin his duty day in RNO and was the flying captain from RNO to MHR.[3]

According to postaccident interviews and company records, the airplane arrived at MHR about 1815 and reached the MHR cargo ramp about 1832. Records indicated that cargo-handling personnel unloaded the inbound cargo from the main and belly cargo compartments then loaded the outbound cargo, finishing about 1930.

Postaccident interviews indicated that while cargo-handling personnel were working, the accident flight engineer conducted a preflight inspection of the exterior of the accident airplane.[4] Additionally, during this time, mechanics from Emery and a contract maintenance company performed routine maintenance inspections and service items (such as servicing the engines with oil, checking the tires and brakes, and refueling).[5] Although

[1] Unless otherwise indicated, all times are Pacific standard time, based on a 24-hour clock.

[2] Douglas Aircraft Company and McDonnell Aircraft Company merged in April 1967 and formed the McDonnell Douglas Company. The Boeing Company and McDonnell Douglas merged in August 1997 and operate under the Boeing name. Subsequent references to Boeing as the manufacturer reflect this merger.

[3] The captain and flight engineer who flew from DAY to RNO were replaced by the accident captain and flight engineer for the flight from RNO to MHR. The first officer who flew to RNO continued on the accident airplane to MHR, where he was replaced by the accident first officer.

[4] For detailed information regarding Emery's DC-8 preflight inspection procedures, see section 1.17.1.2.1.

the investigation revealed that minor maintenance discrepancies existed (for example, an inoperative fuel valve indication and a malfunctioning navigation light), neither the flight engineer nor the mechanics reported observing any significant airplane anomalies during the preflight inspections. Further, the cockpit voice recorder (CVR) did not record any discussion of airplane anomalies while the airplane was on the ground at MHR.[6]

According to CVR information and postaccident interviews, the loading supervisor gave the final load planning information to the accident flight crew after the outbound cargo was loaded. According to Emery's procedures, the pilots were to review this information and use it to calculate the airplane's weight and center of gravity (c.g.)[7] for the accident flight. Postaccident interviews indicated that the cargo loading supervisor received a copy of the signed load planning sheet and the completed weight and balance form from the pilots just before the airplane's doors were closed for departure; there were no anomalies or irregularities with the paperwork or procedures. Postaccident interviews with the cargo loading supervisor, load planner, and cargo loaders who worked on the accident airplane indicated that the unloading/loading process on the night of the accident was routine and that the airplane's load was lighter than usual.[8]

According to the CVR, about 1927:25, the first officer (the flying pilot for the accident flight) performed the takeoff briefing, stating, in part, "[w]e're cleared up to [3,000 feet]. …Standard Emery procedures if there's a problem, we'll come back here and land on [runway 22L]." The captain responded, "Sounds good." About 1932:32, the CVR recorded the flight engineer confirming that the airplane's cargo doors were closed and, about 1932:36, the flight crew began the prestart checklist. About 1939:19, the flight engineer advised ground personnel "we have four good [engine starts], you can go ahead and pull the [auxiliary] air and power."

According to the CVR transcript, the flight crew began the after start/before taxi checklist about 1940:00 and, about 1940:39, advised local airport traffic that Emery flight 17 was taxiing from the southwest cargo area to runway 22L.[9] As the pilots taxied the airplane toward the runway, the captain called for 15° of flaps and a flight control check. The CVR subsequently recorded the first officer stating, "ailerons

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[5] It was dark at the time these tasks and inspections were conducted; however, ground personnel set up light stands along the left side of the airplane, illuminating that portion of the airplane for cargo loading/unloading and inspection operations. Ground personnel reported that there was no significant direct light on the right side of the airplane. (National Transportation Safety Board investigators noted similar lighting conditions during their observation of loading operations on February 21, 2000.)

[6] The CVR recorded the last 33 minutes and 24 seconds of cockpit communications before the accident. See appendix B for an excerpted portion of the CVR transcript.

[7] The position of the c.g. is directly related to the stability of the airplane (that is, the tendency of the aircraft to return to a trimmed equilibrium) and the pitch control input required to maintain a given flight condition.

[8] For additional information regarding the cargo loading on the accident airplane, see section 1.6.1. Also, see the Operational Factors/Human Performance Group Chairman's Factual Report, dated April 13, 2001, and Attachments 1 (interview summaries), 7, and 8 in the public docket for this accident.

[9] Because there is no air traffic control (ATC) facility at MHR, pilots typically broadcast their intentions to other area traffic on a common radio frequency.

left…center…right…center" and the captain stating, "ready on the rudders?…left rudder…center…right rudder…center." About 1942:27, the captain stated, "elevator forward…coming back," and the first officer responded, "EPI [elevator position indicator][10] checks."

According to the CVR, about 1942:31, the flight crew began the taxi checklist. About 1942:43, the flight engineer stated, "controls, EPI;" the first officer responded, "checked;" and the flight engineer repeated, "checked." Flight data recorder (FDR) data indicate that, during the elevator control check, the accident airplane's control column moved from 10.8º forward of its vertical position to 17.3º forward of vertical. During this time, the FDR recorded the elevator surfaces moving from 16.6º trailing edge up (TEU) to 2.8º TEU. No trailing edge down (TED) deflection was recorded during this elevator check. About 1943:23, the flight engineer indicated that the taxi checklist was complete.

According to the CVR, about 1946:58, the first officer contacted Sacramento terminal radar approach control (TRACON), advising the air traffic controllers that Emery flight 17 was number one for takeoff and requesting the flight's IFR release for the flight to DAY.[11] About 1947:14, the controllers at Sacramento TRACON stated, "Emery [17…], Sacramento…you're released for departure, report airborne." The first officer responded, "…we'll call you in the air."

Between 1947:28 and 1948:10, the pilots performed the before takeoff checklist, during which they advised the local airport traffic that they would be taking off on runway 22L with a left downwind departure. About 1948:15, the CVR recorded a sound similar to increasing engine rpm. About 1948:44, the captain stated "airspeed's alive" and the first officer responded "alive here." According to FDR data, as the airplane accelerated through about 60 knots, the control column was moving forward from about 13.7º forward of vertical while the elevator was about 6.4º TEU.[12] About 1948:50, the captain stated "eighty knots" and the first officer responded, "eighty knots…elevator checks." FDR data indicate that, during this elevator check (which occurred between 1948:48 and 1948:53), the control column and elevator positions moved from about 14.4º forward of vertical and 5.4º TEU, respectively, to about 19.0º forward of vertical and 2.2º TEU then returned to their previous values.[13] Also during this time, the airplane's pitch attitude moved from about 0.2º airplane nose up (ANU) to 0.6º airplane nose down (AND), then back to 0.2º ANU.

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[10] Emery's before takeoff checklist procedures included an EPI/elevator check. For additional information regarding the EPI, see sections 1.6.2.1, 1.16.1.2, and 1.17.1.2.2.

[11] Because there is no on-airport ATC facility at MHR to provide pilots with instrument clearances, pilots departing from MHR on IFR flight plans contact Sacramento TRACON for an IFR release before they depart.

[12] FDR data showed that, during the previous takeoff (at RNO), as the airplane accelerated through about 60 knots, the control column position was steady at 13.4º forward of vertical while the elevator remained fairly steady above neutral, about 6.0º to 6.4º TEU.

[13] FDR data showed that, during the previous takeoff (at RNO), as the pilots performed the 80-knot elevator check, the elevator moved below neutral to about 7.8º TED when the control column position moved forward slightly less than it did during the accident flight.

As the takeoff roll continued, the CVR recorded the captain stating, "V one"[14] about 1949:02 and "rotate" about 1949:06. Information from the FDR confirmed that the airplane pitched from 0.2º ANU about 1949:02 to 5.3º ANU at 1949:08; the pitch continued to increase despite the forward movement of the control column. FDR data indicated that, during this time, the control column position moved forward (from 14.5º forward of vertical to 17.4º forward of vertical), and the elevators' TEU deflection increased from about 5.5º to 8.6º TEU.[15] About 1949:08, the CVR began to record a sound similar to the airplane's stabilizer trim-in-motion alert,[16] which continued to sound as the captain stated, "…watch the tail," about 1949:09. (This sound was recorded by the CVR intermittently until 1949:14.) Between 1949:08 and 1949:15, the airplane's pitch rate increased to about 2º per second.

By 1949:12, the airplane's pitch had increased to 11.7º ANU, while the control column and elevators had moved to 15.7º forward of vertical and 15.3º TEU, respectively. About 1949:13, the CVR recorded the captain stating, "V two"[17] then "positive rate," 1 second later; FDR data show the airplane's altitude was increasing at this time. By 1949:15, the airplane's pitch had increased to 18.3º ANU and the control column position was at 16.2º forward of vertical. About 1949:16, the first officer stated, "I got it," the captain asked, "you got it," and the first officer responded, "yep."

FDR data indicated that, almost immediately after the accident airplane lifted off the runway (beginning about 1949:12), it entered a left turn that steepened to about 35º within about 10 seconds. Between 1949:12 and 1949:15, the control column position moved forward from 15.7º to 16.2º forward of vertical and the elevator deflection decreased, moving from about 15.7º TEU to 9.0º TEU. About 1949:19, the CVR recorded the first officer stating, "we're going back…c.g.'s waay [sic] out of limits."

About 1949:25, about 6 seconds after the first officer announced that they would return to the airport, the flight engineer asked, "do you want to pull the power back." Two seconds later, the CVR recorded a sound similar to decreasing engine rpm, followed by a sound similar to the airplane's stick shaker. About 1949:30, the first officer stated, "oh [expletive]," and the captain stated, "push forward." About 1949:36, the CVR recorded the captain advising Sacramento TRACON that the flight had an emergency. During this

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[14] $V_1$ is the takeoff decision speed, which was 126 knots for the accident flight. Rotation speed for the accident flight was 146 knots.

[15] In contrast, the FDR data from the accident airplane's previous departure (from RNO) indicated that when the pilots moved the control column aft (from 14.4º forward of vertical to about 7.8º forward of vertical), the elevator moved from about 5.1º TED to about 7.8º TEU, and the airplane's pitch began to increase during the takeoff.

[16] CVR information indicates that the pilots began adding nose-down stabilizer trim about 4 seconds before the airplane lifted off the runway at 1949:11 and that the stabilizer reached full nose-down trim about 3 seconds after liftoff. There was no evidence that the pilots changed the trim setting during the remainder of the accident flight. Physical evidence was consistent with full nose-down trim at impact. According to the manufacturer, a cable motion sensor connected to the stabilizer detects horizontal stabilizer motion and commands the stabilizer warning horn to sound for 1/2 second when it detects 1º of continuous stabilizer movement; it then sounds repeatedly for every additional 1/2 degree of continuous stabilizer travel.

[17] $V_2$ is the takeoff safety speed, which was 158 knots for the accident flight.

time (between 1949:30 and 1949:40), the FDR recorded the following: the airplane's altitude increased to 1,037 feet mean sea level (msl) then began to decrease; the airplane's left bank decreased from more than 30º to about 13º, then increased to 25º, then decreased to about 12º; the control column position varied between about 17º forward of vertical and 19.5º forward of vertical;[18] and the elevator surface deflections decreased from about 12º TEU to about 5º TEU then increased to about 7.5º to 8.5º TEU.

About 1949:40, the CVR recorded the first officer stating, "you steer, I'm pushing" while Sacramento TRACON asked the pilots of Emery flight 17 to repeat their radio message. About 1949:44, the captain again advised the TRACON controllers that the flight had an emergency.

Also about 1949:44, the flight engineer stated, "we're sinking…we're going down, guys." Two seconds later, the CVR recorded a sound similar to increased engine rpm, followed almost immediately by the ground proximity warning system's (GPWS) "whoop, whoop, pull up" audible alert and the first officer's call for "power." According to FDR data, at this time the airplane was descending through 679 feet msl in a steepening left bank of about 11º. The recorded control column position was about 14º forward of vertical and the elevator surface deflection was about 10º TEU. FDR data showed that the airplane continued to descend until about 1949:50, when it reached about 601 feet msl and began to climb again. About 1949:52, as the airplane climbed through 625 feet msl, the GPWS audible alert ceased and the captain stated, "all right, all right…all right." About 1949:54, as the airplane climbed through 673 feet msl, the first officer stated, "push" and the flight engineer stated, "okay, so…we're going back up."

As the airplane's altitude was increasing (after 1949:50), its left bank also increased, reaching about 45º between 1949:55 and 1949:56, then began to decrease. About 1949:57, the CVR recorded the flight engineer stating, "there you go," then the captain stating, "roll out," followed by an unidentified crewmember saying, "roll out," and the sound of a strained exhale.

About 1950:04, the FDR data indicated that the airplane was in a left bank of about 33º, at an altitude of 901 feet msl. About this time, the CVR recorded the captain advising Sacramento TRACON that, "Emery [17 has an] extreme c.g. problem." FDR data indicated that the airplane continued to climb and its bank continued to decrease during the next 6 to 7 seconds. About 1950:10, as the airplane was rolling out of its left bank on a heading of about 022[19] at 947 feet msl, the CVR recorded the sound of another strained exhale. About 1950:11, the flight engineer stated, "anything I can do, guys," and the captain stated, "roll out to the right." About 1950:12, the CVR recorded the first officer stating, "okay…push."

[18] This control column position (19.5º forward of vertical) was the most forward control column position recorded by the FDR during the accident flight. For additional information on the recorded control column position, see section 1.11.2.4.

[19] All headings presented in this report are in degrees relative to the Earth's magnetic north pole.

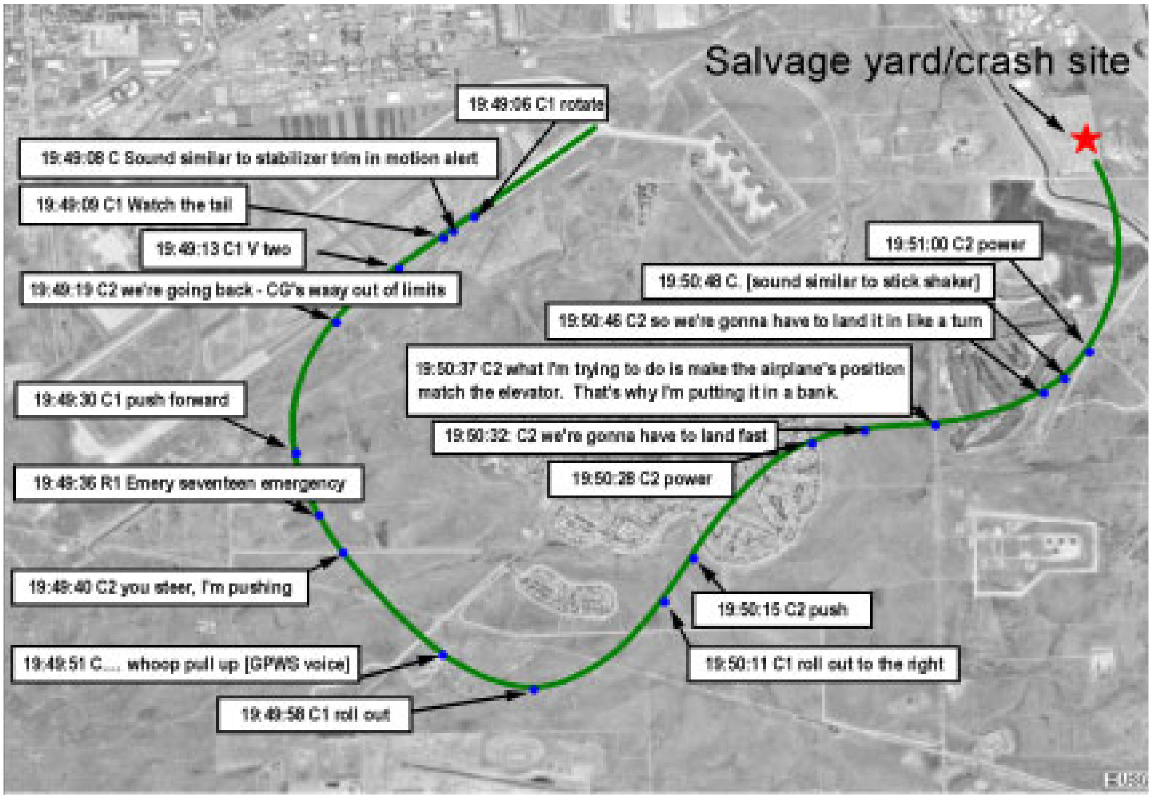
For the next 4 seconds, the airplane continued to fly on a north-northeasterly heading, approximately parallel to the departure runway at an altitude of about 1,000 feet msl. About 1950:16, the CVR recorded a crewmember stating, "push forward" then the first officer saying, "awww." During the next 10 seconds, the airplane banked right to an east-northeasterly heading then climbed, reaching 1,087 feet msl (the maximum altitude obtained for the accident flight) about 1950:18, before it began to descend again. About 1950:26, as the airplane's right bank and altitude were decreasing, the flight engineer asked, "you got the trim maxed?" About 1950:28, the first officer stated, "power;" the flight engineer asked, "more;" and, about 1950:29, the first officer said, "yeah." From 1950:29 to about 1950:35, as the airplane's right bank decreased, the GPWS audible alert sounded again. About 1950:32, as the GPWS alert continued to sound, the first officer stated, "we're gonna have to land fast." Between 1950:33 and 1950:34, the airplane transitioned from a right bank into a left bank.

About 1950:37, the first officer stated, "what I'm trying to do is make the airplane's pitch match the elevator. That's why I'm putting it in a bank." According to FDR data, as the first officer spoke, the airplane continued a left turn back toward the airport; the airplane's left bank steepened to about 30º, and its heading shifted from about 071 through about 047. About 1950:45, the captain replied, "all right…left turn" and, about 1950:46, the first officer added, "so we're gonna have to land it in…a turn." As the airplane turned through a heading of about 035, the captain stated, "bring it around." About 1950:48, the CVR recorded a sound similar to the airplane's stick shaker activating; about 1 second later, the captain repeated, "bring it around."

The CVR transcript indicated that "grunt" and "rustling" sounds were recorded about 1950:51, as the airplane descended through 774 feet and turned through a heading of about 016. About 1950:54, the first officer asked, "you got the airport." About 1950:56, as the airplane turned through a northerly heading, the captain again stated, "bring it around." At 1951:00, the first officer requested more power; 2 seconds later, the CVR recorded the GPWS audible alert again briefly.

According to FDR data, about 1951:03, the accident airplane was at an altitude of 430 feet msl in about a 24º left bank, passing through a heading of about 325. Two seconds later, the airplane was at 423 feet msl in about a 28º left bank, passing through a heading of about 312. At 1951:07, the FDR recorded the airplane at 224 feet msl, in a left turn through a heading of about 308. Also, at 1951:07, the CVR recorded the first officer stating, "power…aww [expletive]." One second later, at 1951:08, the CVR recorded a sound similar to impact. The accident airplane's FDR stopped recording about 1951:08, and the CVR stopped recording about 1951:09; the cessations were consistent with an impact-related loss of electrical power.

The airplane impacted the ground in a left-wing-low, slightly nose-up attitude in an automobile salvage yard, about 1 mile east of the departure runway. Figure 1 shows the airplane's ground track, with selected CVR comments, during the accident flight. (For additional information regarding CVR comments, see the CVR transcript in appendix B).




**Note: C1=recorded on the captain's CVR channel, C2=recorded on the first officer's CVR channel, C=recorded on the cockpit area microphone channel.**

**Figure 1.** The airplane's ground track, with selected CVR comments, during the accident flight.

## 1.2 Injuries to Persons

**Table 1.** Injury chart

| Injuries | Flight Crew | Cabin Crew | Passengers | Other | Total |
|---|---|---|---|---|---|
| **Fatal** | 3 | 0 | 0 | 0 | 3 |
| **Serious** | 0 | 0 | 0 | 0 | 0 |
| **Minor** | 0 | 0 | 0 | 0 | 0 |
| **None** | 0 | 0 | 0 | 0 | 0 |
| **Total** | 3 | 0 | 0 | 0 | 3 |

## 1.3 Damage to Aircraft

The airplane was destroyed by impact forces and postcrash fire.

## 1.4 Other Damage

The accident airplane's left wing tip contacted a concrete and steel support column for an overhang attached to a two-story building, located adjacent to the southeast edge of the salvage yard. The airplane subsequently impacted the vehicles and pavement in the salvage yard; many vehicles in the salvage yard were damaged or destroyed by impact and postimpact fire.

## 1.5 Personnel Information

The National Transportation Safety Board reviewed the flight crew's flight- and duty-time limits and rest records and found no evidence that they were not within the limits established by Federal regulations. According to Emery records, the accident flight crewmembers flew together on two previous trip sequences in February 2000—one that began on February 4 and another that began on February 8.

### 1.5.1 The Captain

The captain, age 43, was hired by Emery on October 19, 1994. He held an airline transport pilot (ATP) certificate with multiengine land and instrument ratings. He had type ratings in five airplane types, including the DC-8 (issued August 5, 1998). The captain's most recent DC-8 proficiency check was completed on June 30, 1999, and his most recent recurrent training was completed on February 11, 2000. His most recent Federal Aviation Administration (FAA) first-class airman medical certificate was issued on February 15, 2000, and contained the limitation that he "must wear corrective lenses for near and distant vision." According to Emery records, at the time of the accident, the captain had flown about 13,329 total flight hours, including 2,128 hours as a DC-8 captain.

According to company records and postaccident interviews, the captain left his home in New York about 1430 on February 15 to commute to MHR, where his duty period was scheduled to begin the next day. Interviews indicated that the captain likely traveled from Albany, New York, to DAY by jumpseat then rode on the jumpseat of Emery flight 18, which was scheduled to fly to MHR, then to RNO, and return to DAY. However, the flight from DAY to MHR was delayed while maintenance personnel completed work on one of the cockpit windows, and the trip sequence was subsequently modified to land at RNO first, then MHR. The captain's flight duty began with the flight from RNO to MHR.

The first officer who was the flying pilot for the flight from DAY to RNO (on which the captain rode jumpseat) and was the non-flying pilot while the accident captain flew the flight from RNO to MHR indicated that he had not flown with the accident captain before. He indicated that the accident captain smoothly hand-flew the airplane to their cruising altitude of 14,000 feet msl, then (again hand-flying) made a normal descent and a "nice" landing at MHR. The first officer stated that he did not note any problems with the airplane during the flight from RNO to MHR, nor did the accident captain indicate to the first officer that there were any problems with the airplane.

### 1.5.2 The First Officer

The first officer, age 35, was hired by Emery on September 15, 1996. He held an ATP certificate with multiengine land and instrument ratings. His most recent DC-8 recurrent training and proficiency checks were completed on October 27 and 29, 1999, respectively. The first officer's most recent FAA first-class airman medical certificate was issued on June 24, 1999, with no restrictions or limitations. According to Emery records, at the time of the accident, the first officer had flown about 4,511 total flight hours, including 2,080 hours as a DC-8 first officer.

The first officer lived in Placerville, California, about 33 miles northeast of MHR, where he joined the accident captain and flight engineer for the accident flight. According to Emery records, the first officer's duty day began with the accident flight.

### 1.5.3 The Flight Engineer

The flight engineer, age 38, was hired by Emery on September 15, 1998. He held an ATP certificate with multiengine land rating and a flight engineer rating for turbojet-powered airplanes. The flight engineer's most recent DC-8 recurrent training and proficiency checks were completed on September 2, 1999. His most recent FAA first-class airman medical certificate was issued on June 22, 1999, with no restrictions or limitations. According to Emery records, at the time of the accident, the flight engineer had accumulated about 9,775 total flight hours, including 675 hours as a DC-8 flight engineer.

The flight engineer lived in Sparks, Nevada, a suburb of Reno, where he joined the accident captain for the flight from RNO to MHR. According to Emery records, the flight engineer's duty day began with the flight from RNO to MHR.

## 1.6 Airplane Information

The DC-8 was originally certificated in 1959, under Civil Aviation Regulations (CAR) Part 4b.[20] The accident airplane, N8079U, serial number (S/N) 45947, was issued a standard airworthiness certificate as a DC-8-61, on March 21, 1968. In July 1983, the

[20] For additional information regarding the DC-8's certification under CAR 4b, see section 1.18.1.

accident airplane was altered (different engines and nacelles were installed) and the airworthiness certificate was amended accordingly to indicate an airplane model DC-8-71. The accident airplane was converted to a freighter in April 1993, and the airworthiness certificate was amended to indicate an airplane model DC-8-71F. The documentation for the freighter conversion included several FAA Form 8110-3s, "Statement of Compliance with the Federal Aviation Regulations."

Emery purchased the airplane from Aero USA, Inc., on March 27, 1994. The airplane was added to Emery's operating certificate on March 31, 1994. According to Emery records, the accident airplane had 84,447 total hours of operation and 33,395 flight cycles[21] at the time of the accident. The accident airplane was equipped with four CFM International (CFMI)[22] CFM56-2-C1 engines.

According to Emery's dispatch documents for the accident flight, the airplane's takeoff weight was calculated to be 279,231 pounds,[23] including 63,764 pounds of cargo and 66,700 pounds of fuel. The dispatch documents indicated that the airplane's takeoff c.g. was calculated to be 28.9 percent of the mean aerodynamic chord (MAC) and that the aft c.g. limit was 33.6 percent MAC for the DC-8-71F airplane. Dispatch documents indicated that the takeoff flap setting was 15º, and the takeoff horizontal stabilizer trim setting was 1.6 units ANU.

### 1.6.1 Cargo Load Information

Postaccident interviews with the cargo-handling personnel who worked on the accident airplane revealed that the airplane arrived at MHR about 1815. The MHR cargo-handling personnel indicated that they removed the cargo that was on the main cargo compartment when the airplane arrived, then loaded 4 pallets and 14 containers of cargo into the main cargo compartment positions. They also loaded 3 cases of mail and several pieces of long freight to the existing 1,784 pounds of cargo in the belly cargo compartments. According to Emery records, the weight of the cargo that was loaded in the accident airplane at MHR was as follows: 59,290 pounds in the main cargo compartment and 2,690 pounds in the belly cargo compartments.

The cargo-handling personnel told investigators that there were no problems during the unloading or loading, and several cargo handlers commented that the operation went "smooth" that night. Additionally, the cargo-handling personnel, including the load planner, reported that the airplane's load was lighter than usual—the load planner estimated that a typical load would involve about 75,000 pounds of cargo. He further stated that his usual load planning goal was to obtain a c.g. of about 23 percent MAC; the

---

[21] A flight cycle is one complete takeoff and landing sequence.

[22] CFMI is a company jointly owned by General Electric Aircraft Engines of the United States and Societe Nationale d'Etude et de Construction de Moteurs d'Aviation of France.

[23] According to the manufacturer's airplane flight manual, the maximum certificated takeoff gross weight for the accident airplane was 328,000 pounds.

accident airplane's c.g. was slightly aft of this (though still forward of its aft c.g. limit of 33.6 percent MAC) because two of the forward-loaded cargo containers were light.

## 1.6.2 DC-8 Longitudinal Flight Control System

The DC-8's elevator flight control system is "tab-driven"—that is, the control columns are mechanically linked to the elevator control tabs, and deflection of the control tabs in flight results in deflection of the elevators, which results in changes in the airplane's pitch attitude. This system includes two linked sets of components (one on the left side and one on the right side), each of which include control columns, cables and linkages, a horizontal stabilizer, and an elevator surface with a control tab and a geared tab.

