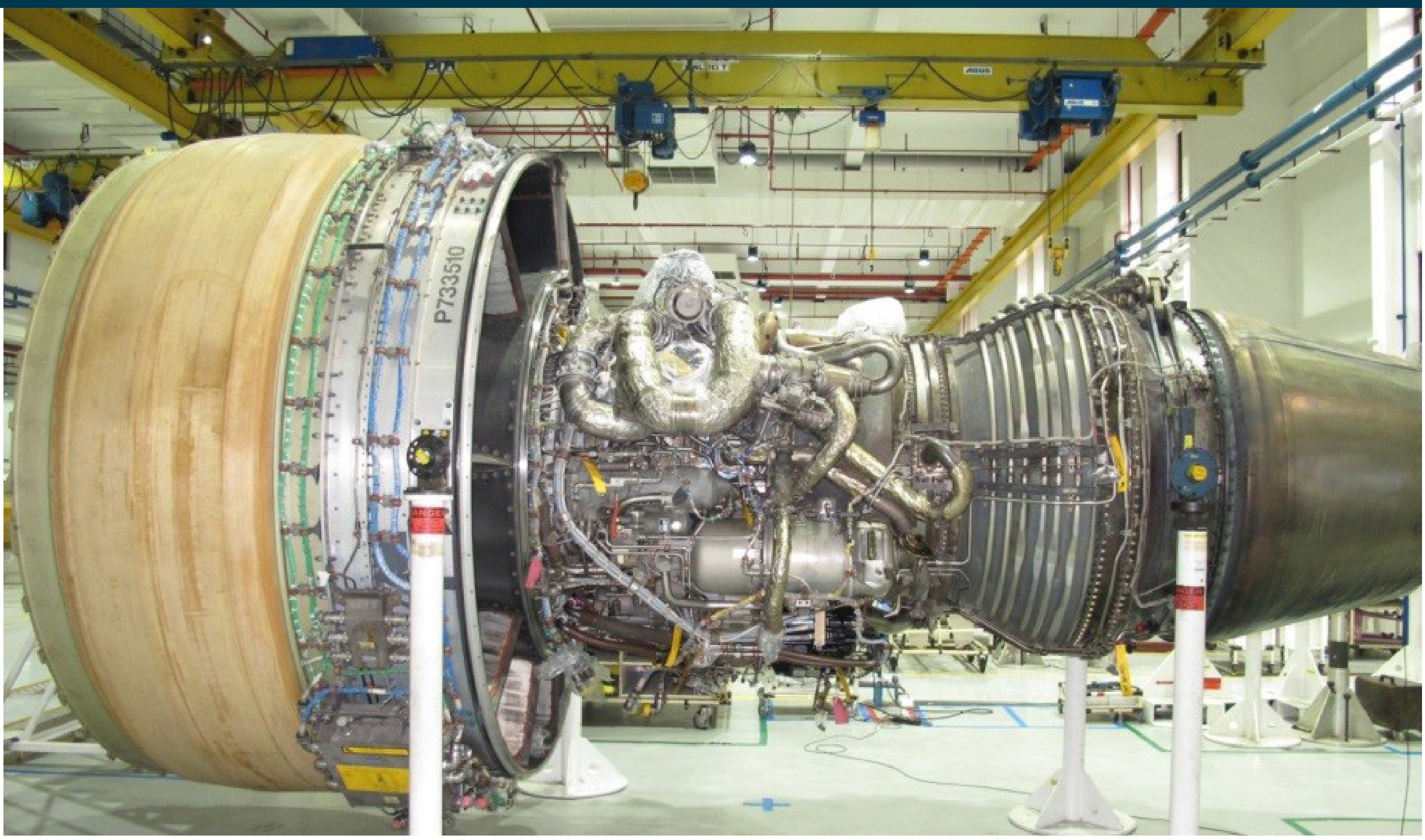
Australian Government
Australian Transport Safety Bureau

Engine failure involving Airbus A330, VN-A371

Melbourne Airport, Victoria | 6 May 2014



Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation
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Addendum

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Safety summary

What happened

On 6 May 2014, an Airbus A330 aircraft, operated by Vietnam Airlines and powered by Pratt and Whitney PW4168A engines, was conducting a regular passenger service from Melbourne, Victoria to Ho Chi Minh City, Vietnam. During the take-off roll, the crew received indications that the right engine had failed. The flight crew responded by discontinuing the take-off. There were no injuries to passengers or crew.

Examination of the right engine determined that it had sustained an uncontained failure of the stage four low-pressure turbine. Fragments of the turbine exited the engine via perforations in the low-pressure turbine front case but were retained within the engine cowls. Turbine debris exiting the exhaust duct damaged the right inboard and outboard flaps, flap fairings and a spoiler.

What the ATSB found

The ATSB found that the engine failed due to high-cycle fatigue cracking and the fracture of a single stage four low-pressure turbine blade. Release of the fractured blade resulted in the subsequent failure of the turbine. The fatigue crack initiation point on the remaining blade stub of the fractured blade was obscured by damage from rotational contact that occurred during the engine failure sequence. This prevented the ATSB from determining whether any pre-existing material anomaly or damage contributed to the crack initiation.

