Aileron control cable failure on a Boeing 737-3TO on takeoff at Seattle, September 27, 1997

Micro-summary: **Flight control system failure on this Boeing 737-300 created control difficulties on takeoff.**

Event Date: **1997-09-27 at 849 PDT**

Investigative Body: **National Transportation Safety Board (NTSB), USA**

Investigative Body's Web Site: **http://www.ntsb.gov/**

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2. Readers are advised that each report is a glimpse of events at specific points in time. While broad themes permeate the causal events leading up to crashes, and we can learn from those, the specific regulatory and technological environments can and do change. ***Your company's flight operations manual is the final authority as to the safe operation of your aircraft!***

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National Transportation Safety Board

FACTUAL REPORT AVIATION

NTSB ID: SEA97IA219	Aircraft Registration Number: N13331
Occurrence Date: 09/27/1997	Most Critical Injury: None
Occurrence Type: Incident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone	
SEATTLE	WA	98158	0849	PDT	

Airport Proximity: On Airport	Distance From Landing Facility:	Direction From Airport:

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
Boeing	737-3T0	Airplane

Sightseeing Flight: No

Air Medical Transport Flight: No

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

On September 27, 1997, at 0849 Pacific daylight time, Continental Airlines flight 1046 (a Boeing 737-3T0, registration number N13331), a scheduled domestic 14 CFR 121 passenger/cargo flight enroute from Seattle/Tacoma International Airport, Seattle, Washington, to George Bush Intercontinental Airport, Houston, Texas, returned to Seattle/Tacoma International when the crew noted immediately after becoming airborne that large amounts of aileron and rudder input were required to maintain wings-level flight. The crew was able to land at Seattle/Tacoma International without damage to the aircraft or injuries to the airline transport pilot-in-command, first officer, 4 cabin crewmembers, or 128 passengers aboard. The aircraft was on an instrument flight rules (IFR) flight plan.

The crew reported that at liftoff, "considerable aileron and rudder input" was required to maintain straight and level flight, and that when aileron input was reduced to zero, at least 5 units of left rudder trim was required to maintain wings-level flight (according to Boeing, a minimum of 16.4 units of rudder trim is available.) Upon returning to the gate, it was noted that the right aileron remained up with the control wheel centered. Postflight troubleshooting revealed that the ABSB-4 aileron bus cable was broken and the ABSA-4 cable was frayed. The cable break and fraying occurred where the cables ride over the right wing/body joint aileron pulleys in the right wing root/main wheel well area. Maintenance personnel did not find any discrepancies with the pulleys. There was also no evidence found to indicate that the cables were, or had become, misrouted.

According to Boeing's records, the aircraft was delivered on August 11, 1986. On its NTSB incident report, Continental Airlines reported the aircraft's airframe total time as 34,633 hours. Continental further indicated on its NTSB incident report that the aircraft had 378 hours in service since its last inspection, a continuous airworthiness inspection performed on August 15, 1997, approximately 6 weeks prior to the incident. Continental reported that this inspection was a segmented "C" check, and that aileron cables were to be inspected during the "C" check segment which was performed at that time. Continental further reported to the NTSB that it was unable to determine whether or not the parted and frayed cables were the original cables installed at the time of aircraft delivery.

The ABSA-4 (frayed) and ABSB-4 (fractured) right wing aileron bus cables, which are both similarly constructed from 3/16 inch diameter, 7x19 wire rope, were sent to the NTSB Materials Laboratory in Washington, D.C., for examination. Examination of the fractured ends of the ABSB-4 cable revealed severe amounts of wear between the individual wires and strands (the NTSB metallurgist's factual report stated that this type of wear is generally referred to as internal cable wear.) On the vast majority of parted wires, wear had reduced the individual wire diameters to knife edges with little or no perceptible fracture surfaces. The only wires showing significant fractures were those from the core strand of wires; the features of these fractures were reported to be typical of overstress separations. It was estimated by the NTSB metallurgist that over 90% of the cable's total section had been removed by the internal wear, which appeared to be present along about 2 inches of the

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cable with some wires showing several locations of severe reduction. Severe external wear was also noted on the cable adjacent to the location of the separation; however, no wires appeared to be fractured at this wear. Energy dispersive x-ray analysis of individual wires found wire composition and tin coating consistent with MIL-W-8342, composition "A" wire rope.

In the NTSB Materials Laboratory examination, magnified optical examinations of the frayed location on the ABSA cable uncovered many of the same features as at the separation on the ABSB cable, including severe internal wear of the wires and strands. Visual examinations of the cables also disclosed several other areas of locally severe external wear, as well as several locations where the overall diameter of the cable had been reduced without damage to the exterior cable surface, which the NTSB metallurgist characterized as indicative of internal cable wear. In some locations, the cable diameter was reduced by as much as 0.03 inches (corresponding to approximately a 30% reduction in cable cross-sectional area for a nominal 3/16 inch diameter cable.)

