FINAL REPORT

AIC11-1010

PAPUA NEW GUINEA
ACCIDENT INVESTIGATION COMMISSION
AIRCRAFT ACCIDENT REPORT

Airlines PNG

P2-MCJ

Bombardier DHC-8-103

Double propeller overspeed

35 km south south east of Madang, Madang Province

PAPUA NEW GUINEA

13 October 2011

The Papua New Guinea Accident Investigation Commission (AIC) was informed of the accident by Air Traffic Services in Port Moresby on 13 October 2011 and commenced an on-site investigation. This Report, made publicly available on 15 June 2014 was produced by the PNG AIC, PO Box 1709, Boroko, NCD, Papua New Guinea.

The report is based upon the investigation carried out by the AIC in accordance with Annex 13 to the Convention on International Civil Aviation, Papua New Guinea (PNG) Civil Aviation (Amendment) Act 2010, PNG Commissions of Enquiry Act 1951, and PNG Civil Aviation Rules 2004. It contains factual information, analysis of that information, findings, and recommendations.

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The AIC believes that safety information is of greatest value if it is passed on for the use of others and readers are encouraged to copy or reprint this report for further distribution, acknowledging the Papua New Guinea Accident Investigation Commission as the source.

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TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. It is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls, and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which ‘saved the day’ or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety action: the steps taken or proposed to be taken by a person, organisation, or agency in response to a safety issue.

SYNOPSIS

In the afternoon of 13 October 2011, a DHC-8-103 aircraft registered P2-MCJ (MCJ) was being operated on a scheduled flight from Nadzab to Madang. The autopilot could not be used because the yaw damper was unserviceable so the aircraft had to be hand-flown by the pilots. The Pilot-in-Command was conducting a low power, steep descent with the propellers set at 900 revolutions per minute (RPM) in an attempt to get below cloud in order to be able to see across the ocean to Madang. Neither pilot noticed the aircraft's speed increasing to its maximum operating speed; when this speed was reached, a warning sounded in the cockpit. The First Officer recalled that the Pilot-in-Command pulled the power levers backwards ‘quite quickly’. Moments later both propellers oversped simultaneously. This occurred 10,090 feet above mean sea level when the aircraft was about to cross the coast at the foot of the Finisterre Ranges with 34 km left to run to Madang.

The overspeeding propellers back-drove the turbines in the engines (instead of the engine turbines driving the propellers) and this caused severe damage to the left engine. The right engine was not as badly damaged; its propeller feathered due to a system malfunction so that the propeller was no longer back-driving the turbine. It was not possible, however, for the pilots to unfeather the right propeller and generate useable thrust from the right engine, which meant that a forced landing without power was inevitable. The aircraft landed in bush land next to the Guabe River and caught fire. Of 32 persons on board, only four survived: the two pilots, the flight attendant, and one passenger.

The investigation found the propellers oversped because the Pilot-in-Command pulled the power levers through the flight idle gate and into the ground beta range during flight. This was prohibited by the Aircraft Flight Manual. Although a 'beta lockout' mechanism did exist for DHC-8-100,-200, and -300 series aircraft which prevented the propellers from going into reverse even if the power levers were moved into the beta range during flight, this mechanism was only required by regulation to be installed in DHC-8 aircraft operating in the USA. It was not required to be fitted to DHC-8 aircraft in Papua New Guinea, and it was not fitted to MCJ.

After the emergency began, the First Officer quickly identified the double propeller overspeed. At about the same time, smoke appeared in the cockpit and various aircraft system malfunction alerts activated. The crew did not respond to any of these alerts by implementing the emergency procedures detailed in company manuals and the quick reference handbook (QRH). One consequence was that the left propeller, which was not feathered promptly, continued to windmill for approximately three minutes. This created very significant drag and made the aircraft descend more rapidly than it otherwise would have. In addition, the crew did not slow the aircraft’s airspeed, further reducing the time available to them to manage the emergency, consider their options, and conduct an approach to land. The fact that the left propeller was not feathered promptly made the aircraft harder to control because of the asymmetry between the windmilling left propeller and the feathered right propeller. Use of the landing gear and flaps was not considered by the pilots, and they were not extended, although the flaps could have been extended until the engines were shut down before impact and the landing gear could have been extended at any time. If the landing gear and flaps had been extended, the impact could have been less severe.

If a beta lockout mechanism had been installed on the aircraft, the double propeller overspeed would not have occurred when the power levers were moved below the flight idle range and in the ground beta range during flight. Installation of this mechanism is now mandatory on DHC-8 aircraft worldwide by 19 June 2016. If the pilots had followed the standard emergency procedures detailed in company manuals, they would have given themselves more time to manage the emergency, consider their options, and carry out the approach and forced landing.

1 FACTUAL INFORMATION

1.1 HISTORY OF THE FLIGHT

On the afternoon of 13 October 2011, an Airlines PNG Bombardier DHC-8-103, registered P2-MCJ (MCJ), was conducting a regular public transport flight from Nadzab, Morobe Province, to Madang, Madang Province under the Instrument Flight Rules (IFR) (Figure 1). On board the aircraft were two flight crew, a flight attendant, and 29 passengers. Earlier in the afternoon, the same crew had flown MCJ from Port Moresby to Nadzab. The autopilot could not be used because the yaw damper was unserviceable so the aircraft had to be hand-flown by the pilots.

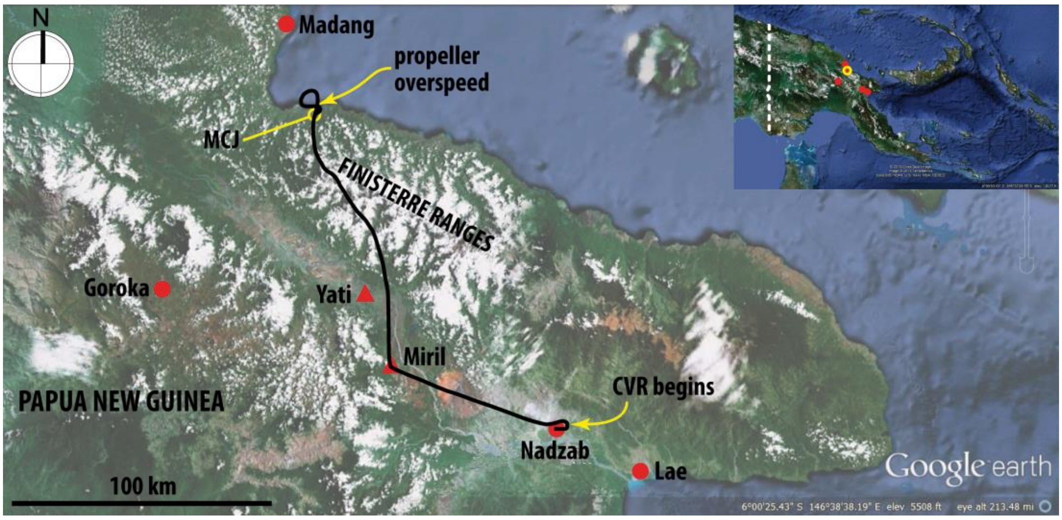

Figure 1: MCJ track from Nadzab towards Madang and accident site location

At Nadzab, the aircraft was refuelled with sufficient fuel for the flight to Madang and a planned subsequent flight from Madang to Port Moresby. MCJ departed Nadzab at 1647[1] LMT[2] with the Pilot-in-Command as the handling pilot. The aircraft climbed to 16,000 ft with an estimated arrival time at Madang of 1717. Once in the cruise, the flight crew diverted right of the flight planned track to avoid thunderstorms and cloud.

The Pilot-in-Command reported that communications between Madang Tower and an aircraft in the vicinity of Madang indicated a storm was approaching the aerodrome. He recalled that he had intended to descend below the cloud in order to be able to see across the sea to Madang and had been concentrating on manoeuvring the aircraft to remain clear of thunderstorms and cloud, so he had been looking mainly outside the cockpit. Because of the storm in the vicinity of the airport, he said there had been ‘some urgency’ to descend beneath the cloud base to position for a right base for runway 07 at Madang, the anticipated approach.

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[1] The aircraft began to taxi at Nadzab at approximately 1641, see Figure 12.

[2] The 24-hour clock is used in this report to describe the local time of day, Local Mean Time (LMT), as particular events occurred. Local Mean Time was Coordinated Universal Time (UTC) + 10 hours.

On this route, the descent to Madang was steep (because of the need to remain above the Finisterre Ranges until close to Madang) and, although the aircraft was descending steeply, the propellers were at their cruise setting of 900 revolutions per minute (RPM). Neither pilot noticed the airspeed increasing towards the maximum operating speed (V_{MO}); the Pilot-in-Command reported afterwards that he had been ‘distracted’ by the weather. When the aircraft reached V_{MO} as it passed through 10,500 ft, with a rate of descent between 3,500 and 4,200 ft per minute, and the propellers set at 900 RPM, the V_{MO} overspeed warning sounded. The Pilot-in-Command reported that he had been about to ask the First Officer to increase the propeller speed to 1,050 RPM to slow the aircraft when this occurred. He raised the nose of the aircraft in response to the warning and this reduced the rate of descent to about 2,000 ft per minute, however, the V_{MO} overspeed warning continued.

The First Officer recalled the Pilot-in-Command moved the power levers back ‘quite quickly’. Shortly after the power levers had been moved back, both propellers oversped simultaneously, exceeding their maximum permitted speed of 1,200 RPM by over 60 % and seriously damaging the left hand engine and rendering both engines unusable. Villagers on the ground reported hearing a loud ‘bang’ as the aircraft passed overhead. The noise in the cockpit was deafening, rendering communication between the pilots extremely difficult, and internal damage to the engines caused smoke to enter the cockpit and cabin through the bleed air and air-conditioning systems.

The emergency caught both pilots by surprise. There was confusion and shock on the flight deck, a situation compounded by the extremely loud noise from the overspeeding propellers. About four seconds after the double propeller overspeed began, the beta warning horn started to sound intermittently, although the pilots stated afterwards they did not hear it.

The left propeller RPM reduced to 900 RPM (in the governing range) after about 10 seconds. It remained in the governing range for about 5 seconds before overspeeding again for about 15 seconds, then returned to the governing range. During this second overspeed of the left propeller, the left engine high speed compressor increased above 110 % N_H, becoming severely damaged in the process. About 3 seconds after the left propeller began overspeeding for the second time, the right propeller went into uncommanded feather due to a propeller control unit (PCU) beta switch malfunction, while the right engine was still running at flight idle (75% N_H).

Nine seconds after the double propeller overspeed event began, the Pilot-in-Command shouted to the First Officer ‘what have we done?’ The First Officer replied there had been a double propeller overspeed. The Pilot-in-Command then shouted a second and third time ‘what have we done?’. The First Officer repeated that there was a double propeller overspeed and said that the right engine had shut down.

The Pilot-in-Command shouted that he could not hear the First Officer, who – just as the left propeller began governing again and the overspeed noise subsided – repeated that the right engine had shut down and asked if the left engine was still working. The Pilot-in-Command replied that it was not working. Both pilots then agreed that they had ‘nothing’.

At this point, about 40 seconds after the propeller overspeed event began, the left propeller was windmilling and the left engine was no longer producing any power because of the damage caused to it by the overspeed. The right engine was operating at flight idle, although the propeller could not be unfeathered and therefore could not produce any thrust. Figures 2 and 3 show the aircraft's flight path during the final minutes of the accident flight.

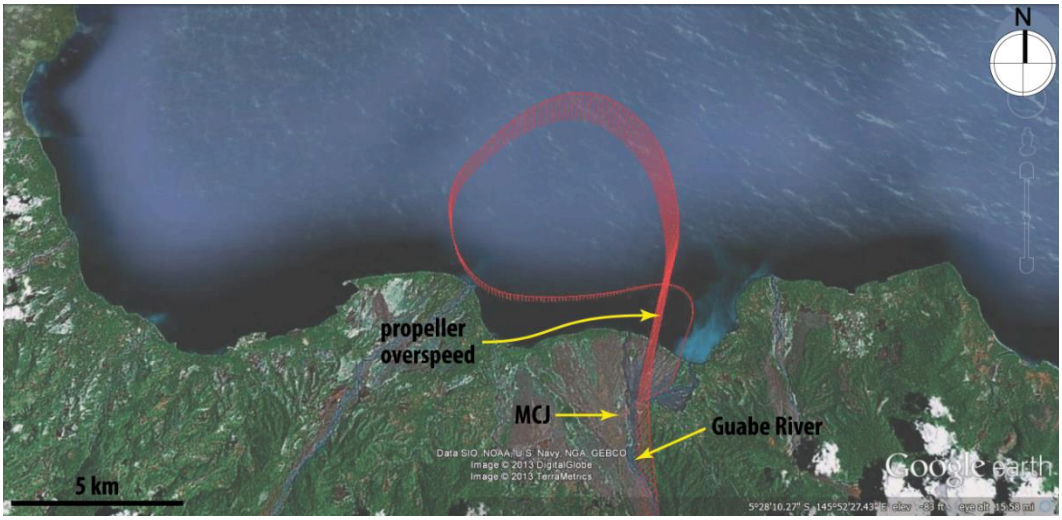

Figure 2: Plan view of flight path during final minutes of flight

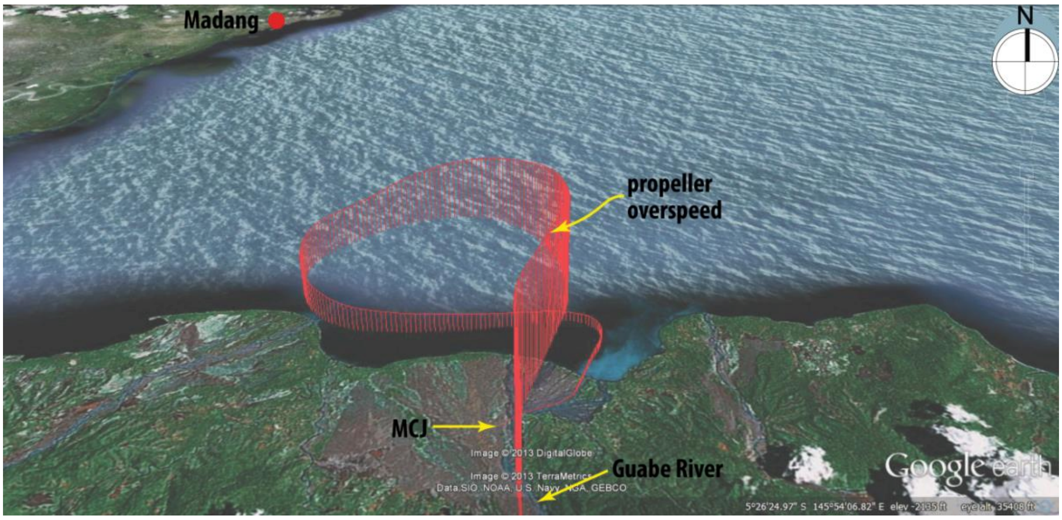

Figure 3: Flight path during final minutes of flight

On the order of the Pilot-in-Command, the First Officer made a mayday call to Madang Tower and gave the aircraft's GPS position; he remained in a radio exchange with Madang Tower for 63 seconds. The flight crew did not conduct emergency checklists and procedures. Instead, their attention turned to where they were going to make a forced landing.

The aircraft descended at a high rate of descent, with the windmilling left propeller creating extra drag. The asymmetry between the windmilling left propeller and the feathered right propeller made the aircraft difficult to control. The average rate of descent between the onset of the emergency and arrival at the crash site was 2,500 ft per minute and at one point exceeded 6,000 ft per minute, and the V_{MO} overspeed warning sounded again.

During his long radio exchange with Madang Tower, the First Officer had said that they would ditch the aircraft, although, after a brief discussion, the Pilot-in-Command subsequently decided to make a forced landing in the mouth of the Guabe River.

The First Officer asked the Pilot-in-Command if he should shut both engines down and the Pilot-in-Command replied that he should shut ‘everything’ down. Approximately 800 feet above ground level and 72 seconds before impact, the left propeller was feathered and both engines were shut down.

The Pilot-in-Command reported afterwards that he ultimately decided to land beside the river instead of in the river bed because the river bed contained large boulders. The area chosen beside the river bed also contained boulders beneath the vegetation, but they were not readily visible from the air. He recalled afterwards that he overshot the area he had originally been aiming for.

The aircraft impacted terrain at 114 knots with the flaps and the landing gear retracted. The Flight Attendant, who was facing the rear of the aircraft, reported that the tail impacted first. During the impact sequence, the left wing and tail became detached. The wreckage came to rest 300 metres from the initial impact point and was consumed by a fuel-fed fire. The front of the aircraft fractured behind the cockpit and rotated through 180 degrees, so that it was inverted when it came to rest. Of the 32 occupants of the aircraft only the two pilots, the flight attendant, and one passenger survived by escaping from the wreckage before it was destroyed by fire.

Table 3 in the section entitled *MCJ flight crew actions following the onset of the emergency* provides a summary of the principal events and flight crew actions following the onset of the emergency.

1.2 INJURIES TO PERSONS

The Pilot-in-Command sustained injuries to his right leg during the impact sequence. The First Officer and the Flight Attendant sustained minor injuries. One passenger survived with severe burns. The remaining 28 passengers were fatally injured during the impact and subsequent fuel-fed fire.

Table 2: Injuries to persons

Injuries	Flight crew	Passengers	Total in Aircraft	Others
Fatal	-	28	-	-
Serious	1	1	-	-
Minor	2	-	-	Not applicable
Nil Injuries	-	-	-	Not applicable
TOTAL	3	29	32	-

The Pilot-in-Command was an Australian citizen and the First Officer was a dual citizen of New Zealand and Australia. The Flight Attendant was a citizen of Papua New Guinea. The surviving passenger was a Malaysian citizen and all other persons on board were citizens of Papua New Guinea.

1.3 DAMAGE TO AIRCRAFT

The aircraft was destroyed.

1.4 OTHER DAMAGE

Apart from burnt and broken vegetation, there was no other damage to property or the environment.

1.5 PERSONNEL INFORMATION

1.5.1 Pilot-in-Command

Age	: 64 years
Gender	: male
Type of licence	: PNG ATPL number P21393, issued 4 July 2011, without revocation or suspension notices
Valid to	: perpetual
Rating	: Bombardier DHC-8
Total flying time	: approximately 18,200 hours
Total on this type	: approximately 500 hours
Total last 90 days	: 148.3 hours
Total on type last 90 days	: 148.3 hours
Total last 7 days	: 14.9 hours
Total on type last 7 days	: 14.9 hours
Total last 24 hours	: 00 hours
Total on the type last 24 hours	: 00 hours
Last recurrent training	: 3 July 2011
Last proficiency check	: 3 July 2011
Last line check	: 12 February 2011
Medical class	: One
Valid to	: 2 December 2011
Medical limitation	: Australian Aviation medical (Class 1 valid to 21 March 2011, Class 2 valid to

21 September 2011) required distance vision correction to be worn and reading correction to be available.

The Pilot-in-Command returned to PNG on 25 September 2011 following a 3-week break overseas. On 9 October 2011 he had a rostered day off. On 10 October 2011 he had flown to Madang and overnighted there, returning to Port Moresby in the morning of 11 October 2011 when he felt unwell (details are given under *Medical and pathological information*). He did not work on 12 October 2013 and reported that he was well rested prior to the accident flight.

