



# Aviation Investigation Final Report

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<b>Location:</b>	Detroit, Michigan	<b>Incident Number:</b>	ENG12IA003
<b>Date &amp; Time:</b>	October 23, 2011, 16:00 Local	<b>Registration:</b>	N661US
<b>Aircraft:</b>	Boeing 747-451	<b>Aircraft Damage:</b>	Minor
<b>Defining Event:</b>	Uncontained engine failure	<b>Injuries:</b>	394 None
<b>Flight Conducted Under:</b>	Part 121: Air carrier - Scheduled		

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## Analysis

On October 23, 2011, 1600 eastern daylight time, a Boeing 747-451, registration number N661US, powered by four Pratt & Whitney PW4056 turbofan engines, experienced a left inboard engine (No. 2) low pressure turbine failure after takeoff from Detroit Metro Wayne Country International Airport (DTW), Detroit, Michigan. According to the flight crew statements, a large compressor stall and a muffled explosion were felt, followed by the No. 2 engine rollback and No. 2 engine fire warning indication. The flight crew performed an air turnback and made a successful three-engine landing at DTW. No injuries were reported.

Examination of the airplane revealed minor impact damage to the left wing, flaps, ailerons, and horizontal stabilizer. Initial examination of the engine revealed evidence of an undercowl fire, three burn-through holes on the No. 2 engine outboard core cowl, numerous exit hole penetrations in the rear turbine case, and a punctured No. 4 bearing compartment oil pressure supply line. Disassembly of the No. 2 engine revealed no damage upstream of the stage 3 low pressure turbine (LPT); one stage 3 LPT outer transition duct segment and two stage 3 LPT vane clusters were missing from their normally installed position, and extensive damage downstream of the stage 3 LPT vane clusters was found. The stage 3 LPT outer transition duct segments were approved but were an older configuration utilizing the riveted rear seal plate design that was prone to failure and had been superseded by a preferred design that incorporated an integral rear seal.

Comparing the airplane and engine damage to the requirements for engine debris containment and safety analysis at the time the engine was certificated revealed that the engine did not comply with the containment requirements set forth in Parts 33.19 and 33.75.

The undercowl fire was due to a failure of the rear riveted seal plates of the missing stage 3 outer transition duct segment that allowed hot gas path air under the duct segment, causing it to thermally distort and disengage from the rear turbine case. Once disengaged from the rear turbine case, the stage 3 outer transition duct segment released into the gaspath where it fractured all of the stage 3 LPT blades, which propelled blade fragments through the rear turbine case that punctured the No. 4 bearing oil pressure supply tube. The atomizing oil mist from the No. 4 bearing oil pressure supply tube ignited when it contacted the hot engine case, which created the undercowl fire.

## Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: The penetration of turbine blade fragments through the rear turbine case, which punctured the No. 4 bearing oil pressure supply tube, allowing misted oil to contact the hot engine case and ignite the undercowl fire.

Contributing to the incident was the installation of approved (but not preferred) stage 3 low pressure turbine outer transition duct segments with the riveted rear seal configuration and the failure of the engine design to comply with the engine debris containment requirements of 14 Code of Federal Regulations 33.13 and 33.75.

### Findings

<b>Aircraft</b>	Engine cowling system - Damaged/degraded
<b>Aircraft</b>	Engine cowling system - Capability exceeded
<b>Aircraft</b>	Turbine section - Failure
<b>Aircraft</b>	Turbine section - Fatigue/wear/corrosion
<b>Aircraft</b>	Turbine section - Related maintenance info
<b>Aircraft</b>	Turbine section - Design

## Factual Information

### History of Flight

Initial climb	Uncontained engine failure (Defining event)
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#### HISTORY OF FLIGHT

On October 23, 2011, about 1600 eastern daylight time, a Boeing 747-451, registration number N661US, powered by four Pratt & Whitney PW4056 turbofan engines, operated by Delta Air Lines as flight 275, experienced a left-hand inboard engine (No. 2) low pressure turbine failure after takeoff from Detroit Metro Wayne Country International Airport (DTW), Detroit, Michigan. According to the flight crew statements, at about 5,000 feet above ground level following clean-up of the airplane, a large compressor stall and a muffled explosion was felt followed by the No. 2 engine rollback. A No. 2 engine fire warning indication illuminated and the No. 2 engine throttle was reduced to idle; however, the fire warning indication did not extinguish. The flight crew performed the engine fire procedure and the fire warning indication extinguished after discharging one fire bottle. The flight crew performed an air turn back and made a successful three-engine landing at DTW. Of the 373 passengers and 19 crewmembers on board the flight, no injuries were reported. The incident flight was a 14 CFR Part 121 international passenger flight from Detroit to Narita, Tokyo Japan (NRT). Day visual meteorological conditions prevailed at the time of the event, and an instrument flight rules flight plan was filed.