The ABSA-4 and ABSB-4 cables were subsequently examined at Boeing's Equipment Quality Analysis (EQA) Laboratory in Renton, Washington. This examination was performed with the NTSB investigator-in-charge (IIC) along with representatives of the FAA, Boeing, and Continental Airlines in attendance. Boeing's examination of the ABSA-4 cable found wear "on the exterior of one side of the cable, the side which contacted the OD of the pulley, and not on the other side." The EQA report also stated that internal wear was also evident on this cable. The EQA report stated that on the ABSB-4 cable, "the wear occurred on the exterior of one side of the cable; the side which contacted the OD of the pulley, and not the other side." The EQA examination also noted wear on the interior of the ABSB-4 cable, between the bundles. Boeing's conclusion was: "The cables exhibited external wear which is believed to have resulted from contact with their respective pulleys. This external wear is likely the cause of the cable fraying and separation....The existence of external wear was evidenced on several portions of the cable....The internal wear was likely subsequent to the excessive external wear...."

A similar B-737 incident to the one involving Continental flight 1046 occurred at Newark, New Jersey, on March 15, 1993 (NTSB incident number NYC93IA059.) In that incident, involving a B-737-130 series aircraft also operated by Continental as flight 1659, the airplane rolled left immediately after liftoff but the pilot controlled the roll with right aileron and was able to return to Newark and land without further incident. Post-incident examinations of the left wing ABSA and ABSB aileron bus cables from that aircraft revealed that the left aileron down cable had parted in the same location (but on the left side) and manner as the parted right wing ABSB cable on Continental 1046. The NTSB determined the probable cause of the 1993 incident to be "inadequate maintenance/inspection by company maintenance personnel, the manufacturer's inadequate inspection and/or replacement procedures for the aileron cables, and subsequent failure of the 'down' aileron control cable due to wear." Based on the March 1993 Continental Airlines B-737 incident at Newark, the NTSB issued Safety Recommendations A-94-64 through A-94-66 to the FAA as follows:

A-94-64. Issue an Airworthiness Directive (AD) to operators of Boeing 727 and 737 airplanes requiring periodic inspection of the aileron cables for both internal and external wear, and for broken wires, with particular attention to the area of the cable contacting the pulleys. The inspection should include releasing cable tension to better detect cable wear and wire breakage and establishing a maximum allowable reduction in cable diameter where pulley contact occurs. Based on the inspections, develop specific flight hour intervals for replacement of the cables.

A-94-65. Require that the Boeing Company examine the consequences of a 737-100 aileron cable failure, and provide appropriate flightcrew operational guidance for the best landing configuration in the event of such a failure.

A-94-66. Conduct a comprehensive study to determine the frequency of spoiler, rudder, and aileron cable failures on airplanes weighing 12,500 pounds or greater. Where the study

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reveals flight control inspection procedures to be inadequate, require appropriate revisions to those inspection procedures and/or issue Airworthiness Directives to mandate •service life limits to assure greater reliability of those control cables.

In response to recommendations A-94-64 and A-94-65, the FAA responded on August 3, 1995, that it had conducted flight simulations in which it determined that the B-737-100 was controllable with a broken aileron cable, that no additional flightcrew guidance was necessary with regard to this condition, and that it did not consider an AD requiring periodic inspections in addition to the existing regular maintenance inspections to be necessary. The FAA also reported it reviewed the flight control cable failure rates for the B-737 fleet and found the failure rate for aileron wing cables to be 8 x 10-8 per flight hour, with the failure rate for aileron body cables being 6.4 x 10-8 per flight hour. The FAA stated that "this system performance further supports the conclusion that a broken aileron cable is an improbable occurrence." Based on the FAA response, the NTSB classified recommendation A-94-65 "Closed-Acceptable Action" on November 20, 1995.

In further response to recommendation A-94-64, the FAA stated to the NTSB on June 28, 1996, that it had examined the maintenance manuals for Boeing airplanes that utilize wire cable operated flight controls. The FAA stated that it found inconsistencies among some of the procedures, and that the best practices possible were not reflected consistently in all manuals. The FAA stated that as a result, Boeing had eliminated the inconsistencies and developed one standard inspection procedure for the Boeing family of airplanes. The new standard procedure, which the FAA stated was to be performed every 12 to 18 months, involved rubbing a cloth along the cable length to catch on broken cable strands and lock-to-lock control wheel rotation to expose cable hidden on the pulleys. Additionally, instructions for checking cable diameter wear were provided as an option. The FAA indicated Boeing would include this procedure in the B-737 maintenance manual by August 1996. In response to the FAA actions with regard to recommendation A-94-64, the NTSB replied on October 30, 1996:

While the Board remains concerned that inspecting aileron cables without releasing cable tension may not provide adequate assurance of detecting internal broken cable wires, the Board finds that FAA and Boeing efforts to standardize and improve cable inspection procedures and to establish specific flight hour intervals for inspecting cables will address most of the concerns that prompted the recommendation. Based on this information, the Board classifies A-94-64 "Closed-Acceptable Alternate Action."

