



AVIATION



HIGHWAY



MARINE



RAILROAD



PIPELINE

# Aviation Investigation Final Report

<b>Location:</b>	DFW AIRPORT, Texas	<b>Incident Number:</b>	FTW97IA144
<b>Date &amp; Time:</b>	March 27, 1997, 08:45 Local	<b>Registration:</b>	N105DA
<b>Aircraft:</b>	Boeing 767-232	<b>Aircraft Damage:</b>	Minor
<b>Defining Event:</b>		<b>Injuries:</b>	198 None
<b>Flight Conducted Under:</b>	Part 121: Air carrier - Scheduled		

## Analysis

During the landing approach, with the flaps extended to 15 degrees and the spoilers deployed, an 18-foot section of the right outboard flap separated from the trailing edge of the right wing. After making a flyby of the tower to allow controllers to view the extent of the damage, the flightcrew landed the airplane without further incident. The flap separation resulted from fatigue cracking of the four aft bolts fastening the flap to the inboard flap carriage support beam. The relief shoulders on three of the bolts exhibited thread contact marks which indicated that the attachment nuts were inserted all the way down to the relief shoulders. Either the bolt grip lengths were longer than necessary for this installation, or not enough shims were installed under the heads of the bolts or attachment nuts. Under these circumstances, the bolts most likely did not receive sufficient preload in tension, since the nuts probably bottomed onto the relief shoulders before the preload could be produced. Maintenance records indicated that the flap had not been removed from the wing since manufacture of the airplane in 1982 and had accumulated 45,577 flight hours and 22,155 flight cycles.

## Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: The manufacturer's improper installation of the flap, which resulted in fatigue cracking of the flap attach bolts and separation of the flap.

## Findings

Occurrence #1: AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION

Phase of Operation: APPROACH

### Findings

1. (C) FLIGHT CONTROL, FLAP ATTACHMENT
2. (C) MAINTENANCE, INSTALLATION - IMPROPER - MANUFACTURER
3. (C) MISCELLANEOUS, BOLT/NUT/FASTENER/CLAMP/SPRING - FATIGUE
4. (C) MISCELLANEOUS, BOLT/NUT/FASTENER/CLAMP/SPRING - CRACKED
5. FLIGHT CONTROL, FLAP - SEPARATION

## Factual Information

### HISTORY OF FLIGHT

On March 27, 1997, approximately 0845 central standard time, a section of the right outboard flap separated from a Boeing 767-232, N105DA, during the airplane's approach to the Dallas/Fort Worth International Airport (DFW), Texas. The airplane was being operated by Delta Air Lines, Inc., under Title 14 CFR Part 121, as scheduled domestic passenger flight 691, from Orlando, Florida, to DFW. After making a flyby of the tower to allow controllers to view the extent of the damage, the flightcrew landed the airplane without further incident. There were no injuries to the 189 passengers or the 9 crewmembers aboard the airplane. The separated flap section came to rest in an open field in Carrollton, Texas, and there were no injuries to ground personnel.

In a written statement provided to the NTSB investigator-in-charge (IIC), the captain of flight 691 reported that the takeoff and departure from Orlando were "routine, as were all aspects of the enroute phase of the flight." During the descent for landing on runway 17C at DFW, with the spoilers fully deployed and the flaps extended to 5 degrees, the first officer, who was the pilot flying, called for 15 degrees of flaps. The captain set the flaps at 15 degrees, and "a few moments later [he] felt a strong jolt." He noted that the first officer was using "a significant amount of left aileron" and had disengaged the autopilot and retracted the spoilers. The captain stated that "despite the unusual control inputs required, [the first officer] had the aircraft under control." He further stated that "there were no cockpit indications of a spoiler or flap problem."