#### AIRCRAFT AND ENGINE DAMAGE

Examination of the airplane revealed impact punctures and holes to: 1) the left-hand wing, flaps, and ailerons, 2) the No. 2 engine strut fairings and panels; and 3) the left-hand horizontal stabilizer. Also noted were superficial scuff and scrape marks on the fuselage and under the left-hand wing. Initial examination of the engine revealed three burn-through holes on the No. 2 engine outboard core cowl and severe low pressure turbine (LPT) damage with many blades and vanes missing from multiple stages. Opening of the fan cowls, thrust reverser, and core cowls for the No. 2 engine revealed thermal distress and sooting from the fan exit rear case back to the rear turbine case, numerous exit hole penetrations in the rear turbine case, and a punctured No. 4 bearing compartment oil pressure supply line.

The No. 2 engine was removed from the airplane and shipped to the Delta Air Lines Engine Maintenance shop in Atlanta, Georgia where the Powerplant Group convened to perform a detailed examination of the engine. Disassembly of the engine revealed that: 1) no damage upstream of the stage 3 LPT was noted, 2) all the LPT blades were corn-cobbed (blades fractured transversely across the airfoil at the blade platform), 3) numerous vane clusters in each stage were either missing or heavily battered, 4) one stage 3 LPT outer transition duct

segment and two stage 3 LPT vane clusters missing from their normally installed position, and 5) the majority of the stage 3 LPT outer transition duct segment rear seal plates were damaged, broken, and loose.

## ADDITIONAL INFORMATION

### Previous Stage 3 LPT Outer Transition duct Segment Failures

Pratt &Whitney (P&W) issued service bulletin (SB) PW4ENG 72-488 to address previously documented problems with the stage 3 LPT outer transition duct segment rear seal plates becoming loose and falling off, allowing hot gases to leak under the transition duct segment and causing them to distort and disengage from the rear turbine case. The SB provided repaired/modified procedures to incorporate new thicker rear seal plates and larger rivets to the existing stage 3 LPT outer transition duct segment configuration and also introduced a new configuration with an integral rear seal that eliminated the rear seal plates entirely. Review of the maintenance records (and later confirmed by physical inspection) revealed that the stage 3 LPT outer transition duct segments that were installed in the engine at the time of the LPT failure were the stage 3 LPT outer transition duct segments with the new thicker rear seal plates and larger rivets but not the integral rear seal configuration.

Including this event, this is the sixteenth known reported stage 3 outer transition duct segment(s) that either partially or fully disengaged from the rear turbine case. All the stage 3 outer transition duct segments liberations to date have been with the riveted seal plate configuration – none with the integral seal configuration. Fifty percent of the reported events were found during a shop visit and did not impact the operation of the engine, while the other half resulted in an in-flight shutdown or aborted takeoff. The first reported events occurred back in 1991, and prior to the release of SB 72-488, there had been 6 such events with 3 resulting in in-flight shutdowns. Of the sixteen known stage 3 outer transition duct segment(s) disengagements, the DAL event is the only one to result in turbine debris penetrating the rear turbine case and the only one where an undercowl fire was the result. Only one other event was investigated and documented sufficiently such that the information collected from that event could be useful in comparing the damage with the DAL event. That event occurred in August 2007 and was investigated by representatives of the P&W Flight Safety Office.

Based on the hardware damage, P&W determined that the cause of the LPT damage in the August 2007 event was related to the failure of the stage 3 outer transition duct segments rear riveted seal plates that allowed hot gas path air under the segments causing them to thermally distort and disengage from the rear turbine case. The liberated transition duct segments contacted the stage 3 vane clusters pushing them into the stage 3 blades resulting in liberation of stage 3 vane segments, fracturing of all the stage 3 blades, and causing downstream collateral damage. Comparing the photo documentation of the August 2007 event and the DAL event, many similarities in the type and extent of the damage to the stage 3 LPT and downstream hardware were observed.

## Engine and Airplane Containment Requirements

### Section 33.19 Durability

The engine containment standards are found in 14 CFR Part 33 Subpart B - Design and Construction; General, Section 33.19 'Durability' and require engine manufacturers to design compressor and turbine rotor cases that must provide for the containment of damage from rotor blade failure. Examination of the engine revealed that the fan case sustained some bulging but no exit holes, penetrations, or uncontainments were noted. At the time that the PW4056 was certificated, FAA Advisory Circular (AC) 33-1B, dated April 22, 1970, provided guidance and acceptable means of compliance by which the engine manufactures test and certificate that the engine is in compliance with and rotor blade containment provisions in CFR Part 33. Under the substantiation criteria for rotor blade containment under AC 33-1B, it states that the engine is acceptable if, during the tests, the damage from rotor blade failures is contained by the engine, e.g., without causing significant rupture or hazardous distortions of the engine casing and the expulsion of blades through or beyond the edge of the engine case or shield. The multiple penetrations documented in the rear turbine case and the piercing of the No. 4 bearing pressure line shows that the PW4056, and more specifically the rear turbine case, did not meet the intent of Part 33.19(a) Amendment 9.