In response to recommendation A-94-66, the FAA responded on August 3, 1995, that it had completed a comprehensive study to determine the frequency of spoiler, rudder, and aileron cable failures on airplanes weighing 12,500 pounds or greater. The FAA reported this study found that in the 10 years preceding the study, there had been 6 aileron cable separations on B-737 aircraft. The FAA reported that its study found inconsistencies in the cable inspection procedures for different Boeing aircraft, and that to address these inconsistencies, Boeing had developed one standard inspection procedure for the Boeing family of airplanes. This standard inspection procedure was included in a maintenance manual revision which was published in August 1996. Based on FAA responses, the NTSB classified recommendation A-94-66 "Closed-Acceptable Action" on April 7, 1997.

The B-737 AMM control cable inspection procedures were revised to incorporate the above procedures pursuant to the above-noted FAA actions following the March 1993 B-737 incident, and following a May 1995 FAA Critical Design Review (CDR) of the B-737 flight control system, which also recommended that the FAA "evaluate the adequacy of the B737 maintenance manual actions addressing flight control cable inspection, rigging procedures and replacement criteria...." (FAA, B-737 Flight Control System [FCS] CDR Report, May 3, 1995, Recommendation -23.) The CDR also recommended that the FAA "require control cable service life limits unless acceptable inspection and/or test procedures are developed and utilized that can determine the continuing serviceability of the control cables" (FAA B-737 FCS CDR Report, Recommendation -24.) In regard to CDR Recommendation -24, Boeing and the FAA determined that, based on in-service experience and airline responses,

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neither life limits for the cables nor any change in cable inspection frequencies was required.

According to Boeing's aircraft maintenance manual (AMM) for the Boeing 737 (B-737), the ABSB-4 aileron bus cable is a replace-on-condition item, with wear criteria for replacement specified via a figure in the AMM (Section 20-20-31, Figure 601) which depicts diagrams of cable wear to aid in gauging the extent of wear. The AMM recommends inspection of exposed cables at each maintenance "C" check (every 3,200 flight hours), with non-exposed cables checked every other "C" check (every 6,400 flight hours.) According to a Boeing air safety investigator, "C" checks are performed approximately once each year at typical airline aircraft utilization rates.

The AMM procedure for inspection of the control cables (Task 20-20-31-206-002) specifies the following procedures: doing a check for broken wires by rubbing a cloth along the length of the cable in both directions (broken wires are indicated where the cloth gets caught on the cable); displacing the control cable system full travel in each direction for complete inspection at seals, pulleys, and fairlead areas; use of a flashlight and mirror to aid inspection in hard to see places; and replacement of a 7x19 control cable upon finding (among other conditions) 4 broken wires in 12 continuous inches of cable, or more than 6 broken wires in a total cable length between the two cable terminals. An "optional as needed" check for wear directs cable replacement if (among other conditions) one strand has worn wires where one wire cross section is decreased by 40% or more. The General section of the AMM "Control Cables - Inspection/Check" procedure states, "Wires break most frequently where cables go through fairlead areas or around pulleys. Examine these areas carefully."

As a result of the September 1997 Seattle incident involving Continental flight 1046, Continental Airlines took the following remedial actions:

1. Issued Fleet Campaign Directive (FCD) number 2711-01011-A, "Inspection of the 737 Aileron Bus System Cables in the MLG Wheel Well Area", on January 9, 1998. This FCD directed a detail visual inspection of aileron bus cables in both main landing gear wheel well bays on its entire B-737 fleet in accordance with AMM section 20-20-31, along with replacement of any cable found damaged or with excessive wear or reduced thickness.

2. Issued Engineering Authorization (EA) 2711-01012, "737 Aileron Bus Cables Inspection and Replacement", effective November 13, 1997. This EA established a repetitive inspection requirement for aileron bus cables on Continental Airlines B-737-100/-200/-300/-500 aircraft for wear, damage, and corrosion every 4,000 hours. In addition, the EA established hard time replacement of the ABSA-1, ABSA-2, ABSA-3, ABSA-4, ABSB-1, ABSB-2, ABSB-3, and ABSB-4 aileron bus cables on Continental Airlines B-737-100/-200/-300/-500 aircraft at every "D" check.