1.5.2 Pilot-in-Command's DHC-8 training

The Pilot-in-Command joined the operator on 26 October 2010. His DHC-8 ground course training certificate was dated 4 November 2010. The company's records indicated that he completed 10 supernumerary familiarisation sectors as an observer on 15 and 16 November 2010. His simulator type endorsement training was conducted between 19 and 27 November 2010 in Melbourne, Australia. It comprised five 'exercises' spread over seven sessions totalling 28 hours, with no exercises or sessions needing to be repeated.

The Pilot-in-Command began his line training in the aircraft in PNG on 13 December 2010 and was checked-to-line on 12 February 2011 following a line check spread over two days (10 and 12 February 2011). His line training was conducted by four training captains, three of whom were interviewed including the training captain who checked the Pilot-in-Command to line. The overall assessments of these training captains were that the ability and handling skills of the Pilot-in-Command had been of 'average' or 'good' standard. His extensive prior experience of flying in PNG had been apparent. One training captain recalled an occasion when, just after top of descent, the Pilot-in-Command had made a rapid change of power; the training captain described it as 'moving the power levers back faster than [was] desirable'. He reported that this manner of handling the power levers did not occur again while he was training the Pilot-in-Command.

On 22 and 23 May 2011, the Pilot-in-Command completed a two day training course in Human Factors and Crew Resource Management.

On 3 July 2011 the Pilot-in-Command underwent a recurrent flight proficiency/instrument check in the simulator in Melbourne and was assessed as 'satisfactory' in all exercises undertaken. There was no record of a propeller overspeed exercise having been conducted during the Pilot-in-Command's endorsement and recurrent simulator training. The Pilot-in-Command did not recall having conducted a propeller overspeed exercise in the simulator during this training.

1.5.3 First Officer

Age : 40 years

Gender : male

Type of licence : PNG ATPL number P21362, issued on 30 May 2011, without revocation or suspension notices
Valid to : perpetual
Rating : Bombardier DHC-8
Total flying time : 2,725 hours
Total on this type : 391 hours
Total last 90 days : 106 hours
Total on type last 90 days : 106 hours
Total last 7 days : 7.1 hours
Total on type last 7 days : 7.1 hours
Total last 24 hours : 5.4 hours
Total on the type last 24 hours : 5.4 hours
Last recurrent training : 13 June 2011
Last proficiency check : 13 June 2011
Last line check : 7 April 2011
Medical class : One
Valid to : 23 March 2012
Medical limitation : none

The First Officer had returned to PNG on 10 October 2011 following a six-week break overseas. On 11 October 2011 he had flown to Madang and overnighted there, returning to Port Moresby in the morning of 12 October 2011. He flew in the afternoon of 12 October 2011. He reported that he was well rested prior to the accident flight and had been called in from reserve at 1230 on the day of the accident.

1.5.4 First Officer's DHC-8 training

The First Officer joined the operator on 17 January 2011. His DHC-8 ground course training certificate was dated 27 January 2011. The company's records indicated that he completed 12 supernumerary familiarisation sectors as an observer in the aircraft between 29 January and 18 February 2011. His simulator type endorsement training was conducted between 5 and 12 February 2011 in Melbourne. It comprised five 'exercises' spread over seven sessions totalling 26 hours, with no exercises or sessions needing to be repeated.

The First Officer began his line training in the aircraft in PNG on 26 February 2011 and was checked-to-line on 7 April 2011. Almost all his line training was conducted by one training captain who recalled the First Officer's flying ability and knowledge of the aircraft had been well above average.

On 14 and 15 April 2011, the First Officer completed a two day training course in Human Factors and Crew Resource Management.

On 13 June 2011 the First Officer underwent a recurrent flight proficiency/instrument check in the simulator in Melbourne and was assessed as ‘satisfactory’ in all exercises undertaken. There was no record of a propeller overspeed exercise having been conducted during the First Officer’s endorsement and recurrent simulator training. The First Officer did not recall having conducted a propeller overspeed exercise in the simulator during this training.

1.5.5 Flight attendant

The Flight Attendant was 28 years old at the time of the accident. He held a valid PNG Certificate number 601/2008 issued on 28 March 2008. He had approximately 2,500 hours of flying experience, all of which was with the operator of MCJ.

1.6 AIRCRAFT INFORMATION

1.6.1 Aircraft

The Bombardier DHC-8-103 is a high wing, twin turboprop, pressurised, retractable tricycle undercarriage aircraft (Figure 4). MCJ was operated with a seating capacity of 36 passengers and was first introduced into the operator’s fleet on 2 October 2003.

Figure 4: Bombardier DHC-8-100 aircraft

1.6.2 Aircraft data

Aircraft manufacturer	: Bombardier Inc.
Model	: DHC-8-103
Serial number	: 125
Date of manufacture	: 1988
Nationality and registration mark	: Papua New Guinea, P2-MCJ
Name of operator	: Airlines PNG

Certificate of Airworthiness	: Issue date 01 May 2006
Certificate of Registration	: Issue date 14 April 2011
Maintenance release	: Valid to 38,464.8 hours / 20 Oct 2011
Total hours since new	: 38,421.3 hours
Total cycles since new	: 48,093 cycles

1.6.3 Engines

MCJ was fitted with two Pratt and Whitney Canada PW-121 engines. The PW-121 is a three spool free turbine turbopropeller engine which delivers up to 2,150 shaft horse power to the propeller. The engine consists of two modules, the reduction gearbox module and the turbo-machinery module, joined to form a single unit. The turbo-machinery includes two independent, coaxially mounted centrifugal compressors, one high speed (N_H) and one low speed (N_L), each driven by a single-stage turbine. A two-stage power turbine (N_P) drives the propeller via the reduction gearbox by means of a coaxial shaft that passes through the compressor shaft (Figure 5).

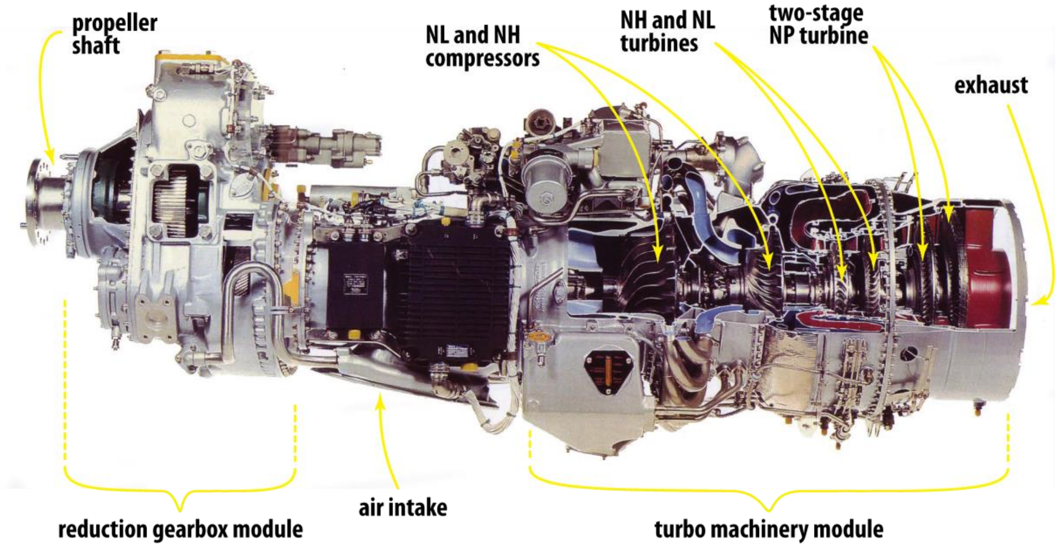

Figure 5: PW-121 engine sectional view

The left engine was fitted to the accident aircraft on 8 August 2010 and had run 1,802.8 hours since being installed. The right engine was fitted to the aircraft on 30 Sept 2010 and had run 1,606.6 hours since installation.

1.6.4 Engine data

Engine type	: Turbopropeller
Manufacturer	: Pratt & Whitney Canada
Type	: PW-121
Engine number one (left)	
Serial number	: PCE-120662

Year of manufacture : 1988
Total time since new : 38,423.5 hours
Total time since overhaul : 2,128.9 hours / 31 Dec 2009

Engine number two (right)
Serial number : PCE-AC0031
Year of manufacture : 2004
Total time since new : 7,175.1 hours
Total time since overhaul : N/A

1.6.5 Propellers

The aircraft was fitted with two Hamilton Sundstrand 14SF-7 propellers. They were flange-mounted, controllable pitch, hydraulic dual-acting, full feathering and reversible propellers with composite blades. The propeller assembly was made up of a hub, actuator, four propeller blades, and an oil transfer tube.

The left propeller was fitted to the aircraft on 30 April 2011 and the right propeller was fitted to the aircraft on 1 June 2011.

1.6.6 Propeller data

Manufacturer : Hamilton Sundstrand
Type : 14SF-7

Propeller number one (left)
Hub serial number : 000113
Total time since installation : 1,118.9 flight hours

Propeller number two (right)
Hub serial number : 2047
Total time since installation : 513.1 flight hours

1.6.7 Engine and propeller controls

1.6.7.1 Cockpit to engine controls

Engine power on the DHC-8-100 is controlled by pilot inputs through the power control system which consists of a separate power control lever and separate condition lever for each engine. Each set of engine controls is completely independent of the other. Movement of the power levers and condition levers in the cockpit is transmitted by various push-pull tubes, cables, bell cranks, and linkages simultaneously to the engine's hydro mechanical unit (HMU) and the propeller control unit (PCU). Figure 6 is a diagram of the engine control system for both engines showing the various push-pull tubes, bell cranks, cables, and linkages.

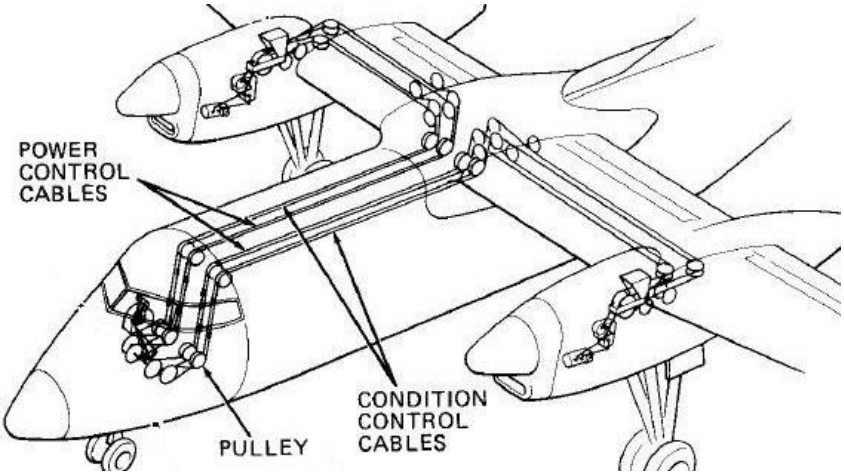

Figure 6: Engine and propeller controls

1.6.7.2 Power and condition levers

The aircraft is equipped with systems to allow the flight crew to manage propeller speed as follows.

- **Engine condition levers** The condition levers control propeller speed between 900 (MIN) and 1,200 (MAX) RPM, engine starting (FUEL ON), propeller feathering, and engine shut-down (FUEL OFF). In Figure 7, the condition levers are in the FUEL OFF position.
- **Engine power levers** In flight mode, the power levers control engine speed between flight idle and take-off power. In ground beta mode, the power levers control propeller pitch directly; this is used for slowing the aircraft after landing and for ground manoeuvring. In Figure 7, the power levers are in the take-off position.

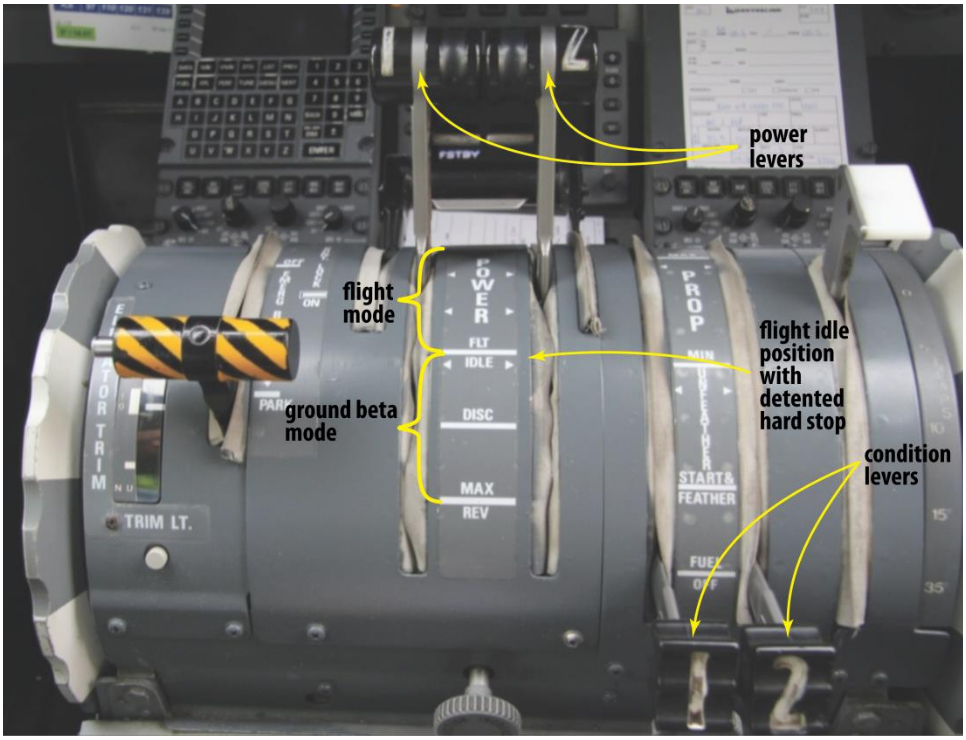

Figure 7: DHC-8 power lever quadrant

1.6.8 Propeller system components

The propeller utilises several components, collectively called the propeller system, for various control and protection functions. The propeller system incorporates the propeller assembly, transfer tube, propeller control unit (PCU), overspeed governor and pump, and auxiliary feather pump and motor (Figure 8).

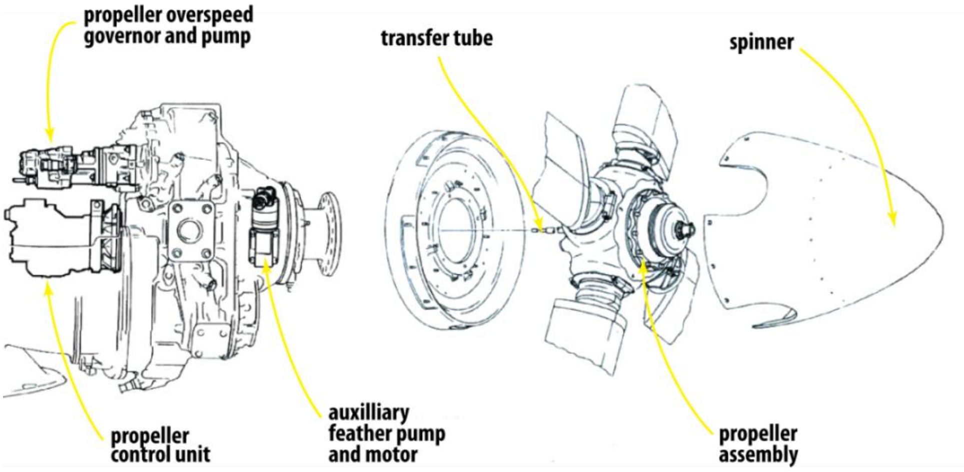

Figure 8: Propeller system components

In normal flight operation, between flight idle and take-off power, the PCU controls and maintains the propeller speed between 900 and 1,200 RPM through its governor and control inputs from the condition levers. The PCU maintains the propeller speed by increasing the pitch angle (coarsening) of the blades to decrease propeller speed or, conversely, decreasing the pitch angle on the blades to increase propeller speed.

An overspeed governor is fitted to the engine for propeller overspeed protection. In the event that the PCU does not govern the propeller to maintain it below its maximum speed of 1,200 RPM, the overspeed governor will sense the propeller overspeed condition at 103 % (1,236 RPM) and increase the blade angle to reduce the propeller speed. At 109 % (1,309 RPM) the overspeed governor will also reduce the engine speed by reducing fuel flow. The system incorporates a beta backup system that increases the blade angle if it senses the blade angle is below the flight idle setting with the power levers above the flight idle gate.

When a pilot positions the power levers to an angle of 13 degrees below the flight idle gate, the governing functions of the propeller control unit and the overspeed governor are inhibited. The beta backup system is deactivated when the power lever is positioned to less than flight idle. This is a design feature that allows the power levers to control propeller pitch directly during ground operations. The propeller does not require speed governing during ground operations (and low airspeeds) because there is insufficient airspeed to drive the propeller to an overspeed condition.

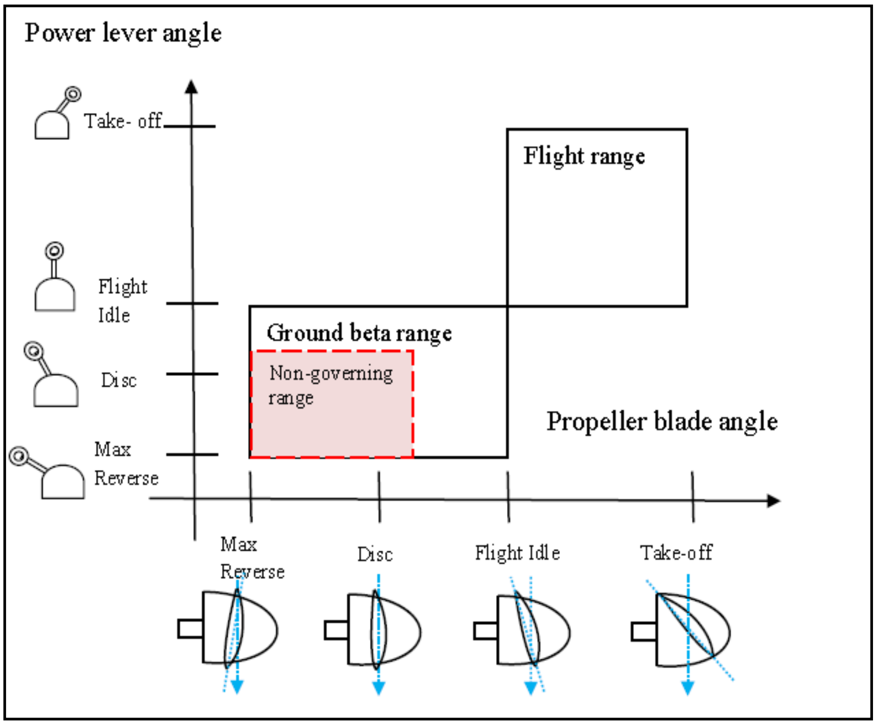

Figure 9: Power lever angle and propeller blade pitch angle

In summary, propeller overspeed is prevented by three systems which work independently on each engine, provided the power levers are maintained above the flight idle gate during flight. If the power levers are moved below flight idle during flight, the propeller speed is no longer controlled by the propeller systems, leaving them susceptible to an overspeed condition that can rapidly lead to engine damage and, in the worst case, engine failure.

Figure 9 shows the relationship between power lever angle and propeller blade pitch angle, and the area in which propeller speed is not governed.