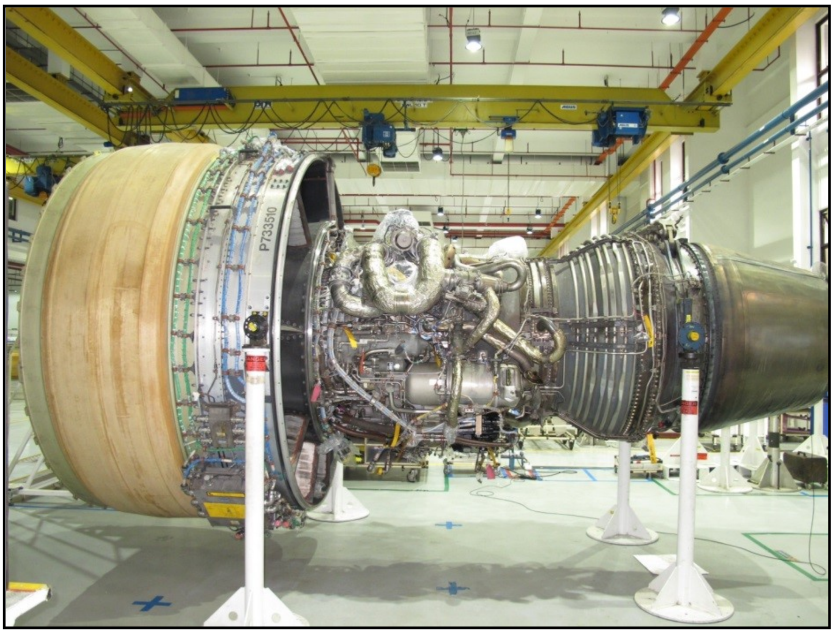
No similar failures in Pratt and Whitney PW4168A engines were identified.

The ATSB found the flight crew's handling of the rejected take-off reduced the risk of a runway excursion, preventing further damage to the aircraft or injury to passengers or crew.

Safety message

Although in this case the cause of the turbine blade failure could not be identified, this occurrence highlights the benefits of timely and appropriate flight crew action in response to an unexpected engine failure on take-off.

PW4168A engine S/N P733510



Source: United States National Transportation Safety Board

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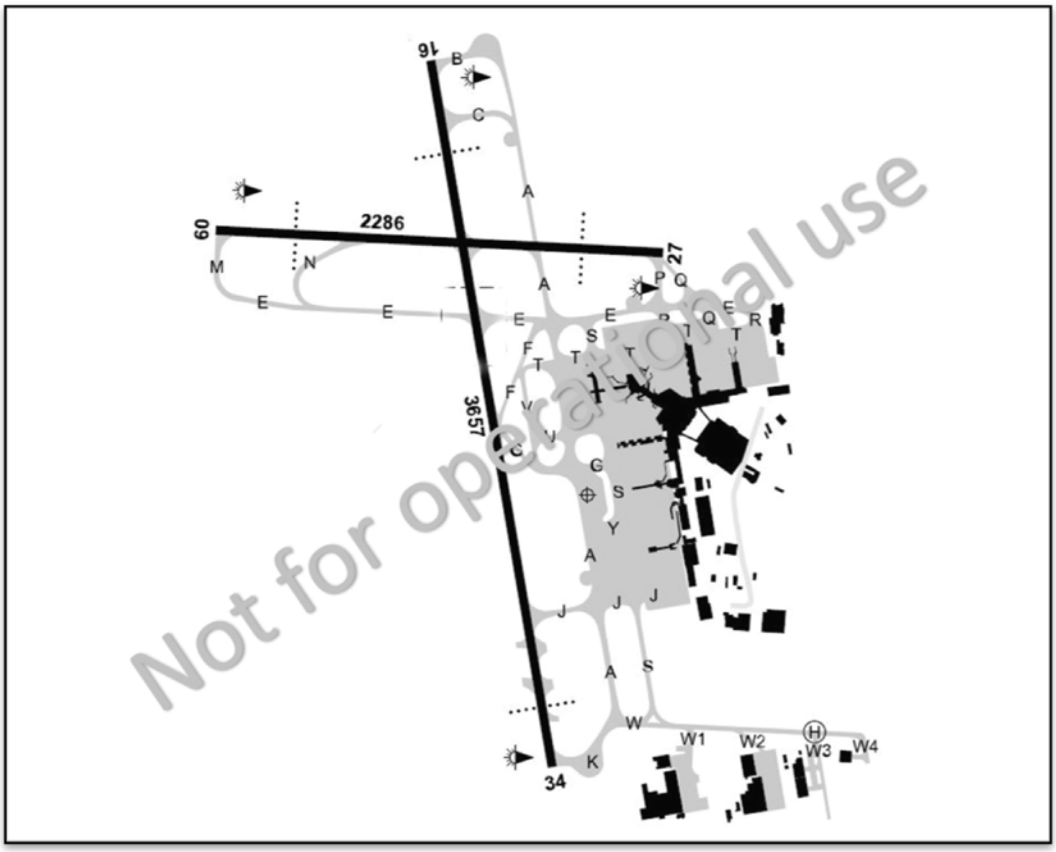
The occurrence

At 1052 Eastern Standard Time[1] on 6 May 2014 the flight crew of an Airbus A330 aircraft, registered VN-A371, commenced a take-off roll on runway 27[2] at Melbourne Airport, Victoria (Figure 1). The flight was a regular passenger service to Ho Chi Minh City, Vietnam and was operated by Vietnam Airlines.

Figure 1: Melbourne Airport runway diagram



Source: Airservices Australia, En Route Supplement Australia. Modified by the ATSB

After positioning the aircraft at the runway threshold, the flight crew advanced the thrust levers for take-off. Both engines spooled up[3] normally, accelerating the aircraft toward a V_1[4] airspeed of 120 kt.