3. Issued Maintenance Specification Amendment (MSA) number 970148, "B737-300/-500 Aileron Bus Cables - Discard", on December 1, 1997. This MSA amended the Continental Airlines B-737-300/-500 maintenance specifications by creation of a specification task to remove, discard and replace the aileron bus cables at an 8 year frequency per EA 2711-01012.

Additionally, in response to the May 1995 FAA B-737 CDR, Continental Airlines issued MSA number 970081 on June 2, 1997. This MSA increased the level of detail of control cable inspections on Continental Airlines B-737s from "General Visual Inspection" to "Detailed Visual Inspection."

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Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
SEATTLE-TACOMA INTL	SEA	429 Ft. MSL	16L	11900	150

Runway Surface Type: Asphalt

Runway Surface Condition:

Type Instrument Approach:

VFR Approach/Landing: Precautionary Landing

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
Boeing	737-3T0	23569

Airworthiness Certificate(s): Transport

Landing Gear Type: Retractable - Tricycle

Homebuilt Aircraft?	Number of Seats:	Certified Max Gross Wt.	Number of Engines:
No	134	135000 LBS	2

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Turbo Fan	Cfm	CFM56-3B	20100 LBS

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
Continuous Airworthiness	08/1997	378 Hours	34633 Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?	ELT Operated?	ELT Aided in Locating Accident Site?
No		

Owner/Operator Information

Registered Aircraft Owner	Street Address	City	State	Zip Code
WILMINGTON TRUST CO.	RODNEY SQUARE NORTH	WILMINGTON	DE	19890

Operator of Aircraft	Street Address	City	State	Zip Code
CONTINENTAL AIRLINES	2929 ALLEN PARKWAY	HOUSTON	TX	77019

Operator Does Business As:

Operator Designator Code: CALA

- Type of U.S. Certificate(s) Held:

Air Carrier Operating Certificate(s): Flag Carrier/Domestic

Operating Certificate:

Operator Certificate:

Regulation Flight Conducted Under: Part 121: Air Carrier

Type of Flight Operation Conducted: Scheduled; Domestic; Passenger/Cargo

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First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File	On File	54

Sex: M | Seat Occupied: Left | Principal Profession: Civilian Pilot | Certificate Number: On File

Certificate(s): Airline Transport; Flight Engineer

Airplane Rating(s): Multi-engine Land

Rotorcraft/Glider/LTA: None

Instrument Rating(s): Airplane

Instructor Rating(s): None

Type Rating/Endorsement for Accident/Incident Aircraft? Yes | Current Biennial Flight Review?

Medical Cert.: Class 1 | Medical Cert. Status: Valid Medical--w/ waivers/lim. | Date of Last Medical Exam: 08/1997

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	20000	6107								
Pilot In Command(PIC)										
Instructor										
Last 90 Days	212	212								
Last 30 Days	68	68								
Last 24 Hours	5	5								

Seatbelt Used? Yes | Shoulder Harness Used? Yes | Toxicology Performed? No | Second Pilot? Yes

Flight Plan/Itinerary

Type of Flight Plan Filed: IFR

Departure Point	State	Airport Identifier	Departure Time	Time Zone
Same as Accident/Incident Location		SEA	0849	PDT

Destination	State	Airport Identifier
HOUSTON	TX	IAH

Type of Clearance: IFR

Type of Airspace: Class B

Weather Information

Source of Briefing: Company

Method of Briefing:

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Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
SEA	0756	PDT	429 Ft. MSL	0 NM	0 Deg. Mag.

Sky/Lowest Cloud Condition: Scattered 4500 Ft. AGL

Condition of Light: Day

Lowest Ceiling: Broken 18000 Ft. AGL

Visibility: 10 SM

Altimeter: 30.00 "Hg

Temperature: 13 °C

Dew Point: 10 °C

Wind Direction: 180

Density Altitude: Ft.

Wind Speed: 15

Gusts:

Weather Condtions at Accident Site: Visual Conditions

Visibility (RVR): 0 Ft.

Visibility (RVV) 0 SM

Intensity of Precipitation: Unknown

Restrictions to Visibility: None

Type of Precipitation: None

Accident Information

Aircraft Damage: None

Aircraft Fire: None

Aircraft Explosion None

Classification: U.S. Registered/U.S. Soil

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot				1	1
Second Pilot				1	1
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants				4	4
Other Crew					
Passengers				128	128
- TOTAL ABOARD -				134	134
Other Ground	0	0	0		0
- GRAND TOTAL -	0	0	0	134	134

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Administrative Information

Investigator-In-Charge (IIC)

GREGG NESEMEIER

Additional Persons Participating in This Accident/Incident Investigation:

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