1.6.9 Propeller control unit beta switch anomalies

While this report was being finalised, the aircraft manufacturer provided the AIC with information about a quality control issue involving propeller control units (PCUs) that had been overhauled at an approved facility in the USA. The issue involved the utilisation of the pre-service bulletin procedure for the refitting of the beta switch to the PCUs during overhaul, which caused the beta switch to stick in the closed position. As a result, an uncommanded feather occurred on a DHC-8-100 aircraft in the USA in a similar way to the uncommanded feather on MCJ (refer to 1.11.9 *Right engine ground beta FDR parameter* for details).

Numerous PCUs that were overhauled at the facility were recalled from service in order to rectify the problem. The Federal Aviation Administration (FAA) released a safety alert for operators (SAFO 13009) on 10 October 2013, an extract of which follows.

> **Subject:** Propeller Control Unit and Adapters Repaired/Overhauled by Pacific Propeller International, LLC from September 2010 to September 2013.
>
> **Purpose:** This SAFO advises about the potential for un-commanded feathering events when Propeller Control Units (PCU) and adapters are improperly repaired or overhauled.
>
> **Background:** On July 25, 2013, an inadvertent feather event occurred shortly after takeoff on a DeHavilland DHC-8-100 series aircraft. Flight data records indicated that the #1 PCU was closed during takeoff when a beta condition did not exist. Examination of the subject PCU revealed that the beta light assembly was installed incorrectly, deforming the switch case. The deformed case interfered with the free action of the switch's internal mechanism, causing the switch to intermittently remain closed as the propeller transitioned above the ground handling range during takeoff. This condition resulted in a propeller over-torque when the aircraft's beta backup system became active and commanded the propeller to feather while the engine was in a high-power condition.
>
> **Discussion:** Service Bulletin 14SF-61-148 was issued in June of 2001 by Hamilton Sundstrand Corporation to address and limit intermittent switch failure on 14SF Propeller Control Units. This failure is caused by the deformation of the switch casing by repeated torqueing of the beta switch retention screws during repair and overhaul cycles. The deformed case interferes with the internal mechanisms causing the switch to fail and remain closed as the propeller transitions above the ground range during takeoff. This condition could result in a propeller over-torque and un-commanded feather when the aircraft's beta backup system becomes active.
>
> Pacific Propeller International, LLC (PPI) had performed maintenance on the PCU installed on the aircraft that experienced an inadvertent feather event on takeoff. PPI subsequently identified an error in the assembly of the beta switch and the mounting spacers. It was determined that technicians

> assembled the switch with parts identified in Service Bulletin 14SF-61-148 while using the instructions that were in the Original Equipment Manufacturers (OEM) Component Maintenance Manual (CMM) instead of following maintenance instructions as defined in the Service Bulletin. This error resulted in providing a repaired/overhauled PCU in a configuration that is not identified with the OEM CMM or Service Bulletin 14SF-61-148. PPI also determined that this error may also affect 466 14SF PCU's overhauled/repaired from September 2010 to September 2013. PPI has notified the owner/operators of 401 of the affected units and this SAFO is intended to ensure all owners and operators are aware of this safety matter.
>
> **Recommended action:** Owners and operators with these units should be familiar with the content of this SAFO and should ensure that any affected PCUs are removed and replaced as soon as possible, beginning with those twin-engine aircraft where affected units are installed on both engines.

According to information received by Transport Canada, overhaul of PCUs is performed according to existing CMM procedures, however, the OEM CMM was not revised to include post SB configuration in this case. According to the FAA, the OEM is now in the process of revising the OEM CMM to incorporate the latest post SB configuration for the beta switch installation.

1.6.9.1 Right propeller control unit (S/N 850148) fitted to MCJ

Maintenance documentation indicated that the right PCU fitted to MCJ had been overhauled by PPI; although it was not one of the units on the recall list, the overhaul paperwork indicated that the service bulletin 14SF-61-148 had been incorporated.

The aircraft manufacturer was informed of the history of MCJ's right PCU, including the service bulletin incorporation, in an effort to ascertain if the PCU may have been affected by the quality escape issues as indicated in SAFO13009, even though it was not one of the units identified in the recall. The manufacturer stated that they:

> "… requested, unsuccessfully to date, to the NTSB (via the TSBC) and to the FAA (via TC) to have a more concerted effort in understanding whether or not the recall on the PCU's should have been expanded."

The AIC also sought clarification on the PCU recall. On 21 May 2014, the AIC was informed by the NTSB that the PCU recall had been extended by the overhaul facility to include any PCU that had been overhauled between 4 June 2001 and 26 September 2013. The right PCU fitted to MCJ at the time of the accident was subject to this extended recall.

The NTSB indicated that the FAA was in the process of updating the Safety Alert for Operators SAFO13009.

1.6.10 Flight idle gate and release triggers

The power lever quadrant includes a mechanical stop, called the flight idle gate, to prevent movement of the power levers below flight idle in flight. Each power lever handle incorporates a flight idle gate release trigger that, when lifted, allows the power levers to bypass the flight idle gate and enter ground beta range.

Testing conducted by the Australian Transport Safety Bureau (ATSB) on an exemplar aircraft confirmed that only one of the triggers needs to be lifted about 6 mm to enable both power levers to bypass the flight idle gate into the ground beta range.

Further testing was conducted from both the Pilot-in-Command's and First Officer's sides, with the seat on each side adjusted to the normal flight position. With the hand placed with the palm on top of the power levers, there was a distinct tendency for the middle two fingers to touch the flight idle gate triggers when moving the power levers rearward. Figure 10 shows the power levers with one of the triggers lifted to the height required to bypass the gate.

Figure 10: Power levers showing flight idle gate triggers, with right trigger lifted

1.6.11 Beta warning horn

The aircraft manufacturer introduced a service bulletin modification in 1999 which recommended the installation of a beta warning horn. Transport Canada mandated this modification in 1999 with Airworthiness Directive (AD) CF-99-18 which was subsequently adopted by airworthiness authorities including the Civil Aviation Safety Authority (CASA PNG) in Papua New Guinea.

The beta warning horn provides an audible warning when the flight idle gate release triggers are lifted in flight. At any power lever setting, raising either release trigger during flight will cause the horn to operate. The horn can be silenced by releasing the triggers with the power levers selected above the flight idle gate. A beta warning horn was fitted to MCJ.

1.6.12 Flight manual warning

Section 2.5.8 of the *Aircraft Flight Manual* stated:

> In-flight operation of the power levers aft of the FLT IDLE gate is prohibited. Failure to observe this limitation will cause propeller overspeed, possible engine failure and may result in loss of control.

1.6.13 Hydraulic system description

Hydraulic power is delivered by two independent main systems to operate various flight controls and the landing gear. The two main systems provide hydraulic power to operate wing flaps, rudder, roll spoilers, wheel brakes, nose wheel steering, and normal landing gear extension and retraction.

The left (No. 1) and right (No. 2) systems are powered from engine driven pumps (EDPs) located on the left and right engine reduction gearboxes respectively. Electrically driven standby hydraulic power units (SPU's) are incorporated into both main systems to provide hydraulic power in the event of EDP failure (Figure 11). Each SPU is powered by AC power supplied from its respective AC generator; however, in the event of power failure on one system, AC power is automatically supplied by the other system. In addition, there is a separate hand pump system for emergency use to pump the main landing gear into the overcentre down-lock at the completion of its gravity-driven extension.

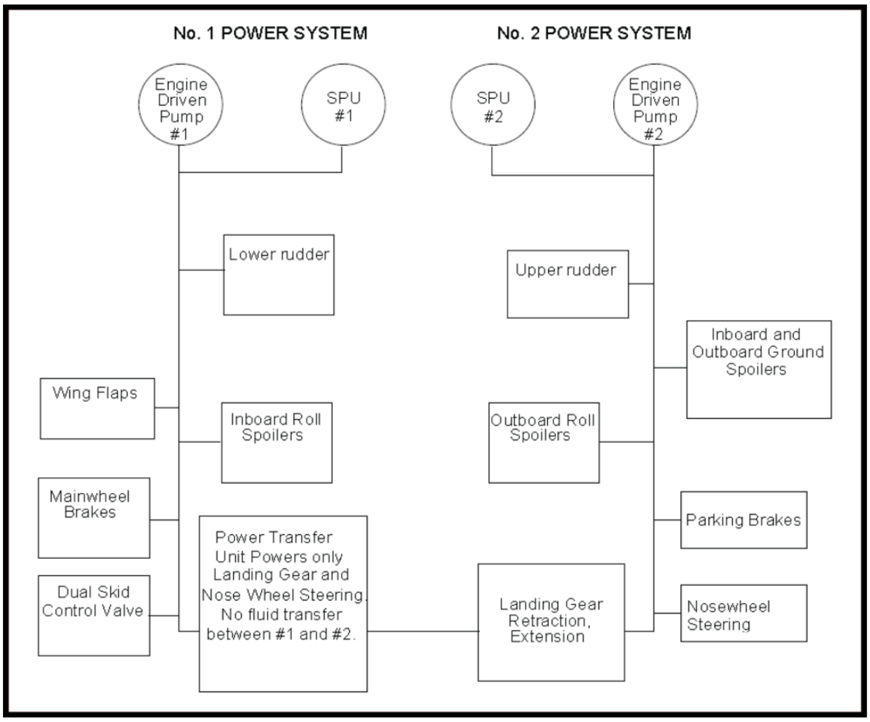

Figure 11: Main hydraulic systems distribution schematic

1.6.14 Electrical supply system description

Each engine was fitted with an alternating current (AC) generator and a direct current (DC) generator which provided power to the aircraft’s various electrical systems.

1.6.14.1 Alternating current generators

The AC generators are mounted on the left and right engine reduction gearboxes. The speed at which the AC generator is rotated has a direct relationship to propeller speed. When the propeller is feathered, the AC generator does not rotate sufficiently quickly to produce AC power.

1.6.14.2 Direct current generators

The DC generators are mounted on the engine accessory gearboxes. The speed at which the generators rotate has a direct relationship to the high speed compressor and turbine speed. The aircraft manufacturer stated that the lowest speed at which the DC generators can operate is 33.3 % +/- 10 % N_H.

1.6.15 Landing gear

1.6.15.1 General description

The retractable landing gear consists of two main gear assemblies, one mounted in each nacelle, and a nose gear assembly mounted in a well in the front of the fuselage.

Both main and nose gear assemblies incorporate shock struts to reduce landing loads imparted on the aircraft. The main gear assemblies retract rearward and the nose gear assembly retracts forward. Normal extension/retraction is hydraulically actuated by the No. 2 (right) main hydraulic system.

1.6.15.2 Emergency extension

Emergency or ‘alternate’ extension of the main gear is accomplished by mechanical release of the uplocks to allow partial extension by gravity. Springs on the main gear drive the over-centre links to the locked position and a hand pump in the cockpit provides backup pressure to the strut. The nose gear has a mechanical release of the uplock and the gear free-falls by gravity. Airflow also forces the nosegear rearward into the locked position. The emergency/alternate extension system does not require normal hydraulic system pressure or electrical power to extend the gear. Extending the landing gear by means of the emergency/alternate extension system may take several minutes.

1.6.16 Wing flaps

The wing flaps consist of a drive system, a control system, and four separate flap sections, two on each wing. The flap system is electro-mechanically controlled and hydro-mechanically operated, and can be selected to move the flaps from the fully up to the 35 degree fully down position, with intermediate positions of 5 and 15 degrees.

Flap position is set by means of a lever located on the right side of the flight compartment centre console. The flap selection lever is mechanically connected to a hydraulic flap drive power unit. Operation of the flap selection lever actuates a switch which directs electrical power to the flap drive power unit.

1.6.17 Engine and aircraft systems operation after propeller overspeeds

Flight Data Recorder (FDR) data indicated that the engines were operating in a degraded state as a result of the propeller overspeeds. Because the electrical and hydraulic systems were reliant on engine/propeller operation, those systems were also operating at less than full capability. The condition of the engines subsequent to the propeller overspeeds was as follows.

1.6.17.1 Left engine and propeller

- The propeller was being governed at 900 RPM.
- The speed of the high speed compressor and turbine had degraded but was sustaining approximately 38 % N_H. Note that normal flight idle speed was about 75% N_H. This was the minimum speed required to provide useful but minimal power to the propeller in flight.

The left engine’s degraded state meant that normal hydraulic supply pressure and AC power would be available, however, DC power may not have been available at the reduced speed of the high speed compressor/turbine. The torque indication reading was zero at that time meaning the engine was not producing useful power to the propeller, and the propeller should therefore have been secured by feathering it to reduce aerodynamic drag in accordance with DHC-8 emergency procedures.

1.6.17.2 Right engine and propeller

- The propeller was in feather but rotating at about 25 to 50 RPM.
- The high speed compressor and turbine was operating at 75% N_H, which was flight idle speed.

With the right propeller in feather, the propeller rotated the reduction gearbox at 25 to 50 RPM. That speed was insufficient for the No. 2 AC generator to produce any power. The No. 2 hydraulic pump would also have had significantly reduced output. The DC generator was operating within the normal operating range and was capable of supplying full DC electrical power.

The ATSB asked the aircraft manufacturer whether it would have been possible for the flight crew to unfeather the propeller so it could produce thrust. Their response was as follows.

> Re-acquisition of control of the propeller after the automated feathering would not have been possible without intrinsic knowledge into the powerplant controls …

The ATSB asked the aircraft manufacturer whether it would have been possible to lower the flaps and landing gear given the degraded state of the engines and, consequently, the electrical and hydraulic systems. The manufacturer stated that even with both propellers feathered, the engine-driven hydraulic pumps still generate enough pressure at propeller feather speeds to allow for landing gear and also flap selection. Emergency/alternate gear extension would also have been possible to extend the landing gear after a complete loss of electrical and hydraulic power.

1.6.18 Aircraft certification and modification history

1.6.18.1 Initial certification requirements

The first DHC-8 model (DHC-8-100) was certified in Canada and the USA in 1984. US Federal Aviation Regulations (FARs) current at the time stated:

> 25.1155 Reverse thrust and propeller pitch settings below the flight regime.
>
> Each control for reverse thrust and for propeller pitch settings below the flight regime must have means to prevent its inadvertent operation. The means must have a positive lock or stop at the flight idle position and must require a separate and distinct operation by the crew to displace the control from the flight regime (forward thrust regime for turbojet powered airplanes).

Similarly, there was no requirement in the Canadian regulations for a means to minimise the likelihood of flight crews moving the power levers below the flight idle gate in flight.

1.6.19 Modified flight idle gate (United Kingdom)

The DHC-8-102 was certified in Europe and the United Kingdom (UK) in the mid-1980s, with the certifying authorities using the US FARs as the basis for certification.

During the certification process, the UK Civil Aviation Authority (CAA) introduced an additional design requirement that mechanically prevented the flight idle gate release triggers from being effective unless both power levers were at the flight idle position. Although the modification reduced the likelihood of flight crew moving the power levers below the flight idle gate, it did not prevent this from occurring.

Flight idle gates modified to the requirements of the UK CAA were only required for DHC-8 aircraft registered in the UK and were not required to be fitted to aircraft certified in other countries. MCJ was not fitted with the modified flight idle gate because it was neither a requirement in Canada, where it was manufactured, nor in PNG.

1.6.20 Beta lockout system

Following a series of accidents and incidents in the 1980s and early 1990s involving intentional and inadvertent selection of ground beta mode in flight in types of turbopropeller aircraft, the US National Transportation Safety Board (NTSB) issued several recommendations to the US Federal Aviation Administration (FAA). These recommendations included the following.

> NTSB Recommendation #A-94-062: The NTSB recommends that the Federal Aviation Administration: revise Title 14 Code of Federal Regulations, Parts 25.1155 and 23.1155 to require a positive means to prevent operation of the propeller in the beta mode while in flight, unless the airplane is certified for such use.
>
> NTSB Recommendation #A-94-063: The NTSB recommends that the Federal Aviation Administration: Review all other turbopropeller airplane designs to determine whether in-flight engine operation in the beta range should be prohibited. Issue appropriate airworthiness directives applicable to those airplanes to install a system to prevent movement of power levers into the beta range, and require appropriate warnings in airplane operating manuals and on cockpit placards to warn pilots not to move power levers into the beta range in flight, unless the airplane is certificated for such use.

As a result of the NTSB recommendations, the FAA issued requirements for many aircraft flight manuals to be modified to include specific warnings to prohibit the use of beta mode in flight. It also introduced a series of airworthiness directives (ADs) for lockout systems designed for specific turbopropeller aircraft types to prevent the power levers from being moved into the beta range in flight. The modifications were applied to all affected aircraft that operated in the USA. For many of the aircraft types, the changes were also adopted by other countries.

On 1 March 2000, the FAA issued AD 2000-02-13 which mandated – within 2 years – the installation of a system that prevented the positioning of the power levers below the flight idle stop in flight on all DHC-8-100, -200 and -300 series aircraft that operated within the USA.

Bombardier designed a beta lockout system as a means of compliance with AD 2000-02-13. Although the system did not prevent flight crews from moving the power levers below the flight idle gate in flight, it prevented such an action from resulting in a propeller overspeed. The manufacturer issued service bulletin SB 8-76-24 on 9 January 2002, and the FAA subsequently approved the manufacturer's beta lockout system and mandated its fitment to all DHC-8 aircraft operating within the USA.

Transport Canada, the airworthiness authority in the State of Design, did not adopt FAA AD 2000-02-13 and did not mandate compliance with the manufacturer's service bulletin. Consequently, the beta lockout system was not mandated in other countries, including Papua New Guinea.

The beta lockout system was not fitted, nor required to be fitted, to MCJ.

1.6.21 Bombardier DHC-8-400 series propeller control system

The Bombardier DHC-8-400 series aircraft was first certified in Canada in 1999 and in the USA in 2000. The DHC-8-400 was designed with a different type of propeller control system to previous DHC-8 models and provided additional protection against the consequences of moving the power levers below the flight idle gate into the ground beta range in flight. The -400 series also has the UK CAA gate fitted, which prevents the flight idle gate release triggers from being raised unless the power levers are at flight idle.

1.6.22 Power lever friction device

During an investigation by the Australian Transport Safety Bureau (ATSB) into a DHC-8 occurrence in Australia, a design issue involving the power lever control quadrant of the first 39 DHC-8-100 manufactured was identified. The problem was related to the friction device on the power levers. When the friction knob was wound to the full out (friction off) position, the flight idle gate – designed to prevent the power levers from going into the ground range in flight – was lifted through contact between the friction device and the flight idle gate. That rendered the flight idle gate inoperative.

Once informed of this, the aircraft manufacturer took prompt action to address the problem and issued a service bulletin to modify the relevant part. That action was subsequently mandated by Transport Canada.

MCJ was manufactured after the design issue had been rectified in the manufacturing process. Additionally, an inspection of the aircraft's power lever friction device was conducted which confirmed MCJ had a post-modification part fitted during manufacture. For more information on the power lever friction device modification refer to ATSB investigation AO-2012-005 on the ATSB's website www.atsb.gov.au.

1.6.23 Beta warning horn test

During the investigation, the manufacturer identified a problem with the beta warning system operational test. The manufacturer issued service bulletin A8-31-29 on 23 November 2011 which stated the following.

> During a recent maintenance check of the beta warning horn system on the Bombardier Corporate Shuttle, it was determined that the operational test procedure currently specified in the Aircraft Maintenance Manual does not adequately check for proper function of the beta warning horn throughout its full range of motion. This Alert Service Bulletin A8-31-29 has been issued to perform an enhanced operational check of the beta warning horn system.

Of 91 aircraft tested, operators reported that five aircraft exhibited failure of the beta warning horn after performing the new test procedure.

