



# National Transportation Safety Board Aviation Incident Final Report

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<b>Location:</b>	Aguadilla, PR	<b>Incident Number:</b>	ENG131A036
<b>Date &amp; Time:</b>	08/30/2013, 2110 AST	<b>Registration:</b>	PH-MCW
<b>Aircraft:</b>	BOEING COMPANY, LONG BEACH DIV BOEING MD-11	<b>Aircraft Damage:</b>	Minor
<b>Defining Event:</b>	Uncontained engine failure	<b>Injuries:</b>	N/A
<b>Flight Conducted Under:</b>	Part 129: Foreign		

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## Analysis

Four LPT stage 4 (S4) vane clusters weakened by an undetected sulfidation/corrosion attack disengaged at their inner attachment. The disengaged clusters displaced aft and contacted the S4 blades during operation. The contact machined a groove into the blade leading edges near the platforms. High cycle fatigue cracks initiating in the machined area of several blades propagated to overload separation. The blade liberation led to the separation of the remaining S4 blades and extensive downstream LPT blade and vane cluster damage. A large amount of metal debris was released into the gas path, loading the engine casings. The P-flange attachment hardware separated in overload, resulting in engine uncontainment.

## Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: an insufficiently robust flange attachment hardware design, which failed to contain engine components that were liberated during an LPT mechanical failure, resulting in engine/nacelle uncontainment.

A factor in the incident was the lack of a module-level LPT inspection and the lack of an inspection requirement to detect/monitor the LPT S4 for advanced sulfidation attack.

## Findings

Aircraft	Turbine section - Fatigue/wear/corrosion Turbine section - Damaged/degraded Turbine section - Failure Turbine section - Design (Cause) Turbine section - Inadequate inspection (Factor)
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## Factual Information

### HISTORY OF THE FLIGHT

On August 30, 2013, at approximately 2110 (local), Martinair Cargo MD-11F Reg. No. PH-MCW, powered by three Pratt & Whitney PW4462 engines, experienced an uncontained engine failure during take-off at Borinquen International Airport, Aguadilla, Puerto Rico (BQN). The flight crew reported hearing a loud bang and noting decreasing No. 1 engine fan speed (N1). The No. 1 engine fire warning activated and the captain discharged the No. 1 fire bottle. The airplane was operating as Martinair flight 1156 scheduled cargo service from BQN to London Stansted Airport, London, England (STN). There was minor damage to the airplane. No injuries were reported. A post-incident airplane inspection found that the No. 1 engine low pressure turbine (LPT)-to turbine exhaust case (TEC) flange (P-flange) was open between 5 and 7 o'clock. Inspection through the engine exhaust found near-platform LPT stage (S)4, S5, and S6 blade airfoil fractures and extensive LPT vane and seal damage. A large amount of internal turbine component debris was recovered from the runway and from the No. 1 nacelle. The engine was removed and was shipped with the debris to a repair facility for investigation.

### AIRPLANE DAMAGE

There were numerous small dents and punctures in the airplane's left wing, including two 3-inch long punctures, and similar damage to the main landing gear assembly. There were five holes in the No. 1 engine nacelle axially in line with the case flange separation. The largest nacelle penetration was an 8 inch by 5 inch hole through the inboard thrust reverser door.

### RECORDERS

The airplane was equipped with a Loral/Fairchild F1000 flight data recorder (FDR) and two dual-channel electronic engine controls (EECs) with non-volatile fault memory. The FDR data showed that a sudden decrease in No. 1 engine EPR occurred about 11 seconds into the takeoff roll, followed by a steady decrease in airplane longitudinal acceleration and that the No. 1 engine fire warning activated 13 seconds after the EPR drop. Maximum recorded ground speed was 17 knots. The No. 1 engine EEC fault memory had stored 192 faults over the last 76 flights/78 ground legs. Both EEC channels recorded one fault during the incident, a surge flag at 9,600 RPM low pressure rotor speed (N1). Review of the fault data from the previous flights/ground legs found no fault records pertinent to the failure.