Pitch trim is provided by the adjustable horizontal stabilizer. The elevator surfaces are hinged to the rear spar of the horizontal stabilizer and are connected to each other by drive rods and a torque tube so that they operate in unison. According to chapter 27 of the DC-8 maintenance manual (MM), when the DC-8 elevator surfaces are properly installed and rigged, they have a maximum TEU deflection of 27.0º ± 0.5º and a maximum TED deflection of 16.5º ± 0.5º from their neutral position, which is in line (or faired) with the horizontal stabilizer.

Each elevator control tab is hinged to the inboard trailing edge of the associated elevator surface, then connected by a mechanical linkage (including a crank fitting, pushrod, and bellcrank assembly) at the inboard edge of the tab to the flight control system on that side of the airplane. Figure 2 is a diagram of the elevator control tab installation. The elevator control tabs are in their neutral position when they are in line with the elevator surfaces and should have a maximum TEU deflection of 8.5º ± 0.5º and a maximum TED deflection of 26.5º ± 0.5º from that neutral position.

The elevator geared tabs are hinged to the middle of the trailing edge of each elevator, immediately outboard of the elevator control tabs. Two longitudinally aligned pushrods, attached to the inboard and outboard ends of the elevator geared tabs, connect the geared tabs to the horizontal stabilizers' rear spar. The geared tabs are in their neutral position when they are in line with the elevator surfaces in their neutral position and are designed (or rigged) to deflect about 4.75º TEU and 26.75º TED from that position. As the elevators' positions change in relation to the horizontal stabilizer, linkages move the elevator geared tabs in the opposite direction, providing an aerodynamic boost to assist the control tabs in moving the elevators. (This reduces the amount of control force required from the pilots.)

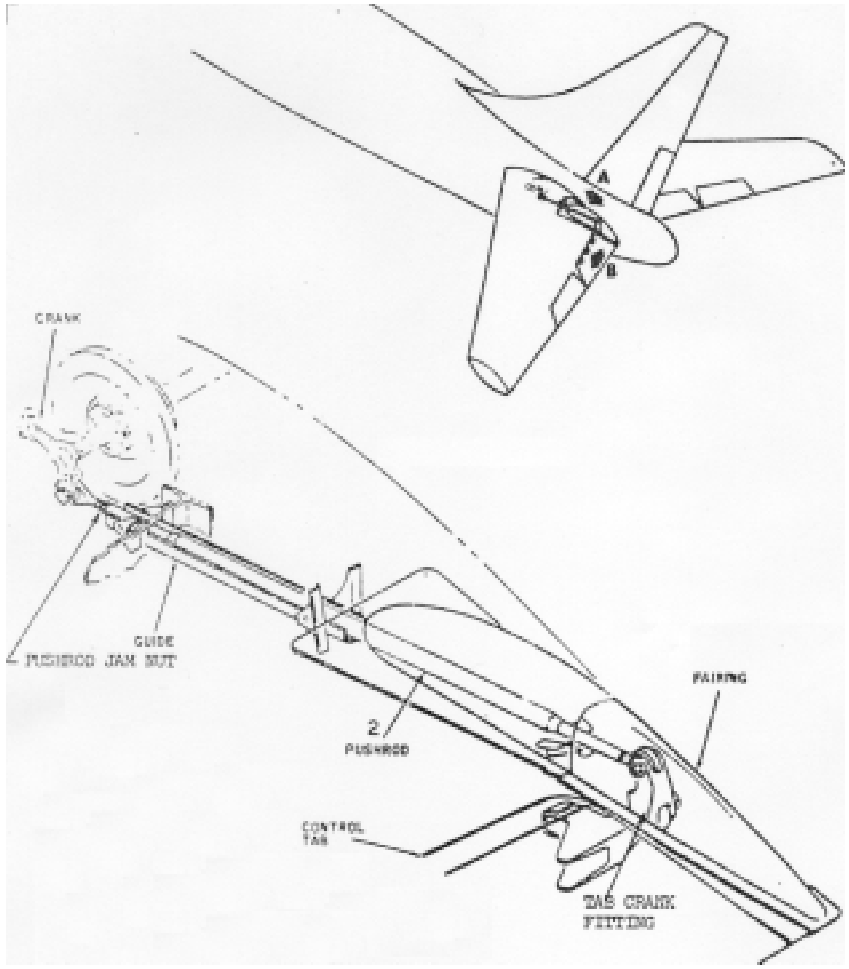



**Figure 2.** A diagram of the elevator control tab installation.

Dampers are installed in each elevator leading edge at the inboard hinge location and provide an opposing force proportional to the rate of elevator movement to prevent elevator flutter. For additional information regarding the elevator dampers on the accident airplane, see section 1.6.3.1.2.

The airplane is also equipped with an elevator load-feel and centering device, which increases the forces felt by the pilots at the control columns above those resulting from the aerodynamic forces acting on the control tabs and helps return the columns to their neutral position when control column force is removed. The control columns are rigged to travel between 23.75º forward and 6.50º aft of a vertical reference position[24] and are connected by cables to the left and right elevator control tab drive linkages. The control column's rigged neutral position is 13.5º forward of the control column's vertical reference position.

[24] The vertical reference position is perpendicular to the cockpit floor. Physical stops prevent control column movement beyond 23.75º forward and 6.50º aft of vertical.

During normal operation in flight, the elevator flight controls work as follows: when a pilot moves the control column forward (commanding an AND movement), the left and right elevator control tabs deflect in a TEU direction and the resultant aerodynamic forces drive the elevator surfaces in the opposite (that is, TED) direction causing the airplane to pitch nose down. When a pilot moves the control column aft (commanding an ANU movement), the left and right elevator control tabs deflect in a TED direction and the resultant aerodynamic forces drive the elevator surfaces in the opposite (TEU) direction causing the airplane to pitch nose up.

When the airplane is on the ground with the gust lock engaged,[25] the centering device positions the control columns about 15º forward of vertical, the elevators are locked in their neutral position, the elevator geared tabs are in line with the elevator surfaces, and the control tabs are deflected slightly above neutral (about 2º TEU). When the gust lock is disengaged (assuming no pilot input), the elevators rotate in a TEU direction because of their leading-edge-heavy balance condition; depending on the wind conditions, the elevators might rotate to their maximum TEU position. Because of the mechanical linkages between the flight control cables and the control tabs, the control tabs rotate to their maximum TEU position. The elevator geared tabs deflect toward their maximum TED position.

### 1.6.2.1 DC-8 Elevator Position Indicator Information

The DC-8 EPI is a 1-inch diameter circular cockpit gauge with a pointer needle and index markings for UP, DN (down), and NEUT (neutral) positions to indicate the position of the elevators. When the EPI is properly calibrated, the up index mark should correspond to the maximum TEU elevator surface position of 27º and the down index mark should correspond to the maximum TED elevator surface position of 16.5º TED. A narrow white band adjacent to the NEUT index mark indicates an elevator surface position between 0º and 5º TEU. Figure 3 is a photograph of an EPI gauge similar to that on the accident airplane.

[25] The gust lock holds the elevator surfaces in a fixed, faired position to prevent damage from gusty winds, etc. The lever for the elevator (and rudder) control surface gust lock is located on the right side of the pilot's center control pedestal. To engage the gust lock, the lever is moved to its aft (down), latched position.


**Figure 3.** A photograph of an EPI gauge similar to the gauge installed on the accident airplane.

The EPI on the accident airplane was located on the lower left side of the first officer's instrument panel. (Figure 4 shows an EPI installation similar to that on the accident airplane.) The EPI gauge was installed in 1979 by the then-operator of the accident airplane, United Airlines, in compliance with Airworthiness Directive (AD) 78-01-15, which required DC-8 operators to install an EPI system in accordance with Douglas Service Bulletin (SB) 27-254, dated March 5, 1975. The FAA issued AD 78-01-15 as a result of a series of accidents and incidents involving DC-8 jammed or restricted elevator surfaces that began in 1970. (For additional information regarding these instances of jammed/restricted DC-8 elevators, see section 1.6.2.2)

AD 78-01-15 specified that operators install the EPI gauge on the first officer's instrument panel such that full forward movement of the control column and wheel would not obstruct the first officer's view of the gauge. The AD did not comment regarding visibility of the gauge from the captain's seat. As a result, DC-8 operators installed the EPI where they found room for it and where the first officer could see it on an airplane's existing instrument panel. Because Emery purchased its DC-8s from several other operators and EPI placement was not standardized, EPI gauges in Emery's fleet were installed in several different locations; according to Emery personnel, however, they were generally installed on the lower portion of the first officer's instrument panel.

**Figure 4.** EPI installation on the lower left side of the first officer's instrument panel (shown by the yellow arrow), similar to that on the accident airplane.

Further, AD 78-01-15 did not include any guidance for DC-8 operators regarding incorporation of EPI checks into the operator's processes and procedures, such as manuals, checklists, cockpit procedures, and training. The Safety Board's survey of the elevator check procedures used by seven DC-8 operators[26] and those recommended by Boeing revealed a variety of practices regarding EPI usage. Of the seven DC-8 operators, only two (Emery and Arrow Air) specifically referenced use of the EPI during the 80-knot elevator check. Emery's 80-knot check procedure calls for "full forward elevator pressure then release slightly forward of neutral…confirm nose DN response…[first officer] looks for EPI to respond to yoke movement." Arrow Air's 80-knot check procedure calls for "full forward yoke and note and feel airplane response, nose strut compression, EPI partial DN." In a flight operations bulletin (FOB) issued on June 4, 2001, Boeing recommended EPI use during the preflight and taxi elevator checks; however, regarding the 80-knot check, Boeing stated "pitch response may be useful as a check for weight distribution, but [the 80-knot check] is not a valid substitute for a properly conducted flight control check."[27]

[26] The seven DC-8 operators were Emery, Air Transport International, Arrow Air, United Air Lines, Airborne Express, DHL, and United Parcel Service.

[27] For additional information regarding Boeing's FOB, see section 1.17.1.3.

### 1.6.2.2 History of the DC-8 EPI Requirement

On September 8, 1970, a Trans International Airlines Corp., DC-8-63, N4863T, crashed on takeoff at John F. Kennedy International Airport, Jamaica, New York. The Safety Board determined that the probable cause of the accident was a loss of pitch control caused by the entrapment of a pointed (asphalt-covered) object between the leading edge of the right elevator and the trailing edge of the horizontal stabilizer, which the flight crew did not detect in time to reject the takeoff.[28] As a result of its initial findings during this investigation, on October 28, 1970, the Board issued Safety Recommendation A-70-54 to the FAA, in which the Board expressed its concern that "an elevator jammed by a foreign object would not be detected by the crew" and could result in an accident. Safety Recommendation A-70-54 recommended the following to the FAA:

> A. All DC-8 operators be advised of the hazardous condition that can be created by foreign object jamming of the aircraft's elevators.
>
> B. Until adequate procedures are developed for positive check of elevator position, all DC-8 operators be advised that takeoff should be aborted whenever premature or unacceptable rotation of the aircraft occurs during takeoff.
>
> C. The DC-8 flight control system be evaluated by the FAA in the interest of developing a standard procedure for checking the system from the cockpit. The procedure should provide for positive detection of a jammed elevator.
>
> D. Consideration be given for a requirement to install an elevator position indicator in the cockpit of all DC-8 aircraft.

The FAA responded to Safety Recommendation A-70-54 in a letter dated November 20, 1970, stating that "additional time is needed to complete the engineering evaluation" and that the FAA would advise the Safety Board of any further action when the evaluation was completed. The FAA's November 1970 letter further stated that the FAA needed clarification on some sections of A-70-54. The FAA addressed some of these issues in a letter to the Safety Board dated March 8, 1971, which stated:

> Following our request for the above clarification, NTSB and FAA representatives met on [December 18, 1970] to discuss the intent of the NTSB recommendation….NTSB personnel fully concurred with FAA representatives that the decisions to abort should be left to the judgment of the pilot.

[28] For additional information regarding this accident, see National Transportation Safety Board, *Trans International Airlines Corp., Ferry Flight 863, Douglas DC-8-63F, N4863T, John F. Kennedy International Airport, New York, September 8, 1970.* Aircraft Accident Report NTSB/AAR-71/12 (Washington, DC: 1971).

> Douglas has developed check procedures involving control yoke movement to check for elevator movement and jamming prior to takeoff. FAA issued an operations alert on [December 1, 1970] outlining this check procedure and requested all principal inspectors to bring this to the attention of all operators utilizing DC-8 aircraft. This pre-takeoff check made by the pilot in accordance with the operations alert will provide adequate assurance to the pilot that there is proper elevator control for the flight.
>
> Compliance with the operations alert, we believe, will be consonant with your first three recommendations made in your [October 28, 1970] letter. In regard to your fourth recommendation for the installation of an elevator position indicator in the cockpit, we believe that due to the design of the aircraft's elevator controls, the usefulness and value of such a position indicator would not justify the large cost and complexities of this installation. The information provided by the elevator position indicator during the pre-takeoff check specified in the operations alert would, at best, only duplicate the information the pilot obtains by moving the control yoke between full forward and full aft.

On February 18, 1972, the Safety Board classified Safety Recommendation A-70-54 "Closed—Acceptable Action." [29]

As previously mentioned, on March 5, 1975, Douglas issued SB 27-254, titled "Flight Controls—Elevator and Tabs—Install Position Indicator," which recommended that operators install an EPI and associated transmitters and circuitry in their DC-8s to help flight crews detect restricted elevator movement. Douglas indicated that the SB was released because of two instances of insufficient or abnormal elevator travel that were discovered by flight crews during preflight checks. SB 27-254 instructed DC-8 operators to install the EPI on the first officer's instrument panel, in a location selected by the operator, such that the first officer's view of the indicator was not obstructed by the full-forward position of the control column.

The FAA subsequently issued AD 78-01-15 (effective June 1, 1978), which required DC-8 operators to install an EPI system within 18 months, unless already accomplished in accordance with Douglas SB 27-254.

## 1.6.3 Maintenance Information

Emery's continuous airworthiness maintenance program for its DC-8 fleet included the following major inspections and intervals:[30]

[29] Although Safety Recommendation A-70-54 contained four distinct subparts, only one recommendation number was assigned. Therefore, the classification "Closed—Acceptable Action" applied to all four parts of Safety Recommendation A-70-54.

[30] Emery's continuous airworthiness maintenance program for its DC-8 fleet also included transit, terminating, and service inspections. For additional information regarding transit, terminating, and service inspections, see the Maintenance Group Chairman's Factual Report, dated October 27, 2000, in the docket for this accident.

- **B Inspections.** B inspections were conducted as a series of four segmented inspections (B-1, B-2, B-3, and B-4), accomplished at 136-hour intervals at Emery maintenance stations, unless a C inspection was accomplished. The B inspections were accomplished by Emery maintenance personnel and by contract maintenance personnel under supervision of Emery personnel, whereas heavier maintenance inspections were accomplished for Emery by FAA-approved repair/overhaul facilities. B inspections included inspections of the wings; main landing gear assemblies, wheel wells, doors, and wing root; the nose section, nose landing gear, nose landing gear wheel well area and tunnel; turbo compressor compartment; external center fuselage; aft fuselage and empennage area; cabin area; time-limited components; main aircraft battery; and main cargo door. Additionally, during a B inspection, the airplane was thoroughly cleaned, flight controls were lubricated, the engines were run, and pressurization was checked. For additional information regarding the accident airplane's most recent B inspections, see section 1.6.3.2.
- **C Inspections.** C inspections were accomplished at 24-month intervals by FAA-approved repair/overhaul vendors that were contracted to conduct maintenance on Emery airplanes. Emery defined a C inspection as "a high level check to insure [sic] the integrity and airworthiness of airframe, fluid quantities, security of components, operational checks of specified components, filter changes, lubrication, overhaul of specific components, systems checks and the accomplishment of principle structural elements per the structural inspection document, or supplemental structural inspection document." (The accident airplane's most recent C inspection was completed as part of the most recent D inspection.)
- **D Inspections.** D inspections were accomplished at 12-year intervals; Emery defined a D inspection as "a high level check to include all of the same checks described in the [B and] C check[s], to include overhaul of the aircraft." For additional information regarding the accident airplane's most recent D inspection, see section 1.6.3.1.

Emery maintenance records indicated that, from November 17, 1999 (the completion date of the accident airplane's most recent D inspection), to the accident date the company had complied with all applicable FAA ADs and accomplished all scheduled maintenance items on the accident airplane in accordance with the provisions of its continuous airworthiness maintenance program.

### 1.6.3.1 Accident Airplane's Most Recent D Inspection

Tennessee Technical Services (TTS),[31] in Smyrna, Tennessee, performed the accident airplane's most recent D inspection between August 27 and November 17, 1999, at an airplane total time of 84,050 hours (33,180 cycles). Emery provided TTS with workscope information and guidance. In general, Emery specified that the inspection include fleet campaign directives (FCD) and other special inspections, applicable ADs,

[31] For additional information regarding TTS, see section 1.17.2.

components that were due to be changed or recertified, powerplant tasks, and supplemental type certificate (STC) modifications to expand the parameters of the FDR. Emery provided TTS with the following work cards for the inspection:

- D inspection work cards for DC-8-50/-60 series airplanes from Emery's Inspection Program Manual—Volume III, revision 17, dated November 15, 1995.
- C inspection work cards for DC-8-50/-60 series airplanes from Emery's Inspection Program Manual—Volume II, revision 19, dated October 18, 1996.
- C supplemental inspection work cards for DC-8-70 series airplanes from Emery's Inspection Program Manual—Volume II, revisions 16 and 19, dated January 15, 1995, and October 18, 1996, respectively.

Emery also provided an amendment to the workscope information, dated September 14, 1999, which stated that the accident airplane's primary flight controls would be removed and replaced with overhauled units during the D inspection work.

#### 1.6.3.1.1 Removal/Replacement of the Right Elevator

Examination of the documentation for the D inspection confirmed that the airplane's existing elevators and their associated (control and geared) tabs were replaced with overhauled assemblies. At Emery's request, TTS sent the removed elevator, control tab, and geared tab surfaces and their associated hardware to Willis Aeronautical Services (Willis), in Tempe, Arizona, in exchange for overhauled components.[32] (The accident airplane's right elevator, control, and geared tabs were removed in accordance with work card 3103D, titled "Remove R/H Elevator and Tabs." This work card instructed maintenance personnel to remove the right elevator, control tab, and geared tab and to bag and attach all loose parts, including hardware, to their respective subassemblies.)

Willis then provided TTS (through Emery) with a replacement elevator, control tab, and geared tab surfaces (with no associated hardware), which had been overhauled by Complete Controls, Inc. (CCI), in Tucson, Arizona. According to the attached work orders and documentation, CCI inspected and overhauled the elevator, control tab, and geared tab surfaces in accordance with the DC-8 overhaul manual.

Records indicate that TTS received the replacement overhauled elevator geared tab on August 20, 1999, and the replacement overhauled elevator and elevator control tab on September 9, 1999. According to testimony presented at the public hearing for this accident, TTS' standard receiving inspection procedure consisted of a general visual inspection (to identify shipping damage, etc.) and confirmation that the necessary documentation was with the part.[33] TTS representatives indicated that the components were inspected in accordance with TTS' standard receiving inspection procedure and that no anomalous condition was noted during this inspection.

[32] According to public hearing testimony, Emery arranged for TTS to receive replacement parts, which typically were used/overhauled components that Emery obtained through brokers. Willis Aeronautical Services was one such airplane parts broker.

A review of the work cards provided by Emery to TTS for this job revealed that the overhauled control and geared tabs were installed on the overhauled elevator in accordance with instructions on work card 3502D, titled "Install Right Elevator Tabs." This work card stated the following:

> NOTE: Use applicable DC-8 M/M [Maintenance Manual], Chapter 27, when performing this card.
>
> 1. Inspection OK to install serviceable elevator control and gear tab to elevator.
> 2. Lube all tab hinge bearings prior to tab installation….
> 3. Install overhauled elevator control tab to elevator.
> 4. Install overhauled elevator gear tab to elevator.
> 5. Inspector verify control and geared tab installation and security.

The Safety Board's review of the completed work card indicated that the required signatures and stamps were present. All five steps were signed off by a mechanic; the first and third steps involved in the installation of the elevator tabs were signed off by a mechanic and stamped by an inspector; and the final step, an inspection verifying the proper installation and security of the elevator control and geared tabs, was stamped by two inspectors. There was no indication of the date of completion of the individual steps, nor did the card call for such an indication; however, the date listed on the completed work card was October 14, 1999.

When TTS received the overhauled elevator components from CCI, the hardware required for installation of the elevator control and geared tabs was not included. TTS personnel indicated that, as a result, they used hardware from TTS stock in accordance with the DC-8 MM chapter 27 guidance (referenced on work card 3502D).[34] Chapter 27 of the DC-8 MM, section 3, subpart D of 27-32-06, titled "Tab, Elevator Control—Removal/Installation," contained instructions to "connect [the control] tab pushrod to the tab crank [fitting] and secure." However, this section of the Emery DC-8 MM did not contain a list of (or other guidance specifically detailing) the required hardware for the proper installation and security of the control tab crank fitting/pushrod attachment or detailed steps regarding the inspection of this attachment. Likewise, the Douglas Master DC-8 MM did not contain this information. An index associated with an illustration in Emery's DC-8 MM, chapter 27-32-06, referenced a figure from Emery's DC-8 Illustrated Parts Catalog (IPC),[35] chapter 27-30-01. This IPC figure then referenced another IPC

[33] The TTS "Repair Station Inspection Procedures Manual" included the following description of TTS' procedures for receiving overhauled components, "…[a]ny repaired or overhauled components received from an FAA certificated repair station require a receiving inspection for shipping damage, traceability of life limits, if applicable, and traceability of overhaul record and or maintenance release tag before being returned to service. Repaired or overhauled components that are received from other than an FAA certificated repair station may not be used on an airplane and must be returned to the vendor."

[34] Work card 3502D did not identify the specific hardware required for this installation.

[35] Although the Emery and Douglas DC-8 IPCs are not FAA-approved items individually, they were included on a list of reference documents that was approved by the FAA as part of Emery's continuous airworthiness maintenance program.

figure, which identified the drilled-shank alloy steel bolt, washer, and castellated nut required for this installation by part number but did not identify the cotter pin required to secure the bolt in this installation.

On May 8, 2002, Boeing issued temporary revisions 27-207, 27-208, 27-561, and 27-562 to the Master DC-8 MM. These temporary revisions instructed DC-8 operators to connect the control tab pushrod to the tab crank fitting by installing a bolt, washer, and nut and tightening and securing with a cotter pin. These temporary revisions also included an illustration depicting the hardware to be installed when connecting the elevator control tab pushrod to the tab crank fitting. In a June 17, 2002, letter to the Safety Board, Boeing stated that it did not plan to issue a similar revision to the DC-8 IPC because the IPC "was not intended to be used for installation and assembly…the IPC does, however, relate the specific part to the appropriate installation drawing, which is what the mechanic should be using to assemble and/or install components on an airplane." Emery did not list Boeing's DC-8 installation drawings in its DC-8 maintenance policy and procedures manual as a reference document, and TTS personnel stated that Emery did not provide them with Boeing's DC-8 installation drawings.

In an August 19, 2002, letter to the Safety Board, the FAA stated "if the air carrier chooses to incorporate the manufacturer's IPC and/or the manufacturer's drawings in its program, then the carrier must define the use of the information with regard to its own aircraft." In a subsequent letter to the Safety Board, dated January 21, 2003, the FAA stated that during surveillance and inspections, it ensures that the maintenance information being used by an operator or repair station is "current and part of the information incorporated into the operator's program." Additional commentary and discussion of FAA, manufacturer, and related correspondence concerning the use of IPCs is included in the public docket of this report.

When properly installed, the cotter pin is inserted through the castellations on the nut and a hole in the bolt's shank, then one leg of the cotter pin is bent up and over the top of the nut and the end of the bolt, while the other leg of the cotter pin is bent down, parallel with the bolt. This method of installation prevents the loosening of the nut during operation. According to the DC-8 overhaul manual (OHM), chapter 27-16-1, the hardware required to secure the elevator control tab's aluminum pushrod end to the aluminum tab crank fitting at this location includes a drilled-shank alloy steel bolt, a washer, a steel castellated nut, and a cotter pin. The Emery work cards and DC-8 MM did not cite the DC-8 OHM as a reference for installing the elevator assemblies.

TTS maintenance records indicate that the installation of the elevator assembly on the horizontal stabilizer was performed in accordance with work card 3504D, titled "Install Right Elevator Assembly." This work card stated the following:

> NOTE: Use applicable DC-8 M/M, Chapter 27, when performing this card.
>
> 1. Inspection OK to install right elevator assembly to horizontal stabilizer.
> 2. Hoist overhauled elevator into position, install eyebolt nuts….

3. Torque elevator hinge eyebolt nuts.
4. Install bolts and shims to inboard elevator hinge fitting.
5. Torque inboard hinge fitting bolts and check clearance.
6. Install control tab drive crank and outboard drive torque tube.
7. Connect and safety control tab pushrod to drive crank.[36]
8. Connect and safety inboard and outboard geared tab drive cranks to horizontal stabilizer rear spar links.
9. Connect inboard elevator damper crank to horizontal stabilizer rear spar fittings.
10. Remove sling and install screws in hoist points of elevator surface.
11. Inspector check elevator assembly for proper installation and security.
12. Rig R/H elevator [assembly] per DC-8 M.M. Chapter 27. [37]

The required signatures and stamps were present on the completed 3504D work card. The first step on work card 3504D was stamped by a TTS inspector and steps 2 through 10 were signed by a TTS mechanic. Steps 11 and 12 were stamped by a TTS inspector; step 12 was also signed by a mechanic. As with work card 3502D, there was no indication of the date of completion of the individual steps, nor did the work card call for such an indication. The completion date listed on the card was November 4, 1999.

TTS's time card database indicated that 19 mechanics/inspectors performed tasks described on work card 3504D between September 27 and November 2, 1999. TTS personnel did not document the specific tasks performed by individual mechanics/inspectors, nor was such documentation required by Emery or the FAA.

Maintenance records indicated that TTS personnel performed a functional check of the right elevator and tab in accordance with work card 3506D, titled "Functionally Check Right Elevator and Tab." This work card stated the following:

NOTE: Use applicable DC-8 M/M, Chapter 27, when performing this work card. (This card to be worked in conjunction with 3504D.)

1. Perform elevator and tab travel check. See work card #3501.
2. Perform elevator and tab system for excessive friction check.
3. Perform geared tab mismatch check.
4. Perform control tab mismatch check.
5. Perform elevator mismatch check.
6. Perform elevator and tab clearance check.

---

[36] This instruction refers to the forward end of the pushrod.

[37] Chapter 27-30-03 of the DC-8 MM contains information regarding elevator assembly rigging and includes after-rigging instructions to "inspect and check…mechanism rods secure and safetied."

7. Perform elevator geared tab mechanism clearance check.

All seven steps were signed off by a TTS mechanic and stamped by a TTS inspector; the overall work card completion date listed on the card was October 14, 1999.

Work card 3601D, titled "L/H and R/H Horizontal Stabilizer and Elevator Close," contained three steps—one step instructing an inspector to verify the inspection areas before access plates and fairings were reinstalled and secured and fairing seams were sealed (this step required an inspector signature) and two closure steps for a mechanic to perform (a mechanic signature was required). This work card contained no specific reference to inspection of the elevator control tab crank fitting/pushrod attachment area. All required signatures were present on the completed work card 3601D for the accident airplane; the completion date listed on the card was October 26, 1999.