An investigation by Bombardier had determined that deformation of the flexible centre console cover could cause the beta warning horn system triggering microswitch to malfunction, resulting in dormant failure of the beta warning horn system.

The manufacturer released service bulletin (SB) 8-76-33 to address the problem by replacing the beta warning horn microswitch attachment bracket.

Transport Canada mandated the service bulletin for all affected aircraft with AD CF-2012-01R1, effective 21 March 2013.

1.6.24 Modified certification requirements

The relevant European certification requirement has historically been the same as FAR 25.1155. In 2003, the European Certification Standard (CS) 25.1155 included the following.

> Each control for selecting propeller pitch settings below the flight regime (reverse thrust for turbo-jet powered aeroplanes) must have the following:
>
> (a) A positive lock or stop which requires a separate and distinct operation by the flight crew to displace the control from the flight regime (forward thrust regime for turbo-jet powered aeroplanes), and it must only be possible to make this separate and distinct operation once the control has reached the flight idle position.
>
> (b) A means to prevent both inadvertent and intentional selection or activation of propeller pitch settings below the flight regime (reverse thrust for turbo-jet powered aeroplanes) when out of the approved in-flight operating envelope for that function, and override of that means is prohibited…

The Acceptable Means of Compliance section relating to the standard stated:

> In-service experience during the late 1980s and 1990s of some turbo-propeller powered transport category airplanes has shown that intentional or inadvertent in-flight operation of the propeller control systems below flight idle has produced two types of hazardous, and in some cases, catastrophic conditions:

> (i) Permanent engine damage and total loss of thrust on all engines when the propellers that were operating below the flight regime drove the engines to over-speed, and;
>
> (ii) Loss of airplane control because at least one propeller operated below the flight regime during flight creating asymmetric control conditions.
>
> As a result of this unsatisfactory service experience, in-flight beta lockout systems were retroactively required (via Airworthiness Directives) on several transport category turboprop airplanes. These beta lockout systems were required only after it was determined that increased crew training, installation of cockpit placards warning crews not to use beta in flight, and stronger wording in AFM warnings and limitations did not preclude additional in-flight beta events.
>
> In addition to the continued airworthiness issues noted above, the FAA also recognized the need to update the FAR requirement to require some form of design improvements for new airplanes. ... Until the rule changes noted above are complete, the FAA is using the no unsafe feature or characteristic provisions of 21.21(b)(2) to require installation of beta lockout systems on new transport category turbo-propeller powered airplanes.

The enhanced certification approach in Europe and the USA did not result in any requirements to modify existing aircraft.

1.6.25 Airworthiness and maintenance

The aircraft operator had a current Air Operator Certificate (AOC) issued by the Civil Aviation Safety Authority (CASA PNG). The aircraft was maintained in accordance with the operator's approved system of maintenance. At the time of the accident the aircraft had a current certificate of airworthiness, a certificate of registration, and was certified as being serviceable for flight.

1.6.25.1 Scheduled maintenance

A review of all the available maintenance documentation was carried out. The aircraft's last scheduled maintenance check was a line check carried out on 9 October 2011. The aircraft's last scheduled major check was an A check which was certified as being completed on 2 September 2011.

The relevant inspections certified as being conducted during the A check were as follows.

- Detailed examination of the engines
- Detailed examination of the propellers
- Functional check of the beta warning horn
- Operational check of the beta back-up system
- Operational check of the power lever switches for the autofeather system
- Operational check of the emergency lighting system
- Operational check of all of the emergency exits.

1.6.26 Minimum Equipment List outstanding defect items

1.6.26.1 Yaw damper

A yaw damper automatically provides compensating rudder inputs whenever the aircraft deviates from coordinated flight. When the system is not operating, the effect is to decrease the lateral stability of the aircraft and to make it more difficult to control.

MCJ had an outstanding defect in the yaw damper system. The yaw damper is a minimum equipment item[3] which meant it was permissible for the aircraft to be dispatched with an unserviceable yaw damper provided certain conditions were met. These conditions were that the defect had to be rectified within 10 days of being reported, the yaw damper had to be switched off, and the auto pilot could not be used. A Minimum Equipment List (MEL) item number 22-4 was certified as being entered in the aircraft defect log on 7 October 2011 and the deferred date for that item (i.e. the date by which the problem had to be rectified) was 17 October 2011 which was four days after the accident.

1.6.26.2 Lighting

Two lighting defects were entered in the defect log on the day of the accident. They concerned the unserviceability of the backlighting for the DC overhead panel and the standby compass light. MEL item 33-1 B was entered into the defect log with a deferred date of 16 October 2011 for both defect items.

1.6.26.3 DME and Glideslope

Two defects involving MCJ’s navigation instruments were entered into the defect log on the day of the accident. The defects concerned the #2 distance measuring equipment (DME) and the fact that the glideslope would not lock on to the signal until within 10 nautical miles. MEL items 39-7 C and 39-8 C were entered into the defect log with a deferred date of 23 October 2011 for both items.

1.6.27 Recent parts replacement

1.6.27.1 Main battery replacement

The main battery was replaced on the day of the accident due to a hot start on the right engine. The start was not considered to be hot enough nor long enough to warrant an engine inspection.

1.6.27.2 No. 1 and No. 2 rudder actuators replaced

The left (No. 1) and right (No. 2) rudder actuators were replaced on 10 October 2011 due to free play exceeding limits and also because of an ongoing yaw damper fault.

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[3] Minimum Equipment Item – An aircraft component whose failure does not delay departure, also called an allowable deficiency or dispatch deviation.

Numerous other components of the rudder actuation system were also disconnected, reconnected, and rigged at that time. All these components were located in the mid-section of the vertical stabiliser.

1.6.27.3 Left hydro-mechanical unit replacement

The left engine hydro-mechanical unit (HMU) was replaced on 2 October 2011 due to a left engine hot-starting issue. The aircraft had flown for 39.2 hours after the HMU replacement with no further reported defects on that engine.

1.6.28 Weight and balance data

The aircraft was last reweighed on 3 July 2010 with its empty weight calculated as 10,520 kg with an arm of 10,228.4 and 107605766.9 index units in the 36 seat configuration. The reweigh was current until 2 July 2013.

MCJ was loaded within the permissible weight and balance limitations on departure from Nadzab. The aircraft’s weight on departure from Nadzab was 14,894 kg which included 1,730 kg of fuel and the flight-planned fuel burn to Madang was 340 kg. The aircraft’s weight at impact was estimated to be approximately 14,600 kg.

1.6.29 Emergency Locator Transmitter

A fixed emergency locator transmitter (ELT) was fitted to the aircraft in the aerodynamic fairing just forward of the vertical stabiliser. That area of the aircraft was in the main post-impact fire zone. The ELT could not be located in the wreckage and it is not known if the ELT worked as intended before it was destroyed by fire.

1.6.30 Fuel information

The aircraft was last refuelled at Nadzab when 940 litres (678 kg) of Jet A1 were uplifted. The tank from which this fuel was sourced was sampled on 14 October 2011 and subjected to laboratory testing in Sydney, Australia. Visible particulates were reported to be present in the samples, but these may have come from the containers into which the fuel samples were placed. All other test results were within standard specification limits for aviation turbine fuel and fuel was not considered to be a factor in the occurrence.

1.6.31 Instrumentation

1.6.31.1 Instrumentation

The Flight Director provides visual lateral and vertical guidance to the flight crew and electronic guidance to the autopilot, although it may be used independently of the autopilot when the aircraft is being hand-flown. The guidance to the flight crew is displayed on the electronic attitude direction indicator (EADI) and shows the pilot how to fly the aircraft to maintain the selected mode, for example, ‘vertical speed’, ‘heading’, or ‘indicated airspeed’.

1.6.31.2 Fast/slow indicator

The fast/slow indicator on the EADI permanently displays the aircraft's speed relative to 1.3 V_S [4], adjusted for configuration and bank angle.

1.7 METEOROLOGICAL INFORMATION

1.7.1 Weather forecast

The area weather forecast covering the flight from Nadzab to Madang, issued by the Bureau of Meteorology for the period 0800 to 2200 LMT on 13 October 2011, indicated there were generally south easterly winds with isolated cumulonimbus clouds between 1,600 and 45,000 ft, with areas of broken stratus between 800 and 3,000 ft in precipitation.

Middle-level cloud was forecast to be areas of scattered cumulus cloud between 1,500 and 15,000 ft with tops up to 25,000 ft, and scattered stratocumulus cloud between 2,500 and 8,000 ft associated with areas of rain and drizzle. Upper-level cloud was forecast to be altocumulus/altostratus with embedded cumulonimbus.

The general forecast was for thunderstorms, rain, and thunderstorms in rain and drizzle, with visibility reduced to 8,000 metres in showers.

The Madang Aerodrome METAR[5] issued at 1618 LMT by Madang Air Traffic Service (ATS) indicated the wind was calm, visibility was greater than 10 km, and there was smoke in the vicinity of the aerodrome.

1.7.2 Weather conditions reported by the flight crew

The Pilot-in-Command reported that he had manoeuvred while crossing the Finisterre Ranges to avoid thunderstorms that were visible on the aircraft's weather radar. Both pilots recalled that the aircraft had been clear of cloud when the propeller overspeeds occurred, although they could not see Madang. The Pilot-in-Command said that communications between another aircraft and Madang Tower indicated there was a storm about 2 km from Madang with heavy rain and a cloud base of about 1,000 ft.

1.8 AIDS TO NAVIGATION

Ground-based navigation aids, on-board navigation aids, and aerodrome visual ground aids and their serviceability were not factors in this accident.

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[4] V_S is the aircraft stall speed.

[5] METAR: an aviation routine weather report issued at hourly or half-hourly intervals. It is a description of the meteorological elements observed at an airport at a specific time.

1.9 COMMUNICATIONS

The automatic voice recording equipment in Madang Tower was found to be serviceable after the occurrence although it had not been recording during the occurrence and therefore there was no ground-based recording of ATS and crew communications during the event. Those communications were, however, recorded by the cockpit voice recorder (CVR).

1.10 AERODROME INFORMATION

The aircraft impacted the ground 35 km south south east of Madang. Aerodrome parameters were not a factor in this accident.

1.11 FLIGHT RECORDERS

The aircraft was fitted with a flight data recorder (FDR) and a separate cockpit voice recorder (CVR). The FDR (part number S800-20000-00, serial number S/N 00973) and CVR (part number S-100-0080-00, serial number 02501) were both solid-state units manufactured by L3 Communications. The FDR and CVR were both located in the tail section of the aircraft and were not damaged by the accident sequence and post-impact fire.

Both recorders were recovered from the accident site and transported to Port Moresby under the control of the AIC before being taken by an ATSB officer to the ATSB's facilities in Canberra for examination and data download. They were received in Canberra on 16 October 2011.

1.11.1 Cockpit voice recorder (CVR)

The CVR records the total audio environment in the cockpit area. This can include crew conversation, radio transmissions, aural alarms, and engine/propeller noises. The CVR installed in MCJ retained the last 30 minutes of information, operating on an endless-loop principle, and the system comprised the CVR itself, a control unit located on the forward centre console, a cockpit area microphone located on the control unit, and inter-connections to the crew's audio panels. There were four cockpit audio input channels: Pilot-in-Command, First Officer, Passenger Address (PA) system, and the cockpit area microphone (CAM).

The CVR was downloaded and examination of the download showed the four audio inputs had been successfully recorded during the accident flight. The 30-minute 33-second recording began during the climb after takeoff at Nadzab (Figure 1) and continued through the accident sequence until power was disrupted during the final stages of the forced landing.

The CVR was designed to be a sound recorder and, in particular, to record crew speech. CVR audio recordings may nevertheless contain background sounds such as airflow noise, aural warnings, and tones relating to engine/propeller speeds. Because the crew's boom microphones and the CAM in MCJ were continuously live to the CVR, crew speech and cockpit sounds on the Pilot-in-Command's, First Officer's, and CAM channels dominated any electrical interference signals. The Cabin Crew channel, however, did not have a continuous input signal and it only recorded speech when a PA was broadcast to the passengers. At other times there was no speech or other audio to mask low-level electrical interference signals. CVR files from MCJ were scrutinised to determine whether any useful information could be derived relating to engine/propeller speeds, aural warnings, and movement of the power levers or power lever flight idle gate triggers.

1.11.2 Flight data recorder (FDR)

The FDR system comprised the FDR, a Teledyne flight data acquisition unit (FDAU), aircraft sensors, and a triaxial accelerometer. The programming of the FDAU determined what parameters were recorded. In the case of MCJ, the recorded parameters included

- pressure altitude
- indicated airspeed
- magnetic heading
- pitch attitude
- roll attitude
- control surface positions (aileron, elevator, spoiler, flap, and pitch trim)
- accelerations (lateral, longitudinal, and vertical)
- outside air temperature
- engine parameters (propeller RPM, torque, N_H[6], and ground beta (active/inactive) (i.e. solenoid valve opened or closed)
- autopilot engaged or disengaged
- yaw damper engaged or disengaged
- radio transmitters keyed or not keyed
- weight on wheels (i.e. airborne or on the ground).

The data recovered from the FDR contained 53 hours 8 minutes of aircraft operation covering the accident flight and 34 previous flights.

1.11.3 Propeller RPM parameters

Propeller RPM was recorded for each engine and was sampled once per second. When being governed, the normal operating range for propeller RPM is 900 to 1,200 RPM[7]. The recorded range of the propeller RPM parameter is 0 to 1,500 RPM which covers the normal operating range. However, if the actual propeller RPM exceeded 1,500 RPM, then the recorded value would be clamped at 1,500 RPM.

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[6] N_H represents the rotational speed of the high pressure turbine.

[7] The maximum permitted propeller RPM (N_P) was 1,212 RPM.

Table 2: FDR sequence of events

Time to end of recording (mm:ss)	Event
-45:40	Power applied to FDR (right engine already operating)
-39:32	Left engine started
-36:49	Aircraft started to taxi
-32:32	Take-off commenced
-17:24	Top of climb (16,000 ft)
-07:15	Top of descent
-04:32	IAS exceeded V_{MO} (duration 10 seconds)
-04:18	Propeller overspeeds commenced (both engines)
-04:06	Left propeller RPM decreased below 1,500 RPM
-04:01	Left propeller oversped again
-03:56	Right propeller RPM decreased below 1,500 RPM later stabilising around 20 RPM
-03:42	Left propeller RPM decreased below 1,500 RPM later stabilising around 910 RPM
-02:56	IAS exceeded V_{MO} (duration 13 seconds)
-01:12	Both engines shutdown
00:00	End of recording

1.11.4 Correlation with local time

Neither the FDR data nor the CVR audio was time-stamped with UTC[8] or local time. No time-stamped ATC recordings were available to correlate with the FDR microphone keying parameter. An approximate correlation with local time was obtained through the ATC time check calls that were recorded on the CVR. Five such calls were made; in four cases the time given was in units of a minute and for one call the time was given as 56 ½. As a consequence, the tolerance of the estimated local time is ± 30 seconds. Figure 12 gives an overview of FDR data from the flight correlated with local time.

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[8] UTC or Universal Time Coordinated is the standard time common to every place in the world (formerly called Greenwich Mean Time or GMT).

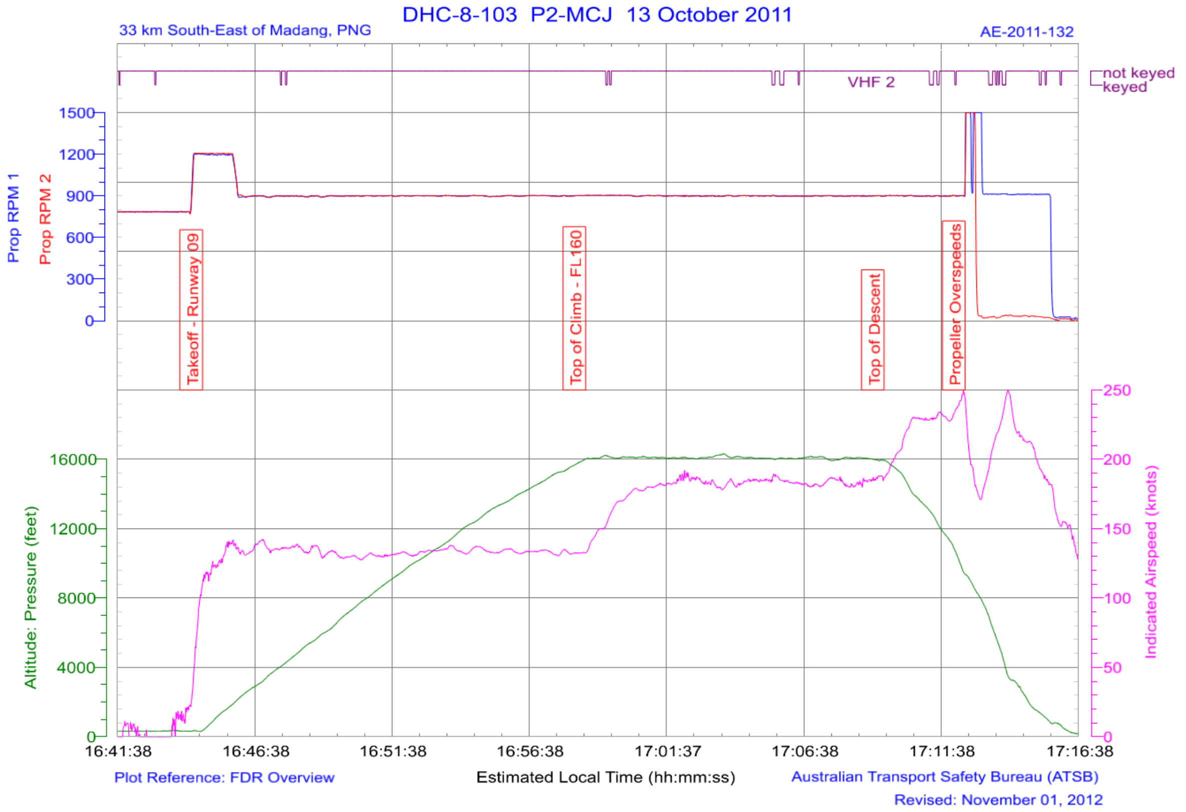

Figure 12: Overview of FDR data

1.11.5 Derived propeller RPM

A spectral analysis of CVR audio was conducted to derive propeller RPM. The derived CVR propeller RPM showed a maximum of 2,056 RPM (about 170 % of max RPM) for the right engine and two separate peaks of 1,903 RPM and 1,816 RPM (157 % and 150 % of max RPM) for the left engine. The tolerance of the propeller RPM derived from the CVR was considered to be ± 30 RPM.

1.11.6 Power lever angle

Power lever angles were not recorded directly by the FDR but they could be estimated from FDR-recorded N_H data. Small differences, due to differences in rigging, can exist between engines and between an engine and the nominal N_H schedule. In MCJ the right engine data were more consistent and therefore easier to analyse than the data from the left engine.

The last significant movement of the power levers towards flight idle appeared to begin approximately seven seconds before the V_{MO} overspeed warning sounded. The manufacturer estimated from the FDR-recorded N_H data that the right engine power lever was at flight idle five seconds before the V_{MO} overspeed warning sounded. Later, there was a very small reduction in the right engine N_H which the manufacturer interpreted as indicating that the right engine power lever may have been moved slightly below the flight idle gate for four to five seconds before the propeller overspeeds occurred.