As the aircraft reached an airspeed of 89 kt, a loud ‘bang’ was heard in the cockpit. In response, the flight crew initiated the rejected take-off procedure by fully retarding the thrust levers.

Retarding the thrust levers initiated maximum autobraking and activated the aircraft’s spoilers. The crew then selected reverse thrust, further decelerating the aircraft. The flight crew maintained directional control and brought the aircraft to a stop at the intersection of runways 09/27 and 16/34 using manual braking.

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1 Eastern Standard Time (EST) was Coordinated Universal Time (UTC) + 10 hours.
2 The runway number represents the magnetic heading of the runway.
3 Acceleration in engine rpm, normally in respect of turbofan or turbojet engines.
4 V_1: the critical engine failure speed or decision speed required for take-off. Engine failure below V_1 should result in a rejected take-off; above this speed, the take-off should be continued.

After shutting down both engines, the flight crew advised air traffic control of the reason for the rejected take-off. Fire and emergency services were mobilised to the aircraft where, after inspection, they informed the flight crew that no engine or wheel brake fire was apparent. The attending ground staff informed the flight crew and control tower that there was debris along the runway and near the right engine. There were also patches of smouldering grass adjacent to the runway.

The aircraft was towed to a terminal gate to disembark passengers. Both runways were re-opened following removal of the aircraft and associated debris. There were no reported injuries as a result of the occurrence.

A subsequent technical examination determined that the right engine had sustained an uncontained failure of the low-pressure turbine (Figure 2).

Recorded information showed that the flight crew did not verbalise any operational anomalies with the aircraft prior to take-off or during the initial take-off roll. Similarly, there were no significant discrepancies recorded in the aircraft's recorded engine data.

Figure 2: Right engine low-pressure turbine damage, looking forward from the exhaust duct

Source: ATSB

Context

Aircraft information

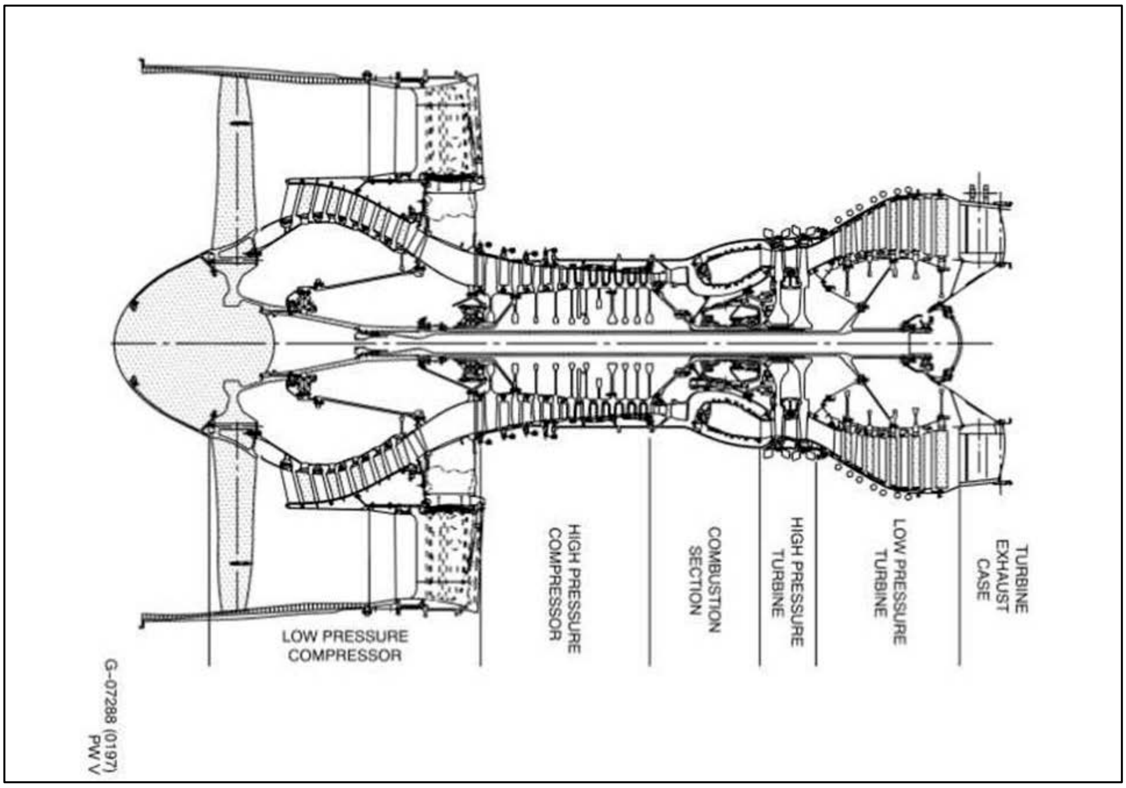
Engine description

The aircraft was powered by two Pratt and Whitney PW4168A high-bypass ratio turbofan engines. The PW4168A is a twin-spool engine consisting of high- and low-pressure rotors (Figure 3). The low-pressure rotor consists of a single stage fan and a 5-stage compressor that is driven by a 5-stage turbine on a common shaft. The high-pressure rotor consists of 11 compressor stages that are driven by a 2-stage turbine.