During this investigation, the Safety Board interviewed personnel from TTS, including the general manager, vice president, director of quality control, a lead mechanic, and two of the three inspectors involved in the installation of the elevator assembly.[38] Subsequently, the Board conducted formal interviews with the president of TTS, the director of quality control, and one inspector; these individuals were also witnesses at the Board's public hearing on this accident. None of the mechanics/inspectors interviewed specifically recalled the work they performed on the accident airplane.

For example, one of the TTS inspectors involved in the installation of the right elevator assembly stated that the elevator control tab crank fitting/pushrod attachment area on the accident airplane would have been inspected at least three or four times (including at the end of the elevator installation and twice during the elevator rigging process) before the fairing would have been replaced. Specifically, he said that TTS mechanics were not allowed to close a panel/fairing unless an inspector was there to inspect the area and witness the closing of that panel/fairing. The TTS inspector stated that he would only stamp the work card for the elevator control tab installation after he had touched the cotter pin to ensure proper installation.

### 1.6.3.1.2 Reversed Installation of Elevator Dampers

The accident airplane's maintenance records revealed that on November 25, 1999, eight days after the D inspection was completed (which included the installation of the elevator assemblies), a pilot reported that he had to apply "more back pressure than normal" on the control column to flare during the preceding landing and during the elevator check before the previous takeoff. The corrective action for this pilot report (performed by Emery maintenance personnel) was described in the accident airplane's maintenance logbook as follows: "Found [left/right] elevator dampers reversed, moved [left to right] side, [right to left] side, ops ck'd good, no defects noted." Figure 5 shows the elevator damper's location on the right elevator of a DC-8.

[38] The third inspector who was involved with the elevator assembly installation was no longer working at TTS and was unavailable when the Safety Board conducted its interviews.

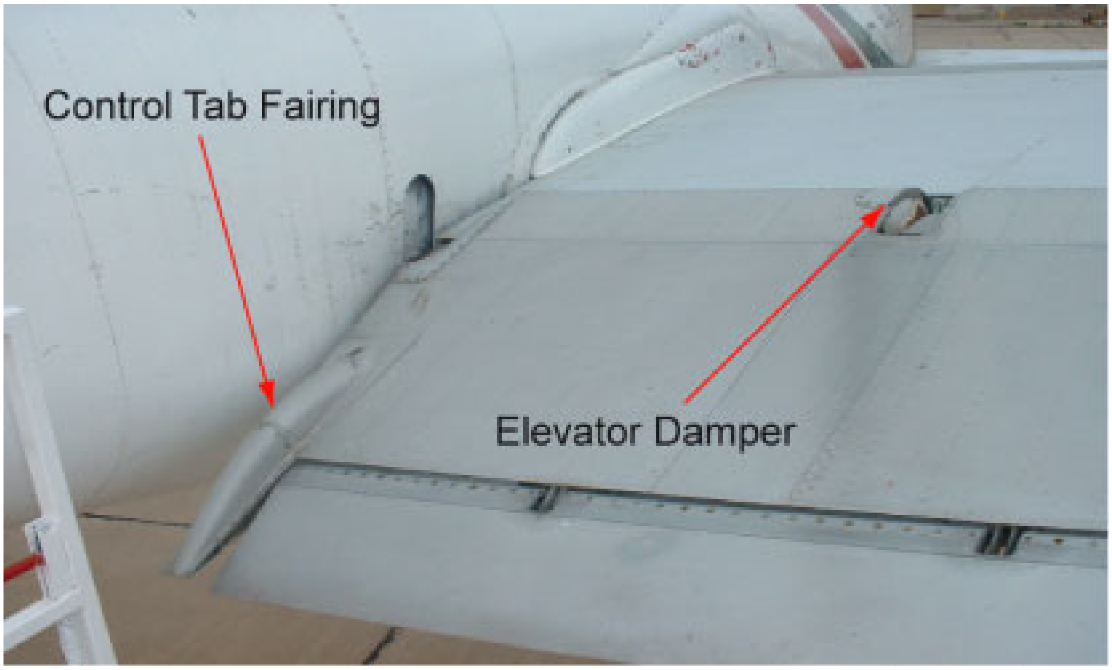



**Figure 5.** Photograph showing the elevator damper's location on the right elevator of a DC-8.

Emery's third-shift lead mechanic at DAY described the troubleshooting efforts that led to the discovery of the reversed dampers. He stated, in part, that he and another Emery mechanic moved the control column in the airplane through its range of motion while other maintenance personnel (including his supervisor) watched the elevator assembly's motion from the ground at the rear of the airplane. The lead mechanic told investigators that during this exercise, his supervisor "noted that there was a problem with the [elevator] dampers and that the mechanical operation wasn't correct." Maintenance personnel confirmed that the dampers were installed in the wrong positions and removed and swapped the dampers. According to the lead mechanic, maintenance personnel did not check cable tensions, access the elevator control tab pushrod fairing, rig the elevator control or geared tabs, or discover any obstructions to control column movement during the troubleshooting efforts.

Postaccident interviews with the mechanics involved in the maintenance action indicated that they had nearly finished swapping the elevator dampers at the end of the third shift when there was a change in lead mechanic personnel. According to the Emery mechanic who moved the control column during the initial troubleshooting efforts (and stayed on duty to complete the elevator damper work), "once the dampers were placed into the correct position, no further maintenance was done…beyond a visual inspection and checking the feel of the flight controls. It seems to me that the flight controls, after swapping of the dampers, felt smoother."

Maintenance personnel reported that after the damper exchange, they noted no excessive control column forces or elevator binding; the damper exchange was examined by an inspector and signed off, and the airplane was returned to service. The maintenance logbooks contained no further pilot complaints regarding this anomaly.

Chapter 27-00-37 of Emery's DC-8 MM, "Mechanical Controls—Trouble Shooting," listed the following procedures, in part, for troubleshooting elevator/tab issues:

A. Part 1

1. Clean and lubricate elevator cable cabin pressure seals per MM….
2. With airplane out of the wind (in hangar), gust lock off, check elevator controls for binding and roughness. Cause of any roughness or binding is to be located. Experience has shown that tab torque tube bearings inside the elevator inboard hinge fitting are very susceptible to binding and rough operation.
3. Check elevator control cable tensions, per MM…and record them.
4. Check cable on elevator autopilot servo drum for binding or damage.
5. Check top and bottom surface contours of elevators outboard of tabs. Top and bottom surfaces to be flat and trailing edge should not bow up or down….
6. Repeat check "5," but on all four elevator tabs.

B. Part 2

1. Check that elevator trailing edge forward of tabs fairs with tab leading edges. Correct any discrepancies.
2. Check control tab pushrods in elevators for clearance per MM….Correct conditions not within limits.
3. Check that elevator servo support rig holes…are aligned per MM….Record any discrepancies.
4. Check elevator controls rigging per MM…record any out-of-tolerance conditions.
5. Remove the RH pilot seat and floorboards and check the MPT (mach pitch trim) controls for evidence of binding….Operate the MPT to the extend position and check elevator controls for binding. Correct any binding.
6. Check end play (looseness) of the elevator load feel/centering mechanism shaft relative to the mechanism housing….If end play exceeds 0.010 inch the mechanism should be replaced. The mechanism can be removed, checked and reinstalled without disturbing its adjustment.
7. Check that elevator control system friction is within the limits of [the MM].

C. Part 3

1. Disconnect elevator control cables and control tab pushrods from tab torque tubes at the elevator inboard end. Check the torque tube bearings for binding or roughness. If bearings do not operate smoothly, replace the elevator hinge fitting. Rerig elevator controls.
2. Correct all discrepancies recorded during accomplishment of parts 1 and 2, preceding.

Additional commentary and discussion of the troubleshooting procedures used to address pilot write-ups regarding elevator controls is included in the public docket of this report.

### 1.6.3.2 Most Recent B-2 Inspection of the Accident Airplane

The accident airplane's most recent B-2 inspection was conducted overnight at Emery's DAY facility, on January 21-22, 2000. One of Emery's DC-8 work cards (B009) for the B-2 inspection of the right elevator control tab stated the following:

**RH AND LH HORIZONTAL STABILIZER EXTERNAL SURFACE INSPECTION**

1. Inspect external surface of RH and LH horizontal stabilizers for signs of damage, deformation, fluid leakage, and security of attachment. Inspect static dischargers for general condition and security.

**RH AND LH ELEVATOR AND TAB INSPECTION**

1. Visually inspect elevators and tabs for general condition, corrosion, leakage, and security of attachment. Inspect static dischargers for general condition and security.

Both steps were signed off by an Emery mechanic.

Because of the DC-8 elevator assembly design, the elevator control tab inboard fairing would have to be removed for maintenance personnel to inspect the inboard hinge fitting and crank fitting/pushrod attachment. During the Safety Board's public hearing on this accident, there was conflicting testimony regarding the intended depth and scope of the B-2 inspection. For example, Emery's Director of Engineering and Director of Line Maintenance indicated that the general visual inspection dictated by the B-2 inspection work cards would not require the removal of any panels or fairings and, therefore, would not include a visual inspection of the elevator control tab inboard hinge fitting or crank fitting/pushrod attachment. Boeing supported this interpretation of the B-2 inspection work card tasks. In a letter to the Board dated June 14, 2002, Boeing's Chief Engineer, Air Safety Investigation, stated that the manufacturer's recommended program work cards "do not call for the removal of the inboard control tab fairing during the B [inspections]. The inboard control tab fairing is not removed until the [C- and D-inspection equivalent]…Therefore, the Emery B-2 inspection work card…would be…an inspection to be accomplished without removing access or inspection panels, fairings, or the like."

However, during his public hearing testimony, the lead mechanic for TTS stated that although the work card did not specifically call for removal of the inboard control tab fairing, TTS mechanics "would remove the fairings on the elevator itself…and the control tab…and the geared tab…to accomplish all of that card." The president of TTS also stated that the company's maintenance personnel would remove the fairings on the elevator, control tab, and geared tab to visually inspect each attachment to accomplish the work card tasks.

The Safety Board is aware that several air carrier operators have tried to provide their mechanics with additional guidance regarding the proper accomplishment of a work card item by enumerating the necessary steps or tasks on that item's work card.

## 1.7 Meteorological Information

The automated weather observation system (AWOS) weather observation taken at MHR on February 16, 2000, at 1950 stated the following:

> Winds calm; visibility 10 miles plus; scattered clouds at 2,000 feet, ceiling 7,000 feet broken; temperature 46° Fahrenheit (F); dew point 46° F; altimeter setting 30.01 inches of Hg [mercury].

According to postaccident interviews with witnesses, the ceiling and nighttime visibility at MHR at the time of the accident were such that the witnesses could clearly observe the airplane as it taxied from the ramp to the runway, took off, climbed out, and turned to return to the airport. The CVR did not record any pilot comments regarding the weather conditions at the time of the accident.

## 1.8 Aids to Navigation

No difficulties with the navigational aids were known or reported.

## 1.9 Communications

No difficulties with communications were known or reported.

## 1.10 Airport Information

MHR is a former U.S. Air Force Base that is currently operated by the County of Sacramento and located about 12 miles east of downtown Sacramento, California. The airport has an elevation of 96 feet and two parallel runways; runway 4L/22R is 6,040 feet long and 150 feet wide and runway 4R/22L is 11,301 feet long and 150 feet wide. The accident airplane departed from runway 22L.

# 1.11 Flight Recorders

## 1.11.1 Cockpit Voice Recorder

The CVR installed on the accident airplane was a Sundstrand AV557, S/N 7286. Examination of the exterior of the CVR revealed evidence of severe fire and heat damage, while the interior exhibited heat damage. When the crash-survivable case containing the CVR tape drive assembly was opened, its contents exhibited no sign of severe heat damage; however, the CVR magnetic tape that was outside of the spool showed some signs of shrinkage, which can be the result of exposure to heat. The sections of tape that had shrunk were permanently damaged, resulting in small areas of unusable audio at the beginning and end of the recording. The overall recording, however, was in playable condition and was successfully downloaded.

The CVR recording consisted of four channels of good quality audio information.[39] One channel contained audio information recorded by the cockpit area microphone, and the other three channels contained audio information recorded through the radio/intercom selector panels at the captain, first officer, and flight engineer positions. The recording began at 1917:45 and ended at 1951:09, 1 second after it recorded a sound similar to impact. A transcript was prepared of the entire 33-minute 24-second recording. See appendix B for a complete transcript of the CVR recording.

## 1.11.2 Flight Data Recorder

The FDR was a Loral Fairchild digital FDR model F800, S/N 04018, part number (P/N) 17M303-282, which recorded 17 parameters[40] of airplane information on a 450-foot long, 1/4-inch wide magnetic tape. The tape is divided width-wise into 6 equally sized tracks, which record a total of 25 hours of data (4 hours 10 minutes of data on each track). The 17 recorded parameters included time, altitude, indicated airspeed, magnetic heading, vertical acceleration, pitch attitude, roll attitude, VHF microphone keying for two VHF channels, engine N1 (rotational fan speed) for all four engines, autopilot engage, longitudinal acceleration, control column position, elevator position, control wheel position, aileron position (left), rudder pedal position, and rudder position.

Visual examination of the FDR revealed evidence of internal and external heat and fire damage, including heat damage to some of the tracks on the tape recording medium.

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[39] The Safety Board uses the following categories to classify the levels of CVR recording quality: excellent, good, fair, poor, and unusable. A good recording is one in which most of the crew conversations can be accurately and easily understood. The transcript that is developed may indicate several words or phrases that are not intelligible. Any loss in the transcript can be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscure each other.

[40] Title 14 CFR Section 121.344 required all airplane FDR systems to be upgraded to record more parameters (airplanes with more than two engines, like the accident airplane, had to be upgraded to record 17 parameters) by August 2001. The accident airplane's FDR was upgraded during the D inspection that was completed in November 1999.

Despite this damage, the FDR installed on the accident airplane yielded data of good quality for the accident flight without any losses of data synchronization.[41]

### 1.11.2.1 Track-Switching Anomaly

The Safety Board's examination of the transcribed FDR data revealed that the FDR erroneously switched to the first track of the tape every time electrical power to the FDR stopped. Thus, the FDR did not record data throughout the length of its 25-hour loop tape (and would not have, unless the FDR was powered nonstop during that 25 hours). As a result of this anomaly, only the last 8 hours and 11 minutes of data for the accident airplane were available; these data included information from portions of the three previous flights (the arrival at DAY and the flights from DAY to RNO and RNO to MHR) and the accident flight. These data were recorded on one complete track and portions of two other tracks; other portions of the tape contained data from various previous flights, including some that took place before the FDR was upgraded in November 1999. As a result of this tracking-switching anomaly, only limited FDR data was available to the Board from flights that occurred in the days leading up to the accident.[42]

Because of previously identified instances of tracking-switching anomalies in F800 FDR systems, Loral Fairchild[43] has identified several potential causes for tracking-switching problems and has issued three field service bulletins (FSB) since February 1988 to address these anomalies. Although two of these FSBs[44] appeared to address anomalies like the one observed in the accident airplane's FDR, Emery personnel stated that its maintenance records showed that the FSBs were not applicable to the accident airplane's FDR unit. The FSBs only applied to F800 FDRs with particular components installed; maintenance records indicated that those components were not installed on the accident airplane's FDR.[45] The FDR damage sustained during the accident precluded physical confirmation of the specific components that were installed on the accident airplane's FDR.

### 1.11.2.2 Elevator Position Data Conversion Anomaly

The Safety Board's examination of the FDR data also revealed an anomaly with the accident airplane's recorded elevator position data. The Board converted the recorded FDR data to engineering units appropriate to each parameter (for example, feet for altitude, knots for airspeed, and degrees for heading, pitch, roll, etc.) using conversion formulas based on documentation provided by Emery through L2 Consulting Services, Inc. (L2 Consulting Services performed the FDR parameter correlation on the accident

[41] A loss of synchronization can result from either a mechanical or electrical interruption of the data.

[42] During the FDR correlation check in November 1999, maintenance personnel evaluated real-time data from the FDR system through a download and diagnostic tool. Because the FDR history was not examined during this check, the tracking-switching anomaly would not have been detected.

[43] Loral Fairchild is now L3 Communications.

[44] Loral Fairchild FSBs Digital Flight Recorder (DFR) 011 and DFR 027.

[45] According to Emery records, the accident FDR contained components addressed by Loral Fairchild FSBs DFR 015, 016, 017, 020, 021, and 029.

airplane in November 1999, after the airplane was upgraded to record 17 parameters.)[46] The documentation for elevator position provided a relationship between elevator position data recorded by the FDR and the degrees of elevator travel that data represents. The Board's subsequent conversion of the data based on this relationship resulted in a potential range of elevator positions from 12.8° TEU to 26.6° TED; the elevator's normal operating range is from 27° TEU to 16.5° TED.

The accident airplane's FDR data indicated that the elevator surfaces were deflected 11º TED relative to the horizontal stabilizer when the airplane was on the ground with the elevator gust lock engaged. However, by design, when the gust lock is engaged, the elevators are physically locked in their neutral, or 0º, position. Additionally, the FDR data recorded during the accident airplane's climb out from RNO (the flight immediately preceding the accident flight) showed the elevators in a significant TED deflection when the control columns were near their rigged neutral position, which normally corresponds to a neutral elevator position of about 0º. The elevator's total range of motion was slightly smaller than and offset from its normal range. Therefore, an 11° offset (based on the elevator's position with the gust lock engaged) in the TEU direction was applied to the elevator recorded position data.

Figure 6 shows the elevator, pitch, and control column plots recorded by the accident airplane's FDR during ground operations before the accident flight. On this plot, the uncorrected data on the far left side of the plot shows an 11º TED elevator deflection when the gust lock was engaged (and the elevator was in its neutral, or 0º, position).

[46] According to the FAA's advisory circular (AC) on this subject (AC 20-141), "a correlation describes the relationship between two variables. In this case the two variables are the raw data stored in the digital FDR and the engineering units or discretes that this raw data represents." The work card provided by L2 Consulting Services, Inc., titled "F800 [FDR] Correlation Test Procedure—17 Parameters," documented the ground test performed on the accident airplane to collect correlation data for Emery's upgrade configuration for that airplane model. For additional information regarding this documentation, see "Addendum 2 to the Digital Flight Data Recorder Factual" in the docket for this accident.

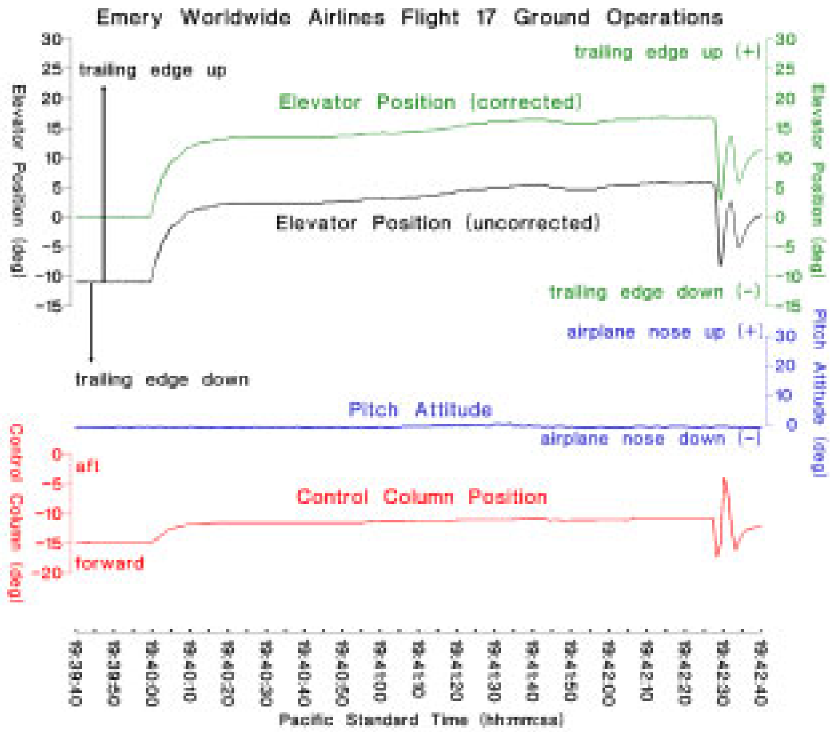


**Figure 6.** Elevator, pitch, and control column plots recorded by the accident airplane's FDR during ground operations before the accident flight. The first 20 seconds of data were recorded while the gust lock was engaged.

The Safety Board's examination of the corrected elevator position data revealed that the airplane's elevator never traveled below its neutral position to a TED deflection during the accident flight, although recorded forward control column inputs should have resulted in a TED elevator deflection. For example, although the FDR data indicated that, during the 80-knot elevator check at MHR, the control columns were moved to about 6º forward of their rigged neutral position, the elevators did not deflect below 2.2º TEU. In contrast, during the 80-knot elevator check on the previous takeoff (at RNO) the FDR recorded elevator movement to 8º TED, with less forward control column movement. Figure 7 shows plots of the pitch attitude, control column position, and elevator position FDR data for the accident flight. Elevator position is shown using the conversion that corrected for the 11º offset. Figure 7 also shows when the 80-knot elevator check and takeoff occurred. Figure 8 shows the same information for the takeoff from RNO.

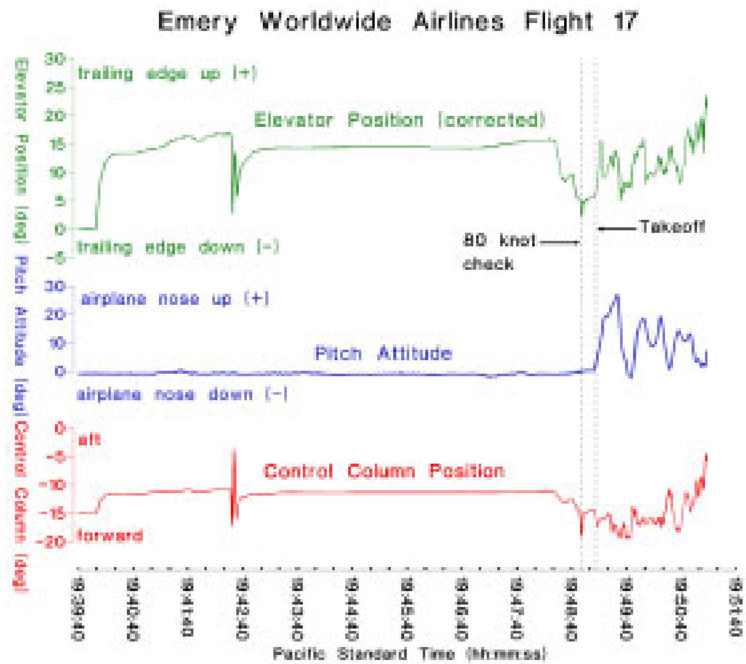


**Figure 7.** Pitch attitude, control column position, and (corrected) elevator position FDR data from the accident flight. About the first 20 seconds of data were recorded while the gust lock was engaged.

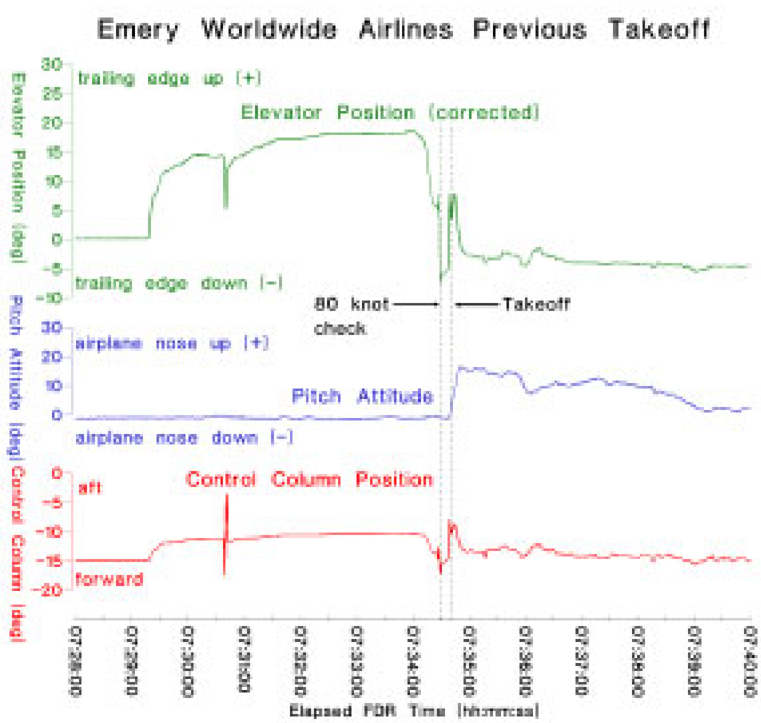


**Figure 8.** Pitch attitude, control column position, and (corrected) elevator position FDR data for the previous takeoff from RNO. About the first 1 minute 20 seconds of data were recorded while the gust lock was engaged.

### 1.11.2.3 Other Examples of Inaccurate FDR Elevator Data

During its investigation of this accident, the Safety Board discovered FDR elevator position conversion problems with the FDR data from other Emery DC-8s. For example, the Board noted that the FDR data from the Emery DC-8 used during the elevator flight control tests (described in section 1.16.1) produced elevator position values that were not consistent with the elevator travel that was physically measured on the test airplane during the ground tests.[47] The Board's initial parameter conversions were performed using documentation provided by Emery that had full TEU and TED engineering values that were the same as those obtained for the accident airplane (12.8º and 26.6º, respectively).

Further investigation revealed that in Emery's DC-8 fleet, a full FDR correlation was only completed on one airplane (as permitted by the Federal Aviation Regulations [FARs]).[48] In this case, Emery's only full correlation was completed on the accident airplane. After that initial full correlation, the correlation for the accident airplane was applied to the rest of Emery's DC-8 fleet as their FDRs were upgraded; the actual control surface positions on those airplanes were not measured.[49]

After the ground tests, the FDR on the test airplane was replaced and the airplane was returned to service. Several weeks later, the test airplane was involved in a landing incident that the Board investigated.[50] Evaluation of the elevator position data recorded by the replacement FDR (converted using conversion data provided by Emery) revealed that, as with the data recorded by the previously installed FDR, the recorded elevator travel data did not match the elevator travel measured during the ground tests.

The Safety Board then examined the FDR data from another Emery DC-8 that was involved in another incident.[51] The Board's evaluation of this recorded elevator position data revealed that the recorded elevator values did not fall entirely within the elevator's normal operating range.

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[47] Because the test airplane's neutral, maximum TEU, and maximum TED elevator positions were measured during the ground tests, these measured elevator position values were used as the basis for the test airplane's elevator conversion and the Safety Board's subsequent examination of that airplane's FDR data.

[48] According to 14 CFR 121.343(j), operators are permitted to establish a single correlation for any group of airplanes if "1) the airplanes are the same type, 2)…the flight recorder system and its installation are the same, and 3)…there is no difference in the type design with respect to the installation of those sensors associated with the flight data recorder system. Documentation sufficient to convert recorded data into the engineering units and discrete values specified in the applicable appendix must be maintained by the certificate holder."

[49] The Safety Board also noted that when the original conversions for the test airplane were used, recorded control column positions were not consistent with the control column input that was physically measured on the test airplane during the ground test; however, the ranges of the recorded and measured control column ranges were almost the same. As with the elevator, the control column values measured during the ground tests were used as the basis for the control column conversion and subsequent examination of the data.

[50] The description of this incident, MIA01IA129, can be found on the Safety Board's Web site at <http:www.ntsb.gov>.

[51] The description of this incident, SEA01IA039, can be found on the Safety Board's Web site at <http:www.ntsb.gov>.

