
Total electrical failure on approach, Boeing 737-232, December 15, 1998

Micro-summary: Electrical failure on approach resulted in a missed approach and difficult troubleshooting for the crew of this Boeing 737-232.


Event Date: 1998-12-15 at 1216 EST


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

Investigative Body's Web Site: <http://www.nts.gov/>

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		NTSB ID: MIA99IA046		Aircraft Registration Number: N327DL	
		Occurrence Date: 12/15/1998		Most Critical Injury: None	
		Occurrence Type: Incident		Investigated By: NTSB	
Location/Time					
Nearest City/Place ORLANDO		State FL	Zip Code 32827	Local Time 1216	Time Zone EST
Airport Proximity: On Airport		Distance From Landing Facility:		Direction From Airport:	
Aircraft Information Summary					
Aircraft Manufacturer Boeing		Model/Series 737-232		Type of Aircraft Airplane	
Sightseeing Flight: No			Air Medical Transport Flight: No		
Narrative					
Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:					
<p>On December 15, 1998, about 1216 eastern standard time, a Boeing 737-232, N327DL, registered to Wilmington Trust Company Trustee, operated by Delta Air Lines Inc., flight 2461, as a 14 CFR Part 121 scheduled domestic passenger/cargo flight, experienced a reported total loss of electrical power on approach for landing at Orlando International Airport, Orlando, Florida. Visual meteorological conditions prevailed and an IFR flight plan was filed. The airplane sustained minor damage. The airline transport-rated pilot-in-command (PIC), first officer (FO), 3 flight attendants, and 51 passengers reported no injuries. The flight originated from Boston, Massachusetts, about 3 hours 16 minutes before the incident.</p> <p>The PIC stated they were cleared for a visual approach to runway 35 at Orlando International Airport. The FO was flying the airplane. All descent and approach checklists were completed. The APU was started on base leg. The FO called for the gear and flaps 15. The airplane experienced a total loss of electrical power as the gear and flaps were extended. The APU did not start, and the battery indicated between 17 to 18 volts. The normal checklist procedures were accomplished followed by the quick reference procedures. Electrical power was unable to be restored. A go-around was initiated to continue the checklist. All communications and electrical equipment failed. The flap indicator indicated an asymmetrical setting. A flight controllability check was accomplished with no anomalies. The flight was continued and landing was made to runway 35. A left main landing gear tire blew out on rollout. The airplane cleared the runway, stopped, and was towed to the ramp.</p> <p>The Solid State Flight Data Recorder (SSFDR) was removed from the incident aircraft and sent to the NTSB Vehicle Recorders Laboratory for readout and evaluation. The SSFDR indicates that the aircraft was descending through 2,700 feet on a heading of about 280 degrees when the data stops recording. The next recorded data shows the aircraft on the ground. The time gap between the last recorded data during the descent and the data recorded while the aircraft was on the ground is unknown. For additional information see NTSB Flight Data Recorder, Specialist's Factual Report of Investigation.</p> <p>A detailed inspection of the aircraft's electrical system was performed; which ultimately required the removal of numerous electrical system components for further teardown inspections, included an operational check of all related cockpit systems, and a verification flight (flight test) following all onboard troubleshooting and component replacements. The components were replaced and sent to Delta's maintenance facility in Atlanta, Georgia, for a preliminary inspection, before being sent to Boeing Aircraft Company in Seattle, Washington for further testing.</p> <p>Testing of the No. 1 and No. 2 Generator Control Units (GCUs) revealed that the AC (alternating current) power supply input fuses (3 each), commonly referred to as point-of-regulation (POR) fuses, had blown (i.e. opened) due to excessive current and that a</p>					
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blocking diode (CR910) was shorted. Although the testing was unable to determine the cause of the shorted CR910 diodes, the testing did prove that an attempt to start the auxiliary power unit (APU) with a weak (i.e. discharged) battery and shorted CR910 diodes, would result in the immediate opening of the POR fuses mounted internal to the No. 1 and 2 GCUs.

Testing of the analog cockpit DC (direct current) voltmeter revealed that the meter consistently indicated 1.5 to 2.0 volts high over its full scale deflection (i.e. 0 to 40 volts).