According to the captain, a few seconds after the event, he received an intercom communication from the mid-station flight attendant reporting that a portion of the right wing had separated. He informed air traffic control that the flight was experiencing a problem and requested a flyby of the tower. Following a low pass "between 1,000 and 1,500 feet MSL" along the centerline of Runway 17L, the tower controller informed the flight that there was "something sticking up from [the] right wing." The captain declared an emergency and requested a visual approach to the longest available runway. The flight was cleared to land on runway 17R, and the approach was flown at "180 KIAS" (knots indicated airspeed), at which speed "the aircraft was controllable and stable." Following the landing, which the captain characterized as "flat and smooth," the flight "taxied in and shut down without further problems."

### DAMAGE TO AIRCRAFT

Examination of the airplane by FAA inspectors and Delta maintenance personnel revealed that approximately 18 feet of the right outboard flap had separated from the trailing edge of the

right wing. The inboard and outboard flap carriage assemblies remained affixed to the wing, and the outboard 14 feet of the flap remained attached to the outboard flap carriage support beam. Collateral damage included separation of the trailing edge of the #9 spoiler and damage to the trailing edge of the #12 spoiler.

The separated section of the flap, which was recovered from an open field approximately 10 miles northeast of DFW, extended from the inboard flap edge at Wing Butt Line (WBL) 355 to approximately 1 foot inboard of the outboard flap carriage support beam at WBL 622. Further examination of the separated section revealed that the six bolts which fastened the lower surface of the flap to the inboard flap carriage support beam at WBL 456 had fractured. The lower pieces of the bolts (threaded portions) and the nuts used to secure the bolts were not recovered. The upper piece of each fractured bolt (head and shank portion) was found protruding through its respective attaching hole in the lower surface of the separated flap section. Portions of the fracture surfaces on three of the four aft bolts displayed dark discoloration. The fracture surfaces on the two forward bolts and the other aft bolt were unremarkable. All six of the bolts were removed, and at the request of the NTSB IIC, delivered by Delta to the NTSB Materials Laboratory, Washington, DC, for metallurgical examination.

#### AIRCRAFT INFORMATION

N105DA, a Boeing 767-232, serial number 22217, was manufactured on January 8, 1983. The airplane had accumulated 45,577 hours and 22,155 flight cycles at the time of the incident. According to Delta safety personnel, the airplane's maintenance records did not indicate any removal of the right outboard flap from the wing since Delta accepted delivery of the airplane from Boeing on January 19, 1983.

In response to questions raised by the IIC regarding recurring inspection procedures, a Boeing representative stated that a visual inspection of the outboard flap attachment bolts was "called out at "C" check intervals," specifically a visual inspection at "1C" checks and a detailed visual inspection at "4C" checks. The representative further stated that "there was no routine maintenance called out to check the bolt torque."

The most recent "1C" check of the airplane was performed on October 22, 1996, at an airframe total time of 44,167 hours (1,410 hours before the incident). On February 15, 1997, at an airframe total time of 45,294 hours (283 hours before the incident), the airplane underwent a service check. The last maintenance inspection performed prior to the incident was a layover check on March 26, 1997. (Delta accomplishes "C" checks, service checks, and layover checks at intervals of 4,000 hours, 400 hours, and once per day, respectively.) According to a Delta representative, both the layover check and the service check provided for a visual inspection of the wings, and both checks required inspection of the flaps for general condition and security. No discrepancies with the right outboard flap were noted during the performance of these three inspections.

#### FLIGHT RECORDERS

The cockpit voice recorder (CVR) was not readout. At the request of the NTSB IIC, the Digital Flight Data Recorder (DFDR) was readout by Delta, and a file containing the raw data was sent to the Safety Board's laboratory in Washington, DC, for evaluation. For details of the DFDR evaluation refer to the Flight Data Recorder Factual Report. The recorded parameters included left and right trailing edge flap positions, left and right inboard aileron positions, and left and right outboard aileron positions. The recorded parameters did not include spoiler position or control wheel position.