1.11.7 Beta warning horn recording

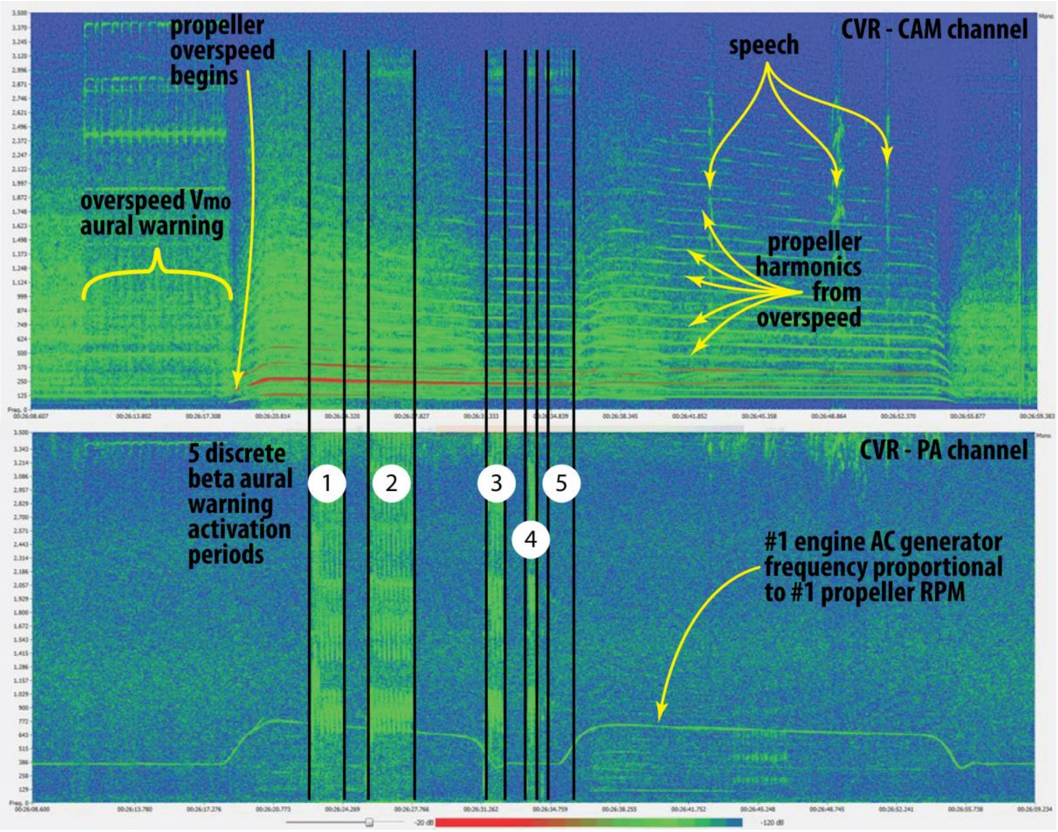

Figure 13: CVR plot showing beta warning horn activation

The CVR recording revealed that the beta warning horn sounded intermittently after the propellers started to overspeed. A plot of the CVR recording illustrates the points at which the beta warning horn sounded (Figure 13). The warning horn was barely discernible above the very loud noise made by the propeller blades and may not have been audible to the flight crew during the propeller overspeed event.

1.11.8 FDR and CVR recordings prior to and during propeller overspeeds

The plot in Figure 13 is a 60-second extract of FDR data that starts about 10 seconds before the propeller overspeeds began. The FDR had a 1,500 RPM upper recording limit for propeller speed so the FDR data was combined with information from the CVR; propeller speed above 1,500 RPM, beta warning horn operation, and an audible click were overlayed on the plot.

Just prior to the propeller overspeeds, the CVR recorded a click (Figure 14) which was consistent with the sound of the flight idle gate triggers being lifted[9]. At the initiation of the propeller overspeeds the left (No. 1) and right (No. 2) engine torque indications dropped to zero[10] and remained there for the remainder of the flight. Within three seconds of departing the 900 RPM governing range, both propellers had increased to a significant overspeed condition of over 60 % above the maximum propeller RPM.

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[9] Because of the importance to the investigation of any movement of the power levers during the period immediately before the propeller overspeeds began, this period was carefully analysed for any background sounds that may have been related to power lever movements. The click that was identified, while not loud against the background of other sounds, was nevertheless distinct. This sound is interpreted by the AIC to be consistent with the flight idle gate(s) being lifted, recognising that it is not possible to determine conclusively what the power lever positions were at any given time because power lever positions were not recorded by the FDR.

The aircraft manufacturer observed that there was only a 0.5 second interval between the click and the increase in propeller speed, but expected that there would be a longer time delay between the flight idle gates being lifted and the start of the increase in propeller speed. With only a 0.5 second delay, the aircraft manufacturer considered that this supported their interpretation that the click was more likely to be the noise of the power levers entering the disking detent (at 20° behind the flight idle position) rather than the sound of the flight idle gates being lifted.

For comparison purposes, the cockpit audio from an event involving VH-SBV, a DHC-8-315 aircraft, (investigation AO-2011-159) was examined. In this event, the power levers were inadvertently moved below flight idle in flight during turbulence. The period between the beta warning horn first activating and the start of the audible propeller speed increase was about 0.7 seconds. The indicated airspeed (IAS) at this time was 210 knots. In the case of MCJ, the time which elapsed between the click and the onset of propeller speed increase was about 0.5 seconds. Given the indicated airspeed (IAS) of MCJ was about 245 knots, the propeller speed increase would have occurred at a faster rate than for VH-SBV, so the 0.5 second gap between the click and the onset of propeller speed increase in MCJ is consistent with what was observed to have occurred in VH-SBV.

[10] Torque is an indication of the engine power that is supplied to the propeller. The FDR could not record negative torques i.e. where the propeller was back-driving the engine rather than the engine driving the propeller, so an FDR value of zero could represent either zero or negative torques.

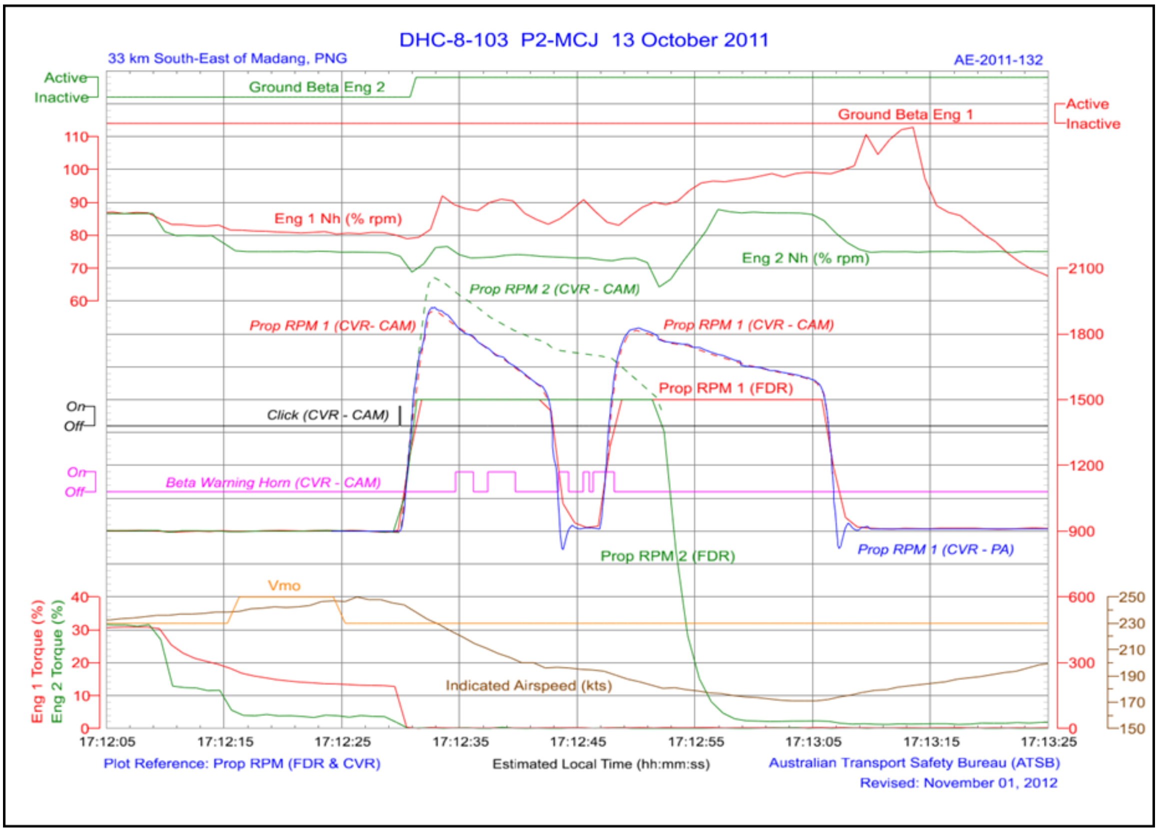

Figure 14: FDR readout of the occurrence with CVR overlay for propeller speed[11]

The high-speed compressor and turbine speeds (N_H) of both engines dipped slightly at the initiation of the propeller overspeed. This was caused by the activation of the pneumatic section of the overspeed governors which reduced fuel flow to the engines when propeller speed (N_P) was greater than 1,309 RPM. It confirmed that the overspeed governor pneumatic sections had operated as designed.

About 12 seconds after the propeller overspeeds began, the left propeller RPM momentarily reduced to 900 RPM within the speed control range of 900 RPM before increasing again to above 1,800 RPM. Shortly after that, the right propeller speed dropped rapidly to feather speed, which was about 50 RPM. The right propeller stayed in feather for the remainder of the flight. The left propeller returned to governing range at 900 RPM, however, it was clear from the other, concurrent FDR data that the left engine had sustained internal damage due to the overspeed and was incapable of providing useful power to the propeller.

1.11.9 Right engine ground beta FDR parameter

When the beta backup system senses a propeller pitch angle below flight idle accompanied by a power lever angle above flight idle, the system coarsens the pitch

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[11] Figure 14 was prepared by the Australian Transport Safety Bureau (ATSB). The N_H scaling used by the ATSB was based on a decoding file (.ffd) received from the aircraft manufacturer. The N_H scaling was not altered by the ATSB.

of the propeller until the propeller pitch angle is above the PCU beta switch setting. If the propeller pitch angle decreases again, the beta backup system will repeat the propeller pitch coarsen function. The system will continue to cycle until the propeller blade angle stabilizes in the flight range.

Two seconds after the propeller overspeed began the propeller discrete[12] for the right engine changed from inactive to active and remained in the active position for the rest of the flight. The initial interpretation of the discrete parameter was that it was an indication of a propeller feather command. Examination by the manufacturer of FDR data from previous flights showed the discrete parameter was in fact an indication that the propeller blade angle had entered the ground range (PCU beta switch set for 2.5 degrees less than the FLT IDLE setting of 10.5 degrees blade angle). This would have caused the beta backup system to activate had the power lever angle (PLA) been positioned in the flight range (greater than or equal to flight idle minus 3 degrees) when the propeller overspeed commenced, as well as illuminating the appropriate propeller ground range advisory light on the pilot's glare shield.

The aircraft manufacturer was asked why the right propeller had feathered, given the power levers were presumed to be below flight idle, why the propeller had feathered when it was supposed to cycle back and forth from fine to coarse pitch, and why the beta backup discrete remained on after the propeller feathered. The manufacturer stated that

> ...activation of the PCU Beta Switch (denoting Ground Range) and a feathered propeller are mutually exclusive. After the #2 propeller overspeed condition, the propeller feathered (indicating a blade angle of approximately 75-80º, whereby the PCU Beta Switch is still indicating Ground Range). This would indicate that the #2 PLA was moved from Ground Range to Flight Range at some point before the feathering of the prop was initiated. This could only indicate a failure of the PCU Beta Switch, because the Ground Range discrete should have changed state during the coarsening of the blade angle towards feather position.

In summary, it is probable that the right engine PCU beta switch failed in the closed position during the initial stage of the propeller overspeed. Any movement of the power lever out of the ground range after that time would have activated the beta backup system. The propeller feathered, instead of cycling in and out of coarse pitch, because the PCU beta switch is used to sense the repositioning of the propeller blade to a coarser angle. The loss of the sensing function provided by the PCU beta switch meant the propeller beta backup system continued to apply coarse pitch until the propeller had feathered.

1.11.10 Propeller twisting moment

1.11.10.1 Aerodynamic twisting moment

An aerodynamic twisting moment tries to twist a blade to a higher angle. This force is produced because the axis of rotation of the blade is at the midpoint of the chord

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[12] A discrete parameter is one that has just two states, for example “on/off”, or “up/down”. In this case, the propeller discrete parameter refers to propeller ground beta operation i.e. “active/inactive”.

line while the centre of lift of the blade is forward of this axis. The force tries to increase the blade angle. Aerodynamic twisting moment is used in some designs to help feather the propeller. Aerodynamic twisting moment force increases with propeller pitch angle.

1.11.10.2 Centrifugal twisting moment

Centrifugal twisting moment acts to decrease the blade angle, and opposes aerodynamic twisting moment. This tendency to decrease the blade angle occurs because all the parts of a rotating propeller try to move in the same plane of rotation as the blade centreline. Centrifugal twisting moment force increases proportionally with propeller speed. This force is greater than the aerodynamic twisting moment at operational RPM and is used in some designs to decrease the blade angle.

1.11.10.3 Twisting moment during propeller overspeed

With regard to centrifugal twisting moment, the aircraft manufacturer reported that

> Propeller pitch control systems are designed to provide the force necessary to change propeller blade pitch throughout the intended operating envelope of the aircraft at all propeller rotational speeds achievable when under either normal PCU control or control of the powerplant overspeed protection system. The propeller blade [centrifugal] twisting loads that the propeller pitch change system must overcome are maximized at low engine power, low altitude, high airspeed, and high propeller rotational speed.
>
> In this particular flight event of idle engine power, rapidly decreasing altitude, and very high airspeed, the addition of a substantial propeller overspeed may result in [centrifugal] blade twisting loads that would exceed the pitch change actuator's ability to increase pitch. Once this stalled condition was attained, the pitch change system would remain stalled with the propeller pitch locked until the blade loads decreased to a level that the actuation system was able to overcome.
>
> Regaining the ability to increase propeller pitch and allow reduction of propeller rotational speed via a propeller pitch change would require a change in operating condition such that the [centrifugal] blade twisting loads are sufficiently reduced.

1.11.11 Propeller speed of sound considerations

At the time of the propeller overspeed the air temperature outside the aircraft was recorded as being 7.6 C. The speed of sound at that temperature is 335.8 metres/second. The propeller circumference was calculated as being 1,245.024 cm. Given these conditions, the estimated RPM required for the propeller tips to reach the speed of sound was calculated as being 1,617 RPM.

Although the FDR data only recorded propeller RPM up to 1,500 the harmonic sound waves recorded on the CVR indicated that the propeller RPM went well above the speed required for the propeller blade tips to exceed the speed of sound. The pilots reported that the noise from the propellers was deafening, this was also confirmed by the cockpit voice recording which indicated that the pilots had to shout in order to communicate with each other. Villagers on the ground reported hearing a loud ‘bang’ as the aircraft passed overhead.

The propeller noise was so loud that it masked the aural warning from the beta warning horn.

1.12 WRECKAGE AND IMPACT INFORMATION

1.12.1 Context of on-site wreckage examination

In the early stages of the investigation a significant amount of evidence from the flight crew, air traffic control, CVR, and FDR indicated that a double propeller overspeed had occurred. Controllability of the aircraft was not reported to have been an issue before the occurrence began. All the wreckage at the accident site was examined, although the collection of evidence was focused especially on the engines and the propeller systems.

1.12.2 Impact sequence and distribution of the wreckage

The accident site was 35 km south south east of Madang. The aircraft impacted sparsely wooded flat and rocky terrain, adjacent to and parallel to the Guabe River. The photograph in Figure 15 was taken looking in the approximate direction of flight, with the accident site highlighted in the middle of the image.

The wreckage trail was approximately 300 metres long, oriented on a magnetic bearing of 175 degrees. Evidence from tree and ground impact marks, and wreckage field length and splay, indicated the aircraft struck the terrain in a controlled state with a shallow angle of entry (Figure 16).

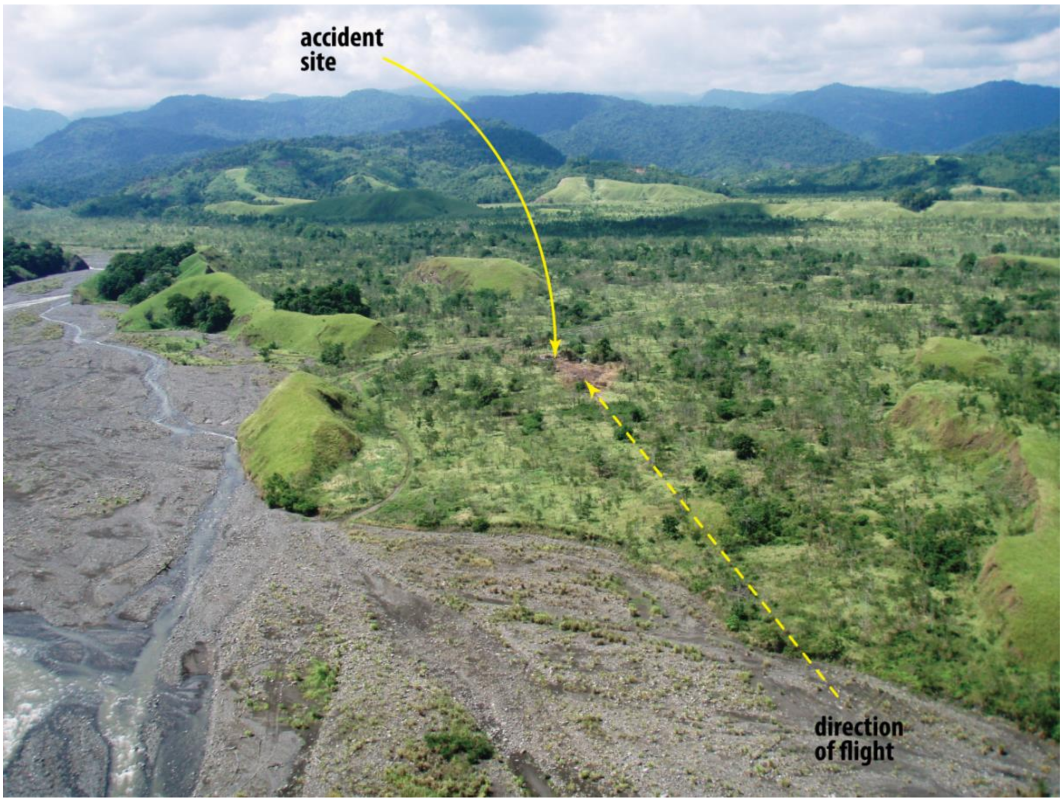

Figure 15: Overview of the area surrounding the accident site

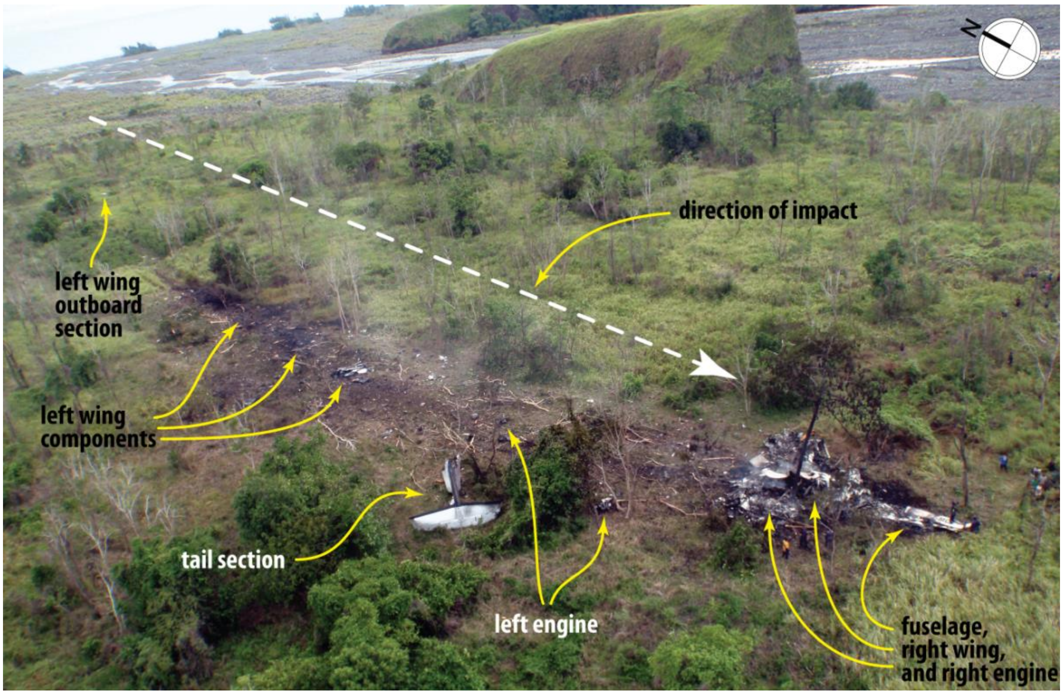

Figure 16: Accident site and wreckage trail

On-site examination of the wreckage revealed the aircraft had been configured with the flaps and landing gear fully retracted. The left engine had separated from the left wing and had broken into two sections (Figure 4). The left propeller hub was still attached to the reduction gearbox although three of the four propeller blades had separated from the hub during the impact sequence. The left propeller actuator was in the feathered position, indicating the propeller blade angles at the time of the impact.