Numbering in all engine modules is from the front to the back of the engine. The fan is stage 1 of the compressor while the low-pressure compressor stage numbers are 1.3, 1.6, 2, 3, and 4. The high-pressure compressor stages are numbered 5 through 15. The high-pressure turbine stages are numbered 1 and 2 and the low-pressure turbine (LPT) stages are numbered 3 through 7. Numbering convention in the compressor sections is that the rotor and stator following it share the same stage number. In the turbine sections, the guide vanes and following rotors share the same stage number.

All directional references in relation to the engine rotors are made from aft, looking forward. Blade numbering is in the circumferential direction starting with number one at the 12 o'clock position and progressing sequentially clockwise. The engine rotates in the clockwise direction.

Figure 3: Cross-section view of the PW4168A engine



Source: Pratt and Whitney

Engine maintenance

As part of their investigation of this occurrence, Pratt and Whitney reviewed the engine records for the last overhaul of the LPT, which occurred in 2011. The document review was focused on the stage four LPT blades and vane clusters and the front case. All repairs were found to be consistent with the module's component inspection and repair manual.

Damage to the aircraft

The engine cowls contained liberated LPT fragments that exited the engine radially via a 38 cm perforation in the LPT front case. There was no other damage associated with the LPT case rupture.

LPT debris exited the exhaust duct and damaged the right inboard and outboard flaps, flap fairings, and the No. 2 spoiler. This damage did not affect the operation of any aircraft systems.

Initial engine disassembly and examination

The right engine, serial number P733510, was removed from the aircraft and shipped to a maintenance facility in Singapore for disassembly and examination under the supervision of the United States National Transportation Safety Board (NTSB). The examination determined that the engine lost power due to a failure in stage four of the LPT. Turbine blade stub number 120 (of 130) exhibited a fracture surface that was visually different to the remainder of the fractured blades (Figure 4).

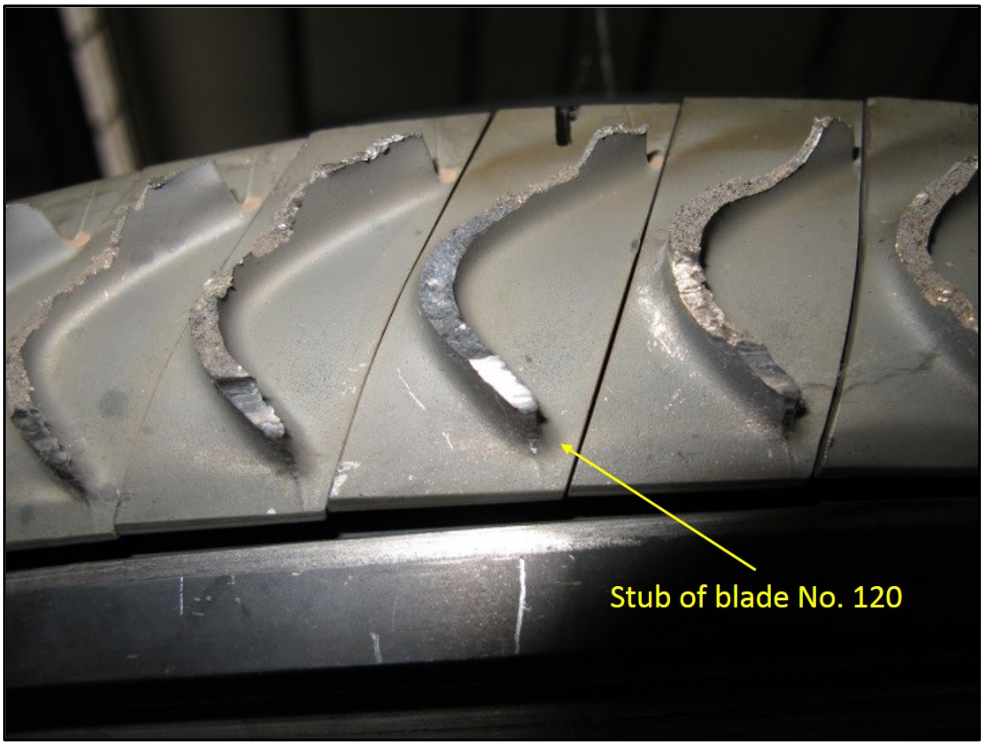
Additionally, stage four LPT vane clusters numbered 40-44 were loose and askew near their originally-installed positions. This area coincided with the tear at the 11–12 o'clock position in the LPT front case (Figure 5).

The ATSB conducted a preliminary examination of the set of fractured stage four LPT blade stubs. All of the blades were fractured close to the blade platform and exhibited similar leading edge damage. This was consistent with rotational contact or 'clashing' between the blades' leading edges and a stationary component.

The fracture surface of the stub of turbine blade 120 contained a significant region of high-cycle fatigue cracking, probably originating from the leading edge (Figure 6). The fatigue crack origin had been machined away by the clashing damage and, as a result, the presence of any pre-existing material anomaly or damage in the blade could not be determined.