The battery was replaced because its voltage remained low (approximately 18 volts, unloaded) and would not accept a charge even with the new battery charger installed. According to the Delta B737 Operation Manual, Expanded Normal Checklist, a battery voltage of 23 volts minimum is required prior to the first flight of each day. Delta reported that 23 volts corresponds to the minimum battery voltage required to start the APU. Per the Delta B737 Service Check (performed every 200 flight hours), the battery is to be replaced if a voltage of 23.5 volts or less is detected.

Inspection of the battery revealed that the individual cell electrolyte levels were not visible and the battery was fully discharged. The cover of the battery case was removed to expose the top of the cells. Overall, the battery appeared to be in good condition externally. However, there appeared to be small areas of corrosion on some of the cell connections and dried electrolyte present on the tops of several cells adjacent to the cell vents. One cell cap was removed for further investigation. However, no electrolyte was visible in the cell. A quick check with a portable voltmeter taken at Boeing Aircraft, a month after the incident revealed that 19 cells measure between 1.2 and 1.3 volts. The remaining cell measured approximately 0.7 volts.

•The No. 1 engine was air started and an attempt was made to bring the No. 1 generator on line. However, the attempt failed and therefore the No. 1 GCU was replaced. The generator subsequently powered up properly and was able to supply both sides of the aircraft electrical distribution system normally (i.e. No. 1 Generator Bus, No. 1 & No. 2 Transfer Bus). No faults were noted while running the No. 1 generator. The generator was loaded to over 50 AC amperes, by supplying the electric fuel pumps, landing lights, pitot heat, windshield heat, and cycling the flaps to 15 degrees without incident. The DC voltmeter indicated 28 volts, the DC ampere-meter (ammeter) indicated 0 amperes. The No. 1 engine-driven generator was then shut down.

Upon replacement of the battery, the APU was started normally and its generator able to supply power to the ship's electrical system without any problems noted. Maintenance personnel were able to reset the APU generator feeder fault initially noted on the M238 annunciator panel once the generator was on line. The DC voltmeter indicated 28 volts subsequent to the APU start. The DC ammeter indicated an initial charge of approximately 50 amperes, that decreased in magnitude following the APU start.

The No. 2 engine was air started and an attempt made to bring its generator on line. The attempt was unsuccessful and therefore the No. 2 GCU was replaced. The No. 2 generator subsequently came on line and functioned normally while powering the starboard buses. The APU remained on line and powered the port buses at this time. AC bus voltages, current, frequency and battery readings were all normal throughout this testing. Maintenance personnel were able to be reset the No. 2 generator feeder fault initially noted on the M238 annunciator panel once the generator was on line. During this phase of testing, maintenance personnel witnessed a chafed No. 2 generator feeder cable short to ground, as indicated by a flash between the cable and the No. 2 engine (No. 4, 4.5, 5, & 6) bearing breather line assembly B-nut This chafing damage was previously noted during the initial examination of the airplane.

Preliminary teardown inspections of the electrical system components removed from N327DL were conducted at Delta's Technical Operations Center in Atlanta, Georgia on December 16, 1998. On January 26, 1999, Delta issued Engineering Authorization No. 376152-14, which documented the results of these component inspections. The teardown inspections were witnessed by an FAA inspector

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from the Delta Certificate Management Office and revealed the following significant findings:

a) The No. 1 and 2 GCUs had experienced identical failures. [i.e. Testing revealed that the POR fuses, mounted internal to each GCU, had opened due to excessive current. These fuses were replaced in order to complete the testing of each GCU using Delta automatic test equipment (ATE). Testing of both units using the ATE revealed that a blocking diode (CR910) had shorted in the battery power supply input circuitry to each of the GCUs.] Note that CR910 is a blocking diode installed in the DC (i.e. battery) power supply circuitry internal to each GCU that allows current flow from the battery to the GCU however prevents current flow in the opposite direction.

b) The battery electrolyte levels were low or non-existent in all cells. The battery voltage was below the minimum serviceable limit.

c) The cockpit DC voltmeter indicated approximately 2.0 volts high over its full scale deflection (i.e. 0 to 40 volts).


An operational check of all related cockpit systems was performed. The following anomalies were noted during these check procedures:


a) The cockpit DC voltmeter indicated 2.0 volts when de-energized. Therefore the meter was removed and replaced at the request of the NTSB. The removed indicator was shipped to Delta's maintenance facility in Atlanta, Georgia, for further testing to verify its full-scale calibration (i.e. error). Note: Although Delta does not require the periodic calibration of the cockpit DC voltmeter when installed, the meter is calibrated during overhauls.

b) During transfers of power from the No. 2 generator to the APU generator (i.e. closing of the No. 2 bus tie breaker), a No. 2 feeder fault would occur on the M268 annunciator panel. The feeder fault could be subsequently cleared with a reset at the panel. However, during the transfer of power from the No. 1 generator to the APU generator no such feeder faults were noted. Maintenance removed and replaced the No. 2 GCU and this problem was eliminated.