The tabular data indicated that the flaps reached 15 degrees extension at FDR subframe reference number 8916. Flap separation occurred 1 minute 54 seconds later, between FDR subframe reference numbers 9030 and 9031, when the airplane was at an altitude of approximately 5,000 feet MSL and an airspeed of 208 knots. During the next 11 seconds (9031 to 9042), the airplane rolled right to a maximum roll angle of 15.12 degrees right wing low and then returned to a wings level attitude.

Prior to flap separation, the right and left inboard ailerons were deflected to -10 and -8 degrees respectively. (With reference to aileron positions, negative numbers indicate trailing edge down deflection.) The inboard ailerons droop 10 degrees when the flaps are extended beyond 5 degrees. The deflection limits for the inboard ailerons are +20 and -20 degrees. Immediately after flap separation, the right inboard aileron deflected to and maintained -20 degrees, its maximum down limit. The left inboard aileron initially deflected to +13.5 degrees and then varied from +10 to +16 degrees before stabilizing around +14 degrees.

Prior to flap separation, the right and left outboard ailerons were deflected to +2 and 0 degrees respectively. The deflection limits for the outboard ailerons are +30 and -15 degrees. Immediately after flap separation, the right outboard aileron deflected to and remained approximately -10 degrees. The left outboard aileron initially deflected to +16 degrees and then varied from +13 to +19 degrees before stabilizing around +17 degrees.

According to graphical data provided by Boeing, the stabilized aileron positions recorded by the DFDR corresponded to a control wheel position of 30 to 35 degrees left. The control wheel deflection limits are 65 degrees left or right.

During a telephone interview, Boeing engineering personnel reported that the DFDR samples each aileron control surface position at 2 second intervals, alternating every second between left and right wings, giving an effective sample interval of 1 second. They further reported that the DFDR receives primary control surface position inputs from the same source as the Engine Indication and Crew Alerting System (EICAS) control surface position display. The EICAS display incorporates a 1 second time lag, only showing a control surface movement if the control surface remains deflected for at least 1 full second. Therefore, rapid control inputs and the corresponding control surface movements are not shown on the EICAS display or captured by the DFDR.

## TESTS AND RESEARCH

Examination of the six fractured bolts in the NTSB Materials Laboratory revealed that the four aft bolts displayed fatigue propagation through 2%, 8%, 30%, and 35%, respectively, of their fracture surfaces. The fracture areas beyond the fatigue regions on the four aft bolts and the entire fracture surfaces on the two forward bolts contained features typical of overstress separation.

All six bolts contained a circumferential thread relief shoulder that was located between the threads and the non-threaded shank. Three of the four aft bolts exhibited thread contact marks on the thread relief shoulder, as if the thread relief shoulder was making contact with the threads of an attachment nut. All six bolts displayed fretting damage on the shank. For a detailed description of the metallurgical findings refer to the Metallurgist's Factual Report.

The NTSB metallurgist noted that the measured grip lengths of the four aft bolts did not correspond to the grip lengths of the bolts specified in the Boeing installation drawing for the outboard trailing edge flap (Drawing No. 113T13000.) Additionally, review of the figure, entitled "Flap Instl - Outbd TE," on pages 0-14 of the Boeing 767 Illustrated Parts Catalog (IPC) 27-51-21-01, by the IIC established that the IPC called out a specific grip length bolt for each of the six flap carriage support beam bolts.

In response to questions raised by the IIC regarding grip lengths of bolts, a Boeing representative stated that "the assembly and installation diagrams give the factory authority to vary the bolt grip lengths to accommodate the various shim requirements." The representative further stated that "the shims are required to achieve proper fit and fair of the flap with the rest of the wing surface. Therefore, the shim thickness and bolt grip lengths will be different for every airplane."