The right engine was still attached to the right wing. It was severely damaged by fire. The reduction gearbox outer case had completely disintegrated and the right propeller blades were in the fully feathered position (Figures 18 and 33).

Both engines and propellers were removed from the accident site for detailed disassembly and inspection.

Figures 17, 18, 19, and 20 show the wreckage from the sides, front, and rear of the aircraft.

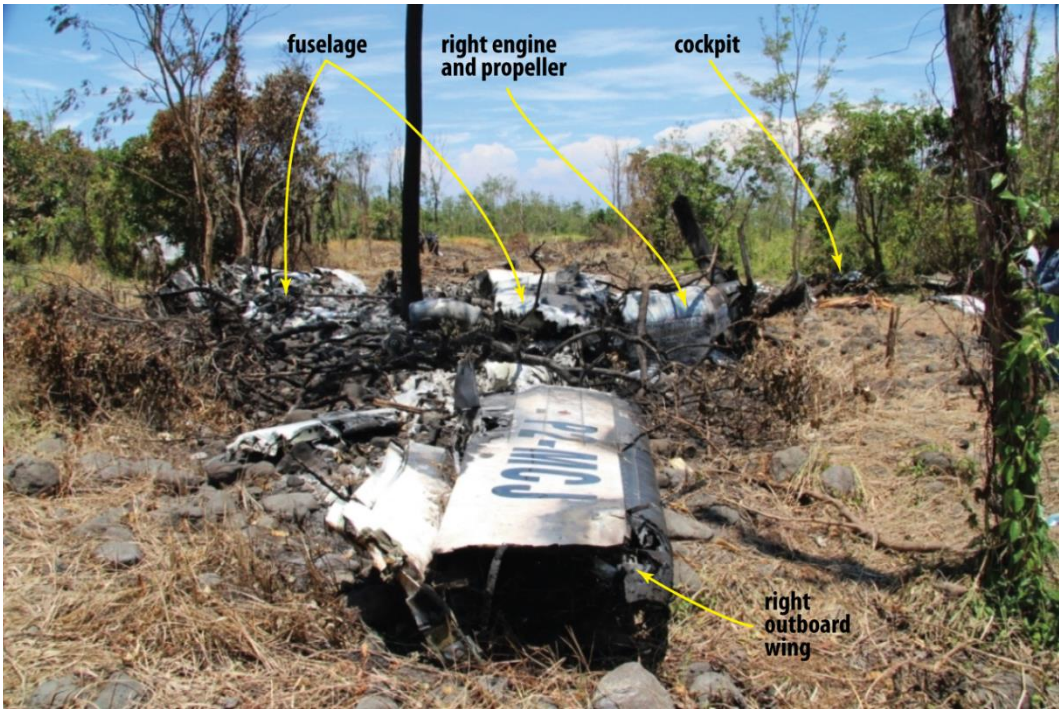

Figure 17: Main wreckage viewed from the right

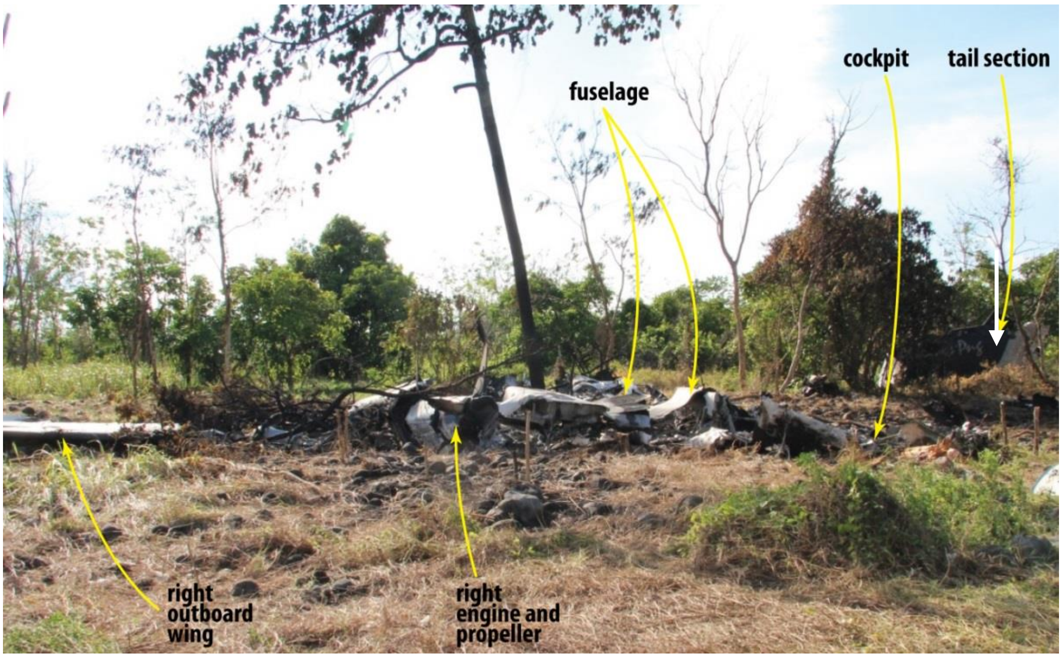

Figure 18: Main wreckage viewed from the front

Figure 19: Main wreckage viewed from the left in the direction of flight

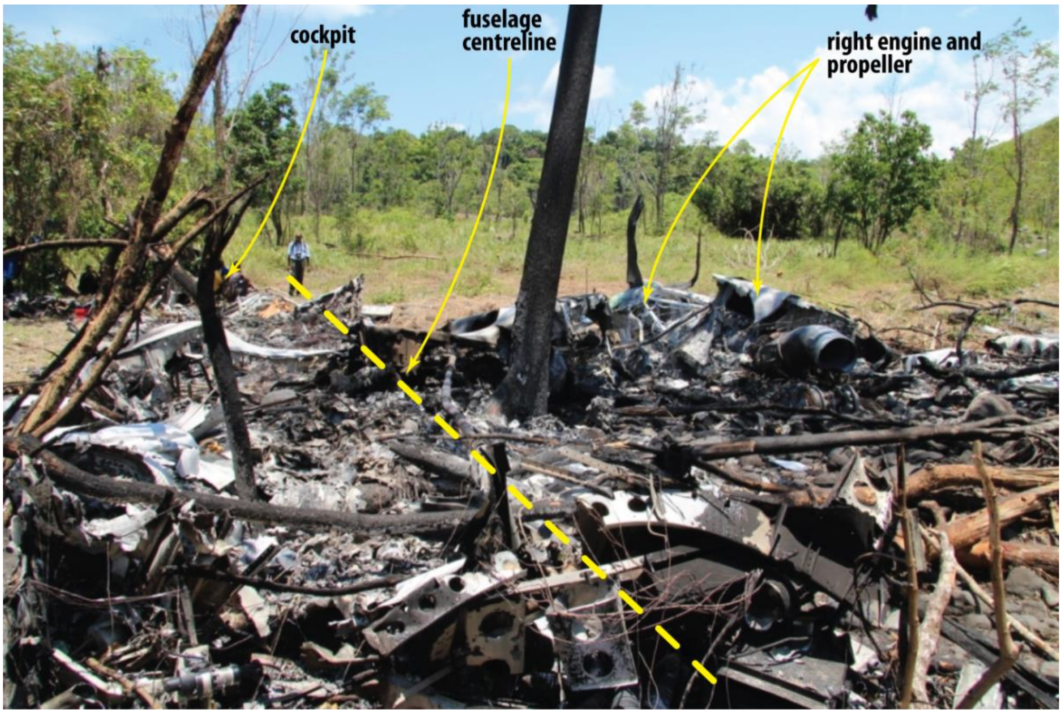

Figure 20: Main wreckage viewed from the rear

1.12.3 Fuselage

The fuselage was completely incinerated down to ground level by the post impact fire.

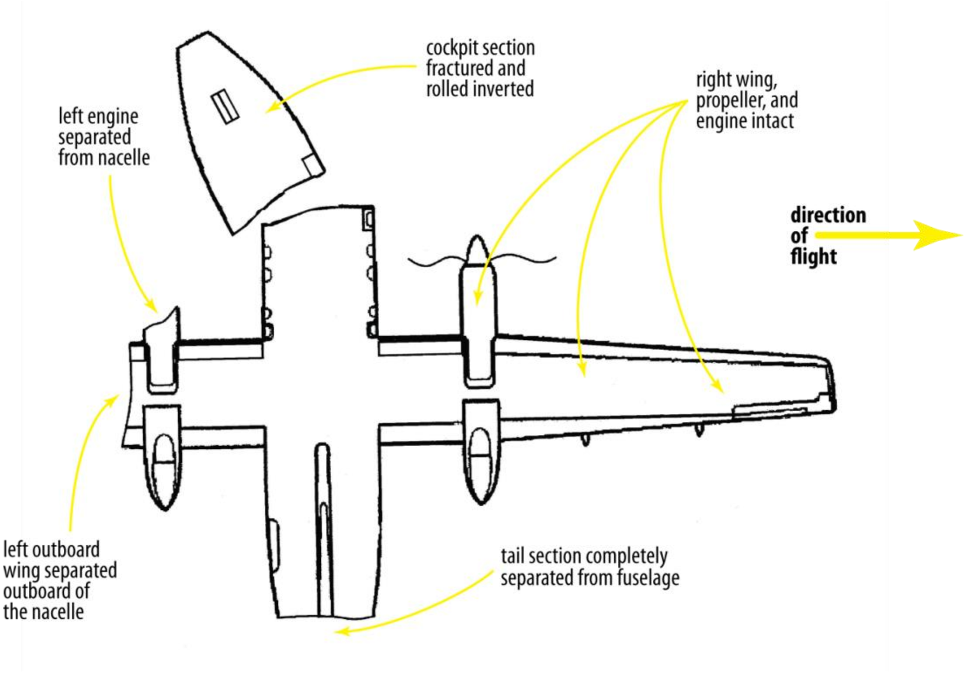

Figure 21: Main wreckage layout

On-site examination of the fuselage revealed that it had fractured around the forward entry door and forward service door. The cockpit had rotated approximately 180 degrees so that it was up-side down, while the cabin area remained upright (Figure 21).

1.12.4 Tail section

The tail section was located approximately 20 meters behind the fuselage in the direction of flight (Figure 22). It had remained clear of the fire zone and was relatively intact.

Flight control systems were inspected within the tail and no defects were identified. All tail section flight control components were accounted for. The FDR and CVR racks were located in this area of the wreckage

Figure 22: Tail section

During the on-site investigation, in a period when the investigation team was off-site, persons not associated with and unknown to the investigation team removed a panel from the vertical stabiliser mid-section without permission (Figure 23).

Figure 23: Missing panel on vertical stabiliser

The panel was an access cover for the actuators and controls for the rudder system. On inspection, the components in the area did not appear to have been tampered with. The investigation was unable to determine who had removed the panel and why.

1.12.5 Landing gear

The left and right main landing gear were inspected on site and noted to be in the retracted position (Figure 24).

Figure 24: Left main landing gear in retracted position

The nose landing gear could not be located in the wreckage. It was found by representatives of the operator and the Coroner in March 2012 approximately 1 km from the accident site, partially buried in the silt of a dry stream bed. Local villagers explained they had removed it from the accident site and, finding no use for it, had later discarded it the stream where it was ultimately found.

1.12.6 Flight controls

The flight controls were all accounted for on the accident site. It was possible to inspect most of the flight controls for security and movement with the exception of the left aileron which was destroyed during the accident sequence. No pre-impact defects were identified in the flight control surfaces. Given the level of destruction of the wreckage, continuity of the flight control runs could not be established.

Elevator, rudder and aileron trims

No anomalies were identified in the sections of the trim systems which remained after the accident. Given the disturbed state of the flight controls, an accurate assessment of trim positions could not be made.

Flaps

The ball screw type flap actuators were located on the accident site. Flap position can be determined from the flap ball screw actuator position on its worm gear. The ball screw actuator positions were noted to be in the fully retracted position (Figure 25).

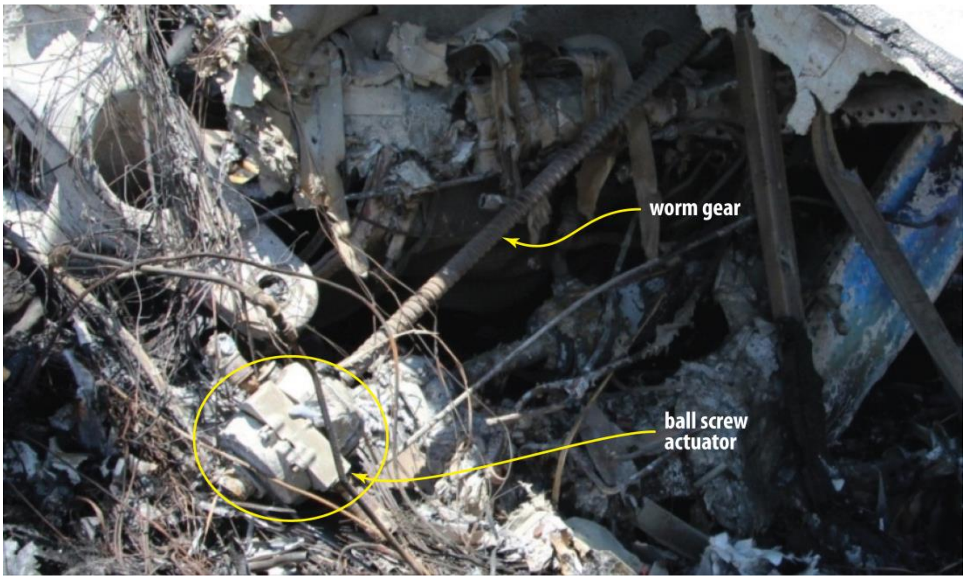

Figure 25: Flap actuator in fully retracted position

1.12.7 Cockpit instruments and control settings

The complete destruction of the cockpit section prevented a detailed inspection of cockpit instruments and switch settings. Figure 26 shows the cockpit completely incinerated in an upside down position.

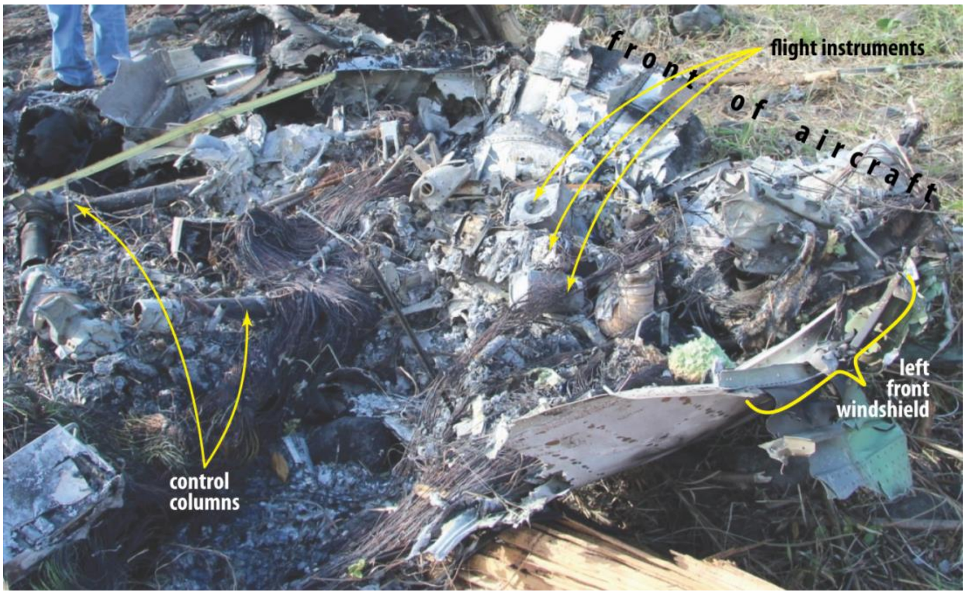

Figure 26: Cockpit section

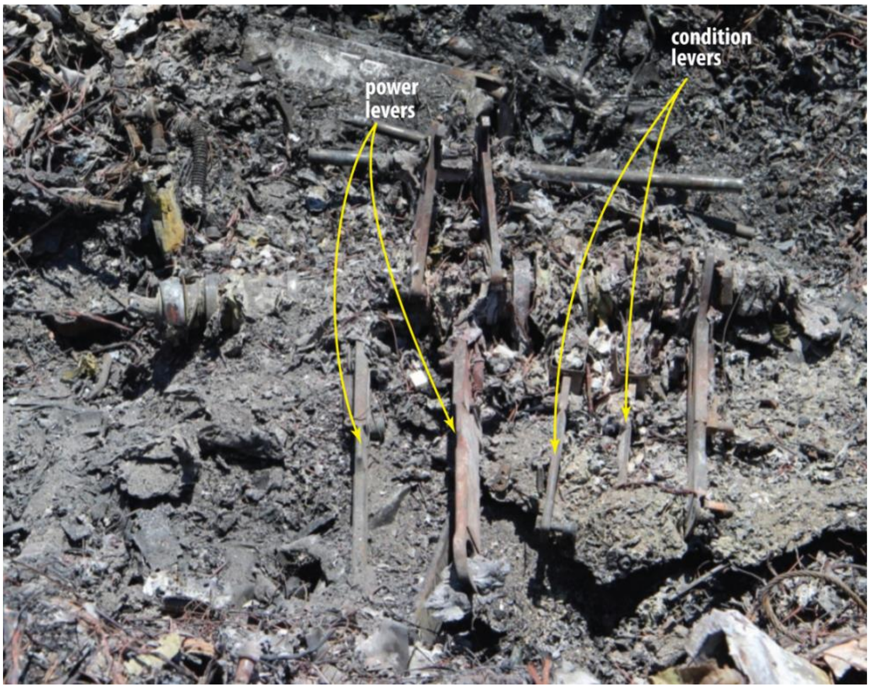

Figure 27: Power lever quadrant components as found on-site

The power lever quadrant and its remaining components were identified in the burnt remains of the cockpit section. Power lever and condition lever settings could not be ascertained due to the significant disruption of the cockpit.