### Section 33.75 Safety Analysis

Subpart E – Design and Construction; Turbine Aircraft Engines, Section 33.75 Safety Analysis requires that engine failures or malfunctions do not result in a hazardous or unsafe condition and that any probable malfunction or any probable single or multiple failure, or any probable operation of the engine will not cause the engine to catch fire, burst (penetrate its case), generate loads greater than those specified in Section 33.23(a), or lose the capability of being shut down. The engine and the left hand core cowl sustained fire damage as a consequence of the internal engine failure; thus the PW4056 did not meet the intent of 33.75 Amendment 6 requiring the engine not catch fire due to an engine failure or malfunction.

## Information

<b>Certificate:</b>	<b>Age:</b>
<b>Airplane Rating(s):</b>	<b>Seat Occupied:</b>
<b>Other Aircraft Rating(s):</b>	<b>Restraint Used:</b>
<b>Instrument Rating(s):</b>	<b>Second Pilot Present:</b>
<b>Instructor Rating(s):</b>	<b>Toxicology Performed:</b>
<b>Medical Certification:</b>	<b>Last FAA Medical Exam:</b>
<b>Occupational Pilot:</b>	<b>Last Flight Review or Equivalent:</b>
<b>Flight Time:</b>	

## Aircraft and Owner/Operator Information

<b>Aircraft Make:</b>	Boeing	<b>Registration:</b>	N661US
<b>Model/Series:</b>	747-451	<b>Aircraft Category:</b>	Airplane
<b>Year of Manufacture:</b>		<b>Amateur Built:</b>	
<b>Airworthiness Certificate:</b>	Transport	<b>Serial Number:</b>	23719
<b>Landing Gear Type:</b>	Tricycle	<b>Seats:</b>	450
<b>Date/Type of Last Inspection:</b>		<b>Certified Max Gross Wt.:</b>	
<b>Time Since Last Inspection:</b>		<b>Engines:</b>	4 Turbo jet
<b>Airframe Total Time:</b>		<b>Engine Manufacturer:</b>	P&W
<b>ELT:</b>		<b>Engine Model/Series:</b>	PW4056
<b>Registered Owner:</b>	U S BANK TRUST NA TRUSTEE	<b>Rated Power:</b>	56750 Lbs thrust
<b>Operator:</b>	DELTA AIR LINES INC	<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>		<b>Condition of Light:</b>	
<b>Observation Facility, Elevation:</b>		<b>Distance from Accident Site:</b>	
<b>Observation Time:</b>		<b>Direction from Accident Site:</b>	
<b>Lowest Cloud Condition:</b>		<b>Visibility</b>	
<b>Lowest Ceiling:</b>		<b>Visibility (RVR):</b>	
<b>Wind Speed/Gusts:</b>	/	<b>Turbulence Type Forecast/Actual:</b>	/
<b>Wind Direction:</b>		<b>Turbulence Severity Forecast/Actual:</b>	/
<b>Altimeter Setting:</b>		<b>Temperature/Dew Point:</b>	
<b>Precipitation and Obscuration:</b>			
<b>Departure Point:</b>	Detroit, MI (DTW )	<b>Type of Flight Plan Filed:</b>	VFR
<b>Destination:</b>	(NRT )	<b>Type of Clearance:</b>	VFR
<b>Departure Time:</b>		<b>Type of Airspace:</b>	

## Airport Information

<b>Airport:</b>	Detroit International Airport DTW	<b>Runway Surface Type:</b>	
<b>Airport Elevation:</b>		<b>Runway Surface Condition:</b>	
<b>Runway Used:</b>		<b>IFR Approach:</b>	Unknown
<b>Runway Length/Width:</b>		<b>VFR Approach/Landing:</b>	Unknown

## Wreckage and Impact Information

<b>Crew Injuries:</b>	21 None	<b>Aircraft Damage:</b>	Minor
<b>Passenger Injuries:</b>	373 None	<b>Aircraft Fire:</b>	In-flight
<b>Ground Injuries:</b>	N/A	<b>Aircraft Explosion:</b>	None
<b>Total Injuries:</b>	394 None	<b>Latitude, Longitude:</b>	42.349647,-83.059921(est)

## Administrative Information

**Investigator In Charge (IIC):** Scarfo, Jean-Pierre

**Additional Participating Persons:**

**Original Publish Date:** December 7, 2012

**Last Revision Date:**

**Investigation Class:** [Class](#)

**Note:**

**Investigation Docket:** <https://data.nts.gov/Docket?ProjectID=82141>

The National Transportation Safety Board (NTSB) is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable causes of the accidents and events we investigate, and issue safety recommendations aimed at preventing future occurrences. In addition, we conduct transportation safety research studies and offer information and other assistance to family members and survivors for each accident or event we investigate. We also serve as the appellate authority for enforcement actions involving aviation and mariner certificates issued by the Federal Aviation Administration (FAA) and US Coast Guard, and we adjudicate appeals of civil penalty actions taken by the FAA.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, “accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties ... and are not conducted for the purpose of determining the rights or liabilities of any person” (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB’s statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)). A factual report that may be admissible under 49 *United States Code* section 1154(b) is available [here](#).