The FAA had previously notified Emery of deficiencies with its DC-8 FDR documentation. On December 1, 1998 (about 11 months before the accident airplane's FDR was upgraded to 17 parameters), the FAA's principal avionics inspector for Emery sent a letter to Emery's Director of Quality Control, in which he listed the following FDR-related findings:

> There are no correlation documents required by FAR 121.343(j) on file for any of Emery Worldwide Airlines DC-8 aircraft. As discussed with you and Mr. Robbins the minimum correlation requirement is derived from FAR 25.1459(c).[52]
>
> There is no current maintenance manual procedure for the upgraded 11 parameters of each make/model of DFDR [digital flight data recorder] in use.

### 1.11.2.4 FDR Control Column Position Data

In the original correlation measurements (intended to establish a relationship between the geometry of the accident airplane's control column and the corresponding data recorded by the FDR), the FDR recorded the airplane's control column position at 15º forward of vertical when the gust lock was engaged. The control column correlation also showed that the total range of control column position at the time of the FDR upgrade was 29.6º (nearly the DC-8 design control column maximum range of 30.25º) and fell within the design range of forward and aft movement.

However, the recorded control column range of motion at the time of the accident was less than that observed during the original correlation. Although the recorded forward and neutral control column positions came close to those indicated by the original correlation, the maximum recorded aft control column range was significantly reduced from that indicated by the original correlation. The Safety Board did not determine the cause of this reduction in recorded control column range.

### 1.11.2.5 Previous FDR Data-Related Safety Recommendations

The Safety Board has previously encountered problems related to the absence of reliable FDR data[53] and has made a series of safety recommendations regarding these issues since the early 1970s. In its correspondence with the FAA regarding these safety recommendations, the Board has noted that the FDR-related problems were especially prevalent for airplanes that were originally equipped with six-parameter FDRs and subsequently retrofitted to record additional parameters in accordance with

[52] As previously discussed, Emery personnel were able to provide the Safety Board with conversion documentation for the accident airplane and the airplanes involved in the other incidents. L2 Consulting Services, Inc., the company that correlated and verified the FDR parameter upgrades on Emery's DC-8s, provided Emery with the documentation.

[53] Accidents in which unreliable or missing FDR data were discovered included four accidents involving DC-9 airplanes operated by ValuJet in 1996; the February 16, 1995, accident involving an ATI DC-8; the November 12, 1996, accident in Orebro, Sweden, involving an Express One Boeing 727; the August 7, 1997, accident involving a Fine Airlines DC-8-61, and the February 9, 1998, accident involving an American Airlines 727. Other accidents are discussed later in this section.

Section 121.343(c).[54] As a result of its ongoing concerns, the Board issued Safety Recommendations A-97-29 and A-97-30 on May 22, 1997.[55] Safety Recommendation A-97-29 asked the FAA to do the following:

> Take action within 180 days to ensure compliance of the U.S. carriers subject to 14 CFR 121.343(c). Actions should include (a) performing a readout of each retrofitted airplane's 11-parameter flight data recorder (FDR) to determine that all required FDR parameters are being recorded and to verify that each parameter is working properly; and (b) reviewing the FDR system documentation to determine compliance with the range, accuracy, resolution, and recording interval specified in 14 CFR Part 121, Appendix B.

In a letter to the Safety Board dated July 14, 1997, the FAA stated that it agreed with the intent of this safety recommendation. In response, the FAA issued Flight Standards Handbook Bulletin for Airworthiness (HBAW) 97-13C, which became effective on December 15, 1997. HBAW 97-13C provided FAA airworthiness inspectors with "policy/guidance to ensure continued proper operation and recording of data" by FDRs. The bulletin outlined items inspectors should look for in a comprehensive FDR maintenance program, defined time requirements for addressing identified discrepancies in FDR maintenance programs, and described a functional evaluation as a "recorded data dump, conversion to engineering units and assessing that the [FDR] is receiving, transcribing and decoding sensor information properly."

In a July 10, 1998, safety recommendation letter to the FAA (regarding the August 1997 accident involving Fine Airlines flight 101 in Miami, Florida[56]), Safety Recommendation A-97-29 was classified "Closed—Unacceptable Action/Superseded" (the recommendation that superseded A-97-29 is discussed later in this section). The Board indicated that this classification was based on "the continued discovery of malfunctioning 11-parameter FDRs" and the findings of the Fine Air investigation, which indicated that "it is advisable to require air carriers to maintain the records of FDR readout."

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[54] There have been two required FDR upgrades that apply to Emery's DC-8s (which were manufactured before May 26, 1989, and type certificated before September 30, 1969). The first upgrade, which became effective on May 26, 1995, required that the following additional parameters be recorded: pitch attitude, roll attitude, longitudinal acceleration, control column or pitch control surface position, and $N_1$ (rotational speed) of each engine. The second upgrade required the affected airplane to be upgraded to record 17 parameters; this upgrade had to be completed by the airplane's first heavy maintenance inspection after August 18, 1999. As previously mentioned, the accident airplane was modified to record these additional parameters during its most recent D inspection in November 1999.

[55] In this safety recommendation letter, the Safety Board listed a series of recent accidents and incidents that involved malfunctioning FDRs, including the October 22, 1996, accident involving a Millon Air Boeing 707 and the May 28, 1995, accident involving a Millon Air DC-8.

[56] See National Transportation Safety Board, *Uncontrolled Impact with Terrain, Fine Airlines Flight 101, Douglas DC-8-61, N27UA, Miami, Florida, August 7, 1997,* Aircraft Accident Report NTSB/AAR-98/02 (Washington, DC: NTSB, 1998).

Safety Recommendation A-97-30 asked the FAA to do the following:

> Complete the planned flight data recorder (FDR) advisory circular (AC) to define FDR certification requirements and FDR maintenance requirements, and incorporate the FDR documentation standards contained in Notice N8110.65. The AC should be released no later than January 16, 1998.

In a July 14, 1997, letter, the FAA stated that it agreed with the intent of this safety recommendation and promised to complete an AC for FDR certification and maintenance requirements by January 1998. In its July 10, 1998, safety recommendation letter regarding the Fine Air accident, the Safety Board classified Safety Recommendation A-97-30 "Open—Unacceptable Response," pending completion of the proposed AC.

In its July 10, 1998, safety recommendation letter, the Safety Board also issued Safety Recommendations A-98-53 through -56. Safety Recommendation A-98-53, which superseded Safety Recommendation A-97-29, asked the FAA to do the following:

> Require an immediate readout of all 11-parameter retrofitted…flight data recorders (FDR) to ensure that all mandatory parameters are being recorded properly; that the FDR system documentation is in compliance with the range, accuracy, resolution, and recording interval specified in 14 CFR Part 121, Appendix B; and require that the readout be retained with each airplane's records.

In response to Safety Recommendation A-98-53, the FAA indicated that it would complete a survey of all FDR-equipped airplanes (not just those with 11-parameter retrofitted FDRs) by February 2001. However, as of June 2003, the FAA had not initiated this survey, and the gradual implementation of new FDR system upgrade rules in the interim has increased the scope of the survey significantly.[57] Because the FAA's response did not satisfy the intent of the recommendation (which, in part, was to ensure that FDRs were being properly retrofitted and that the retrofitted equipment was recording parameters properly), the Safety Board classified Safety Recommendation A-98-53 "Open—Unacceptable Response" on March 12, 2001. The Safety Board has received no correspondence from the FAA regarding Safety Recommendation A-98-53 since its March 12, 2001, classification.

[57] Implementation of the 1997 rule for Section 121.344 required upgraded parameters for all aircraft by August 18, 2001.

Safety Recommendation A-98-54 asked the FAA to do the following:

> Require maintenance checks for all…flight data recorders (FDR) of aircraft operated under…14 CFR Parts 121, 129, 125, and 135 every 12 months or after any maintenance affecting the performance of the FDR system, until the effectiveness of the proposed advisory circular and new FAA inspector guidance on continuing FDR airworthiness (maintenance and inspections) is proven; further, these checks should require air carriers to attach to the maintenance job card records a computer printout, or equivalent document, showing recorded data, verifying that the parameters were functioning properly during the FDR maintenance check and require that this document be part of the permanent reporting and recordkeeping maintenance system.

On October 5, 1999, the FAA issued AC 20-141, "Airworthiness and Operational Approval of Digital Flight Data Recorder Systems," which addressed design, installation, and continued airworthiness of FDR systems. AC 20-141 instructs operators to "establish a schedule for accomplishing an operational and functional [FDR] ground check at intervals not to exceed 12 calendar months." As previously mentioned, the FAA indicated that it would conduct a survey of all FDR-equipped airplanes by February 2001. In part, this survey was intended to determine the effectiveness of AC 20-141 and whether any changes were needed. Pending the results of the FAA's survey, on March 12, 2001, the Safety Board classified Safety Recommendation A-98-54 "Open—Acceptable Response." There has been no further correspondence from the FAA regarding Safety Recommendation A-98-54.

Safety Recommendation A-98-55 asked the FAA to do the following:

> Provide FAA principal avionics inspectors with training that addresses the unique and complex characteristics of flight data recorder systems.

In response to Safety Recommendation A-98-55, the FAA developed a training course in evaluating the certification and maintenance of FDRs for all FAA PAIs. The implementation of this course began in October 2000. The curriculum addresses FDR regulatory requirements, flight recorder systems specifications, certification records and documentation, maintenance program requirements, and maintenance program data analysis. The course is intended to help PAIs determine whether FDR systems comply with the FAR requirements and evaluate an operator's FDR maintenance/inspection and training program. The course should train PAIs to identify whether FDR recorded values are within required specifications and to evaluate the reasonableness and quality of the recorded data.[58] On March 12, 2001, the Safety Board classified Safety Recommendation A-98-55 "Open—Acceptable Response," pending the completion of this training by all of the FAA's PAIs.

[58] According to the FAA, as of May 8, 2003, all active FAA PAIs had completed the required training; three non-active PAIs had not completed the FAA's training because of other commitments.

Safety Recommendation A-98-56 asked the FAA to do the following:

> Create a national certification team of flight data recorder (FDR) system specialists to approve all supplemental type certificate changes to FDR systems.

In response to Safety Recommendation A-98-56, the FAA trained a team of electrical systems engineers and avionics inspectors to approve all STC changes to FDR systems and to determine if the modified FDR installations would record the required FDR parameters effectively. As a result of the FAA's actions, on January 11, 2000, Safety Recommendation A-98-56 was classified "Closed—Acceptable Action."

## 1.12 Wreckage Recovery and Documentation

The airplane wreckage was located in an automobile salvage yard about 1 mile east of MHR. The wreckage path was oriented approximately on a heading of 295 and was strewn over an area about 1,500 feet long by 450 feet wide. Examination of the wreckage revealed that the main fuselage was broken into several sections. Several pieces of airplane wreckage were located along the wreckage path to the southeast of the main wreckage, including the engines, engine components, nacelles, pylons, landing gear assemblies, flight control surfaces, sections of each wing, stabilizers, the tail cone, and numerous systems components.

Portions of all major sections of the airplane were accounted for in the wreckage. However, significant portions of the airframe, its associated systems, and onboard cargo were severely damaged and/or consumed by fire. Continuity of the flight control cables and components, including those that control the elevator tabs, could not be established because of the breakup of the airplane and postaccident fire.

The cockpit wreckage and portions of the fuselage nose section were located about 30 feet south of the center of the main wreckage and exhibited evidence of severe impact and fire damage, with much of the associated structure missing. Additional cockpit/forward fuselage components, including the control column torque tube, pitch trim compensator (PTC) motor and actuator, throttle quadrant, throttle handles, flap handle, spoiler handle, and thrust reverser levers, were located beneath a section of cockpit floor. The PTC actuator was found in its retracted position.[59]

The flap handle was found with its lever latched in the third detent aft of its stowed position, which corresponded to 15º of flap extension. The flap position gauge was recovered but was unreadable because of mechanical and fire damage. The spoiler handle was found in its retracted position, and the thrust reverser levers were found in their

[59] The PTC system is installed to prevent the airplane's tendency to nose-down while operating at higher Mach numbers. According to the system design, when the airplane is operating at low altitudes and airspeeds, such as during takeoff and landing, the PTC actuator is retracted and exerts no force on the control columns.

stowed positions. The landing gear lever was not recovered; however, CVR data and physical evidence indicate that the landing gear were extended throughout the accident flight.

The left and right wings were fractured; portions of the wings were recovered separate from the fuselage and exhibited severe impact, heat, and fire damage. Portions of the left aileron and the flap surfaces and spoiler panels from both wings were found scattered throughout the debris.

All four engines were recovered and examined; FDR data and engine damage were consistent with a high power setting at impact. There was no indication of any preimpact engine damage, fire, or uncontainment.

The tail section wreckage was located aft of the rear fuselage. Portions of the vertical stabilizer rear spar were located adjacent to the tail structure. However, the remaining vertical stabilizer and rudder structures were not recovered and were presumed consumed by fire based on the presence of previously melted and resolidified aluminum adjacent to the tail section wreckage. The horizontal stabilizer center section and surrounding tail structure exhibited evidence of heat and fire damage. The horizontal stabilizer jackscrew and associated drive mechanisms exhibited severe heat damage. Both jackscrews were fully extended, corresponding to a full nose-down trim position.

## 1.12.1 Longitudinal Flight Control Surfaces

The right horizontal stabilizer was recovered largely intact, whereas the right elevator was recovered in several pieces. The inboard section of the right elevator, with the control tab and the inboard 2 feet of the geared tab, remained mostly intact and attached to the stabilizer. The right elevator geared tab inboard crank arm, which connects the geared tab pushrod to the horizontal stabilizer, was manufactured of aluminum and was found fractured.[60]

Portions of the left horizontal stabilizer (about 75 percent, including the inboard portions of the left stabilizer, elevator, and control tab surfaces) were not recovered; because they were located in an area that was exposed to intense fire, they were presumed consumed by postcrash fire. The left elevator inboard geared tab crank arm was manufactured of aluminum and was found fractured, similar to the inboard geared tab crank arm on the right elevator. (Although the left and right geared tab outboard crank arms, which were manufactured of steel, exhibited severe twisting and other impact-related damage, they were recovered intact.)

### 1.12.1.1 Flight Control Connections at the Elevator Control Tabs

The right elevator control tab crank fitting was found structurally intact and attached to the control tab inboard hinge fitting on the inboard section of the right elevator.

[60] For additional information regarding fractured elevator geared tab crank arms, see section 1.16.1.3.

(See figure 2, in section 1.6.2, for a diagram of the elevator control tab installation.) The right control tab pushrod was recovered separately, with its aft rod end (which would normally have been bolted to the tab crank fitting) intact. Examination of the forward edges of the elevator control tab crank fitting lugs revealed evidence of repeated contact damage (including gouge marks and indentations). (Figure 9 is a photograph of damage to this area.) The internal surfaces of the pushrod aft rod end bearing and the bushings in the crank fitting lugs showed no visible signs of damage or deformation. The bolt and associated hardware that normally secures the right elevator control tab pushrod to the tab crank fitting[61] was missing and not recovered.

Although the inboard portions of the left elevator, control tab, crank fitting, and attachment hardware were not recovered and were presumed consumed by postcrash fire, the left elevator control tab pushrod was recovered. Unlike the right control tab pushrod, the left control tab pushrod's aft rod end (normally attached to the tab crank fitting) was fractured and about 75 percent of it and its associated bearing were missing. The forward end of this pushrod was fractured at its rod end attachment holes, and the pushrod had about an approximately 90º bend at its midpoint. No fire damage was observed on the left control tab pushrod assembly.

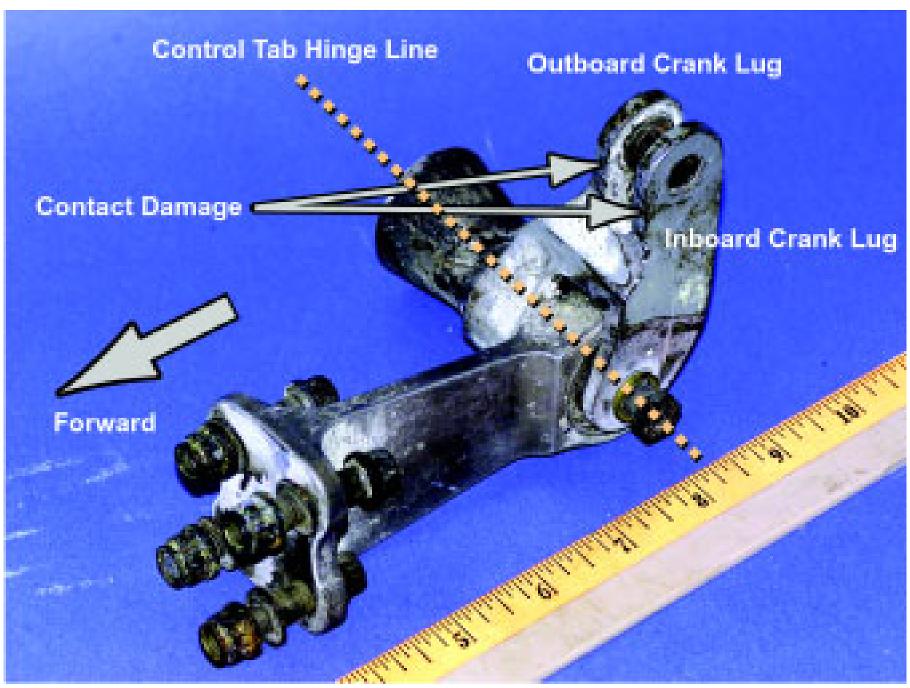


**Figure 9.** A photograph of the accident airplane's right elevator control tab crank fitting. Note damage on forward face of control tab crank fitting lugs.

[61] As previously stated, the hardware required to secure the elevator control tab pushrod to the tab crank fitting at this location includes a 5/16-inch drilled-shank alloy steel bolt, a washer, a steel castellated nut, and a cotter pin. The bolt has a rated shear strength of 7,300 pounds; if properly installed, the attachment hardware has a tensile strength of 3,250 pounds. The alloy steel hardware had a melting temperature of about 2,700º F, whereas the aluminum crank fitting and pushrod aft rod end had a melting temperature of about 1,000º F.

# 1.13 Medical and Pathological Information

## 1.13.1 Flight Crew Information

Tissue specimens from the captain, first officer, and flight engineer were sent to the FAA's Civil Aerospace Medical Institute in Oklahoma City, Oklahoma, for examination. The specimens tested negative for all drugs of abuse,[62] as well as prescription and over-the-counter medications.

## 1.13.2 Cargo Handlers—Postaccident Drug and Alcohol Testing

The FARs do not require postaccident drug or alcohol testing of cargo handlers. The provisions of 14 CFR Part 121, Appendix I, titled "Drug Testing Program," state the following:

> Each employer shall test each employee who performs a safety-sensitive function for the presence of marijuana, cocaine, opiates, phencyclidine (PCP), and amphetamines, or a metabolite of those drugs in the employee's system if that employee's performance either contributed to an accident or can not be completely discounted as a contributing factor to the accident. The employee shall be tested as soon as possible but not later than 32 hours after the accident. The decision not to administer a test under this section must be based on a determination, using the best information available at the time of the determination, that the employee's performance could not have contributed to the accident.

Additionally, the provisions of 14 CFR Part 121, Appendix J, titled "Alcohol Misuse Prevention Program," state the following:

> As soon as practicable following an accident, each employer shall test each surviving covered employee for alcohol if that employee's performance of a safety-sensitive function either contributed to the accident or cannot be completely discounted as a contributing factor to the accident. The decision not to administer a test under this section shall be based on the employer's determination, using the best available information at the time of the determination, that the covered employee's performance could not have contributed to the accident.
>
> If a test required by this section is not administered within 2 hours following the accident, the employer shall prepare and maintain on file a record stating the reasons the test was not promptly administered. If a test required by this section is not administered within 8 hours following the accident, the employer shall cease attempts to administer an alcohol test and shall prepare and maintain the same record. Records shall be submitted to the FAA upon request of the Administrator or his or her designee.

[62] The five drugs of abuse for which specimens are tested in postaccident analysis are marijuana, cocaine, opiates, phencyclidine, and amphetamines.

Appendixes I and J specify "safety-sensitive" functions to which the postaccident drug and alcohol testing requirements apply. These functions include the duties of flight crewmembers, flight attendants, flight instructors, aircraft dispatchers, aircraft maintenance or preventive maintenance personnel, ground security coordinators, aviation screeners, and air traffic controllers. Cargo handler duties are not included under "safety-sensitive" functions, nor are load planners or ramp supervisors.[63] Although testing was not required, voluntary drug tests were conducted on eight cargo handlers, the load planner, and the ramp supervisor who were involved with the cargo loaded on the accident airplane; all tests were conducted between February 17 and February 22, 2000. The load planner tested positive for amphetamines and was relieved of duties on February 25. A cargo handler who was tested on February 22 tested positive for amphetamines and cocaine metabolites and was relieved of duties on March 2, 2000.

## 1.14 Fire/Explosion

A fuel-fed fire occurred after impact.

## 1.15 Survival Aspects

The airplane was destroyed by impact and postimpact fire. According to the Sacramento County Coroner's Office, the captain and flight engineer died as a result of thermal and traumatic injuries, and the first officer died of thermal injuries and inhalation of combustion products.

## 1.16 Tests and Research

### 1.16.1 DC-8 Elevator Flight Control Tests

Using an Emery DC-8-71F that was equipped and had been operated similarly to the accident airplane, the Safety Board conducted tests to document the deflections of the test airplane's elevator, control columns, and control tabs (with the right elevator control tab disconnected from its pushrod) while the elevators were moved to duplicate a range of travel consistent with that recorded by the FDR from the accident airplane. The Board also conducted tests to determine the test airplane's EPI indication during elevator checks before taxi, during taxi, and at 80 knots during a simulated takeoff roll to identify what a flight crew might see at various elevator deflections under normal conditions.

[63] The Safety Board notes that on May 8, 2003, the FAA proposed rulemaking that would broaden its existing regulations regarding hazardous materials training by requiring such training for all personnel who might be involved in the handling of hazardous materials; this proposal reinforces the safety-sensitive nature of these functions.

During these tests, the Safety Board also examined the fractured geared tab crank arms and surrounding test airplane structure to determine whether the fractures might have occurred before the accident. For additional information regarding the geared tab crank arm fractures, see section 1.16.1.3. For information regarding other tests conducted, see Airworthiness Group Chairman's Factual Report, dated February 28, 2002, in the docket for this accident.

### 1.16.1.1 Disconnected Elevator Control Tab/Interference Tests

After the test airplane's baseline deflections were measured, investigators removed the right elevator control tab aft pushrod attachment bolt from its crank fitting. With no additional manual input, the right elevator control tab moved to a 29º TED deflection, where it contacted the geared tab linkage fairing. With this control tab movement, the aft end of the pushrod moved free of the crank fitting.

When the aft end of the test airplane's pushrod cleared the crank fitting, it shifted slightly inboard so that it was aligned with the inboard leg of the forward face of the crank fitting. When the test airplane's control tab was manually raised TEU (simulating the effects of aerodynamic forces that would be experienced during the takeoff roll), the crank fitting contacted the aft rod end, obstructing any attempt to further deflect the elevator control tab in the TEU direction. Figure 10 shows the test airplane's pushrod in this position.

**Figure 10.** Photograph of the test airplane's right elevator control tab pushrod contacting the crank fitting.

When the test airplane's elevator surfaces were manually moved to their TEU limit (about 27º TEU) in this condition, the control columns moved aft from 15.0º forward of vertical (the position in which they were held by the centering device) to about 8.8º forward of vertical, and both elevator geared tabs moved to 27.5º TED. The left elevator control tab deflected fully to about 8.5º TEU; however, the right elevator control tab could not be moved further in the TEU direction than 15.9º TED because of interference with the disconnected pushrod.

The test airplane's elevator surfaces were then moved manually to various TEU deflections (simulating the range of elevator travel that occurred during the accident flight), and measurements were taken to document the right and left elevator control tab deflections and control column positions at those elevator deflections. Based on the Safety Board's test and measurements, an average mismatch of 25º was noted between the left and right elevator control tabs (or about 8 inches of vertical separation if measured at the trailing edge), with TEU movement of the right elevator control tab restricted by contact between the pushrod and the crank fitting. This mismatch between the left and right elevator control tab positions existed regardless of elevator or control column position.

Because a free elevator control tab pushrod might not necessarily always displace itself inboard into alignment with the crank fitting as it did on the test airplane (especially if the pushrod is disconnected while the airplane is in flight and aerodynamic forces are acting on the flight control surfaces), the Safety Board examined other potential interference modes between a free elevator control tab pushrod and crank fitting. These tests revealed that in general, contact between a free pushrod and the forward face of either crank fitting lug (accounting for rod end misalignment, etc.) resulted in a mismatch of approximately 25º between the left and right control tabs. These tests also revealed that a disconnected control tab could be rotated about 3º to 4º in the TEU direction if the crank fitting remained centered about the pushrod; however, further movement was restricted by contact between the crank fitting and shoulders of the aft end of the pushrod. Figure 11 is a photograph of the test airplane's control tab in this position.

**Figure 11.** Photograph of the test airplane's disconnected right elevator control tab pushrod centered between the lugs of the crank fitting with the control tab rotated 3º to 4º in the TEU direction after the attachment bolt was removed.

### 1.16.1.2 EPI Indication Checks

The Safety Board also conducted tests to document the test airplane's elevator movements and the corresponding EPI indications during the 80-knot elevator check during a simulated takeoff roll.[64] During the 80-knot elevator check, the horizontal stabilizer trim was set to approximate the accident airplane's trim setting for takeoff. When the test airplane accelerated to 80 knots, the right seat pilot (provided by Emery) moved the control column to its maximum forward position; the EPI needle immediately deflected to a position about 45 percent of the distance between the neutral and nose-down index marks, corresponding to about 10º of TED elevator travel. The pilot then relaxed the forward pressure on the control column and rejected the takeoff. A review of the data recorded by the test airplane's FDR during this test confirmed an elevator deflection of about 10º.

[64] The EPI on the test airplane was located on the lower left side of the first officer's instrument panel, like that on the accident airplane. During these tests, the Safety Board noted that the EPI installed on the ground test airplane was not accurately calibrated such that when full down elevator was applied, the EPI needle moved about 75 percent of the distance between the neutral and nose-down marks.

### 1.16.1.3 DC-8 Elevator Geared Tab Crank Arm Fractures

As a result of several elevator jam events in which the jams were caused by interference from a fractured geared tab crank arm, in April 1977, Douglas issued Alert Service Bulletin (ASB) 27-262, titled "Flight Controls—Elevator and Tab—Inspect Elevator Geared Tab Mechanism and Gust Lock Crank Assembly." The ASB advised all DC-8 operators of an aborted takeoff incident that resulted from the failure of the elevator geared tab pushrods (inboard and outboard) and recommended that the elevator gust lock be engaged at all times when the airplane is parked to prevent elevator damage caused by high/gusting winds and/or jet blast.

In July 1977, Douglas issued SB 27-262, titled "Flight Controls—Elevator and Tab Modify Elevator Geared Tab Mechanism," which indicated that "replacing the existing aluminum geared tab crank assemblies with forged stainless steel crank assemblies and improving the crank assembly clearance will minimize the possibility of crank failure when the aircraft is parked in high gusty wind."