### FIRE

Airport fire and rescue personnel responding to the aircraft determined that no fire was present. Subsequent inspections of the No. 1 nacelle and engine found no evidence of undercowl fire. Soot found on the engine rear mount, TEC lower left surface, and deposited in an aftward pattern from one of the cowling penetrations was consistent with a release of combustion products through the engine breach.

### ENGINE EXAMINATION

External examination of the engine found that the P-flange attachment hardware was missing from 62 of 132 bolt holes (bolt holes 40 through 102). There was local case distortion and the flange was separated up to two inches. External component discrepancies were minor with the exception of the No. 4 bearing oil pressure tube, which was dented and deformed where it spans the P-flange. Inspection of the recovered debris found 71 bolt segments consistent with

P-flange attachment hardware (36 shanks with bolt heads and 35 shanks with nuts installed). Engine borescope inspections found no mechanical failure upstream of the second LPT stage (S4). Disassembly of the LPT section exposed an advanced corrosion attack at the S4 vanes with extensive internal corrosion damage (cracking and material breakouts) and visible corrosion products. The lower left quadrant displayed the most severe damage and the inner diameter (ID) attachments of four vane clusters in this quadrant had disengaged and displaced aft into S4 blade path. The aft edges and honeycombs of the displaced clusters were scored consistent with rotational contact with the S4 blade leading edges (LEs) during operation.

All of the S4 blades were fractured off close to the platform. An approximately 0.25-inch deep groove was machined into the LEs of all of the S4 blades; undamaged areas of several blade fracture surfaces displayed fatigue features just aft of the consumed LE area.

All of the S5 and S6 turbine blades displayed near-platform separations and undamaged blade fracture surfaces exhibited coarse and grainy appearances. Four S4 vane clusters and over half of the S5 and S6 vane clusters were liberated and were missing from the engine. The remaining LPT gas path components and the LPT case, TEC and exhaust nozzle internal surfaces were severely battered and scored consistent with impacts from liberated hardware exiting the engine through the exhaust.

## TESTS AND RESEARCH

### Metallurgy

Metallurgical examination of four exemplar S4 vane clusters found significant corrosion/oxidation consumption of vane airfoil wall thicknesses. Chemical analysis of the corrosion attack fronts revealed sulfur-rich particles, indicative of sulfidation as the corrosion mechanism. EDS and WDS spectra and elemental maps collected at multiple locations along the attack fronts confirmed a consistent sulfur presence and the presence of chromium. Inspection of the displaced S4 vane clusters found that corrosion-induced material loss resulting in loss of structural stiffness had allowed the clusters to disengage at the inner attachment.

Four exemplar S4 blade fracture surfaces displayed machining-type LE damage typical of rotor contact with static hardware during operation. Metallurgical examination of the fracture surfaces immediately aft of the consumed LEs revealed high cycle fatigue crack propagation leading to airfoil overload fracture.

## ADDITIONAL INFORMATION

### LPT service history

The incident LPT was manufactured in 1990 and underwent overhaul in 2003. It was placed in storage at 23,536 hours and 10,112 cycles since new, 5,245 hours and 2,203 cycles since overhaul. In 2006, it was removed from storage and installed on the incident engine. Module-level inspections were performed during scheduled engine shop visits in 2008 and 2009. At the time of the incident the LPT/engine had accumulated 14,406 hours and 2,765 cycles since the 2009 shop visit.

The S4 LPT vane clusters installed in the LPT (P/N 51N674-01) were affected by Federal Aviation Administration (FAA) airworthiness directive (AD) 2012-14-09, however the engine was within the specified compliance.