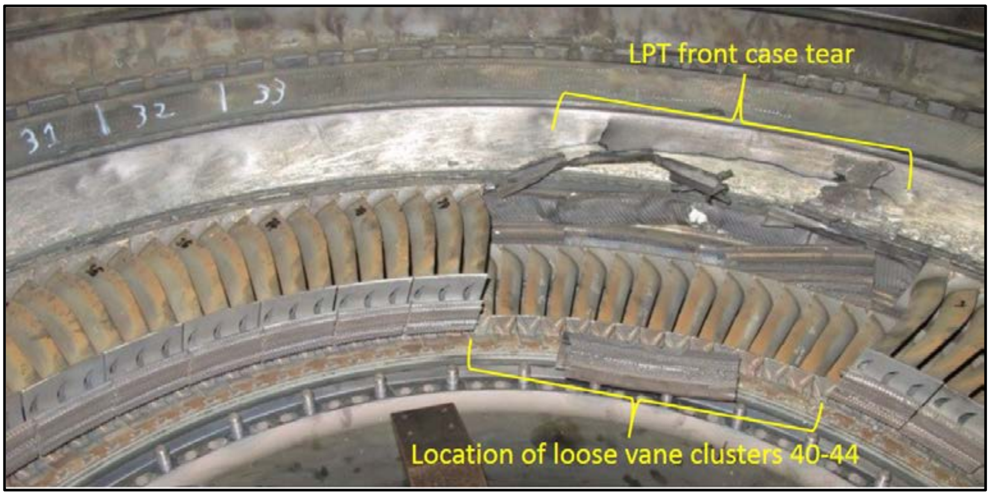
The stage four LPT blade stubs, vane clusters and front case were subsequently forwarded to Pratt and Whitney in the United States for detailed examination under the supervision of the NTSB.

Figure 4: A number of the fractured stage four low-pressure turbine blade stubs, with the stub of blade 120 highlighted



Source: NTSB, annotated by the ATSB

Figure 5: Case tear and the location of the loose vane clusters (vane clusters 40–44 are not present in the image)



Source: NTSB, annotated by the ATSB

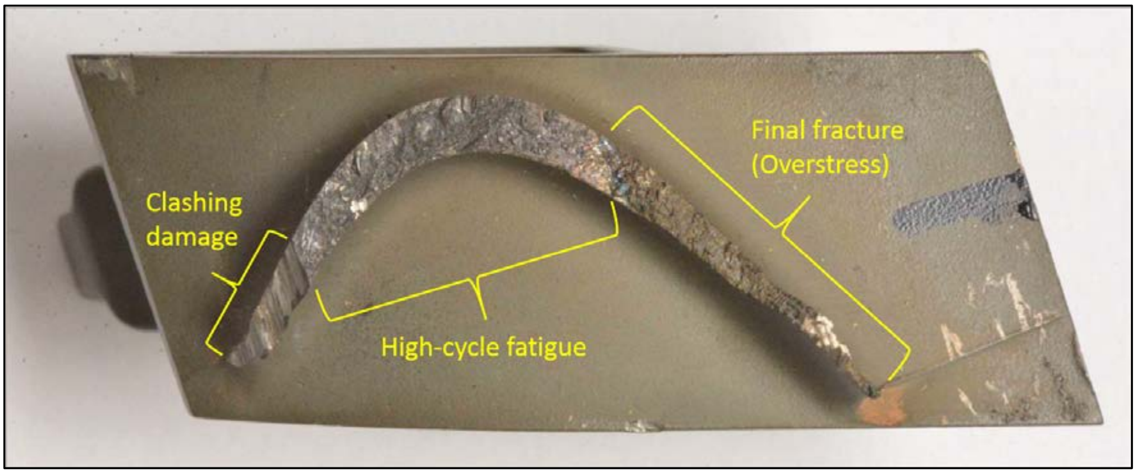
Pratt and Whitney component examination

Stage four low-pressure turbine blades

In addition to confirming the high-cycle fatigue cracking in turbine blade 120, detailed examination by Pratt and Whitney identified evidence of fatigue crack progression adjacent to the leading edge damage in 19 other blades. However, blade 120 exhibited 0.7 inches (18 mm) of fatigue progression, which was significantly greater than the 0.01 to 0.089 inches (0.25–2.3 mm) on the other 19 blades. The fatigue region of blade 120 was also more heavily oxidised, due to exposure to the gas stream, than the next most fatigued blade (blade 18). Blade 120 was therefore considered likely to have been the first to fracture (Figure 6).

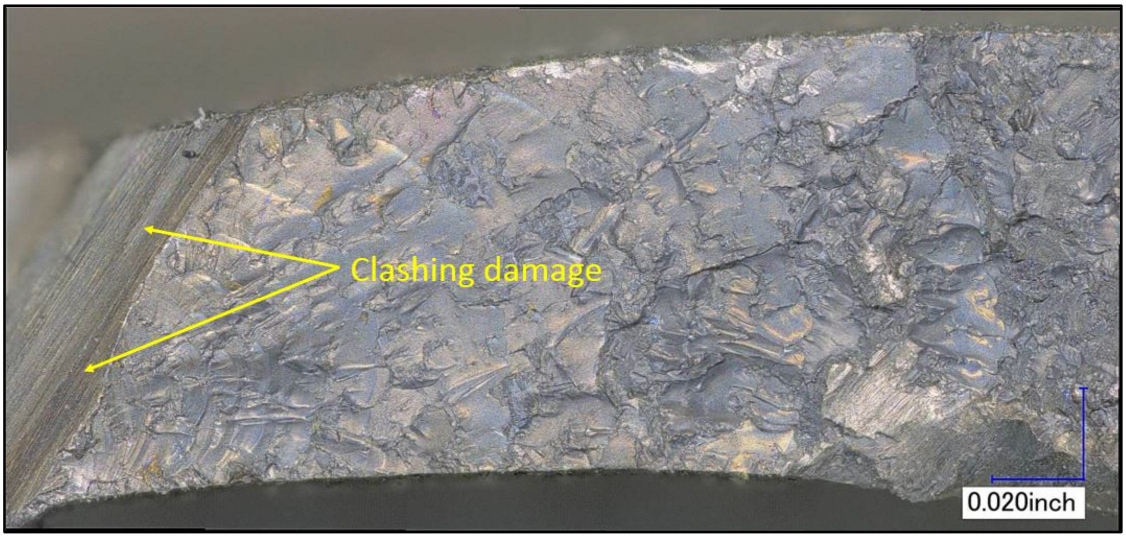
The origin of the fatigue cracks in each blade had been machined away by clashing damage (Figure 7). Blade material was also smeared over portions of the fatigue region of blade 120, adjacent to the clashing damage. This indicated that the fatigue cracking preceded the clashing damage (Figure 8). By contrast, no smearing was observed over the fracture surface of blade 18 (Figure 9).