Subsequently, the FAA issued AD 78-01-15 (effective June 1, 1978), which required, in part, all DC-8 operators to modify the clearances in the elevator geared tab crank assembly in accordance with Douglas SB 27-262 and to inspect and replace fractured geared tab crank arms; however, it did not require DC-8 operators to replace all existing aluminum crank assemblies with stainless steel crank assemblies.

The Safety Board's review of DC-8 elevator-related service difficulty reports (SDR) submitted to the FAA during the 5 years preceding the Emery flight 17 accident revealed six SDRs involving fractured elevator geared tab crank arms. One of these was detected during an elevator ground check, one was detected in flight, and four were detected during elevator checks during the takeoff roll, resulting in aborted takeoffs. (Although the SDRs did not always reference an EPI gauge, it is likely that all airplanes involved were equipped with EPIs because AD 78-01-15 required DC-8 operators to install an EPI system within 18 months of the AD's June 1978 issuance unless an EPI had already been installed in accordance with SB 27-254.)

Additionally, the Safety Board investigated a December 12, 2002, aborted takeoff event involving a Tampa Airlines DC-8-71F that did not rotate/lift off normally during the takeoff roll.[65] According to Tampa Airlines personnel, the pilots performed an 80-knot elevator/EPI check and observed that the EPI did not respond to the control column. The pilots indicated that they aborted the takeoff when the airplane failed to rotate normally once it reached rotation speed. Subsequent examination revealed that the elevator jammed because the inboard and outboard aluminum crank arm assemblies on the left geared tab had fractured (which Tampa Airlines personnel believed to be the result of jet blast from a DC-10 while the DC-8 was waiting to takeoff).

[65] This anomalous behavior is consistent with an elevator jam/restriction in a position near or below neutral.

Because the Emery accident airplane's elevator geared tab inboard crank arms were found fractured and because interference from such a fracture could have resulted in restricted movement of the elevators, the Safety Board evaluated the fractures on the recovered right elevator geared tab inboard crank arm from the accident airplane relative to the surrounding structure on a test airplane to determine the possible effects of various interference modes. Investigators installed the forward end of the accident airplane's fractured right elevator geared tab crank arm to the link assembly on the horizontal stabilizer rear spar on the test airplane. Tests on this airplane and further examination of the accident airplane wreckage revealed no evidence of damage on the horizontal stabilizer or the right geared tab crank arm itself that was consistent with any observed interference position.

## 1.16.2 Airplane Performance Studies

### 1.16.2.1 Center of Gravity Calculations

Because the Emery flight 17 accident involved a nose-up pitch anomaly,[66] the Safety Board conducted an airplane performance study to evaluate whether an aft c.g. problem was involved in the accident. The Safety Board extracted the aerodynamic forces and moments that acted on the airplane to produce the recorded aircraft motion then used the pitching moment and lift to calculate the accident airplane's pitch stability, which can be related directly to c.g. The study concluded that the basic stability of the aircraft during the accident flight was consistent with a c.g. within the c.g. limits.[67] The study also found that the airplane's motion was consistent with elevators in a highly deflected nose-up position.

### 1.16.2.2 Elevator Control Tab Deflection Study

Although the FDR recorded the elevator position, it did not record the left and right elevator control tab positions. Therefore, the Safety Board conducted an airplane performance study (assuming a disconnected right control tab) to determine which position(s) of the right[68] control tab would match the elevator positions and airplane motions recorded during the accident flight. To determine the left elevator control tab's position during the accident flight, investigators used the recorded control column and elevator position data and the known relationship between the control tab, the control column, and the elevator on a properly functioning system.

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[66] Potential indications of an aft c.g. problem included the first officer's statement, recorded by the CVR almost immediately after takeoff, that the airplane's c.g. was "way out of limits" and FDR data showing excessive nose-up pitching and unusual elevator positions.

[67] Further, the Safety Board's review of the loading reports and dispatch records for the accident flight, examination of the airplane wreckage, and postaccident statements from cargo loading personnel revealed no evidence indicating that the airplane was improperly loaded or that a c.g. shift occurred.

[68] The performance study could not differentiate between failures of the right or left control tab. However, a disconnected right elevator control tab was assumed because physical evidence (for example, the missing aft pushrod attachment bolt at impact) indicated that the accident airplane's right elevator control tab linkage was disconnected.

The results of this portion of the performance study were consistent with a left elevator control tab at or near its TEU stop throughout the accident flight. The performance study further indicated that the right control tab position required to match the recorded elevator position and airplane motion with a left control tab deflected fully TEU was about 17º TED to 25º TED. The results of the study were consistent with a 25º to 33º difference between the left and right control tab positions when the left control tab was at its TEU stop. As previously discussed, physical testing with a fully functioning and responsive left control tab and a disconnected right control tab, with movement restricted by contact with the free end of the control tab pushrod (see figure 10), showed a differential between the left and right control tabs of about 25º at all control column positions. The results of the performance study were consistent with a large split between the left and right control tabs, which is consistent with the physical evidence.

### 1.16.2.3 Control Column and Elevator Position Data

The FDR data showed that the control columns were positioned forward of their neutral position throughout most of the accident flight, and the airplane performance study showed that the flight crew maintained a forward force on the control column throughout the accident flight. The performance study also indicated that the left control tab was at its TEU physical stop throughout most of the accident flight. After the control column moved forward to the point where the left control tab's TEU stop was reached, the pilots could force the control columns further forward because of cable stretch; however, no additional nose-down elevator input would result.

Figure 12 shows the control column position required for the left elevator control tab to reach its TEU physical stop (with no cable stretch) and the recorded control column position for the recorded elevator position during the accident flight. The plot indicates that at most points during the accident flight, the flight crew was trying to command additional forward control column.

The Safety Board's examination of the FDR data for the flights preceding the accident flight revealed that a change in the relationship of control column movement to elevator response occurred about 8 minutes and 20 seconds before the accident airplane landed at MHR. The Board's performance study derived the control tab positions at the time of this change. The study showed that the change in FDR data could be explained by a shift of about 3º to 4º in the TEU direction of the right control tab, assuming that the right control tab's pushrod to crank fitting attachment bolt separated at this time. This change in the FDR data was evident until the airplane landed at MHR. As previously discussed, a scenario in which a disconnected pushrod remained between the lugs of the aft crank fitting (shown in figure 11) resulted in a 3º to 4º control tab shift in the TEU direction.

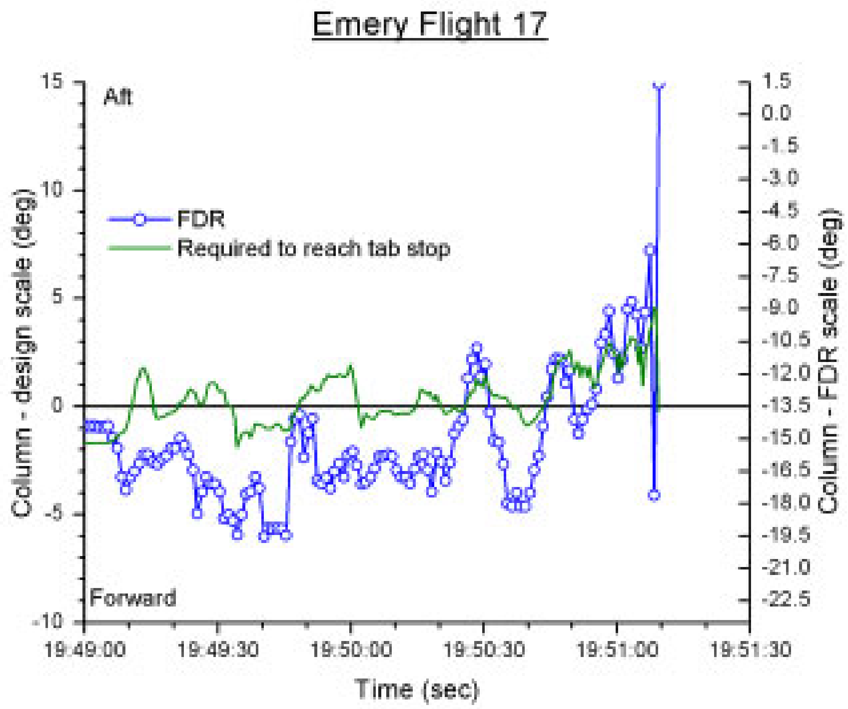


**Figure 12.** The control column position required for the left elevator control tab to reach its TEU physical stop (for the recorded elevator position) and the actual recorded control column position for the accident flight.

The study also showed that the stabilizer moved in an ANU direction at the same time that the pilot pushed the control column forward to resume the descent after a brief period of level flight at 10,000 feet. The direction of this stabilizer movement was opposite that which would be expected when the pilot provided a forward control column input. The study showed that the slight ANU stabilizer shift balanced the effect of the change in the relationship between the recorded elevator and control column movements and that the elevator remained responsive to pilot input. Figure 13 shows plots of the control column and elevator for the accident takeoff roll and the previous takeoff roll (from RNO).

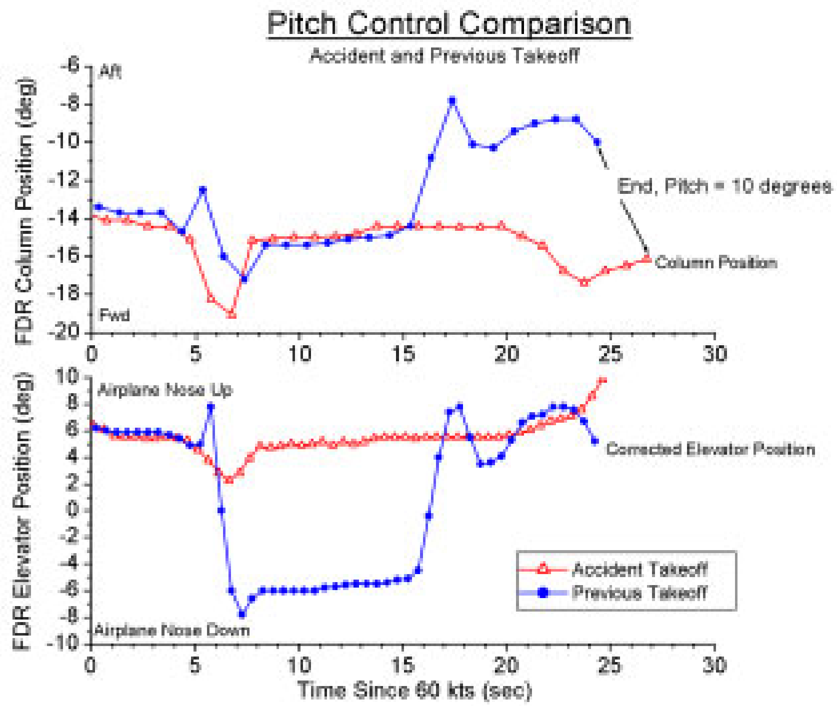


**Figure 13.** Plots of the control column and corrected elevator position recorded by the accident FDR during the accident takeoff roll and the previous takeoff roll (from RNO).

## 1.17 Operational and Management Information

### 1.17.1 Emery Worldwide Airlines, Inc.

Emery received its initial air carrier certification in May 1987 under the name of Air Train, Inc. When Emery began operating, its corporate offices were located in Redwood City, California, and its hub operations were located at DAY. In January 1990, the company name was changed to Emery Worldwide Airlines, Inc. Emery held air carrier certificate number RRXA558B and was authorized to conduct operations in accordance with 14 CFR Part 121, as a domestic and international airfreight carrier. Emery relocated its corporate offices from Redwood City to DAY in 1990. However, the FAA oversight responsibility for the airline remained with the San Jose Flight Standards District Office (FSDO) until December 1999, when Emery's certificate was transferred to the FSDO in Cincinnati, Ohio. At the time of the accident, Emery operated 43 DC-8 and 2 DC-10 freighters, with most of its airplanes based at its main hub and corporate headquarters at DAY.

The FAA's August 13, 2001, news release indicated that in January 2000, about a month before the accident, the FAA placed Emery under a "heightened state of oversight" because several inspectors reported observing numerous apparent violations of the FARs. After more than 1 1/2 years under this heightened oversight, on August 13, 2001, Emery signed an interim agreement with the FAA stating that it would immediately cease operating until it satisfactorily resolved the safety issues identified by the FAA during a series of inspections.[69]

According to the FAA's news release regarding the interim agreement:

> Emery…has been under a heightened state of oversight by the FAA since January 2000. The FAA has conducted several special inspections of the airline, most recently in May and June. Those inspections uncovered more than 100 apparent violations of the Federal Aviation Regulations, including:
>
> - Improper/inadequate repairs to mechanical irregularities, including numerous repetitive pilot write-ups of the same problem on the same aircraft over extended time periods;
> - Unapproved aircraft installations/alterations;
> - Operating unairworthy aircraft;
> - Not following the policies and procedures in their manuals;
> - Inadequate record keeping;
> - Failure to distribute and use current manuals.

The interim agreement indicated that a final settlement agreement must be signed within 30 days of the interim agreement. On September 17, 18, and 19, 2001, Emery and FAA representatives signed the final settlement agreement, stating that both parties would "use their best efforts…to conclude the process described [in the agreement—including disposition of aircraft and other assets, etc.], on an expedited basis." However, Emery and FAA representatives subsequently signed an amendment (dated December 4, 2001) to the final settlement agreement, which indicated that Emery had informed the FAA that it did not wish to resume commercial air carrier flight operations and that it intended to dispose of its airplanes. On December 4, 2002, in accordance with the December 2001 agreement, Emery returned its operating certificate to the FAA.

#### 1.17.1.1 Emery's MMs and Practices

Emery's continuous airworthiness maintenance program was governed by a series of manuals, including the maintenance policy and procedures manual (MPPM), the reliability program manual, the inspection program manual, the time limits manual, maintenance manuals from the airplane's former operators, the manufacturer's maintenance manual, the structural repair manual, original equipment manufacturer manuals, the fueling manual, the minimum equipment list (MEL) manual, FAA-approved STCs, the airplane flight manual, and the airplanes' weight and balance documentation.[70]

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[69] For additional information regarding the FAA's inspections of Emery, see section 1.17.3.1.

More than 300 full-time mechanics who worked at various Emery facilities at the time of the accident performed airplane transit, terminating, service, and B inspections. Emery used contract repair facilities (including TTS) for heavy maintenance (C and D inspections) and major alterations of airframes, aircraft engines, and other components. A list of approved overhaul and repair facilities was contained in Emery's MPPM.[71]

### 1.17.1.2 Operational Guidance Regarding the DC-8 Elevator

#### 1.17.1.2.1 Emery's DC-8 Preflight Inspection Procedures

Emery's DC-8 Aircraft Operating Manual (AOM), "Normal Operations," stated, in part, the following regarding the flight engineer's preflight inspection:[72]

**Initial exterior inspection, elevators and tabs – with gust lock on**

Elevators……………………………………………………………CHECK
Ensure elevators locked in faired position (gust lock on). If the gust lock is not on, contact maintenance for possible inspection requirement.

**Initial pilots' station preflight**

Gust lock……………………………………………………………………OFF

**Exterior preflight, elevators and tabs**

[Left and right side] elevators…………..TAB ALIGNMENT AND CONDITION
With gust lock off, elevator should be up, control tabs up, and geared tabs down.

---

[70] Title 14 CFR Part 121.369(b), states, in part, "the certificate holder's manual must contain the programs required by §121.367 that must be followed in performing maintenance, preventive maintenance, and alterations of that certificate holder's airplanes, including airframes, aircraft engines, propellers, appliances, emergency equipment, and parts thereof and must include the following…a designation of the items of maintenance and alteration that must be inspected (required inspections), including at least those that could result in a failure, malfunction, or defect endangering the safe operation of the aircraft, if not performed properly or if improper parts or materials are used… [and] procedures to ensure that all required inspections are performed."

[71] According to Section 121.363, "Responsibility for airworthiness:"

(a) Each certificate holder is primarily responsible for –

(1) The airworthiness of its aircraft, including airframes, aircraft engines, propellers, appliances, and parts thereof; and

(2) The performance of the maintenance, preventive maintenance, and alteration of its aircraft, including airframes, aircraft engines, propellers, appliances, and parts thereof, in accordance with its manual and the regulations of this chapter.

(b) A certificate holder may make arrangements with another person for the performance of any maintenance, preventive maintenance, and alterations. However, this does not relieve the certificate holder of the responsibility specified in paragraph (a) of this section.

Horizontal stabilizer and elevator……………………………………..CHECK
Check between trailing edge of stabilizer and elevator for foreign objects, ice or snow. Check all access plates for security. Check condition of static dischargers.

#### 1.17.1.2.2 Emery's DC-8 Flight Control Operational Checks

Emery's DC-8 AOM section titled "Ground Operations, Taxi Procedures," dated November 15, 1995, contained the following guidance regarding elevator checks:

> After the ailerons and rudder are checked, the captain and the first officer will check the elevator together. It is important that both pilots exert pressure on their yokes [control columns] to prevent excessive stress on either yoke. The normal indication of the [EPI] when the gust lock is off shows the elevator full nose up. If there is a strong headwind or a substantial amount of power is coming from the engines, [the EPI] may indicate a position between full nose up and neutral.
>
> To check the elevator, both pilots will push forward on their respective yokes until they reach the forward stop. This will require a substantial force, especially if there is a tailwind. The first officer should monitor the EPI during the check. When the yokes are full forward, expect to see the EPI indicate between neutral and very slightly nose up. Then both pilots should pull the yokes to the aft stop; expect to see the EPI move to full nose up.

Additionally, in its section titled "Normal Operations, Taxi Checklist," dated October 25, 1999, Emery's DC-8 AOM stated the following:

> Check control freedom about all three axes. Aileron and rudder reversion light should remain off during the check. When checking the ailerons, check for spoiler pressure drop indicating spoiler operation. The first officer should call out "EPI checks" after the elevator check.

Further, the Emery DC-8 AOM section titled "Normal Operation, Flight Control System, Elevator—Elevator Position Indicator Operative—Captain and First Officer (Perform Check Together)," dated May 1, 1989, stated the following:

- Ensure that gust lock is disengaged.

  Disengagement of the gust lock should cause the following:

A. The elevators will move to command aircraft nose-up condition (trailing edge up), due to their static balance characteristics.

B. The elevator control tabs will have trailing edge up.

C. The…control column moves slightly aft.

[72] Postaccident interviews confirmed that the flight engineer conducted at least one preflight walkaround inspection of the airplane. The Safety Board reviewed the CVR and FDR information to further document the preflight inspections; however, such documentation was not possible because electrical power to the recorders was interrupted for about 50 of the more than 60 minutes that the airplane was parked on the ramp at MHR.

D. The elevator position indicator should move to the "UP" mark.

- Pull control column aft until it reaches full travel against the [aft] stop.

  The [EPI] needle will remain pointing to the UP mark. The elevator control tabs will move to command aircraft nose up condition (trailing edge down). The force required to position the control column aft will be relatively light, since the elevators already have their trailing edge up and only the control tabs are being deflected. Variations of required force may, however, be expected, contingent upon wind conditions.

- Push control column forward until it reaches full travel against [the forward] stop.

  Barring unusual wind conditions, the force required on the control column is initially light while only the control tabs are being deflected to command aircraft nose-down condition (tabs trailing edge up). The control tabs having reached their full throw, a substantial increase in required force to move the control column can be noted as the elevator itself deflects to a trailing edge down condition.[[73]] The elevator position indicator needle should now point between the [neutral] mark and the [down] mark. Movement of the elevator's trailing edge to the full down position is not possible. Therefore, the position indicator needle will not reach the [down] mark. Freedom of the elevator to move is established by the indicator needle moving from the UP mark to a position just more than half-way between the [neutral] mark and the [down] mark.

  NOTE: If tailwinds prevail during control check and no elevator movement is indicated, turn the aircraft into the wind and repeat this procedure.

Emery's DC-8 AOM section titled "Takeoff, General, Takeoff Roll," dated November 11, 1995, contained the following guidance regarding the 80-knot elevator check:

> Between 80 and 100 knots, the pilot flying shall exert a forward pressure on the elevator to the stop and then release the yoke to slightly forward of neutral. The crew should confirm a nose down response. Depending on weight and loading, the pilot flying may need to apply the nose down elevator more than once to get a satisfactory response. Once the check is complete the pilot flying should state, "Elevator checks." The first officer looks for the EPI to respond to yoke movement when the elevator check is made. The captain must know the elevator is working properly early in the takeoff roll. If he is in doubt, he should consider aborting the takeoff.

[73] During the Safety Board's public hearing on this accident, the chief pilot for Boeing's Douglas Product Division stated that forces up to about 100 pounds could be required to move the control column as specified during this check.

In addition, this section of the DC-8 AOM contained a table titled “Takeoff Roll—Callouts or Duties of Flight Crew” that included the following guidance regarding pilot duties during and after the 80-knot check:

**Table 2.** Takeoff Roll—Callouts or Duties of Flight Crew (from DC-8 Aircraft Operating Manual).

| | Captain | First Officer | Pilot Not Flying | Pilot Flying |
|---|---|---|---|---|
| **At 80 [knots indicated airspeed]** | Watch for nose strut compression. | Watch EPI during the elevator check. | 1. Callout “80 knots” | 1. Callout “80 here”<br>2. Push forward on the yoke<br>3. Callout “elevator checks” |

#### 1.17.1.3 Manufacturer’s Guidance Regarding Flight Control Operational Checks

As previously mentioned, on March 5, 1975, Douglas issued SB 27-254, titled “Flight Controls – Elevator and Tabs – Install Position Indicator,” which recommended that operators install an EPI and associated transmitters and circuitry in their DC-8s to help flight crews detect restricted elevator movement. Douglas indicated that the SB was issued because of two instances of insufficient or abnormal elevator travel that were discovered by flight crews during preflight checks.[74] SB 27-254 instructed DC-8 operators to install the EPI on the first officer’s instrument panel, in a location selected by the operator, such that the first officer’s view of the indicator was not obstructed by the full forward position of the control column.

Another Douglas ASB (SB A27-264, issued on May 14, 1977) stated “Douglas is of the opinion that had [SB] 27-254…been accomplished on the aircraft involved, flight crews would have determined that the elevator surfaces were not moving normally. Therefore, Douglas strongly recommends prompt incorporation of DC-8 [SB] 27-254.” With regard to flight control checks, the SB stated the following:

> If it is not possible to check the elevator control with the aircraft turned into the wind, an optional procedure can be used during the initial takeoff roll (60 – 80 knots) by checking the response of the aircraft in relation to small up and down elevator inputs. The optional procedure should not be used when the takeoff is made on wet or icy runways or when moderate crosswind conditions exist. Incorporation of SB 27-254 constitutes terminating action for this alert Service Bulletin.

[74] The SB was also partially responsive to Safety Recommendation A-70-54, which the Safety Board issued on October 28, 1970, as a result of the September 8, 1970, accident involving a Trans International Airlines Corporation DC-8-63, which crashed during takeoff from John F. Kennedy International Airport. See section 1.6.2.2 for further discussion of this accident.

Subsequently, the FAA issued AD 78-01-15 (effective June 1, 1978), which required all DC-8 operators to install an EPI system in accordance with Douglas SB 27-254.

On June 4, 2001, as a result of the Emery flight 17 accident, Boeing issued a FOB, restating the recommendations contained in the DC-8 AOM and SB A27-264 for the elevator portion of the preflight control check. Specifically, the FOB stated the following:

> The proper functioning of the flight controls should be verified before every flight. If the exterior walk-around is made with the gust lock engaged, the flight crew should verify that the elevators and the tabs are faired, and that the Elevator Position Indicator (EPI) indicates in the white neutral band. If the check is made with the gust lock released, the elevators and control tabs should be positioned toward UP (symmetrically) and the geared tabs DOWN (again symmetrically). Then, during the flight control rollout check elevator function should be verified by first applying full up elevator and confirming that the needle on the EPI moves in the UP direction; followed by full down elevator to the [control] column mechanical stop and verifying that the needle moves through the faired position to a point below the white band. Because the elevator system's viscous dampers resist rapid surface movement, flight crews should be aware that rapid application of full forward [control] column, followed by an immediate release, is not an effective check in that the [control] column release will interrupt elevator travel well short of its limit travel. Also, since the forces on the [control] column during these checks are high, Boeing recommends that a downward (forward) force be applied to both columns by both pilots simultaneously.
>
> Service Bulletin A27-264 (issued May 14, 1977 and mandated by AD 78-01-15), and "Know your DC-8" letter No. 53A, issued on May 25, 1977, state that if the [elevator control] checks cannot be made into the wind such that satisfactory elevator movement is verified, an optional procedure to check for airplane response to small up and down elevator movements during initial takeoff roll (60-80 knots) was allowed. Upon reviewing this procedure with the FAA, Boeing has determined that although the pitch response may still be useful as a check for weight distribution, it is not a valid substitute for a properly conducted flight control check as described above. Boeing no longer recommends it as an alternative to the rollout check. Operators who wish to continue the 60-80 knot check may do so, but are advised that the only acceptable alternative to a satisfactory flight control check is a positive visual check.[[75]]

#### 1.17.1.4 Emery's Postaccident Fleetwide Campaign Directive

After discussions with Safety Board investigators, on March 16, 2001, Emery issued FCD A27-8, titled "Elevator Push/Pull Rod End Bolt Installation Inspection," to ensure that on each of the 29 DC-8s Emery operated at the time, the elevator control tab pushrods were properly installed and secured at the crank fitting with a bolt, washer, nut, and cotter pin. The FCD also called for inspections of Emery's DC-8 fleet for damage to

[75] According to ASB A27-264, subpart E, this alternative was only acceptable on airplanes on which the EPI was inoperative.

the pushrod and orientation of the bolt used to attach the aft end of the pushrod to the control tab crank fitting.

On March 22, 2001, Emery issued FCD A27-8, Revision 1, titled "Elevator Push/Pull Rod End Bolt Installation Inspection and Clearance Check," which was required to be accomplished on the Emery DC-8 fleet no later than April 12, 2001. Revision 1 to FCD A27-8 changed the part number of the bolt and corrected a figure. It also added a parts list and extended the time limit to accomplish the FCD by 10 days. The title was also changed to reflect the clearance check not incorporated into FCD A27-8.

The findings from the inspections that followed the issuance of FCD A27-8 indicated that the attachment hardware, including cotter pins, were installed at the forward and aft ends of each control tab pushrod on each airplane in Emery's DC-8 fleet. Although orientation of the pushrod attachment bolts was not consistent across Emery's fleet or from one side to the other on some airplanes, the manufacturer has indicated that orientation of the bolt is not critical if the bolt is properly installed and secured. One control tab pushrod was found installed incorrectly, and three control tab pushrods were replaced because of wear and/or suspected damage.

## 1.17.2 Tennessee Technical Services

TTS, located in Smyrna, Tennessee, has been an FAA-approved 14 CFR Part 145 Repair Station since May 29, 1998, when it was issued Air Agency Certificate number T64R1640. TTS's certificate was reissued on January 26, 2000, with the following limited ratings: airframe, powerplant, accessories, radio, instrument, non-destructive testing, and specialized services. This certificate allowed TTS to perform inspections, maintenance, modifications, and alterations on several airplane models, including DC-8-50/-60/-70 airplanes. TTS's certificate stated that all work was to be accomplished in accordance with the customer's 14 CFR Part 121 requirements for continuous airworthiness per 14 CFR Section 145.2, the manufacturer's current technical data, or other data acceptable to the FAA administrator.