The instructions contained in the Boeing 767 Airplane Maintenance Manual (AMM) 27-51-20, pages 402-411 and 417-426, for installation of the outboard flaps were reviewed by the IIC. The procedure for achieving proper fit and fair of the flap directed the mechanic to adjust the shims to change the position of the flap. No mention was made in the AMM of the need to adjust bolt grip length in conjunction with the addition or removal of shims in order to ensure proper installation. (In November 1997, the AMM was revised, and a note was added to page 419, which stated, "make sure the bolts have the correct grip length.")

## ADDITIONAL INFORMATION

On April 1, 1997, Boeing issued Alert Service Bulletin 767-27A0151 calling for an inspection of the outboard flap attachment bolts on Boeing 767 airplanes with more than 25,000 hours or 10,000 flight cycles. Revision 1 to the service bulletin, which made corrections to the original, was issued on April 2, 1997. On the same day, the FAA issued Telegraphic Airworthiness Directive (AD) T97-08-51, applicable to "all model 767 series airplanes," mandating "an inspection to check the bolt torque, bolt length, and type of all bolts of both hinge fittings on

the left- and right-hand outboard trailing edge flaps," in accordance with the Boeing service bulletin.

On April 10, 1997, Boeing issued Revision 2 to the service bulletin. This revision added a note to the accomplishment instructions stating, in part:

Due to shimming requirements, the nominal stack-up of shims at the forward and aft locations may vary plus or minus 0.25 inches. During bolt installations adjust the bolt grip length plus or minus 4 grip lengths from the nominal grip length specified in IPC 27-51-21 as required to ensure proper installation.

On June 15, 1997, Boeing sent a message to "all Boeing 767 operators" containing the following fleet summary of the results from accomplishment of the service bulletin:

Number of airplanes reported: 212 (848 joints, 5088 bolts) Joints with loose bolts: 176 (176/848 = 21%) Bolts too long/short: 138 (138/5088 = 2.8%) Airplanes with bolt type different from drawing: 10 Fatigue cracked bolt: 6 (on 3 aircraft) Bolts fractured on retorquing: 5 Cracked nuts (also of wrong type): 5 Missing radius filler: 1

The message stated that the above results included "several airplanes that were inspected with less than 10,000 flight cycles or 25,000 flight hours." It further stated that based on the data, Boeing intended to revise the service bulletin by lowering the threshold for initial inspection to 5,000 flight cycles or 12,500 flight hours. On July 7, 1997, Revision 3 to the service bulletin, which incorporated this change, was issued.

In correspondence with Safety Board staff, Boeing has indicated that it intends to issue a new service bulletin on the outboard flap attachment bolts in the second quarter of 1998, which "will define terminating action and recommend periodic checks."

The six fractured bolts were released to Delta on June 18, 1997.

## Pilot Information

<b>Certificate:</b>	Airline transport; Commercial; Flight engineer	<b>Age:</b>	55,Male
<b>Airplane Rating(s):</b>	Single-engine land; Multi-engine land	<b>Seat Occupied:</b>	Left
<b>Other Aircraft Rating(s):</b>	None	<b>Restraint Used:</b>	
<b>Instrument Rating(s):</b>	Airplane	<b>Second Pilot Present:</b>	Yes
<b>Instructor Rating(s):</b>	None	<b>Toxicology Performed:</b>	No
<b>Medical Certification:</b>	Class 1 Valid Medical-w/ waivers/lim	<b>Last FAA Medical Exam:</b>	February 7, 1997
<b>Occupational Pilot:</b>	Yes	<b>Last Flight Review or Equivalent:</b>	
<b>Flight Time:</b>	15000 hours (Total, all aircraft), 150 hours (Last 90 days, all aircraft)		