Figure 6: Blade 120 fracture surface, showing the region of high-cycle fatigue, the clashing damage and the final overstress fracture



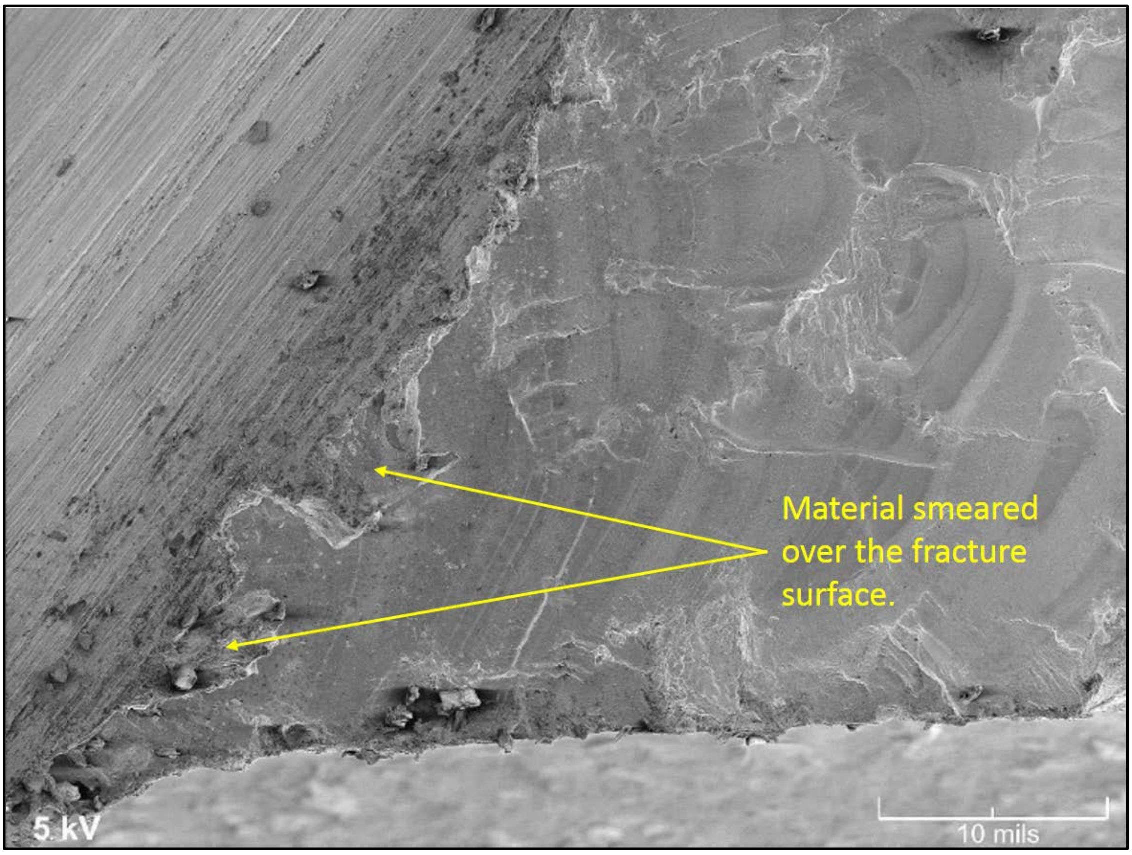
Source: Pratt and Whitney, annotated by the ATSB

Figure 7: Blade 120 fatigue region, with leading edge clashing damage indicated on the left