In October 1998, upon successful completion of an Emery audit, TTS was added to Emery's list of approved repair stations/vendors. TTS performed a variety of services for Emery, including heavy maintenance, special maintenance services (such as lighter maintenance [B] inspections, off-site maintenance assistance with ramp checks and ramp damage, and short- and long-term airplane storage), and off-base maintenance support for Emery. At the time of the Safety Board's review of TTS facilities in 2001, TTS operated from a hangar that would accommodate four DC-8 airplanes and from another building in which it overhauled various components. Examination of TTS records indicated that from the time the company began operating as a repair station until March 1, 2001, TTS had performed maintenance on 173 airplanes, including many of Emery's airplanes (TTS records contained 99 invoices for Emery airplanes).

At the time of the accident, TTS employed about 91 certificated mechanics and 3 repairmen. Emery had designated 20 TTS inspectors to work on its airplanes.[76] TTS was awarded the FAA's "Diamond Certificate of Excellence Award" in 1998, 1999, 2000, and 2001, for actively participating in the FAA Aviation Technician Training Program.[77] The Board's review of the training records for the mechanics that participated in the installation of the elevator assembly on the accident airplane during its most recent D inspection revealed no discrepancies.

### 1.17.2.1 Reference Documents/Maintenance Manuals Provided by Emery

TTS and Emery personnel indicated that when TTS maintenance personnel worked on Emery's DC-8s, they followed the guidance on the work cards provided by Emery. However, the work cards provide only general guidance regarding the steps involved in a procedure and typically referred the mechanic to other DC-8 documents or manuals for more specific guidance regarding procedures and/or components. In accordance with its MPPM and FAA requirements, Emery provided TTS with pertinent DC-8 manuals and documents, including the Douglas Master DC-8 MM; the Douglas DC-8 Aircraft OHM; the Douglas DC-8 IPC, 60/70 series; and temporary revisions to manuals, as applicable, when Emery added TTS to its list of approved maintenance facilities. Emery also provided TTS with the DC-8 MM and IPC that were applicable for the accident airplane.[78]

According to TTS personnel, mechanics working on the accident airplane would have used the United Airlines DC-8 MM as the primary reference for their work cards, using other available manuals and documents to augment as necessary. TTS personnel indicated that there is no consolidated list/description for these manuals and documents; however, because of their experience, mechanics would know that the manuals and documents existed and would know the information each item contained.[79] According to TTS personnel, if a mechanic did not know about all the available reference materials, his lead mechanic/supervisor would.

The Safety Board's examination of the documents and manuals available to TTS revealed that the DC-8 MMs provided by Emery did not contain detailed drawings, lists, or other specific instructions indicating the hardware and actions required for the proper installation and securement of the pushrod attachment bolt connecting the elevator control

[76] When Emery added TTS to its list of approved repair stations/vendors, Emery sent quality control representatives to TTS to train TTS inspectors regarding Emery's procedures and processes. The Emery-trained TTS inspectors were then the only inspectors designated to work on Emery's airplanes.

[77] In an attempt to improve the training of maintenance technicians and employers, the FAA set up an award-oriented training program that maintenance technicians and organizations could participate in voluntarily. The "Diamond Award" is the highest recognition from the FAA for technicians and employers that participate in available initial and recurrent maintenance training courses. According to TTS management personnel, the company designed its training program around the FAA's program.

[78] Emery's DC-8 MM for the accident airplane was formerly a United Airlines DC-8 MM.

[79] According to postaccident interviews and information contained in the TTS party submission for this investigation, the TTS workforce was very stable. All maintenance personnel who performed work on Emery's DC-8s had years of experience working on DC-8s (the lead mechanics and inspectors who worked on the accident airplane had between 20 and 40 years of maintenance experience, mostly on DC-8s), and all such work was performed under the oversight of at least one Emery technical representative.

tab pushrod to the tab crank fitting. The DC-8 IPC provided by Emery identified the control tab crank/pushrod attachment point hardware except for the cotter pin. The DC-8 OHM provided by Emery did contain such information.

#### 1.17.2.2 TTS DC-8 Elevator Control Tab Inspection Memorandum

On October 24, 2001, based on information learned during this investigation, the TTS Director Of Quality Assurance issued a memorandum to all inspection personnel, requiring them, on an ongoing basis, to remove the inboard fairings on the right and left elevator control tabs on all DC-8s. The memorandum instructed personnel to do the following before an airplane leaves the facility:

- Ensure that the correct hardware, per aircraft effectivity, is installed and properly safetied on each control tab pushrod to drive crank fitting. Use the appropriate Illustrated Parts Catalog.
- Ensure that the bolt is installed with the head of the bolt being inboard, as illustrated in the Douglas Overhaul Manual 27-16-1, page 13/14.
- Any discrepancies will be documented and corrected prior to the airplane departing our facility.

### 1.17.3 FAA Oversight of Emery Worldwide Airlines' Certificate

FAA oversight responsibility for the company's certificate was located with the San Jose FSDO until December 1999, when Emery's certificate was transferred to the Cincinnati FSDO.[80] Because the transfer of FAA oversight responsibility occurred about 2 months before the accident, investigators interviewed FAA personnel at the San Jose and Cincinnati FSDOs during this investigation.

The San Jose FSDO principal operations inspector (POI) indicated that most of the violations and issues discovered during the inspections conducted by that FSDO were maintenance/airworthiness related; he did not remember any specific operational changes as a result of these inspections. Emery's POI from the Cincinnati FSDO indicated that managing Emery's certificate was a heavy workload; he stated that he interacted frequently with Emery management personnel at DAY, oversaw the rewriting of several of Emery's manuals, and was extremely busy conducting checkrides.

The San Jose FSDO principal maintenance inspector (PMI) was responsible for the Emery certificate from September 1997 until the certificate was transferred in December 1999. He stated that he thought FSDO personnel were working productively with Emery personnel to address ongoing maintenance issues, including repetitive

[80] According to Emery personnel, the company requested that the certificate be transferred from the San Jose FSDO because that FSDO was unable to provide adequate checkride support. According to FAA personnel, the oversight responsibility was reassigned to the Cincinnati FSDO because that FSDO was closer to Emery's corporate offices and main base of operation and, thus, was better able to support/oversee the air carrier.

write-ups and instances of possible improper maintenance sign-offs. However, he characterized Emery as a "troubled carrier," adding that "[t]here were a lot of issues."

When the Emery certificate was transferred, Cincinnati FSDO PMI personnel met with the San Jose FSDO PMI to become familiar with the issues involved with management of Emery's certificate. Further, in January 2000, the Cincinnati FSDO conducted a Regional Aviation Safety Inspection Program (RASIP) inspection of Emery to evaluate the company. (For additional information regarding this RASIP, see section 1.17.3.1.) The Cincinnati FSDO PMI noted that of the 98 initial findings, 81 were maintenance related.

### 1.17.3.1 FAA Inspections of Emery

Before the accident, the FAA conducted the following inspections of Emery: a National Aviation Safety Inspection Program (NASIP) inspection in June 1992; a RASIP inspection in June 1995;[81] a focused RASIP in February 1999,[82] and another RASIP inspection in January 2000. The FAA also conducted several postaccident inspections of Emery, including a surveillance inspection from May 11 to May 18, 2000; another RASIP inspection from October 16 to November 2, 2000; and a logbook review inspection in May/June 2001.[83]

The NASIP inspection, conducted June 8 to 26, 1992, resulted in 50 findings, 24 of which were maintenance-related, including multiple findings in the following areas: manuals and procedures (3 findings), records systems (2 findings), contractual agreements (5 findings), and MEL/deferred maintenance (3 findings). Several of these findings cited improper maintenance manual revisions. Other findings cited lengthy periods of operation with a maintenance discrepancy, inadequate corrective actions for repetitive flight crew write-ups in aircraft maintenance logbooks, and inconsistent/conflicting guidance in maintenance manuals. There were no discrepancies noted in Emery's maintenance training program.

The RASIP inspection conducted June 12 to 23, 1995, resulted in 18 findings, 12 of which were maintenance related, including multiple findings in the following areas: maintenance facilities (5 findings), training programs (2 findings), and maintenance manuals and procedures (3 findings). Specific maintenance-related findings included use

[81] A RASIP is initiated by the FAA regional office with oversight responsibility for the operator being inspected and involves FAA personnel from that region, whereas a NASIP is initiated by FAA headquarters and involves both FAA headquarters and regional personnel. NASIP inspections are generally lengthier, involve more inspectors and are, therefore, more thorough than RASIP inspections. NASIP and RASIP inspections are conducted to evaluate whether an operator is in compliance with all applicable FARs, approved company procedures and policies, and other written FAA guidance.

[82] The San Jose FSDO POI stated that a focused RASIP is one in which the inspectors look at specific areas within the airline. During the 1999 focused RASIP, the FAA examined loading procedures and the condition of unit loading devices (ULD). This focused RASIP resulted in 21 findings, 18 of which were maintenance related (including manuals/procedures, deferred maintenance, and maintenance program findings). There was no evidence to indicate that loading procedures and ULD condition were involved in this accident.

[83] Emery's responses to the FAA's NASIP/RASIP findings are in the docket for this accident.

of an unapproved/unaccepted "part number cross reference" manual and an out-of-date MPPM in the stores area, an unqualified company technical representative, an untrained company technical representative, and Emery's use of contract facilities not listed in the then-current MPPM.[84]

The FAA indicated that the RASIP conducted from January 18 to 28, 2000, was intended to evaluate the condition of the Emery certificate when it was transferred from the San Jose FSDO to the Cincinnati FSDO. This RASIP resulted in 98 findings, 81 of which were maintenance related. There were multiple findings in many areas, including the following: operations manuals and procedures (4 findings), maintenance manuals and procedures (11 findings), training program (6 findings), MEL/deferred maintenance (3 findings), reliability program (7 findings), and maintenance inspection system and required inspection items (9 findings). The report on this inspection noted that some company manuals had not been properly updated, instructions in manuals were not always followed, there was no AD compliance list, there was no traceability on C inspection work cards for non-routine items, Emery's maintenance training program lacked sufficient formal training courses, and maintenance logbook entries were inadequate (specifically, they lacked detailed descriptions of work performed and/or lacked a reference for compliance).

### 1.17.3.2 FAA Inspection of TTS

The FAA conducted a RASIP inspection of TTS between February 14 and 18, 2000. The RASIP focused on management and administration, certificate and operation specifications, manuals and procedures, training program, records system, maintenance facilities, contractual arrangements, AD compliance, maintenance inspection system and required inspection items, mechanical reporting procedures, major repair and alteration conformity, aging aircraft program, and part traceability and documentation. The FAA's RASIP inspection report, dated July 25, 2000, noted findings in the following areas: manuals and procedures (1 finding), records systems (5 findings), maintenance facilities (4 findings), and maintenance inspection system and required inspection items (2 findings). The report indicated that all findings had been closed satisfactorily.[85] The RASIP inspection report indicated that the FAA reviewed a random sample of training files for 10 mechanics and 10 inspectors for proper training and authorizations and that no discrepancies were noted in this area.

[84] TTS was listed in Emery's MPPM.

[85] The TTS employee numbering system was clarified and an explanatory memorandum was issued; information regarding proper maintenance documentation and signoffs was disseminated; lapses in parts documentation were corrected; shop test stand instruments were calibrated; and calibration of precision tools in the shop was confirmed.

# 1.18 Additional Information

## 1.18.1 Design and Certification of DC-8 Elevator System

As previously discussed, the DC-8 was originally type-certificated in 1959 under CAR 4b (dated December 31, 1953). (The DC-8 type certificate [TC No. 4A25] was amended on April 13, 1982, to include DC-8-71F model airplanes.) For example, CAR Section 4b.320, "Control Systems, General," states the following:

> [A]ll controls and control systems shall operate with ease, smoothness, and positiveness appropriate to their function. The elements of the flight control system shall incorporate design features, or shall be distinctively and permanently marked to minimize the possibility of incorrect assembly which could result in malfunctioning of the flight control system. Tab control systems shall be such that disconnection or failure of any element…cannot jeopardize the safety of flight.

CAR Section 4b.303, "Standard Fastenings" (the predecessor to FAR 25.607), states, "self-locking nuts shall not be used on bolts which are subject to rotation in operation." FAR 25.607[86] states, in part, the following:

> (a) Each removable bolt, screw, nut, pin, or other removable fastener must incorporate two separate locking devices if –
>
> (1) Its loss could preclude continued flight and landing within the design limitations of the airplane using normal pilot skill and strength; or
>
> (2) Its loss could result in reduction in pitch, yaw, or roll control capability.

In its submission on this accident, Boeing stated that a failure/disconnection of the control tab crank fitting/pushrod attachment was considered by the manufacturer and the FAA during DC-8 development and certification. The submission noted, however, that "the TED [control] tab motion and the subsequent [push]rod end escape from between the crank [fitting] lugs was a mode that had not been anticipated, nor had it been experienced prior to this accident."

Boeing indicated it has "begun developing an enhanced design of the control tab pushrod that will prevent the pushrod from dropping or otherwise moving in front of the control tab crank should the bolt migrate out of the connecting joint. The front end of the pushrod is also being reviewed for consequences should it become disconnected." In a letter to the Safety Board dated May 14, 2003, Boeing stated that a "prototype part has been built. The design and installation will be ground tested on a DC-8."

[86] FAR 25.607 did not apply to the certification of the DC-8.

Additionally, Boeing indicated that it examined more than 180 attachment points on the DC-8 elevator, aileron, and rudder flight control systems to determine the effect of a separation of the securing hardware (that is, the castellated nut and cotter pin) at those attachment points. According to Boeing, this evaluation indicated that a disconnection at any of these attachment points would result in "mostly minor or no degradation in the control system operation."

Boeing also conducted an evaluation of tab-driven flight controls on its other airplanes, including the DC-9, MD-80/90, and 717, to determine whether similar unanticipated failure modes might exist in those airplanes. Specifically, Boeing tried to identify other "previously unanticipated adverse consequences of a single joint disconnect in the tab mechanisms of tab-driven flight control systems." (Boeing's evaluation of the tab-driven flight controls on the 707 was ongoing at the time of this writing. The primary flight controls on all other Boeing airplanes are hydraulically actuated (not tab-driven) and, therefore, were not evaluated.) Boeing described the results of its evaluations in its May 14, 2003, letter to the Safety Board, stating "[t]he only tab surface that can pose a loss-of-control disconnect concern is the elevator control tab."

## 1.18.2 Party Submissions Regarding Contact/Possible Contact with the Bolt

In its submission on this accident, Emery stated that although Emery maintenance personnel performed maintenance on the accident airplane after TTS performed the D inspection, these maintenance activities did not result in contact with the bolt at the control tab crank fitting to pushrod attachment. Further, Emery proposed the following probable cause for the accident:

> …loss of elevator control that resulted from the loss of the bolt connecting the right-hand elevator pushrod to the elevator control tab crank fitting. The loss of the bolt was due to the failure of the TTS mechanics conducting the D check to install the cotter pin, or the nut and cotter pin, to safety the bolt properly. Contributing to the accident was the failure of the TTS inspector to identify the missing hardware at the time that the work on the elevator control tab installation was completed during the D check installation.

In contrast, TTS stated in its submission on this accident that several maintenance actions performed by Emery after TTS completed the D inspection could have resulted in contact with the bolt connecting the right elevator control tab pushrod to the elevator control tab crank fitting. Specifically, TTS cited Emery's troubleshooting efforts during damper-related maintenance, work performed as a result of repeated pilot writeups about PTC anomalies, and the B-2 inspection. The TTS submission proposed the following probable cause for the accident:

> …a mechanical failure in the elevator control system. The likely cause was a failure at the control tab clevis fitting due to either a failure of or improper securing of the nut, bolt, and/or cotter pin. This resulted in the pilot's inability to control the aircraft. Improper and inadequate maintenance performed by [Emery] likely caused the bolt/nut assembly to come loose or fail during the fatal takeoff.

In its submission on this accident, the Air Line Pilots Association (ALPA) stated that the accident "was the result of a disconnect and subsequent jam in the linkage of the pitch control system, which rendered the aircraft uncontrollable." ALPA's submission further stated the following:

> Evidence and analysis indicates that the bolt which attaches the pushrod to the tab crank fitting for the right-hand…elevator control tab was jammed in the airplane nose up (ANU) position….Although the root cause for the loss of the bolt is unknown, the most likely scenario is that the bolt's locking hardware was either never or improperly installed after maintenance activity by Emery.…given the…vague and/or ambiguous work card and maintenance guidance, the sparse aircraft logbook write-ups…regarding both the damper reversal and the B-checks, it seems highly likely that the elevator system linkage was parted by [Emery] during one of those maintenance actions, and that locking hardware was either never or improperly reinstalled.

In its submission on this accident, Boeing stated the following:

> Based on the factual evidence and the analytical studies conducted for this investigation, Boeing believes that the probable cause of this accident was improper maintenance practices that led to the separation of the control tab pushrod from the control tab crank [fitting], a subsequent restriction of the control tab in an extreme trailing edge down position, and the subsequent loss of control of the airplane." Boeing's submission also stated "the right elevator control-rod-to-control-tab-crank joint was improperly installed either during the…'D' check at TTS, or during troubleshooting at Emery for the flight crew-reported difficulty with flaring the aircraft.

# 2. Analysis

## 2.1 General

The captain, first officer, and flight engineer were properly certificated and qualified and had received the training and off-duty time prescribed by Federal regulations and company requirements. No evidence indicated any preexisting medical or behavioral conditions that might have adversely affected the flight crew's performance during the accident flight.

The accident airplane was certificated, equipped, and dispatched in accordance with applicable regulations and industry practices. Cargo loading for the accident flight was routine, and the airplane was operating within prescribed c.g. limits.

At the time of the accident, light winds and scattered clouds were in the area; no significant meteorological conditions were present that might have disrupted the flight. The Safety Board's review of air traffic control (ATC) information revealed no evidence of any ATC problems or issues related to the accident. Therefore, weather and ATC were not factors in this accident.

## 2.2 The Accident Sequence

There was no indication that the pilots were concerned about the airworthiness of the accident airplane as they prepared to depart from MHR. The airplane's performance during ground operations and CVR evidence indicated that the initial takeoff roll did not appear to cause the pilots any concern and the takeoff continued in an apparently routine manner through the 80-knot elevator check.[87]

However, FDR and CVR evidence indicate that as the airplane reached its rotation speed, it began to pitch nose-up although neither pilot had moved his control column aft to command this movement, as would normally be expected at this time in the takeoff. To the contrary, CVR and FDR evidence indicates that the first officer began to move the control column forward, countering the airplane's unusual nose-up pitch rate, about the time the airplane reached its rotation speed. Further, CVR evidence indicates that the first officer began to add nose-down stabilizer trim about 4 seconds after the airplane passed its rotation speed and attained full nose-down trim about 3 seconds after liftoff.

CVR and FDR evidence indicates that as the pilots maneuvered the airplane in the traffic pattern in an attempt to return to the airport to land, the first officer primarily worked to maintain nose-down force on the control column, while the captain primarily tried to bank the airplane in an apparent attempt to control the pitch. The flight engineer

[87] The pilots actions during the airplane's ground operations and takeoff are discussed in section 2.4.

adjusted the engine power in response to the first officer's requests. Throughout the accident flight, the airplane rolled and pitched and climbed and descended, as the pilots tried different combinations of flight control inputs and engine power settings to counter the airplane's uncommanded pitch-up while they attempted to maneuver back to the runway. The investigation focused on discovering the reason for this pitch-up anomaly.

### 2.2.1 Disconnection of the Right Elevator Control Tab

The Safety Board's examination of the airplane wreckage revealed that the bolt that usually attaches the right elevator control tab crank fitting to its pushrod was missing. This bolt and its attaching hardware were not recovered.[88] The aluminum control tab crank fitting and the aft end of the pushrod were intact and exhibited no evidence of internal damage, indicating that the bolt was not in place at impact. By contrast, the aft end of the left control tab pushrod (the only piece of the left control tab crank fitting/pushrod attachment that was not consumed by fire) showed evidence of damage consistent with the bolt having been in place until impact; it was fractured and about 3/4 of the aft pushrod end and its associated bearing were missing.

The Safety Board tried to determine when the right elevator control tab bolt separated, disconnecting that control tab from its pushrod. Examination of FDR data for the accident airplane's previous departure (from RNO) revealed no evidence of anomalous elevator movement—elevator deflections followed control column movements proportionally throughout that takeoff roll and rotation. Therefore, it is likely that the right elevator control tab bolt was still in place at that time.

However, FDR data revealed that a 1º to 2º change in the relationship between the airplane's control column movement and elevator response began about 8 minutes 20 seconds before the airplane landed at MHR and continued until touchdown. The Safety Board's subsequent airplane performance study indicated that the change observed in the FDR's control column and elevator data at this time could be explained by a 3º to 4º TEU shift in the airplane's right control tab position relative to the left control tab. This shift in control tab position is consistent with one of the scenarios considered by the Board during this investigation—specifically, a scenario in which an elevator control tab disconnected in flight and shifted in a TEU direction (with the disconnected pushrod remaining between the lugs of the crank fitting), resulting in about a 3º to 4º TEU mismatch with respect to the left control tab.

Postaccident ground tests conducted on an Emery DC-8 similar to the accident airplane showed that when the right elevator control tab bolt was removed and no aerodynamic loads were present, the right control tab deflected to about 29º to 30º TED, which allowed the pushrod to disengage from the lugs of the crank fitting. Assuming the bolt separated before the accident airplane landed at MHR, the control tab would likely have shifted TED when the aerodynamic loads decreased as the airplane decelerated after landing.

[88] For additional discussion regarding the maintenance-related issues in this accident, see section 2.3.

FDR data revealed abnormal elevator movements during the accident takeoff roll, indicating that the bolt had certainly migrated free by this time and was no longer securing the pushrod end bearing. Specifically, FDR data indicated that during the accident flight's 80-knot check, the pilots moved the control column forward significantly, but the elevators moved relatively little (from about 5.5º TEU to about 2.2º TEU). By contrast, during the accident airplane's previous takeoff (from RNO), when the pilots applied less forward control column motion, the elevators moved from about 5.4º TEU to about 7.8º TED. Further, FDR data showed that as the airplane rotated during the accident takeoff, the control columns were positioned to command a nose-down elevator deflection while the elevators remained in an extreme nose-up deflection.

When the aerodynamic forces on the airplane increased as it accelerated during the accident takeoff roll, the right control tab would have moved to a point where the crank fitting lugs contacted the end of the disconnected pushrod (about 16º to 17º TED). From that point on, the right control tab's TEU motion would have been restricted to a deflection that was about 25º lower than the left control tab positions. This scenario is consistent with evidence of contact damage observed on the forward edges of the accident airplane's right control tab crank fitting and would have resulted in the abnormal nose-up pitching observed in the FDR data as the airplane neared rotation speed. Therefore, the Safety Board concludes that at some time after the previous takeoff (from RNO) and before the accident takeoff roll, the bolt connecting the right elevator control tab crank fitting to the pushrod migrated out of the fitting, allowing the control tab to disengage from its pushrod and shift to a TED position.

DC-8 ground tests conducted with a disconnected right control tab pushrod showed that the pilots' nose-down control column inputs resulted in a full (about 8º) TEU left control tab deflection and an extreme (about 16º to 17º) TED right control tab deflection. During the accident flight, the aerodynamic forces acting on the extreme TED-deflected right control tab would have driven both elevator surfaces abnormally TEU, resulting in a strong airplane nose-up elevator effect throughout the accident flight, regardless of the flight crew's inputs. This TEU elevator movement was consistent with the elevator data recorded by the accident FDR.

Therefore, the Safety Board concludes that when the aerodynamic forces increased as the airplane accelerated during the takeoff roll, the right elevator control tab crank fitting contacted the disconnected pushrod, restricting that control tab's further TEU movement and leaving it in an extreme TED deflection. The Safety Board further concludes that as a result of the right elevator control tab's extreme TED deflection, the accident airplane's elevator surfaces were driven to command an extreme airplane nose-up pitch attitude; despite the large nose-down forces the pilots applied to the control columns, the pilots were unable to overcome the effects of the restricted right elevator control tab.

## 2.3 Role of Aircraft Maintenance in the Accident

The FDR data and the physical evidence indicated that the bolt that normally attaches the right elevator control tab pushrod to the control tab crank fitting separated before the accident takeoff. There was no physical damage or other evidence indicating that the bolt failed or fractured, and failure of an installed castellated nut and/or cotter pin during normal operation would be very unlikely. Therefore, the bolt must have separated because it had not been properly secured; that is, the required castellated nut was either never installed, or it was improperly installed (for example, installed without a cotter pin). The Safety Board reviewed the accident airplane's maintenance history to determine when and where the improper installation of the attachment bolt may have occurred. On the basis of its review, the Safety Board concludes that the bolt attaching the accident airplane's right elevator control tab was improperly secured and inspected, either during the most recent D inspection or subsequent maintenance; however, the Board was unable to determine when this improper securement and inspection occurred.

The installation of the overhauled elevator assembly during the D inspection completed by TTS in November 1999 was the last documented maintenance action involving attachment of the right elevator control tab to the pushrod. According to documentation and postaccident interviews, TTS maintenance personnel installed the overhauled elevator assembly in accordance with work cards and the maintenance manual MM that were provided by Emery. TTS maintenance personnel told the Safety Board that they were aware that this connection should be secured with a drilled-shank bolt, a castellated nut, and a cotter pin.

TTS maintenance personnel had another opportunity to come into contact with the bolt at that attachment during the postinstallation testing and rigging procedures. If adjustments to the pushrod length were required during the rigging process (as they commonly are), the aft rod end bolt, nut, and cotter pin might have been removed and the bolt reinstalled upon completion of the rigging. However, because the forward rod end is designed to be the adjustable end of the pushrod, it is possible to adjust the rod length without removing the aft rod end hardware; therefore, an experienced mechanic might not have removed this bolt during the rigging process.[89]

In its submission on this accident, Emery contends that TTS mechanics failed to properly secure the bolt during the D inspection. However, submissions received from several other parties to the investigation suggested that there was an opportunity for Emery maintenance personnel to access this bolt/attachment after TTS completed the D inspection. Specifically, these submissions referenced work accomplished by Emery

[89] Emery's postaccident inspection of its DC-8 fleet (which was maintained and inspected by both TTS and Emery personnel) revealed that control tab attachment hardware (including cotter pins) was installed at the forward and aft ends of each control tab pushrod on each airplane. In addition, physical damage to the accident airplane's left control tab pushrod (the only piece of wreckage from that attachment that was recovered) indicated that the bolt at the left control tab crank fitting to pushrod attachment was in place at the time of impact.

(to address a pilot report of increased control column forces) about 1 week after the accident airplane's D inspection was completed.

Emery's DC-8 MM contained troubleshooting procedures for the reported problem that included inspecting the control tab pushrods and their linkage; had Emery mechanics followed these procedures, their work could have involved contact with the bolt at the inboard control tab fitting. However, during postaccident interviews, Emery's lead mechanic stated that they identified and corrected the reversed elevator damper installation early in their troubleshooting efforts and, therefore, never accessed the control tab pushrods.

## 2.4 Preflight Inspection and Flight Control/EPI Checks

### 2.4.1 Preflight Inspection

Emery's procedures required the flight engineer to examine the elevator control surfaces twice during his preflight inspections of the airplane—once with the elevator gust lock engaged and once with the gust lock disengaged. Although it was not possible to determine what position the control tabs were in during the flight engineer's preflight inspection of the airplane, if the right elevator control tab was disconnected when the preflight inspections were conducted, an asymmetry between the right and left control tabs would likely have existed.