A verification flight was conducted prior to returning N327DL to service. The duration of the flight test was approximately 30 minutes. The landing gear were extended and retracted several times in flight as were the leading edge slats /flaps. No abnormal indications were noted throughout the flight. The approach and landing were conducted in an aircraft configuration similar to that of the incident flight and were uneventful. For additional information see NTSB Systems Group Chairman Factual Report.

The airplane was released to Mr. Rick Hoy, Delta Air Lines Inc., on December 17, 1998. All components retained for further analysis were released to Mr. Hoy on February 4, 1999.

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Landing Facility/Approach Information					
Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
ORLANDO INTERNATIONAL	MCO	96 Ft. MSL	35	10000	150
Runway Surface Type: Concrete					
Runway Surface Condition: Dry					
Type Instrument Approach: NONE					
VFR Approach/Landing: Traffic Pattern					
Aircraft Information					
Aircraft Manufacturer		Model/Series		Serial Number	
Boeing		737-232		23099	
Airworthiness Certificate(s): Transport					
Landing Gear Type: Retractable - Tricycle					
Homebuilt Aircraft? No	Number of Seats: 124	Certified Max Gross Wt.	119500 LBS	Number of Engines: 2	
Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:		
Turbo Fan	P&W	JT8D-15A	15500 LBS		
- Aircraft Inspection Information					
Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time		
Continuous Airworthiness	12/1998	44 Hours	39347 Hours		
- Emergency Locator Transmitter (ELT) Information					
ELT Installed? No	ELT Operated?	ELT Aided in Locating Accident Site?			
Owner/Operator Information					
Registered Aircraft Owner		Street Address			
WILMINGTON TRUST COMPANY		RODNEY SQUARE NORTH			
		City	State	Zip Code	
		WILMINGTON	DE	19890	
Operator of Aircraft		Street Address			
DELTA AIR LINES INC		PO BOX 20706			
		City	State	Zip Code	
		ATLANTA	GA	30320	
Operator Does Business As:			Operator Designator Code: DALA		
- 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 On File	City On File	State On File	Date of Birth On File	Age 37
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Sex: M	Seat Occupied: Left	Principal Profession: Civilian Pilot	Certificate Number: On File
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Certificate(s): Airline Transport

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?
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Medical Cert.: Class 1	Medical Cert. Status: Valid Medical--no waivers/lim.	Date of Last Medical Exam: 08/1998
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- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Multi-Engine	Night	Instrument		Rotorcraft	Glider	Lighter Than Air
						Actual	Simulated			
Total Time	8000	1550								
Pilot In Command(PIC)										
Instructor										
Last 90 Days	150	150								
Last 30 Days										
Last 24 Hours										

Seatbelt Used? Yes	Shoulder Harness Used? Yes	Toxicology Performed? No	Second Pilot? Yes
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Flight Plan/Itinerary

Type of Flight Plan Filed: IFR

Departure Point BOSTON	State MA	Airport Identifier BOS	Departure Time 0900	Time Zone EST
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Destination Same as Accident/Incident Location	State	Airport Identifier MCO	
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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
MCO	1253	EST	96 Ft. MSL	0 NM	0 Deg. Mag.
Sky/Lowest Cloud Condition: Unknown			0 Ft. AGL	Condition of Light: Day	
Lowest Ceiling: Overcast		2800 Ft. AGL		Visibility: 10 SM	Altimeter: 29.00 "Hg
Temperature: 16 °C	Dew Point: 9 °C	Wind Direction: 310		Density Altitude: Ft.	
Wind Speed: 10	Gusts:	Weather Conditions 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: Minor	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				3	3
Other Crew					
Passengers				51	51
- TOTAL ABOARD -				56	56
Other Ground	0	0	0		0
- GRAND TOTAL -	0	0	0	56	56

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Occurrence Type: Incident

Administrative Information

Investigator-In-Charge (IIC)

CARROL A. SMITH

Additional Persons Participating in This Accident/Incident Investigation:

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