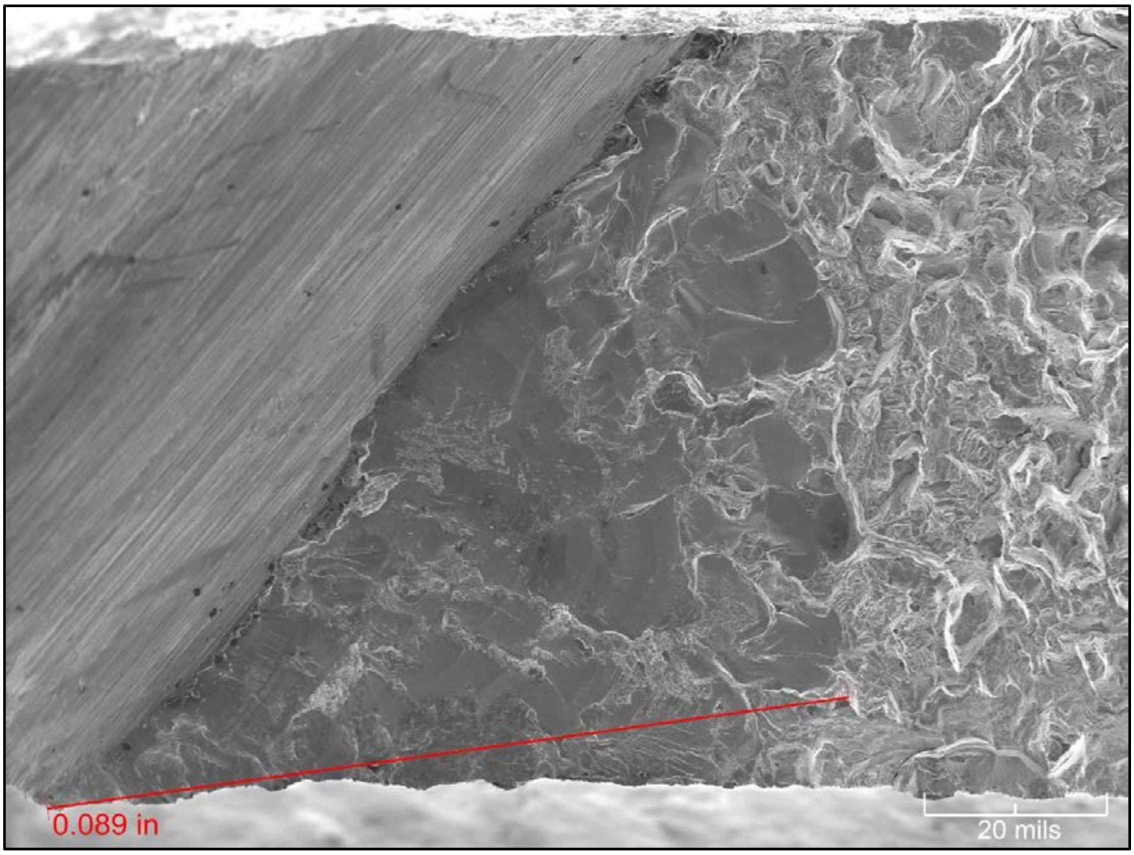
Source: Pratt and Whitney, annotated by the ATSB

Figure 8: Blade 120 fracture surface, showing metal smearing



Source: Pratt and Whitney, annotated by the ATSB

Figure 9: Blade No. 18, showing a fatigue progression of 0.089 inches (as compared to 0.7 inches in blade No. 120 before failure)



Source: Pratt and Whitney

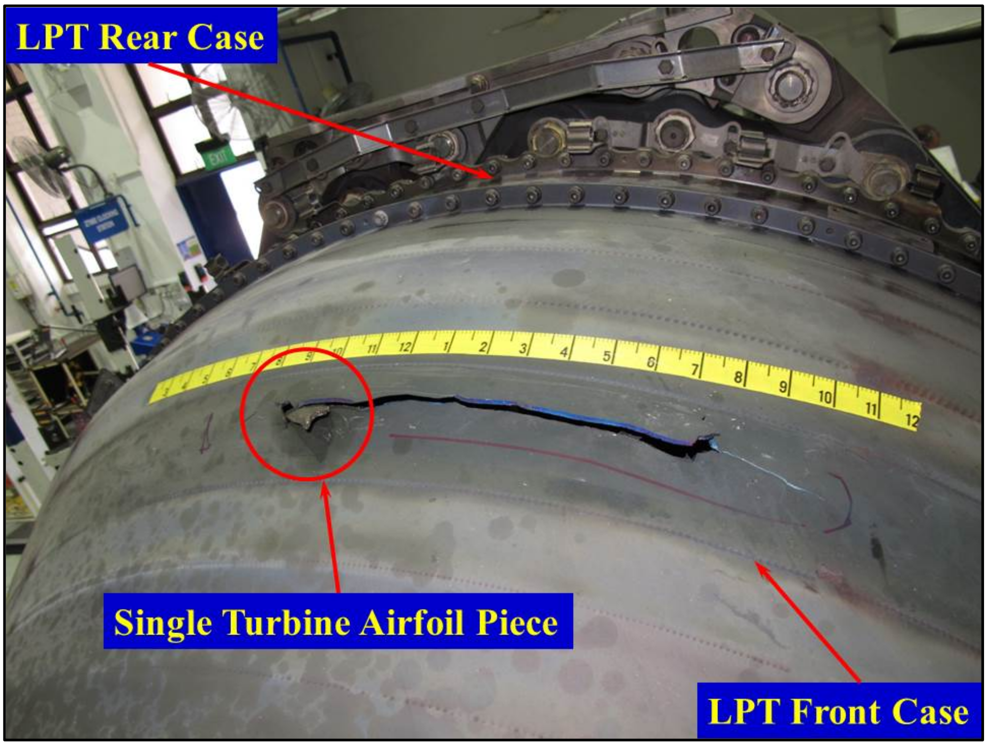
Low-pressure turbine front case

The LPT front case exhibited a 38 cm circumferential tear, with associated outward deformation, from the 11 to the 12 o'clock position in the stage four rotor's plane of rotation. A single, unidentified airfoil was wedged in the breach (Figure 10). In addition, a 2.5 cm circumferential puncture was observed at the 6 o'clock position of the front case in the stage four rotor plane of rotation (Figure 11).

Sections of the LPT front case adjacent to the 38 cm and 2.5 cm perforations were tested for hardness, wall thickness and grain size. The results of these tests found that the:

- hardness measurements were consistent with applicable standards
- wall thickness and grain size measurements for both sections conformed to Pratt and Whitney specifications.