## Aircraft and Owner/Operator Information

<b>Aircraft Make:</b>	Boeing	<b>Registration:</b>	N105DA
<b>Model/Series:</b>	767-232 767-232	<b>Aircraft Category:</b>	Airplane
<b>Year of Manufacture:</b>		<b>Amateur Built:</b>	
<b>Airworthiness Certificate:</b>	Transport	<b>Serial Number:</b>	22217
<b>Landing Gear Type:</b>	Retractable - Tricycle	<b>Seats:</b>	207
<b>Date/Type of Last Inspection:</b>	February 15, 1997 Continuous airworthiness	<b>Certified Max Gross Wt.:</b>	335000 lbs
<b>Time Since Last Inspection:</b>	283 Hrs	<b>Engines:</b>	2 Turbo fan
<b>Airframe Total Time:</b>	45577 Hrs	<b>Engine Manufacturer:</b>	GE
<b>ELT:</b>		<b>Engine Model/Series:</b>	CF6-A2
<b>Registered Owner:</b>	DELTA AIR LINES, INC.	<b>Rated Power:</b>	48670 Lbs thrust
<b>Operator:</b>		<b>Operating Certificate(s) Held:</b>	Flag carrier (121)
<b>Operator Does Business As:</b>		<b>Operator Designator Code:</b>	DALA



## Meteorological Information and Flight Plan

<b>Conditions at Accident Site:</b>	Visual (VMC)	<b>Condition of Light:</b>	Day
<b>Observation Facility, Elevation:</b>	DFW ,603 ft msl	<b>Distance from Accident Site:</b>	9 Nautical Miles
<b>Observation Time:</b>	08:53 Local	<b>Direction from Accident Site:</b>	225°
<b>Lowest Cloud Condition:</b>	Unknown	<b>Visibility</b>	10 miles
<b>Lowest Ceiling:</b>	Broken / 8500 ft AGL	<b>Visibility (RVR):</b>	
<b>Wind Speed/Gusts:</b>	6 knots / None	<b>Turbulence Type Forecast/Actual:</b>	/
<b>Wind Direction:</b>	170°	<b>Turbulence Severity Forecast/Actual:</b>	/
<b>Altimeter Setting:</b>	30 inches Hg	<b>Temperature/Dew Point:</b>	14°C / 8°C
<b>Precipitation and Obscuration:</b>	No Obscuration; No Precipitation		
<b>Departure Point:</b>	ORLANDO (MCO )	<b>Type of Flight Plan Filed:</b>	IFR
<b>Destination:</b>	(DFW )	<b>Type of Clearance:</b>	IFR
<b>Departure Time:</b>	00:00 Local	<b>Type of Airspace:</b>	Class B

## Airport Information

<b>Airport:</b>	DALLAS-FT. WORTH INTL DFW	<b>Runway Surface Type:</b>	Concrete
<b>Airport Elevation:</b>	603 ft msl	<b>Runway Surface Condition:</b>	Dry
<b>Runway Used:</b>	17R	<b>IFR Approach:</b>	Visual
<b>Runway Length/Width:</b>	13400 ft / 200 ft	<b>VFR Approach/Landing:</b>	Full stop

## Wreckage and Impact Information

<b>Crew Injuries:</b>	9 None	<b>Aircraft Damage:</b>	Minor
<b>Passenger Injuries:</b>	189 None	<b>Aircraft Fire:</b>	None
<b>Ground Injuries:</b>	N/A	<b>Aircraft Explosion:</b>	None
<b>Total Injuries:</b>	198 None	<b>Latitude, Longitude:</b>	

## Administrative Information

<b>Investigator In Charge (IIC):</b>	Snyder, Georgia
<b>Additional Participating Persons:</b>	VINCENT L COLLAMORE; DFW AIRPORT , TX PAUL VISLOSKY; ATLANTA , GA JOHN HAMILTON; SEATTLE , WA JIMMY D SHAW; HERNDON , VA
<b>Original Publish Date:</b>	November 10, 1998
<b>Last Revision Date:</b>	
<b>Investigation Class:</b>	<a href="#">Class</a>
<b>Note:</b>	
<b>Investigation Docket:</b>	<a href="https://data.nts.gov/Docket?ProjectID=20067">https://data.nts.gov/Docket?ProjectID=20067</a>

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