The power lever quadrant components (Figure 27) were removed from the accident site so that a detailed examination could be conducted. For further details of that examination refer to *Tests and research*.

1.12.8 Engines and propellers

Left engine

The left engine had separated from the left wing and had broken into two sections, the reduction gear box section and the turbo-machinery section. Both engine sections came to rest outside the fire zone of the main aircraft wreckage. The reduction gear box was still attached to part of the nacelle and its engine mount points.

The reduction gear box section contained the propeller hub, one propeller blade, the propeller transfer tube, the propeller control unit (PCU) assembly, and the overspeed governor and pump. The hydro-mechanical unit (HMU) controls to the PCU were present in the reduction gearbox section, still attached to the PCU. No pre-impact anomalies were identified within the reduction gear box section or its components during the onsite inspection (Figure 28).

Figure 28: Left engine reduction gear box section

The turbo-machinery section had significant post impact damage (Figure 29). It was inspected on site through the air intake to the compressor and through the exhaust outlet to the power turbine. The first stage centrifugal compressor had small nicks and gouges present in the blades' leading edges.

Figure 29: Left engine turbo-machinery section

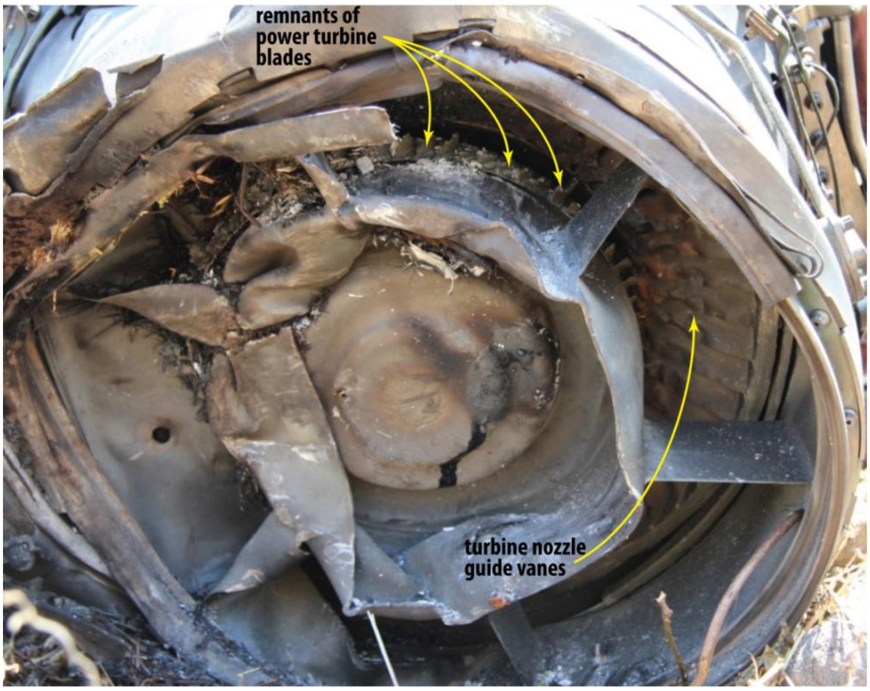

Figure 30: Left engine turbine exhaust outlet

The HMU and electronic engine control, which are normally located on the turbo-machinery section, had separated from the engine and only small sections of these components were located in the wreckage field.

Left propeller

The left propeller hub was attached to the reduction gearbox. Three of the four propeller blades had been liberated from the hub during the impact sequence. The liberated blades were all located within the wreckage trail.

Figure 31 shows all the components of the left propeller relocated adjacent to the propeller hub. Note that, although the propeller blade which remained attached may have the appearance of being in fine pitch, it had been rotated 180 degrees so that the leading edge was facing opposite to the direction of rotation. The pitch change link had sheared inside the hub, which allowed the blade to rotate freely.

The lack of rotational damage to the propeller blades was consistent with little to no power being delivered to the propeller by the engine at the time of impact.

Figure 31: Left propeller blades relocated next to propeller hub

The left propeller actuator pitch change collar was in the fully aft position, which indicated that the propeller was feathered at the time of impact (Figure 32).

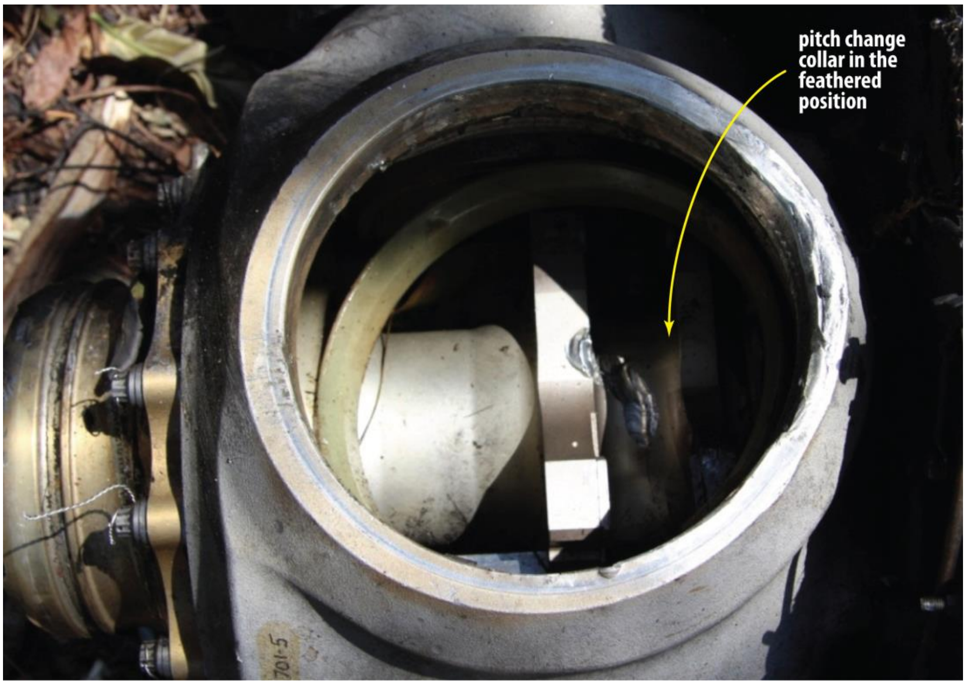

Figure 32: Left propeller actuator

The left engine controls from the HMU to the PCU were inspected with no pre-impact defect identified. Continuity checks of the engine controls from the engine nacelle to the cockpit could not be conducted due to the wreckage disruption and post-impact fire. About half of the engine controls could still be inspected. Of the control runs, none had any identifiable pre-impact defects.

Right engine

The right engine was still attached to the right wing. It had sustained considerable thermal damage in the post-impact fire (Figure 33).

The reduction gearbox to the compressor outer case had been completely incinerated. All of the engine's external components had significant thermal damage which precluded any type of detailed examination (Figure 34).

Figure 33: Right engine and propeller assembly

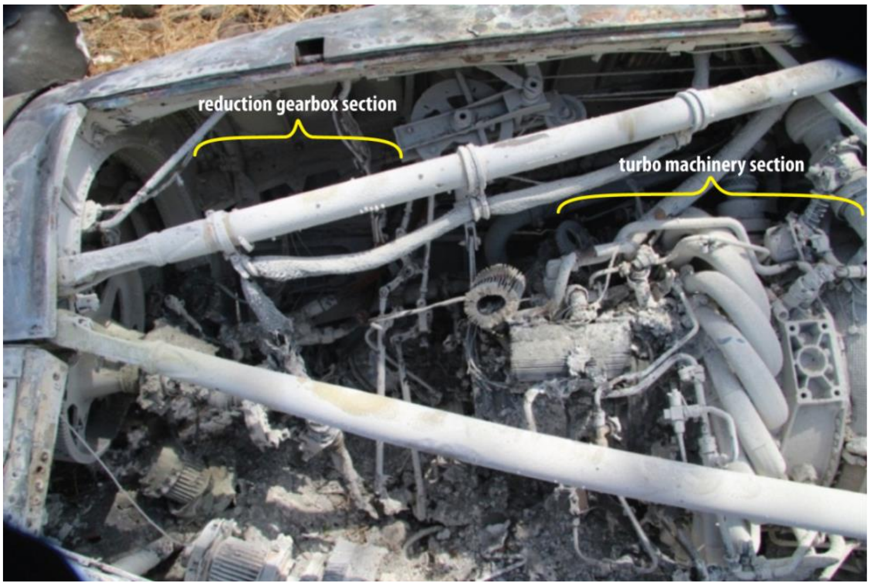

Figure 34: Right engine with left cowl removed

The turbo-machinery section remained relatively intact (Figure 35). Inspection through the turbine exhaust outlet revealed that the final stage turbine was relatively undamaged, in contrast to the damage observed in the left engine (Figure 30). No pre-impact damage was identified during the on-site inspection of the right engine.

Figure 35: Right engine turbo-machinery section viewed from the rear

Right propeller

The propeller was found to be intact with all four blades retained within the hub. Damage observed on the propeller blades indicated that they were rotating in the feathered position at slow speed when the aircraft impacted terrain (Figure 36).

Figure 36: Right propeller assembly with spinner removed

Right engine controls

The right engine controls and cable runs were inspected where possible. Figure 37 shows the engine controls inside the nacelle still connected to the hydro-mechanical unit (HMU) control arms even though the HMU had completely disintegrated. The propeller control unit (PCU) linkages from the HMU were also present even though the PCU had disintegrated. Continuity of the controls within the engine nacelle was confirmed, with no defects identified.

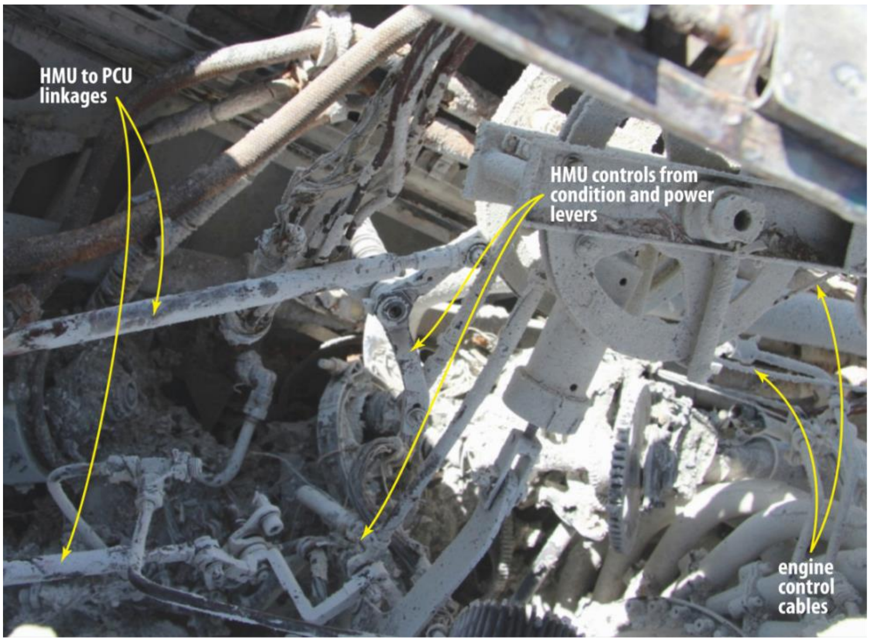

Figure 37: Right engine controls inside nacelle

A significant amount of the engine control system between the engine bay and the cockpit control quadrant was destroyed by the accident and post-accident fire. Continuity between the cockpit controls to the engine could not be fully established.

Further engine and propeller examinations

Both engines and both propellers were removed from the accident site so that a detailed disassembly and inspection could be conducted in a more suitable environment with appropriate personnel and equipment. Refer to *Tests and research* for further details.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

The Pilot-in-Command reported that he had been unwell with a throat infection prior to the accident and had been taking medicine prescribed by his designated aviation medical examiner (DAME) when the accident occurred. On 10 October 2011 he had overnighted in Madang and had not felt well on the morning of 11 October 2011, although he flew an aircraft back to Port Moresby and then took the rest of the day off. That afternoon, he consulted his DAME. The following day, 12 October 2011, he had taken the day off. He reported that on 13 October 2011 he had felt rested and well enough to fly. Expert medical advice provided to the AIC was that the medication the Pilot-in-Command was taking would not have affected his ability to operate the aircraft.

1.14 FIRE

There was no evidence of a pre-impact fire. On the basis of the fuel uplifted at Nadzab, there would have been approximately 1,820 litres (3,200 lbs) of fuel on board the aircraft when it impacted the ground. Fire damage to aircraft parts and foliage indicated that a post-impact fuel-fed fire began during the impact sequence when the aircraft was about halfway along the wreckage trail. When the aircraft finally came to rest, the fire completely consumed much of the wreckage with the exception of the tail section.

There were no fire-fighting personnel and no fire-fighting equipment in the area around the accident site. Villagers were the first on the scene and they attempted to put out the fire with water from the nearby river carried in bamboo stems, but the fire was too intense and could not be extinguished by any such means.

1.15 SURVIVAL ASPECTS

The aircraft was configured with 36 passenger seats. Exits were located at the passenger entry door just forward of row 1 on the left, a service entry door just forward of row 1 on the right, two emergency exits (left and right) at row 4, and an exit was provided in the roof of the cockpit for use by the pilots in the event of an emergency. Of the 32 people on board, the Pilot-in-Command, First Officer, Flight Attendant, and one passenger located in row 7B were the only survivors (Figure 38).

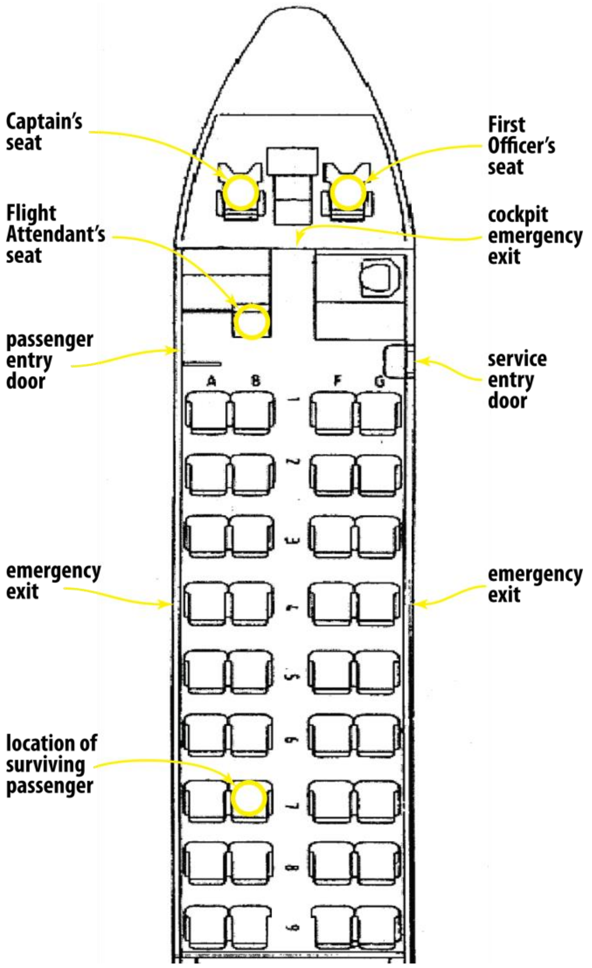

Figure 38: Aircraft configuration and survivors' seating positions

Four basic requirements must be met in order for the occupants of an aircraft to survive an accident. They are

- impact loads must be within human tolerance
- a liveable volume must be maintained within the structure
- occupants must be adequately restrained
- occupants must have a means of escape (post-accident survival).

Impact loads

On-site examination showed that the aircraft's impact angle was relatively shallow at approximately 5 degrees, and the landing distance from the first ground impact to the main wreckage site was about 200 metres (the distance from the initial impact on vegetation to the main wreckage was about 300 metres).

The landing gear was not extended prior to the landing. If the landing gear had been extended it would have lessened the initial vertical ground impact loads imparted on the fuselage and its occupants.

The flaps were in the fully retracted position during the landing sequence. At the landing weight of approximately 14,600 kg, V_{REF}[13] flap 0 was 120 knots and V_{REF} flap 35 was 89 knots, a difference of 31 knots. The FDR showed the speed at which the initial impact (with vegetation) occurred was 114 knots. If the flight crew had used flap 35, this initial impact could have occurred close to 89 knots, a reduction of 25 knots.

Although MCJ was not configured with gear down and flaps, it is likely that the g-forces imparted on the all aircraft's occupants through deceleration were survivable because four of the occupants did survive.

Liveable volume

The significant post-impact fire damage to the aircraft precluded a detailed examination of the fuselage for liveable volume. However, the burnt outline of the aircraft that remained after the fire indicated that the fuselage had been more-or-less intact before the fire. That meant the fuselage may have provided adequate liveable volume for the occupants and this is consistent with the survival of the passenger in row 7.

Occupant restraints

The more the movement of an aircraft's occupants is limited, the lower the probability that they will sustain flail-type injuries during an accident. There are generally four types of seat belt/harness fitted to aircraft seats, as follows.

- Lap belt – provides restraint to the occupant's mid-section allowing full movement of the upper body. This is the most common type of aircraft passenger seat belt. Lap belts provide the least amount of restriction in movement.
- Lap sash belt – provides restraint to the occupant's mid-section and also limits movement of the upper body with a strap over one shoulder and diagonally across the body. This is the most common type of car seat belt.
- Four-point harness – provides restraint to the occupant's mid-section and also limits upper body movement with two straps that support the shoulders. This is a common type of belt for flight attendant seats.
- Five-point harness – similar to the four point harness, but with an added belt between the legs to prevent 'submarining' of the body down and out of the harness. This is a common type of harness for pilot seats. It provides the greatest restriction of movement and therefore the greatest protection from flail type injuries.

Fire damage to MCJ precluded any examination of the occupants' seats and seat belts to ascertain if they were fitted and if they functioned as designed.

The passenger seats in MCJ were fitted with standard lap type belts. The Flight Attendant had a four-point harness which restricted upper body movement. Further, he had a rear-facing seat. Rear facing seats are known to be safest because the occupant is forced back into the padded seat rather than away from it during

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[13] V_{REF} = final approach speed.

deceleration under forward movement. The pilot seats were fitted with five-point harnesses.

Post-accident survival

The flight crew seats were the furthest away from the fuel tanks and the source of the post impact fire. The cockpit section had partially separated from the fuselage and was rotated so that it was upside down, blocking the ceiling-mounted cockpit emergency exit. According to the flight crew, there was a gap in the side of the fuselage large enough for the Pilot-in-Command, First Officer, and Flight Attendant to crawl through. When the crew members had exited the aircraft they noticed that one of the passengers was already outside the wreckage. The surviving passenger stated the smoke and fire were very intense and that he had escaped through a gap in the roof above his seat position.

The accounts given by the flight crew and the surviving passenger of the voracity and speed with which the post-accident fuel fed-fire consumed the wreckage indicated that the other occupants had very little time to evacuate before the cabin was completely engulfed by fire.