Figure 10: Low-pressure turbine front case tear at the 11–12 o'clock position. Note that the scale is in inches and the view is looking aft



Source: NTSB

Figure 11: Low-pressure turbine front case tear at the 6 o'clock position. Note that the scale is in inches and the view is looking aft

Source: NTSB

Stage four low-pressure turbine vanes

Nine consecutive stage four LPT vane clusters from positions 36–44 exhibited clashing damage on the aft end of their inside diameter shrouds. Of these clusters, three also exhibited trailing edge clashing damage on the vane aerofoils (Figure 12). The clashing damage resulted from contact with the rotating stage four LPT blades.

Figure 12: Stage four low-pressure turbine vane cluster showing clashing damage to the inside diameter of the shroud and aerofoils

Source: NTSB

Previous occurrences

Pratt and Whitney advised the ATSB of three previous stage four LPT failures in the PW4000 fleet of engines which includes PW4168A engine. Although the reported events occurred in stage four of the LPT, the failure mechanisms differed from this event.

Safety analysis

Introduction

At 89 kt during the take-off roll, the aircraft's right engine failed. The flight crew responded appropriately, successfully bringing the aircraft to a stop on the runway. Although the failure was uncontained, debris that exited via the low-pressure turbine (LPT) front case perforations was retained within the engine cowls. Debris exiting via the exhaust duct, damaged several flight control surfaces, however, this did not affect their operation.

This analysis will consider the engine failure sequence and the possible origins of the fatigue cracking in the stub of turbine blade 120 in stage four of the LPT. In addition, the high-cycle fatigue (HCF) cracking identified with 19 of the engines other stage four LPT blades will be discussed.

Engine failure

Turbine blade 120 failed as a result of HCF crack initiation and progression from the blade's leading edge, to the point where the remaining material failed in overstress. The crack origin could not be examined for material anomaly or damage due to clashing damage from a number of stage four vane clusters. However, metal smearing over the HCF crack surface indicated that the cracking preceded the clashing damage. Despite being unable to determine the factors contributing to the cracking of blade 120, the extent of the cracking indicated that it was most likely the first blade to be released in the failure sequence.

The ATSB and Pratt and Whitney were not able to conclusively determine why the vane clusters contacted the fourth stage LPT blades. The case tear resulting from the failure of blade 120 was in the same location as the vane clusters that were identified as being loose and disengaged. It is possible that distortion and damage to the structure retaining the stage four vane clusters resulted in their contact with the rotating blades of the stage four LPT rotor. However, it is also possible that the vane clusters were displaced by an unidentified mechanism resulting in contact with the stage four blades and the initiation of HCF fatigue cracking in blade 120. In this scenario, further aft movement followed, resulting in the metal smearing observed on the fracture surface of blade 120.

In addition to blade 120, HCF cracking was found in 19 other stage four LPT blades. These blades exhibited minor cracking when compared to blade 120 but also exhibited similar clashing damage as sustained by blade 120. Less oxidisation on blade 18, compared to blade 120, indicated that the blade 18 fracture surface was exposed to the gas stream for less time than blade 120. Further, the HCF fracture surface on blade 18 was less advanced at the same distance from the blade's leading edge compared to blade 120. This supports the cracking in blade 18 occurring later in the engine failure sequence than the cracking in blade 120, probably after the clashing commenced. It was therefore considered that the most likely initiator of the minor fatigue cracking in the 19 other blades resulted from their contact with the fourth stage vanes.

The ATSB did not identify any other similar failures that would indicate a systemic issue with the Pratt and Whitney PW4168A engines. No anomalies with the previous maintenance and repair of the LPT module or blade 120 were identified.

Crew actions

Recorded aircraft data indicated that the flight crew's preparation of the aircraft for take-off was appropriate. During the rejected take-off, the flight crew responded effectively and communicated with the control tower and attending emergency services.

Findings

From the evidence available, the following findings are made with respect to the uncontained engine failure in Airbus A330, registered VN-A371 and operated by Vietnam Airlines, which occurred at Melbourne Airport, Victoria on 6 May 2014. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing factors

- The engine failure was initiated by the failure of a blade in stage four of the low-pressure turbine due to high-cycle fatigue cracking, which originated at the aerofoil's leading edge.
- Cascading fracture and release of stage four turbine blades resulted in perforation of the low-pressure turbine front case and damage to the airframe from debris exiting via the exhaust duct.

Other findings

- The flight crew's handling of the rejected take-off reduced the risk of a runway excursion, preventing further damage to the aircraft and/or injury to passengers or crew.

General details

Occurrence details

Date and time:	6 May 2014 – 1051 EST	
Occurrence category:	Serious incident	
Primary occurrence type:	Engine Failure	
Location:	Melbourne Airport, Victoria	
	Latitude: 37° 40.4' S	Longitude: 144° 50.6' E

Aircraft details

Manufacturer and model:	Airbus A330	
Registration:	VN-A371	
Operator:	Vietnam Airlines	
Type of operation:	Air Transport High Capacity	
Injuries:	Crew – nil	Passengers – nil
Damage:	Substantial	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- United States National Transportation Safety Board
- Pratt and Whitney
- Vietnam Airlines
- Airbus.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the aircraft operating flight crew, Airbus, Vietnam Airlines, the Civil Aviation Authority of Vietnam, Pratt and Whitney, the United States National Transportation Safety Board, the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile and the Civil Aviation Safety Authority.

Submissions were received from Airbus, Pratt and Whitney, Vietnam Airlines and the Civil Aviation Safety Authority. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

The ATSB is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to operations involving the travelling public.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Australian Transport Safety Bureau

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Investigation

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