Emery's AOM instructed pilots to check the elevator and tabs for "alignment and condition" and specified "with gust lock off, elevator should be up, control tabs up, and geared tabs down." Although this guidance is accurate, it should more strongly emphasize the importance of pilots ensuring that the right and left side elevators and tabs are deflected symmetrically during the preflight inspection. After the accident, Boeing emphasized flight control symmetry in its June 19, 2001, FOB, which stated the following:

> The proper functioning of the flight controls should be verified before every flight. If the exterior walk-around is made…with the gust lock released, the elevators and control tabs should be positioned toward UP (symmetrically), and the geared tabs DOWN (again symmetrically).

The Safety Board concludes that DC-8 operators' procedures and training should more clearly emphasize that DC-8 flight crewmembers need to verify symmetry between the right and left side elevators, control tabs, and geared tabs during the preflight inspection. Therefore, the Safety Board believes that the FAA should require all DC-8 operators to train DC-8 flight crewmembers to look for symmetry between the right and left side elevators, control tabs, and geared tabs during the preflight inspection, consistent with Boeing's June 2001 FOB guidance.

## 2.4.2 Elevator Checks/Use of the EPI Gauge

FDR and CVR evidence indicates that the pilots attempted to verify elevator movement (presumably using the EPI) during the elevator taxi check. However, the EPI gauge would not have provided the pilots with an indication of a restricted control tab during this check (regardless of the range or direction of control column input).

CVR evidence indicates that the pilots also attempted to verify the elevator's proper operation during the 80-knot elevator check by checking the EPI indication in accordance with Emery's procedures and practices. The flight crew appeared satisfied with the results of the 80-knot elevator check and continued the takeoff roll. However, because the aerodynamic forces acting on the elevator and control tabs would have been significant as the airplane accelerated during the takeoff roll, the abnormal control tab condition would have prevented the elevator from moving to its full TED position. Therefore, under the circumstances of this accident, the EPI needle would not have moved below the neutral mark during the 80-knot elevator check, thus providing an indication that the elevator was not fully operational.

Emery's AOM regarding the use of the EPI during the 80-knot elevator check instructed pilots to apply "full forward" control column pressure, then "release slightly forward of neutral…confirm nose DN response…look for EPI to respond to yoke movement." Although the AOM did not explicitly describe the expected EPI indications during the 80-knot elevator check, Emery's AOM guidance for the ground taxi check stated that, with the control columns full forward, the EPI needle "should now point between [neutral] mark and the [down] mark." On an airplane with a properly functioning elevator, a similar indication would be expected during the 80-knot elevator check. AOM guidance to this effect might have been helpful to the pilots because when the accident airplane's EPI needle did not move below the neutral mark, they might have been alerted to the elevator's abnormal operation.

Review of other DC-8 operator's procedures indicated that Emery's guidance regarding EPI usage was among the most thorough in the industry. The AOMs of five of the other six DC-8 operators surveyed did not mention using the EPI during the 80-knot elevator check.[90] Postaccident interviews with Emery personnel and FDR data indicate that Emery's pilots used the EPI but only to confirm elevator response in the proper direction. Observation of EPI needle movement below the neutral mark during the 80-knot elevator check would provide a more quantitative determination that the elevator was functioning properly.

The Safety Board found that there is no standardization of EPI guidance and EPI use across DC-8 operators. The 80-knot elevator check provides flight crews with their last chance to detect abnormal elevator performance (which could result from foreign object damage, fractured geared tab arms, mechanical failure [as with the accident flight], and/or damage to components that might have occurred since the earlier elevator checks)

[90] AD 78-01-15 did not require operators to use the EPI during 80-knot elevator checks.

before the airplane lifts off the runway.[91] However, the procedures and practices currently in use appear to make minimal use of the EPI's potential as a go/no-go tool during the 80-knot check, resulting in pilots continuing a takeoff with a potentially unsafe elevator condition.

The Safety Board concludes that DC-8 operators, including Emery, do not use the EPI to confirm elevator movement indications above and below the neutral range during the 80-knot elevator check and, thus, do not take full advantage of the EPI's capabilities to provide pilots with an indication of an abnormal elevator condition. Therefore, the Safety Board believes that the FAA should require the development of DC-8 80-knot elevator check procedures that will ensure that pilots are clearly made aware of whether the elevator is functioning properly before the airplane lifts off, then require all DC-8 operators to incorporate these procedures into their training and normal operations. The procedures should contain specific guidance regarding an expected range of EPI needle movement (including EPI needle movement well below the neutral mark with forward control column movement) and specific criteria for aborting a takeoff as a result of an inadequate elevator movement indication.

The Safety Board's review also indicated that there is no ongoing calibration requirement for the EPI gauge/system. Although the Board could not determine the calibration of the accident EPI, it notes that the EPI installed on the test airplane was not accurately calibrated when the ground tests were performed. The Safety Board concludes that the EPI needs to be periodically calibrated to ensure that it provides the most accurate information possible to the pilots. Therefore, the Safety Board believes that the FAA should require all DC-8 operators to incorporate periodic EPI calibration inspections into their maintenance programs to ensure that the EPI indications observed by pilots accurately represent the condition of the elevator.

Finally, the Board noted that the small (1-inch diameter) EPI gauge was installed in a location on the accident airplane (the lower left side of the first officer's instrument panel) that was not ideally visible for either pilot. The Safety Board concludes that the EPI gauge should be readily visible to both pilots. Therefore, the Safety Board believes that the FAA should require DC-8 EPIs to be located and sized so that they are visible and usable for both the captain and first officer.

## 2.5 Elevator Design Issues

CAR 4b.320 amendment 4b-3, under which the DC-8 was certificated, stated that "Tab control systems shall be such that disconnection or failure of any element…cannot jeopardize the safety of flight." According to Boeing's submission on this accident, the company and the FAA considered the possibility of a failure of the crank fitting/pushrod attachment during the development and certification of the DC-8; however, subsequent

[91] For example, during the December 12, 2002, Tampa Airlines aborted takeoff, the pilots performed an 80-knot elevator check and observed that the EPI did not respond to their control column inputs. See section 1.16.1.3 for more information on this event.

control tab and pushrod end movements, such as those that likely occurred on the accident airplane, and the resultant jam/restricted movement of the control tab were not considered. The submission further stated that Boeing has "begun developing an enhanced design of the control tab pushrod that will prevent the pushrod from dropping or otherwise moving in front of the control tab crank should the bolt migrate out of the connecting joint. The front end of the pushrod is also being reviewed for consequences should it become disconnected."

Boeing also conducted a postaccident review of more than 180 additional attachment points on the DC-8 elevator, aileron, and rudder flight control systems to identify other potentially vulnerable attachments. In a letter to the Safety Board dated May 14, 2003, Boeing stated that its review showed that a disconnection at any of these other attachment points would result in "minor or no degradation" in the associated system's operation. Further, Boeing stated that its survey of flight control attachment points on other tab-driven airplanes (including the DC-9, MD-80/90, and 717)[92] indicated that the DC-8 elevator control tab was the "only tab surface that can pose a loss-of-control disconnect concern."

The Safety Board concludes that the circumstances of the Emery flight 17 accident show that the current DC-8 design does not preclude a catastrophic result from a disconnection or failure of the existing control tab crank fitting to pushrod attachment. Therefore, the Safety Board believes that the FAA should require Boeing to redesign DC-8 elevator control tab installations and require all DC-8 operators to then retrofit all DC-8 airplanes with these installations such that pilots are able to safely operate the airplane if the control tab becomes disconnected from the pushrod.

Current Federal regulations (14 CFR Section 25.607) require manufacturers of transport-category airplanes to incorporate two separate locking devices at every removable bolt (or other fastener) if the loss of the bolt could result in reduction in pitch, yaw, or roll control capability. The use of dual-locking devices at critical flight control attachments was intended as additional protection against a catastrophic result from disconnection of a flight control. However, airplanes certificated under CAR 4b were not required to incorporate dual-locking devices. The Safety Board concludes that there may be airplanes that were certificated to CAR 4b standards other than the DC-8 on which the disconnection of a critical flight control could have catastrophic results. Therefore, the Safety Board believes that the FAA should evaluate airplanes other than the DC-8 certificated to CAR 4b standards to evaluate whether disconnection or failure of critical flight control systems could have catastrophic results and, if so, require that they also be redesigned and retrofitted and/or equipped with dual-locking devices to preclude such catastrophic results.

[92] Boeing's evaluation of the flight controls on the 707 was ongoing at the time of the letter.

### 2.5.1 Elevator Geared Tab Crank Arm Fractures

During this investigation, the Safety Board reviewed the history of fractured DC-8 geared tab crank arms, which, though not a factor in this accident, have been involved in other elevator jam events over the years. Although AD 78-01-15 required DC-8 operators to modify the clearances for the geared tab crank arms, DC-8 elevator system jams caused by fractured aluminum geared tab crank arms are still occurring. The Board notes that AD 78-01-15 does not require operators to replace the existing aluminum crank arms with forged stainless steel crank arms, as suggested by Douglas in SB 27-262. The SB stated that "replacing the existing aluminum geared tab crank assemblies with forged stainless steel crank assemblies and improving the crank assembly clearance will minimize the possibility of crank failure."

Stainless steel is stronger than aluminum and the Safety Board is not aware of any fractures of stainless steel DC-8 geared tab crank arms that have occurred in normal operation. In fact, although both elevator geared tab aluminum crank arms on the accident airplane (the inboard crank arms) fractured as a result of the impact forces, the elevator geared tab stainless steel crank arms were twisted but not fractured. Therefore, the Safety Board concludes that replacement of the DC-8 aluminum elevator geared tab crank arms on DC-8 airplanes with stainless steel elevator geared tab crank arms would likely eliminate the possibility of a jam resulting from fractured geared tab crank arms. Therefore, the Safety Board believes that the FAA should require all DC-8 operators to replace all DC-8 aluminum elevator geared tab crank arms on their DC-8 airplanes with stainless steel elevator geared tab crank arms.

## 2.6 Emery's DC-8 Maintenance Documents and Guidance

### 2.6.1 Required Inspection Items

The Safety Board notes that Emery's work cards for installation of the right elevator tabs (work card 3502D) and right elevator assembly (work card 3504D) contained specific instructions for verification of proper "installation and security" and that an inspector stamp/signoff was required for these steps. However, Emery's work card 3504D contained another step after the inspector verification of installation and security—"rig R/H elevator [assembly] per DC-8 MM chapter 27." Although an inspector stamp/signoff was required for this task and the MM cited inspection of elevator "mechanism rods secure and safetied," there was no discrete work card step requiring an inspector to re-verify the security of attachments after the rigging work was completed. Thus, it is possible that a once-properly secured bolt, which was inspected and signed off during the installation inspection, could be returned to service after the postinstallation rigging process without a properly secured bolt or subsequent inspection.

The Safety Board notes that 14 CFR 121.369[b][2] requires operators to designate "items of maintenance…that must be inspected…including at least those that could result in a failure, malfunction, or defect endangering the safe operation of the airplane, if not performed properly." Although the instructions and steps contained on Emery's DC-8 work card 3504D were consistent with industry standards that have been in use for decades, the Board is concerned that the lack of specificity regarding a postrigging inspection could result in a hazardous condition. As demonstrated in this accident, if a missing securing device at a critical attachment goes undetected, it can have catastrophic consequences. Although the Board did not determine whether the lack of specific information on Emery's work cards was directly related to the improper securement of the bolt in this case, the addition of discrete inspection items, specifically identifying the attachments/fittings to be inspected, could only help ensure the security of this critical flight control[93] attachment. (The Board is aware of one carrier that included in in its maintenance documents a specific "safety check" work card, requiring inspection of all previously installed/assembled/inspected components.)

The Safety Board concludes that DC-8 elevator rigging procedures should be fully addressed in a separate work card that specifically lists required inspection items, including verifying the security of elevator control tab attachments after the rigging is completed. Therefore, the Safety Board believes that the FAA should require all DC-8 operators to create or revise DC-8 work cards to ensure they specifically include a postrigging inspection of the elevator assembly, including verifying the security of elevator control tab attachments.

Because carriers customarily base their maintenance programs on the manufacturer's recommendations, Emery's DC-8 work card 3504D was most likely based on a generic work card originally prepared by the manufacturer as part of an overall recommended DC-8 maintenance program. Therefore, the Safety Board is concerned that other DC-8 work cards based on that set of generic work cards may contain a similar level of detail, or lack thereof. The Safety Board concludes that all DC-8 work cards related to critical flight controls should identify required inspection items as discrete tasks with individual inspection signoff requirements. Therefore, the Safety Board believes that the FAA should require all DC-8 operators to review their work cards related to critical flight controls, and revise them as necessary to ensure that appropriate tasks are identified as discrete tasks with individual inspection signoff requirements.

### 2.6.2 Emery's B-2 Inspection

The B-2 inspection conducted by Emery between the November 1999 D inspection and the accident included instructions for maintenance personnel to "visually inspect elevators and tabs for general condition, corrosion, leakage, and security of attachment." However, when the control tab fairing is installed, it prevents any visual examination of the control tab crank fitting to pushrod attachment or the inboard hinge

[93] The DC-8 elevator control tab is a critical flight control because certain failures of this flight control can be catastrophic.

fitting, making it impossible to inspect either attachment point for "security of attachment," as called for by the B-2 inspection work card.

During postaccident interviews, Emery maintenance personnel stated that they did not remove the control tab fairing or inspect the crank fitting/pushrod attachment during the B-2 inspection. In public hearing testimony, witnesses from Emery indicated that its B-2 inspection was intended to be a general visual inspection, to be accomplished without removing access or inspection panels or fairings. However, witnesses from TTS stated that, although not specifically listed as a step, removal of the control tab fairing was necessary to satisfactorily perform the tasks described in Emery's B-2 work card. Further, the Safety Board's survey of several other DC-8 operators revealed inconsistent interpretation and application of the work card task regarding the inspection of the elevator and control tab for security of attachment.

Emery's interpretation of its B-2 work card was consistent with Boeing's position that the manufacturer's recommended program work cards "do not call for the removal of the inboard control tab fairing during the B [inspections]. The inboard control tab fairing is not removed until the [heavy maintenance inspection equivalent to Emery's C- and D-inspections]…Therefore, the Emery B-2 inspection work card…would be…an inspection to be accomplished without removing access or inspection panels, fairings, or the like." (Emery performed C inspections about every 2 years and D inspections about every 12 years.)

The Safety Board notes that several air carrier operators have tried to clarify the intended scope of maintenance tasks by including in work cards an enumeration of the actions that are necessary for the proper accomplishment of the associated work task. Although this additional detail on work cards is not required by the FAA, its inclusion should result in more consistent accomplishment of maintenance tasks. The Safety Board concludes that all air carrier operators should provide maintenance personnel with more detailed information regarding the steps or actions that are necessary to satisfactorily accomplish a maintenance task. Therefore, the Safety Board believes that the FAA should require all 14 CFR Part 121 air carrier operators to revise their task documents and/or work cards to describe explicitly the process to be followed in accomplishing maintenance tasks.

### 2.6.3 DC-8 MM Information

The information regarding the control tab installation that was in Emery's DC-8 MM and IPC in use at the time of this accident did not specify that a cotter pin was required. However, the Safety Board has no evidence that the lack of specific reference to, or depiction of, a cotter pin at this attachment in the DC-8 MM and/or IPC was a factor in this accident. In fact, that information had been used for years with no other known instance of an incorrectly safetied bolt separating. Boeing subsequently improved the related information in its DC-8 MM, revising it to explicitly state that a cotter pin is needed to secure the elevator control tab crank fitting to pushrod attachment. The five primary U.S. operators (that is, those who operate multiple DC-8s) have all adopted this revision in their MMs.

Boeing did not issue a similar revision to the DC-8 IPC because it was not intended to be used as a reference for installation and/or assembly of components; rather, Boeing intended that mechanics use its installation drawings for installation and assembly tasks. However, the Safety Board notes that Emery did not list the manufacturer's installation drawings as a reference to be used in Emery's maintenance program, and Emery did not provide TTS with Boeing's DC-8 installation drawings. In the absence of installation drawings, it is possible that a mechanic would use the IPC as a reference for installation and/or assembly of components. Because the IPC is not required to be updated, the information contained in that document might be incomplete or might not accurately reflect an airplane's configuration. The Safety Board concludes that the use of outdated, incomplete, or otherwise unsuitable reference materials by maintenance personnel during the installation and/or assembly of airplane components can occur and is a potentially unsafe practice. Therefore, the Safety Board believes that the FAA should require all air carrier operators to either: 1) provide all pertinent maintenance personnel with the manufacturer's current installation drawings for pertinent airplanes, update those installation drawings as needed, and require use of those drawings during installation and/or assembly of that airplane's components; or 2) list the IPC on that operator's operation specifications, provide maintenance personnel with up-to-date IPCs for reference, continue to update those IPCs as needed, and require maintenance personnel to use the pertinent updated IPCs during installation and/or assembly of an airplane's components.

## 2.7 FDR-Related Issues

The elevator data conversion problems encountered with the accident airplane's FDR complicated this investigation and delayed the Safety Board's recognition of the significance of the elevator movement during the accident sequence. Observing abnormalities in the recorded elevator data, the Board reviewed the data more thoroughly and determined that the elevator's neutral position was not accurately identified during the original correlation. Specifically, the Board noted that an 11° TEU adjustment to the elevator conversion value resulted in an elevator position of 0° when the gust lock was engaged.

In compliance with Federal regulations, the accident airplane's FDR was upgraded to record additional parameters (including elevator position) during its most recent heavy maintenance inspection in November 1999. The accident airplane was the first of Emery's DC-8 fleet to be so upgraded, and a full correlation of the data recorded by the FDR to the actual elevator positions was performed and documented. Given that the total range of elevator travel from the documented data from the accident airplane's original correlation was similar to the elevator's normal operating range and that the recorded travel above and below neutral (when corrected) was consistent with its design, it is apparent that the entire range of elevator travel, including the elevator neutral position, was not accurately identified during the original correlation.

Fortunately, the Board was able to adjust the conversion for use in this investigation; however, the Board's identification of the incorrect elevator conversion delayed a thorough evaluation of the elevator's behavior during the accident and previous flights. This problem could have been identified and corrected at the time of the upgrade if L2 Consulting Services, Inc. (the company that performed the correlation after the upgrade) or Emery had verified that the accident airplane's original correlation reflected the elevator's actual (design) range of travel during the correlation or after the correlation was completed.

The subsequent readout and evaluation of three other Emery DC-8 FDRs (two of which were installed at different times on the Emery DC-8 used in postaccident tests) also indicated problems with the elevator data conversions. According to documentation the Safety Board received from Emery and L2 Consulting Services, Inc., the accident airplane's FDR system was the only FDR system on which a complete correlation of recorded FDR data to actual elevator position was accomplished. The other two airplanes examined were only subjected to a verification test during which the elevator was moved to its neutral, full up, and full down positions,[94] then the measured values from the accident airplane's correlation were applied. Unfortunately, the elevator position correlation for the accident airplane, which was used by Emery for the remainder of its upgraded DC-8 fleet, was incorrect. The FARs (specifically, Section 121.343[j]) permit the use of a single correlation for airplanes of the same type if they have the same FDR and sensors, presumably because full correlations on similar equipment would be expected to be similar. However, the Board observed significant differences in the conversions required for Emery's DC-8s. The correlation problems observed during this investigation raise concerns about the use of a single correlation for a fleet of airplanes.

The Safety Board's discovery of a shift in the control column range of travel between the time of the original correlation and the accident provides further evidence of inconsistencies with the FDR-to-actual position correlations. Although the shift in control column range of travel did not result in a change to the control column conversion, the Board is concerned about the cause of the shift, which was not determined.

The Safety Board has found that FDR correlation inconsistencies occur more frequently on airplanes manufactured on or before August 18, 2000, that have been retrofitted to record additional parameters (in compliance with Federal regulations). Consequently, the use of a single correlation document for an existing fleet, while permitted by regulation, may be more problematic when applied to older airplanes that have been retrofitted to record additional FDR parameters. These difficulties have often resulted in more difficult and time-consuming investigations.[95]

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[94] These elevator movements were not physically measured; rather, the erroneous correlations from the accident airplane were applied to data obtained from the other two airplanes.

Because older airplanes with retrofitted FDRs are not required to record as many parameters as newly manufactured airplanes,[96] the loss of data from just one parameter on an older retrofitted airplane can significantly hamper and slow progress in an investigation. Although investigators are often able to estimate the values for the lost or invalid data using data from other parameters and sources of information, this reconstruction of the data takes time and can delay the identification of potentially critical safety issues (and can potentially lead to incorrect conclusions regarding the recorded data). When more recorded data is available during an investigation, it is more likely that investigators will be able to identify critical safety issues early in the investigation and not spend a significant amount of investigative time compensating for lost or unreliable FDR data.

The Safety Board concludes that the use of a single airplane's FDR parameter correlation for all airplanes of the same type is inadequate to ensure accurate correlations for older airplanes that have been retrofitted to record additional FDR parameters. Therefore, the Safety Board believes that the FAA should require operators of airplanes manufactured before August 18, 2000, that have been retrofitted with additional FDR parameters in compliance with Federal requirements and for which an operator maintains a common correlation document for that airplane type to conduct a full correlation of all such airplanes' FDR parameters at the airplanes' next required FDR maintenance inspection to verify accurate FDR system documentation and sensor function.

Additionally, a thorough evaluation of the accident airplane's elevator behavior was further complicated by the abnormal FDR track switching. As previously noted, the FDR switched to the first track every time electrical power to the FDR stopped. The process of viewing all 25 hours of data recorded on the FDR's six tracks, identifying the locations of track switching, and identifying the data that corresponded to the airplane's most recent operations was time consuming. Further, because of the tracking-switching anomaly, the Safety Board had only the most recent 8 hours 11 minutes of elevator data to examine instead of the required 25 hours of recent data. (The remaining data recorded by the FDR was from unidentified previous flights, some of which occurred at least 3 months prior to the accident [before the FDR was upgraded to 17 parameters].)

The Safety Board has previously observed tracking-switching anomalies with other F800 model FDRs. The F800 manufacturer, Loral Fairchild,[97] identified several potential causes of tracking-switching anomalies and issued three FSBs to correct them. Two of the three FSBs appear to address a condition like that of the accident FDR (S/N 04018, P/N 17M303-282). However, according to Emery's records, none of the

[95] The Safety Board has issued many related safety recommendations to the FAA to remedy these difficulties throughout the years and has included improvements in on-board recording devices on its list of most wanted safety improvements since 1997.

[96] Airplanes manufactured on or before August 18, 2000, are required to be upgraded as necessary to record 17 parameters (as with the accident airplane) or 34 parameters, while newly manufactured airplanes are required to record 57 or 88 parameters (depending on the date of manufacture).

[97] Loral Fairchild is now L3 Communications.

components of the accident FDR were subject to modifications per any of the FSBs regarding track switching.

The Safety Board considered two possible explanations for the accident airplane's tracking-switching anomaly: 1) the accident FDR's tracking-switching condition was a previously unidentified condition for which no remedy had been developed, and therefore none of the FSBs applied, or 2) one or more of the existing FSBs were applicable to the accident FDR, but Emery's paperwork did not reflect installation of the relevant components (whether accomplished or not). Regarding the second scenario, although the FSB's targeted replacement of one or more specific components on a board in the FDR and such component revisions should be marked on the boards, a mechanic could easily remove one board and replace it with another without documenting the components on the replacement board if slight differences exist. Thus, it is possible that one or more of the FSBs designed to address track switching applied to the accident airplane's FDR but this was not indicated in Emery's documentation for that FDR. (The condition of the recorder prevented the Board from physically verifying the components installed on the accident FDR.)

The Safety Board concludes that Loral Fairchild Model F-800 FDRs with unaddressed or unidentified tracking-switching anomalies may currently be in operation. Therefore, the Safety Board believes that the FAA should require all operators of airplanes equipped with Loral Fairchild Model F-800 FDRs to comply with Loral Fairchild FSBs DFR 011 and DFR 027 for recorders with applicable part numbers and installed component numbers. Further, the Safety Board believes that the FAA should require overhaul facilities that service Loral Fairchild Model F-800 FDRs to monitor those recorders to determine whether abnormal track switching is occurring and to report any such findings to the FAA and the manufacturer.

## 2.8 Drug and Alcohol Testing of Ground Personnel

The FARs require that all employees who perform a "safety-sensitive" function be tested for drugs or alcohol if their performance could have contributed to or could "not be completely discounted as a contributing factor to the accident." Drug testing and alcohol testing are required to be accomplished as soon as possible but no later than 32 and 2 hours after the accident, respectively. However, the ground personnel at MHR who were involved with the accident airplane (including cargo handlers, load planners, and ramp supervisors) were not required to submit to drug or alcohol testing promptly after the accident, in part because the applicable regulations (specifically 14 CFR Part 121, Appendixes I and J) do not define their duties as "safety-sensitive."

Although not required, voluntary drug tests were eventually conducted on eight cargo handlers, a load planner, and the ramp supervisor involved with the accident flight. Samples were taken from the 10 tested employees between 1 and 6 days after the accident; 2 of the 10 employees tested positive for drugs and were subsequently relieved of their duties.

Although it was determined that the performance of cargo-handling personnel was not a factor in this accident, improper loading of the airplane's cargo and/or a cargo shift during takeoff have been involved in previous accidents and were considered possibilities during the early stages of this investigation. As evidenced by the history of cargo-related accidents, the way cargo-handling personnel conduct their duties (whether those duties involve the loading of cargo in cargo compartments; the loading/packing of the containers, pallets, and other items for placement within the cargo compartments; or planning the placement of the load) can have a significant effect on the safety of a flight. This potential effect is no less serious than several of the functions that are currently defined as safety-sensitive by the FARs, including aircraft dispatcher duties, ground security coordinator duties, aviation screening duties, and aircraft maintenance or preventive maintenance duties.

Therefore, the Safety Board concludes that the current regulatory definition of safety-sensitive functions is too narrow for the issue of postaccident testing because it does not include cargo handlers, load planners, and ramp supervisors, all of whom have a demonstrated potential to affect the safety of a flight. Therefore, the Safety Board believes that the FAA should modify the list of safety-sensitive functions described in 14 CFR Part 121, Appendixes I and J, to include all personnel with direct access to the airplane and a direct role in the handling of the flight, including cargo handlers, load planners, and ramp supervisors.

# 3. Conclusions

## 3.1 Findings

1. The captain, first officer, and flight engineer were properly certificated and qualified and had received the training and off-duty time prescribed by Federal regulations and company requirements. No evidence indicated any preexisting medical or behavioral conditions that might have adversely affected the flight crew's performance during the accident flight.

2. The accident airplane was certificated, equipped, and dispatched in accordance with applicable regulations and industry practices.

3. Cargo loading for the accident flight was routine, and the airplane was operating within prescribed center of gravity limits.

4. Weather and air traffic control were not factors in this accident.

5. At some time after the previous takeoff (from Reno, Nevada) and before the accident takeoff roll, the bolt connecting the right elevator control tab crank fitting to the pushrod migrated out of the fitting, allowing the control tab to disengage from its pushrod and shift to a trailing edge down position.

6. When the aerodynamic forces increased as the airplane accelerated during the takeoff roll, the right elevator control tab crank fitting contacted the disconnected pushrod, restricting that control tab's further trailing edge up movement and leaving it in an extreme trailing edge down deflection.

7. As a result of the right elevator control tab's extreme trailing edge down deflection, the accident airplane's elevator surfaces were driven to command an extreme airplane nose-up pitch attitude; despite the large nose-down forces the pilots applied to the control columns, the pilots were unable to overcome the effects of the restricted right elevator control tab.