AD 2012-14-09

On October 5, 2012, the FAA published AD 2012-14-09 in response to reports of Pratt & Whitney PW4000 94" and 100" LPT S3 and S4 vane fractures that caused uncontained engine failure, LPT case puncture and multiple in-flight shutdowns. The AD requires the assembly of the LPT S4 rotor by alternating heavy and light blades and by balancing blades of similar weights 180° across the rotor; the dimensional examination of LPT S3 vane clusters; the removal from service of S4 vane clusters with certain casting identifications. It also requires that heavy and light blades are alternated and blades of similar weights are balanced 180° across when assembling the HPT S2 at HPT overhaul.

## History of Flight

<b>Takeoff-rejected takeoff</b>	Powerplant sys/comp malf/fail Loss of engine power (total) Uncontained engine failure (Defining event) Part(s) separation from AC
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## Aircraft and Owner/Operator Information

<b>Aircraft Make:</b>	BOEING COMPANY, LONG BEACH DIV	<b>Registration:</b>	PH-MCW
<b>Model/Series:</b>	BOEING MD-11 F	<b>Aircraft Category:</b>	Airplane
<b>Year of Manufacture:</b>		<b>Amateur Built:</b>	No
<b>Airworthiness Certificate:</b>		<b>Serial Number:</b>	48788
<b>Landing Gear Type:</b>	Unknown	<b>Seats:</b>	
<b>Date/Type of Last Inspection:</b>		<b>Certified Max Gross Wt.:</b>	630499 lbs
<b>Time Since Last Inspection:</b>		<b>Engines:</b>	Turbo Fan
<b>Airframe Total Time:</b>		<b>Engine Manufacturer:</b>	Pratt & Whitney
<b>ELT:</b>		<b>Engine Model/Series:</b>	PW4462-3
<b>Registered Owner:</b>	The Can Do Leasing Ltd.	<b>Rated Power:</b>	
<b>Operator:</b>	Martinair Holland N.V.	<b>Operating Certificate(s) Held:</b>	None

## Meteorological Information and Flight Plan

Conditions at Accident Site:	Unknown	Condition of Light:	Night/Dark
Observation Facility, Elevation:		Distance from Accident Site:	
Observation Time:		Direction from Accident Site:	
Lowest Cloud Condition:		Visibility	
Lowest Ceiling:		Visibility (RVR):	
Wind Speed/Gusts:	/	Turbulence Type Forecast/Actual:	/
Wind Direction:		Turbulence Severity Forecast/Actual:	/
Altimeter Setting:		Temperature/Dew Point:	
Precipitation and Obscuration:			
Departure Point:	Aguadilla, PR (BQN)	Type of Flight Plan Filed:	
Destination:	London, FN (STN)	Type of Clearance:	Unknown
Departure Time:	AST	Type of Airspace:	

## Airport Information

Airport:	RAFAEL HERNANDEZ (BQN)	Runway Surface Type:	N/A
Airport Elevation:	237 ft	Runway Surface Condition:	
Runway Used:	N/A	IFR Approach:	None
Runway Length/Width:		VFR Approach/Landing:	

## Wreckage and Impact Information

Crew Injuries:	N/A	Aircraft Damage:	Minor
Passenger Injuries:	N/A	Aircraft Fire:	None
Ground Injuries:	N/A	Aircraft Explosion:	None
Total Injuries:	N/A	Latitude, Longitude:	18.494722, -67.129444 (est)

## Administrative Information

Investigator In Charge (IIC):	Carol M Horgan	Adopted Date:	04/04/2016
Additional Participating Persons:	Dave Keenan; AVP-100; Washington, DC Vincent Brand van Straaten; Martinair Cargo (Technical Advisor); Amsterdam, FN Atze Samplonius; Dutch Safety Board (Accredited Representative); Amsterdam, FN Douglas Zabawa; Pratt & Whitney; East Hartford, CT Kurt Leach; Pratt & Whitney; East Hartford, CT		
Publish Date:	04/04/2016		
Investigation Docket:	<a href="http://dms.nts.gov/pubdms/search/dockList.cfm?mKey=87963">http://dms.nts.gov/pubdms/search/dockList.cfm?mKey=87963</a>		

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