8. The bolt attaching the accident airplane's right elevator control tab crank fitting to the pushrod was improperly secured and inspected, either during the most recent D inspection or subsequent maintenance; however, the Board was unable to determine when this improper securement and inspection occurred.

9. DC-8 operators' procedures and training should more clearly emphasize that DC-8 flight crewmembers need to verify symmetry between the right and left side elevators, control tabs, and geared tabs during the preflight inspection.

10. DC-8 operators, including Emery, do not use the elevator position indicator (EPI) to confirm elevator movement indications above and below the neutral range during the 80-knot elevator check and, thus, do not take full advantage of the EPI's capabilities to provide pilots with an indication of an abnormal elevator condition.

11. The elevator position indicator needs to be periodically calibrated to ensure that it provides the most accurate information possible to the pilots.

12. The elevator position indicator gauge should be readily visible to both pilots.

13. The circumstances of the Emery flight 17 accident show that the current DC-8 design does not preclude a catastrophic result from a disconnection or failure of the existing control tab crank fitting to pushrod attachment.

14. There may be airplanes that were certificated to Civil Aviation Regulations 4b standards other than the DC-8 on which the disconnection of a critical flight control could have catastrophic results.

15. Replacement of the DC-8 aluminum elevator geared tab crank arms on DC-8 airplanes with stainless steel elevator geared tab crank arms would likely eliminate the possibility of a jam resulting from fractured geared tab crank arms.

16. DC-8 elevator rigging procedures should be fully addressed in a separate work card that specifically lists required inspection items, including verifying the security of elevator control tab attachments after the rigging is completed.

17. All DC-8 work cards related to critical flight controls should identify required inspection items as discrete tasks with individual inspection signoff requirements.

18. All air carrier operators should provide maintenance personnel with more detailed information regarding the steps or actions that are necessary to satisfactorily accomplish a maintenance task.

19. The use of outdated, incomplete, or otherwise unsuitable reference materials by maintenance personnel during the installation and/or assembly of airplane components can occur and is a potentially unsafe practice.

20. The use of a single airplane's flight data recorder (FDR) parameter correlation for all airplanes of the same type is inadequate to ensure accurate correlations for older airplanes that have been retrofitted to record additional FDR parameters.

21. Loral Fairchild Model F-800 flight data recorders with unaddressed or unidentified tracking-switching anomalies may currently be in operation.

22. The current regulatory definition of safety-sensitive functions is too narrow for the issue of postaccident testing because it does not include cargo handlers, load planners, and ramp supervisors, all of whom have a demonstrated potential to affect the safety of a flight.

## 3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was a loss of pitch control resulting from the disconnection of the right elevator control tab. The disconnection was caused by the failure to properly secure and inspect the attachment bolt.

# 4. Recommendations

As a result of the investigation of the Emery Worldwide Airlines flight 17 accident, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require all DC-8 operators to train DC-8 flight crewmembers to look for symmetry between the right and left side elevators, control tabs, and geared tabs during preflight inspection, consistent with Boeing's June 2001 flight operations bulletin guidance. (A-03-22)
>
> Require the development of DC-8 80-knot elevator check procedures that will ensure that pilots are clearly made aware of whether the elevator is functioning properly before the airplane lifts off, then require all DC-8 operators to incorporate these procedures into their training and normal operations. The procedures should contain specific guidance regarding an expected range of elevator position indicator (EPI) needle movement (including EPI needle movement well below the neutral mark with forward control column movement) and specific criteria for aborting a takeoff as a result of an inadequate elevator movement indication. (A-03-23)
>
> Require all DC-8 operators to incorporate periodic elevator position indicator (EPI) calibration inspections into their maintenance programs to ensure that the EPI indications observed by pilots accurately represent the condition of the elevator. (A-03-24)
>
> Require DC-8 elevator position indicators to be located and sized so that they are visible and usable for both the captain and first officer. (A-03-25)
>
> Require Boeing to redesign DC-8 elevator control tab installations and require all DC-8 operators to then retrofit all DC-8 airplanes with these installations such that pilots are able to safely operate the airplane if the control tab becomes disconnected from the pushrod. (A-03-26)
>
> Evaluate airplanes other than the DC-8 certificated to Civil Aviation Regulations 4b standards to evaluate whether disconnection or failure of critical flight control systems could have catastrophic results and, if so, require that they also be redesigned and retrofitted and/or equipped with dual-locking devices to preclude such catastrophic results. (A-03-27)
>
> Require all DC-8 operators to replace all DC-8 aluminum elevator geared tab crank arms on their DC-8 airplanes with stainless steel elevator geared tab crank arms. (A-03-28)

Require all DC-8 operators to create or revise DC-8 work cards to ensure they specifically include a postrigging inspection of the elevator assembly, including verifying the security of elevator control tab attachments. (A-03-29)

Require all DC-8 operators to review their work cards related to critical flight controls, and revise them as necessary to ensure that appropriate tasks are identified as discrete tasks with individual inspection signoff requirements. (A-03-30)

Require all 14 *Code of Federal Regulations* Part 121 air carrier operators to revise their task documents and/or work cards to describe explicitly the process to be followed in accomplishing maintenance tasks. (A-03-31)

Require all air carrier operators to either: 1) provide all pertinent maintenance personnel with the manufacturer's current installation drawings for pertinent airplanes, update those installation drawings as needed, and require use of those drawings during installation and/or assembly of that airplane's components; or 2) list the IPC on that operator's operation specifications, provide maintenance personnel with up-to-date IPCs for reference, continue to update those IPCs as needed, and require maintenance personnel to use the pertinent updated IPCs during installation and/or assembly of an airplane's components. (A-03-32)

Require operators of airplanes manufactured before August 18, 2000, that have been retrofitted with additional flight data recorder (FDR) parameters in compliance with Federal requirements and for which an operator maintains a common correlation document for that airplane type to conduct a full correlation of all such airplanes' FDR parameters at the airplanes' next required FDR maintenance inspection to verify accurate FDR system documentation and sensor function. (A-03-33)

Require all operators of airplanes equipped with Loral Fairchild Model F-800 flight data recorders to comply with Loral Fairchild Field Service Bulletins digital flight recorder (DFR) 011 and DFR 027 for recorders with applicable part numbers and installed component numbers. (A-03-34)

Require overhaul facilities that service Loral Fairchild Model F-800 flight data recorders to monitor those recorders to determine whether abnormal track switching is occurring and to report any such findings to the Federal Aviation Administration and the manufacturer. (A-03-35)

Modify the list of safety-sensitive functions described in 14 *Code of Federal Regulations* Part 121, Appendixes I and J, to include all personnel with direct access to the airplane and a direct role in the handling of the flight, including cargo handlers, load planners, and ramp supervisors. (A-03-36)

## BY THE NATIONAL TRANSPORTATION SAFETY BOARD

**ELLEN G. ENGLEMAN**
Chairman

**MARK V. ROSENKER**
Vice Chairman

**CAROL J. CARMODY**
Member

**JOHN J. GOGLIA**
Member

**RICHARD F. HEALING**
Member

**Adopted: August 5, 2003**

# Board Member Statements

**Member John J. Goglia's Statement**

I concur with the findings and probable cause of the accident; but I would like to emphasize the significance of information contained in the public docket for this accident that is not included in the report.

This is clearly a maintenance accident, related to many operations of each of the organizations involved. There is concern regarding the accuracy of company and aircraft manufacturer manuals, poor quality of task documentation and job cards, and a lack of sufficient detail to satisfactorily complete the tasks.

Both the report and the public docket identify deficiencies that are not unique. There are similar examples in the recent past contained within the NTSB accident database.

The Board has made recommendations in this report which attempt to focus attention on the inconsistent use of and responsibility for maintenance manuals, illustrated parts catalog, and task documents used to accomplish maintenance on aircraft.

Detailed task descriptions, well trained mechanics, thorough inspection of work, along with complete and accurate documentations is the only method for ensuring that a maintenance task is properly completed.

Chairman Engleman, Vice Chairman Rosenker, and Members Carmody and Healing concurred with this statement.

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# 5. Appendixes

## Appendix A
## Investigation and Hearing

### Investigation

The National Transportation Safety Board was initially notified of this accident on the evening of February 16, 2000. Investigators from the Safety Board's Southwest Regional Office went immediately to the scene of the accident. A full go-team was assembled and departed Washington, D.C., early on the morning of February 17, arriving at the accident site by late morning Pacific standard time. The go-team was accompanied by then-Safety Board Member George Black and representatives from the Safety Board's Office of Government, Public, and Family Affairs.

The following investigative groups were formed during the course of this investigation: Airworthiness (Structures/Systems), Maintenance Records, Maintenance Inspection, Powerplants, Air Traffic Control, Operations/Human Performance, Aircraft Performance, Flight Data Recorder, Cockpit Voice Recorder (CVR), CVR Sound Spectrum, and Hazardous Materials.

Parties to the investigation were the Federal Aviation Administration (FAA); the Boeing Company; Emery Worldwide Airlines, Inc. (Emery); the Air Line Pilots Association (ALPA); Miami Aircraft Support (now known as Worldwide Flight Services); Tennessee Technical Services (TTS); and General Electric Aircraft Engines.

### Public Hearing

A public hearing was conducted for this accident on May 9 and 10, 2002, in Washington, D.C. Member John Goglia presided over the hearing. Parties to the public hearing were the FAA, Boeing, Emery, TTS, and ALPA.

# Appendix B
## Cockpit Voice Recorder Transcript

The following is an excerpted transcript of the Sundstrand AV557 cockpit voice recorder (CVR) installed on the accident airplane. Only radio transmissions to and from the accident airplane were transcribed. The full CVR transcript (available in the public docket for this accident) reflects the 33 minutes and 24 seconds before power was lost to the CVR. All times are Pacific standard time, based on a 24-hour clock.

### LEGEND

| | |
|---|---|
| **CAM** | Cockpit area microphone voice or sound source |
| **RDO** | Radio communications transmitted to and from N8079U |
| **APR** | Radio transmission from Sacramento approach controller |
| **GND** | Radio transmission from Mather Field ramp personnel |
| **-1** | Voice identified as the Captain |
| **-2** | Voice identified as the First Officer |
| **-3** | Voice identified as the Second Officer |
| **-4** | Unidentified female voice |
| **-?** | Voice unidentified |
| * | Unintelligible word |
| # | Expletive |
| @ | Non-pertinent word |
| ( ) | Questionable insertion |
| [ ] | Editorial insertion |
| ... | Pause |

Note 1: Times are expressed in pacific standard time (PST).

Note 2: Generally, only radio transmissions to and from the accident aircraft were transcribed.

Note 3: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Note 4: A non-pertinent word, where noted, refers to a word not directly related to the operation, control or condition of the aircraft.

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:42:17 **CAM-1** | ready on the rudders? | | |
| 19:42:18 **CAM-3** | yep. | | |
| 19:42:20 **CAM-2** | you're ah... clear right. | | |
| 19:42:21 **CAM-1** | left rudder. center. | | |
| 19:42:23 **CAM-3** | checked. | | |
| 19:42:24 **CAM-1** | right rudder. center. | | |
| 19:42:25 **CAM-3** | checked. | | |
| 19:42:27 **CAM-1** | elevator forward. coming back. | | |
| 19:42:29 **CAM-2** | EPI checks. | | |

| INTRA-COCKPIT COMMUNICATION | | AIRCRAFT-TO-GROUND COMMUNICATION | |
|---|---|---|---|
| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
| 19:42:30 **CAM-1** | taxi check. | | |
| 19:42:31 **CAM-3** | taxi check list. flaps and slots. | | |
| 19:42:36 **CAM-1** | ahh fifteen. fifteen. fifteen. slot light's out. | | |
| 19:42:39 **CAM-2** | fifteen. fifteen. fifteen. slot light's out. | | |
| 19:42:43 **CAM-3** | controls EPI. | | |
| 19:42:44 **CAM-2** | checked. | | |
| 19:42:45 **CAM-3** | checked. | | |
| 19:42:46 **CAM-3** | fuel panel set. spoilers. | | |
| 19:42:49 **CAM-2** | retracted. lights out. | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:42:51 **CAM-3** | fuel levers. | | |
| 19:42:52 **CAM-2** | on in detent. | | |
| 19:42:53 **CAM-3** | yaw damper. | | |
| 19:42:54 **CAM-2** | on. | | |
| 19:42:55 **CAM-3** | stabilizer. | | |
| 19:42:58 **CAM-1** | one point six. | | |
| 19:43:00 **CAM-2** | set one point six. | | |
| 19:43:01 **CAM-3** | one six. | | |
| 19:43:03 **CAM-3** | shoulder harness. | | |

| INTRA-COCKPIT COMMUNICATION | | AIRCRAFT-TO-GROUND COMMUNICATION | |
|---|---|---|---|
| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
| 19:43:06 **CAM-1** | on the left. | | |
| 19:43:06 **CAM-2** | on the right. | | |
| 19:43:08 **CAM-3** | (rear). | | |
| 19:43:09 **CAM-3** | take off data briefing. | | |
| 19:43:12 **CAM-?** | [sound of throat clearing] | | |
| 19:43:13 **CAM-1** | set left reviewed. | | |
| 19:43:15 **CAM-2** | set and reviewed. | | |
| 19:43:16 **CAM-?** | set ***. | | |
| 19:43:19 **CAM-3** | flight nav instruments. | | |

**INTRA-COCKPIT COMMUNICATION**



**AIRCRAFT-TO-GROUND COMMUNICATION**

| Time (PST) **SOURCE** | **CONTENT** | Time (PST) **SOURCE** | **CONTENT** |
|---|---|---|---|
| 19:43:20 **CAM** | [sound of click] | | |
| 19:43:21 **CAM-1** | set left. | | |
| 19:43:22 **CAM-2** | set right. | | |
| 19:43:23 **CAM-3** | taxi checklist complete. | | |
| | | 19:43:26 **RDO** | [transmission from guard helicopter one six seven one nine – position report to Mather] |
| 19:43:30 **CAM-?** | **. | | |
| 19:43:30 **CAM** | [sound of laughter] | | |
| 19:43:32 **CAM-2** | sounds like he's getting a massage. | | |
| 19:43:39 **CAM-3** | whirling dervish. | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:43:43 **CAM-2** | that'd be fun. I've never been I've been in one of those airstar helicopters you know like the Cadillac of helicopters. I've never really been in a a helicopter you know. | | |
| 19:43:53 **CAM-3** | I went up one those R twenty two Robinsons. | | |
| 19:43:56 **CAM-2** | yeah... | | |
| 19:43:56 **CAM-3** | that was a * thing. | | |
| 19:43:57 **CAM-2** | ...now that was a helicopter. | | |
| 19:43:58 **CAM-2** | yeah. | | |
| 19:43:59 **CAM-3** | went up to * and did some autorotations. that was a blast. | | |
| 19:44:04 **CAM-3** | really weird going that slow in the air though. I don't like it. [sound of chuckle] | | |
| 19:44:09 **CAM-2** | hey you're you're hanging by that bolt you know. | | |

| INTRA-COCKPIT COMMUNICATION | | AIRCRAFT-TO-GROUND COMMUNICATION | |
|---|---|---|---|
| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
| 19:44:12 **CAM-3** | yeah... Jesus nut. | | |
| | | 19:44:14 **APR** | [Sacramento approach release for UPS nine fifty five] |
| 19:44:15 **CAM-2** | yep. | | |
| | | 19:44:28 **RDO** | [UPS nine fifty five transmission departing Mather] |
| 19:44:40 **CAM-1** | he must be in a hurry. | | |
| 19:44:42 **CAM-2** | he must be yeah. | | |
| 19:44:48 **CAM** | [sound similar to engine rpm increasing] | | |
| 19:44:49 **CAM-2** | he probably gets ICP. | | |
| 19:45:13 **CAM** | [sound of snap] | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| | | 19:46:12 **RDO** | [UPS nine fifty five in left hand turn to zero nine zero heading] |
| | | 19:46:43 **RDO** | [guard helicopter seven one nine crossing the numbers for two two left for taxi to north helipad] |
| 19:46:52 **CAM-2** | oh there he is. | | |
| 19:46:53 **CAM-1** | yeah. *. | | |
| | | 19:46:58 **RDO-2** | Sacramento departure Emery seventeen heavy number one two two left Mather. need our release to ah... Dayton. |
| 19:47:07 **CAM-2** | * position lights? | | |
| 19:47:07 **CAM-1** | clear right. | | |
| 19:47:08 **CAM-2** | yeah just that one beacon. | | |
| 19:47:11 **CAM-3** | no I I see 'em. | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:47:12 **CAM-?** | ***. | | |
| 19:47:13 **CAM-2** | that's * light. yeah that's an instrument light. | | |
| | | 19:47:14 **APR** | Emery seventeen heavy Sacramento approach you're released for departure report airborne. |
| 19:47:16 **CAM** | [sound of four clicks] | | |
| 19:47:18 **CAM** | [sound of clicking] | | |
| | | 19:47:20 **RDO-2** | Emery seventeen heavy we'll call you in the air. |
| 19:47:21 **CAM-?** | ** position lights. | | |
| 19:47:24 **CAM-1** | before takeoff. | | |
| 19:47:25 **CAM** | [sound similar to brake release] | | |

| INTRA-COCKPIT COMMUNICATION | | AIRCRAFT-TO-GROUND COMMUNICATION | |
|---|---|---|---|
| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
| 19:47:28 **CAM-1** | before takeoff checklist. | | |
| 19:47:29 **CAM** | [sound similar to increasing engine rpm] | | |
| | | 19:47:30 **RDO-2** | Mather area traffic Emery seventeen heavy runway two two left be a left downwind departure Mather. |
| 19:47:30 **CAM** | [sound of a clunk] | | |
| 19:47:34 **CAM** | [sound of two clunks] | | |
| 19:47:40 **CAM-?** | [sound of clearing throat] | | |
| 19:47:40 **CAM-2** | okay you're clear on the right. | | |
| 19:47:52 **CAM-3** | anti-skid. | | |
| 19:47:55 **CAM-2** | armed. light's out. | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:47:56 **CAM-3** | ignition. | | |
| 19:47:57 **CAM-2** | all engines both. | | |
| 19:47:58 **CAM-3** | transponder. DME. | | |
| 19:47:59 **CAM-2** | on. | | |
| 19:48:00 **CAM-2** | reverse switch. | | |
| 19:48:01 **CAM-2** | open pressure checks. | | |
| 19:48:02 **CAM-3** | spoiler pumps normal. stand by rudder pump start. packs are off. boost pumps boost and feed. landing lights. | | |
| 19:48:07 **CAM-1** | on. | | |
| 19:48:08 **CAM-3** | parking brake. | | |

**INTRA-COCKPIT COMMUNICATION**  **AIRCRAFT-TO-GROUND COMMUNICATION**

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:48:09 **CAM** | [sound of three clicks] | | |
| 19:48:10 **CAM-1** | released. | | |
| 19:48:10 **CAM-3** | before takeoff checklist complete. | | |
| 19:48:11 **CAM-1** | your brakes. | | |
| 19:48:12 **CAM-2** | yeah. | | |
| 19:48:15 **CAM** | [sound similar to increasing engine rpm] | | |
| 19:48:16 **CAM** | [sound of click] | | |
| 19:48:21 **CAM** | [sound of creak] | | |
| 19:48:23 **CAM-2** | stand by four. there we go. | | |

| INTRA-COCKPIT COMMUNICATION | | AIRCRAFT-TO-GROUND COMMUNICATION | |
|---|---|---|---|
| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
| 19:48:24 **CAM-3** | four spooled. | | |
| 19:48:40 **CAM-1** | set reduced. | | |
| 19:48:44 **CAM-1** | airspeed's alive. | | |
| 19:48:44 **CAM-2** | alive here. | | |
| 19:48:45 **CAM** | [sound of two clicks, first louder than second] | | |
| 19:48:50 **CAM-1** | eighty knots. | | |
| 19:48:51 **CAM-2** | eeighty knots... | | |
| 19:48:52 **CAM** | [sound of two clunks, first softer than second] | | |
| 19:48:53 **CAM-2** | ...elevator checks. | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:48:54 **CAM** | [sound of two clunks, first louder than second] | | |
| 19:48:55 **CAM** | [sound of ratcheting noise, ending with clunk] | | |
| 19:48:57 **CAM** | [sound of clunk] | | |
| 19:49:02 **CAM-1** | V one. | | |
| 19:49:06 **CAM-1** | rotate. | | |
| 19:49:08 **CAM** | [sound similar to stabilizer trim in motion alert] | | |
| 19:49:08 **CAM-1** | ** (go)... | | |
| 19:49:09 **CAM** | [sound similar to stabilizer trim in motion alert] | | |
| 19:49:09 **CAM-1** | ...watch the tail. | | |

| INTRA-COCKPIT COMMUNICATION | | AIRCRAFT-TO-GROUND COMMUNICATION | |
|---|---|---|---|
| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
| 19:49:11 **CAM** | [sound similar to stabilizer trim in motion alert] | | |
| 19:49:12 **CAM** | [sound similar to stabilizer trim in motion alert] | | |
| 19:49:13 **CAM-1** | V two. | | |
| 19:49:14 **CAM** | [sound similar to stabilizer trim in motion alert] | | |
| 19:49:14 **CAM-1** | positive rate. | | |
| 19:49:16 **CAM-2** | I got it. | | |
| 19:49:17 **CAM-1** | you got it? | | |
| 19:49:17 **CAM-2** | yep. | | |
| 19:49:18 **CAM-1** | all right. | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:49:18 **CAM** | [sound of two clicks] | | |
| 19:49:19 **CAM-2** | we're going back. | | |
| 19:49:20 **CAM-3** | what the #? | | |
| 19:49:20 **CAM-2** | CG's waay out of limits. | | |
| 19:49:25 **CAM-3** | #. do you want to pull the power back? | | |
| 19:49:27 **CAM** | [sound similar to decreasing engine rpm] | | |
| 19:49:29 **CAM** | [sound similar to stick shaker] | | |
| 19:49:30 **CAM-2** | oh #. | | |
| 19:49:30 **CAM-1** | push forward. | | |

**INTRA-COCKPIT COMMUNICATION**  **AIRCRAFT-TO-GROUND COMMUNICATION**

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:49:31 **CAM-2** | goddd... #. | | |
| 19:49:34 **CAM-2** | god. | | |
| | | 19:49:36 **RDO-1** | Emery seventeen emergency. |
| 19:49:38 **CAM-2** | ahhh #. | | |
| | | 19:49:40 **APR** | Emery seventeen Sacramento departure radar contact say again? |
| 19:49:40 **CAM-2** | you steer. I'm pushing. | | |
| | | 19:49:44 **RDO-1** | Emery seventeen has an emergency. |
| 19:49:44 **CAM-3** | we're sinking. we're going down guys. | | |
| | | 19:49:46 **APR** | Emery seventeen go ahead. |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:49:46 **CAM** | [sound similar to increased engine rpm] | | |
| 19:49:47 **CAM** | whoop whoop pull up whoop whoop pull up whoop whoop pull up whoop whoop pull up whoop... | | |
| 19:49:47 **CAM-2** | power. | | |
| 19:49:51 **CAM-2** | #. | | |
| 19:49:51 **CAM** | ... whoop pull up. [GPWS voice] | | |
| 19:49:52 **CAM-1** | all right all right... all right. | | |
| 19:49:54 **CAM-2** | push. | | |
| 19:49:54 **CAM-3** | okay so... we're going back up. | | |
| 19:49:55 **CAM** | [sound of two clunks] | | |

| INTRA-COCKPIT COMMUNICATION | | AIRCRAFT-TO-GROUND COMMUNICATION | |
|---|---|---|---|
| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
| 19:49:57 **CAM-3** | there you go. | | |
| 19:49:58 **CAM-1** | roll out. | | |
| 19:49:59 **CAM-?** | roll out. | | |
| 19:50:01 **CAM-?** | [sound of strained exhale] | | |
| | | 19:50:04 **RDO-1** | Emery seventeen extreme CG problem. |
| | | 19:50:06 **APR** | Emery seventeen roger. |
| 19:50:07 **CAM-3** | #. | | |
| 19:50:10 **CAM-?** | [sound of strained exhale] | | |
| 19:50:11 **CAM-3** | anything I can do guys. | | |

| **INTRA-COCKPIT COMMUNICATION** | | **AIRCRAFT-TO-GROUND COMMUNICATION** | |
|---|---|---|---|
| Time (PST) **SOURCE** | **CONTENT** | Time (PST) **SOURCE** | **CONTENT** |
| 19:50:11 **CAM-1** | roll out to the right. | | |
| 19:50:12 **CAM-2** | okay. | | |
| 19:50:15 **CAM-2** | push. | | |
| 19:50:16 **CAM-?** | push forward. | | |
| 19:50:18 **CAM-2** | awww... | | |
| 19:50:19 **CAM** | [sound of creaking] | | |
| 19:50:19 **CAM-2** | ...#. | | |
| 19:50:22 **CAM-?** | #. | | |
| 19:50:25 **CAM-2** | okay. | | |

| INTRA-COCKPIT COMMUNICATION | | AIRCRAFT-TO-GROUND COMMUNICATION | |
|---|---|---|---|
| Time (PST) **SOURCE** | **CONTENT** | Time (PST) **SOURCE** | **CONTENT** |
| 19:50:26 **CAM-3** | you got the trim maxed? | | |
| 19:50:28 **CAM-2** | power. | | |
| 19:50:28 **CAM-3** | more? | | |
| 19:50:29 **CAM-2** | yeah. | | |
| 19:50:29 **CAM** | whoop whoop pull up whoop whoop pull up whoop... | | |
| 19:50:32 **CAM-2** | we're gonna have to land fast. | | |
| 19:50:32 **CAM** | ...whoop pull up whoop whoop pull up. [GPWS voice] | | |
| 19:50:36 **CAM-1** | left turn. | | |
| 19:50:36 **CAM-2** | okay. | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:50:37 **CAM-2** | what I'm trying to do is make the airplane's position match the elevator. that's why I'm putting it in a bank. | | |
| 19:50:45 **CAM-1** | all right. | | |
| 19:50:45 **CAM-2** | okay. | | |
| 19:50:46 **CAM-1** | left turn. | | |
| 19:50:46 **CAM-2** | so we're gonna have to land it in like a turn. | | |
| 19:50:47 **CAM-1** | bring it around. | | |
| 19:50:48 **CAM** | [sound similar to stick shaker] | | |
| 19:50:49 **CAM-1** | bring it around. | | |
| 19:50:49 **CAM-2** | god #. | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:50:51 **CAM-?** | [sound of grunt] | | |
| 19:50:51 **CAM** | [sound of rustling] | | |
| 19:50:53 **CAM-3** | #. | | |
| 19:50:54 **CAM-2** | you got the airport? | | |
| 19:50:56 **CAM-1** | bring it around. | | |
| 19:50:56 **CAM** | [sound of snap] | | |
| 19:51:00 **CAM-2** | power. | | |
| 19:51:02 **CAM** | whoop whoop pull up whoop. [GPWS voice] | | |
| 19:51:02 [audio interruption on all four channels due to CVR tape heat damage] | | | |

| Time (PST) SOURCE | CONTENT | Time (PST) SOURCE | CONTENT |
|---|---|---|---|
| 19:51:07 **CAM-2** | power. | | |
| 19:51:07 **CAM-2** | aww #. | | |
| 19:51:08 **CAM-?** | **. | | |
| 19:51:08 **CAM** | [sound similar to impact] | | |
| 19:51:09 **End of Transcript** **End of Recording** | | | |