Damage to the aircraft precluded any examination of the emergency exits for function or position. However, photographs taken by a third party on the morning after the accident showed that two deceased passengers were located outside the fuselage on the right side; their position was adjacent to the row 4 emergency exit.

1.16 Tests and Research

1.16.1 Examination of the engines, engine components, and propellers

The left and right engines, remaining engine components, and propellers were removed from the accident site and taken to a hanger in Port Moresby. The reduction gear box sections were inspected externally, and the turbo-machinery sections of both engines were disassembled and inspected by specialist personnel using specialist tooling under the supervision of the ATSB.

Further specialist inspections and testing of some components were conducted by Hamilton Sundstrand (propeller system manufacturer) and Woodward (overspeed governor and pump manufacturer) at their facilities in the USA under the supervision of the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA). A summary of all the inspections is provided below.

1.16.1.1 Left engine disassembly and inspection

General

The engine sustained significant damage during the impact sequence, separating from the airframe and splitting into two sections. The hydro-mechanical unit (HMU) and the electronic engine control (EEC) were destroyed during the accident sequence which precluded them from examination.

Figure 39 shows the left engine and components in the condition they were delivered to the hangar in Port Moresby. The propeller blade that remained attached to the hub was cut in its mid-section to facilitate airlifting it from the accident site. The external general inspection did not reveal any anomaly that was not attributable to the propeller overspeed and/or impact damage.

Figure 39: Left engine and propeller after recovery

Turbo-machinery section

The turbo-machinery section was completely disassembled and inspected. The following is a short summary of the inspection findings.

The left engine displayed signs of pre-impact engine failure. The power turbine shaft that connected the two power turbines with the reduction gearbox displayed signs of circumferential rubbing contact marks (Figure 40). The rubbing contact marks were consistent with deflection of the power turbine shaft into the concentric low pressure turbine shaft due to the propeller overspeed reaching or exceeding the power turbine shaft bending critical speed of approximately 130 % N_P.

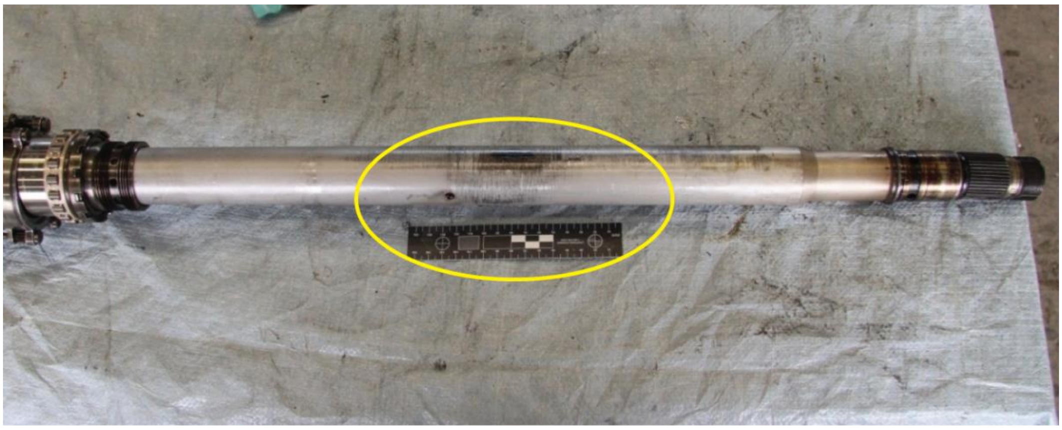

Figure 40: Power turbine shaft with circumferential rub marks

The first and second stage power turbine blade aerofoils were fractured uniformly in overload at their roots. All of the blade fracture surfaces displayed coarse features typical of those found with an overload mechanism, with no indications of fatigue or other progressive fracture mechanism.

The power turbine blade shedding observed is characteristic of the propeller overspeed reaching the power turbine blade design separation speed of approximately 145 % N_P. The fracture surfaces themselves displayed signs of thermal damage. The damage indicated that the engine had still been running after the power turbine blades had released due to the propeller overspeed. Figure 41 shows first and second stage power turbine blade separation at the roots and significant mechanical damage to the second stage power turbine nozzle guide vanes.

Figure 41: Left engine first and second stage power turbine and nozzle guide vanes

Reduction gearbox

The reduction gearbox and propeller were inspected externally. The propeller could be rotated and the input shaft attachment point was observed to rotate at the same time, confirming continuity between the input shaft and the propeller. The reduction gearbox metal detector was removed and inspected, and a small amount of ferrous metal debris was found on the chip detector.

1.16.1.2 Left propeller system inspection and testing

In order to allow detailed measurements to be taken during the disassembly process, the reduction gearbox with the propeller assembly, propeller control unit, transfer tube, and overspeed governor and pump were sent in an assembled state to Hamilton Sundstrand in the USA. The examination was conducted under the supervision of the National Transportation Safety Board (NTSB).

Transfer tube

The transfer tube operates by transferring movement from the PCU into corresponding propeller movements via the propeller actuator screw gear. When the transfer tube is installed it is important the PCU screw gear and the propeller actuator worm gear are in the correct position, otherwise the propeller and PCU will be mismatched resulting in problems such as incorrect full fine pitch and feather positions.

The transfer tube rigging between the PCU worm gear and the propeller actuator worm gear was confirmed to be correct. The transfer tube was removed from the propeller to facilitate removal of the PCU and propeller actuator. The transfer tube was noted to be in good condition with no defects identified.

Propeller control unit

The PCU was removed from the gearbox and checked for rigging position. It was confirmed to be in the feather position. The PCU had sustained accident damage which precluded bench testing of its governing function. The unit was tested for beta light actuation position and found to be within overhaul tolerance. The unit was completely disassembled and inspected with no internal defects identified.

Propeller and propeller system inspection

Disassembly and inspection revealed that the propeller actuator was matched to the PCU in the feathered position. The propeller actuator was removed from the propeller hub and inspected with no defects identified.

Overspeed governor and pump

The overspeed governor and pump were removed from the reduction gearbox and sent to the manufacturer for testing under the supervision of the NTSB. The functional test showed that the overspeed governor and pump worked as designed and were within all tolerances and limits.

Summary

The engine had sustained significant mechanical damage prior to impact with terrain due to the propeller back-driving the power turbines into an overspeed condition, which led to power turbine blade separation. At that point the engine was no longer capable of providing useful power to the propeller after the propeller RPM had returned to the normal operating range.

The inspection and testing conducted on the left propeller system speed control components showed that they were capable of governing propeller speed and providing overspeed protection. The engine, engine components, and propeller system did not display any defect that may have contributed to the propeller overspeed event.

1.16.1.1 Right engine disassembly and inspection

General

The right engine was significantly damaged by post-impact fire. The reduction gearbox, overspeed governor and pump, hydro-mechanical unit, and propeller control unit outer casing were incinerated which precluded them from inspection. The PCU worm gear could still be inspected (Figure 42).

Figure 42: Right engine and propeller as recovered

Turbo-machinery section

The turbo-machinery section was relatively intact and was disassembled and inspected in detail (Figure 43). The turbo-machinery section exhibited no internal mechanical damage, nor any evidence that it had been back-driven by a significant propeller overspeed. This was in contrast to the left engine which had significant propeller overspeed-related damage. Further, the turbo-machinery section did not display any signs of pre-impact defects.

Figure 43: Disassembled right turbo-machinery section

Reduction gearbox and propeller

The reduction gearbox housing was completely consumed by fire. The reduction gearing was contained in the nacelle area and was recovered separately. The remaining components of the reduction gearbox were inspected, including all the internal gears, propeller control unit worm gear, and the propeller transfer tube which was still connected to the core of the PCU (Figure 44). No pre-impact anomalies were identified in any of these components.

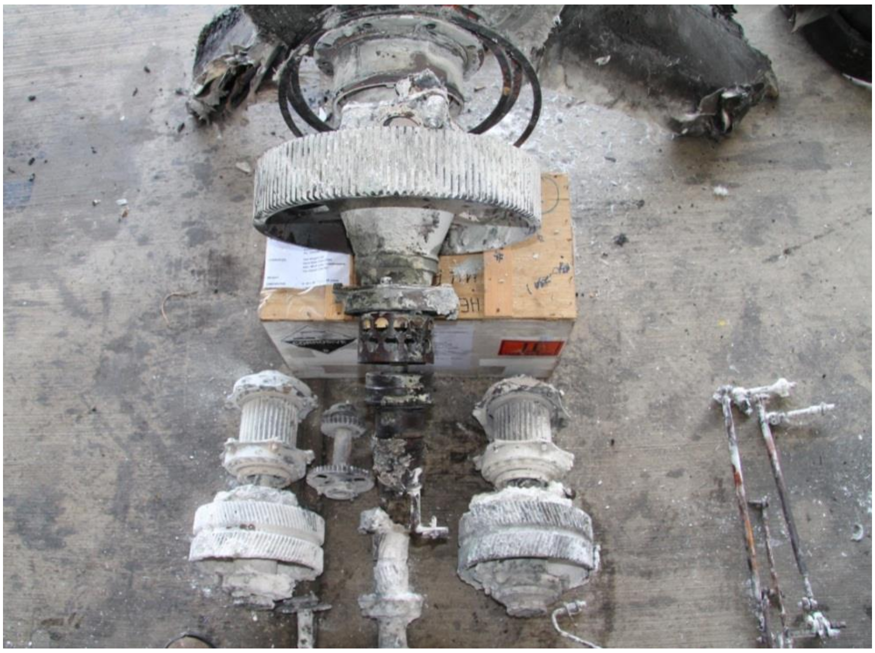

Figure 44: Right engine reduction gearbox section as recovered

Transfer tube

The transfer tube rigging between the PCU worm gear and the propeller actuator worm gear could not be confirmed because the remaining section of the PCU was free to rotate, which meant that the rigging position information was lost. The transfer tube had to be cut at the PCU input spline because it was seized in the spline due to heat exposure. The transfer tube was inspected post-removal with no pre-accident defects identified.

Propeller control unit

The only remaining section of the PCU available for inspection (Figure 45) was the servo control unit which was still attached to the propeller transfer tube. No pre-impact anomalies were identified within the servo control unit.

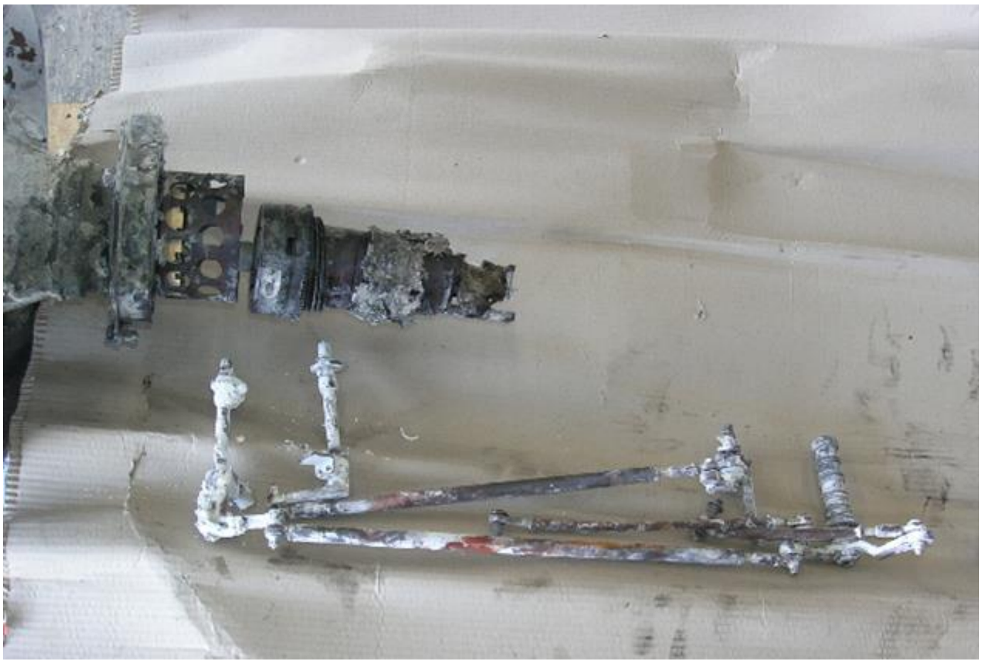

Figure 45: Remaining section of PCU and PCU to HMU linkages

Overspeed governor and pump

The overspeed governor and pump were completely destroyed by post-impact fire, and could not be inspected.

Propeller and propeller system inspection

The propeller and the remaining propeller system and reduction gearbox components were sent to the propeller manufacturer in the USA for disassembly and inspection under the supervision of the NTSB.

The disassembly and inspection revealed that the PCU actuation section was still attached to the propeller transfer tube. However, without the outer body to secure it, the actuation section was free to turn. This meant an accurate assessment of the propeller actuator to PCU rigging could not be made. The PCU to HMU control linkages were still intact, and their control rod ends were still connected.

Worm gear type actuators have a tendency to lock in the position they were last set, regardless of ground impact forces, making them an accurate source of information about their pre-impact disposition. The measurement taken from the propeller actuator indicated that the propeller was in the feathered position when the aircraft impacted terrain.

The propeller actuator was inspected through the propeller hub with no pre-impact defects identified.

Summary

The right engine, engine components, and propeller did not display any defect that might have contributed to the propeller overspeed event. Further, they did not appear to have sustained damage due to the propeller overspeed.

1.16.2 Power turbine blade release anomaly

The left engine power turbines released their blades, as designed, after the theoretical design release speed of 145 % N_P was reached. This is a design feature which is meant to prevent the bursting of a turbine disc leading to an uncontained engine failure in the event of a propeller overspeed.

The right engine power turbines did not release their blades even though the propeller reached 170 % N_P.

1.16.3 Power lever quadrant inspection

A detailed examination of the remaining components of the power lever quadrant (Figure 46) was conducted. The inspection revealed that the springs that hold down the power lever triggers were in place and intact.

Figure 46: Power lever quadrant components

The spring that held the flight idle gate in the down position was also identified. It was intact and still attached to the power lever quadrant. The flight idle gate itself had completely disintegrated and the spring was therefore no longer attached at its upper end.

When exposed to heat, a spring may stretch if it has pretension. The spring that held the flight idle gate in the down position normally had a certain amount of pretension. In addition, it was exposed to significant heat during the post impact fire. It displayed evidence that it had been stretched at one end indicating that it was attached to the flight idle gate and intact at the time of the accident (Figure 47).

A detailed inspection of all the power lever quadrant components was conducted with no pre-accident defects identified.

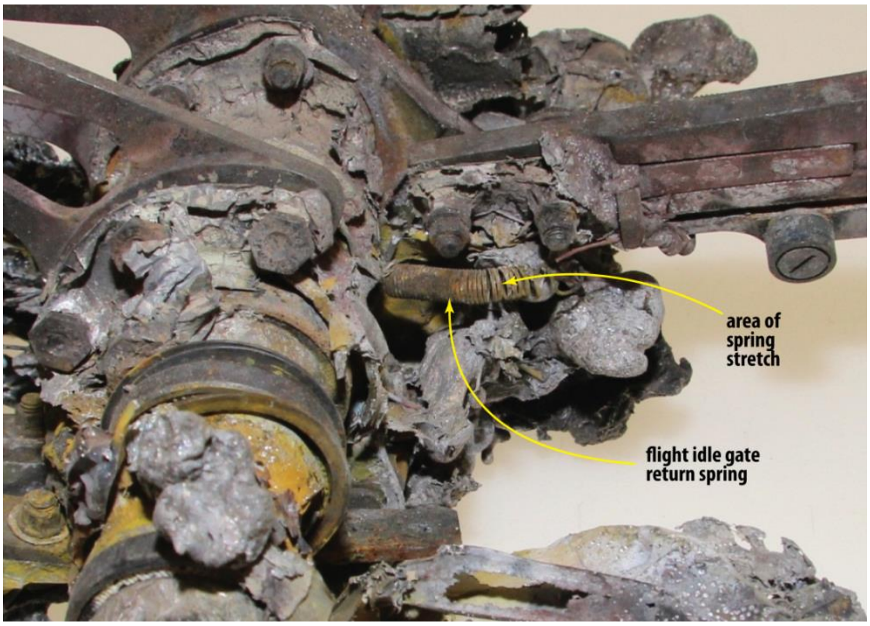

Figure 47: Close-up of power lever quadrant with flight idle return spring

The microswitch that activates the beta warning horn was recovered. It had significant thermal damage which precluded any type of functional test (Figure 48).

Figure 48: Close-up of the beta warning horn microswitch

1.17 ORGANISATIONAL AND MANAGEMENT INFORMATION

1.17.1 Recency requirements

The Pilot-in-Command returned to PNG on 25 September 2011 after an absence from flying of 22 days and the First Officer returned to PNG on 10 October 2011 after an absence from flying of 6 weeks.

When they acted as flight crew for the first time after these breaks, both pilots fulfilled the recency requirements of PNG Civil Aviation Rule (CAR) Part 61.37 *Recent flight experience* and the operator's Flight Operations Policy and Procedures Manual Section 5.17 *Recency requirements*.

1.17.2 Operator's DHC-8 training program

The operator was approved by CASA PNG to conduct company personnel training and competency assessment for DHC-8 operations in accordance with PNG Civil Aviation Regulations (CARs) Part 121 Subpart I and J.

The company's DHC-8 training program for pilots with no prior experience on the aircraft comprised an engineering systems ground course, at least five supernumerary sectors in the aircraft as an observer, five simulator exercises totalling 26 to 28 hours and concluding with a base check, and line training (detailed below) concluding with a base check and a check-to-line.

Prior to the widespread use of simulators, aircraft type-endorsements were conducted in the aircraft itself. For safety reasons, aircraft-based training cannot include many abnormal and emergency situations that can be conducted in a simulator. One of the operator's senior training captains stated that, prior to the accident, the company's DHC-8 simulator endorsement program had been based on sequences from an older, aircraft-based endorsement program where emphasis was placed on basic aircraft handling and certain abnormal/emergency situations that can be safely practised in an aircraft. This endorsement program did not, therefore, include exercises such as propeller overspeed or forced landing that cannot be safely conducted in an aircraft. (The operator's simulator endorsement did include 'impact' exercises but these were directed towards practising engine shutdown/aircraft evacuation procedures once an aircraft had landed, rather than engine failure in flight leading to forced landing.)

The senior training captain said that propeller overspeed and forced landing procedures were practised by the operator's flight crew in recurrent simulator training sessions at the discretion of the check captain. Pilots were nevertheless expected to know how to respond to all emergency/abnormal situations by following procedures detailed in the Flight Crew Operating Manual, and knowledge of these procedures was tested and discussed during line training and line checks.

The company's line training program for captains comprised

- a minimum of 75 hours line training to be completed within 120 days of its commencement
- trainee to act exclusively as pilot flying (PF) or pilot monitoring (PNF) for the first 10 sectors of line training
- a progress check after completion of approximately ⅔ of the line training.

The captain would act as PF for the first 10 sectors after being checked-to-line, with a line check between two to four months after the initial check-to-line.

The company's line training program for first officers comprised

- a minimum of 75 hours line training which could be reduced in cases where the trainee had prior experience on the DHC-8 or in PNG

- trainee to act exclusively as pilot flying (PF) or pilot monitoring (PNF) for the first 10 sectors of line training
- a progress check after completion of approximately ⅔ of the line training.

1.17.3 Operator’s flight crew manuals

The operator’s manuals current at the time of the accident contained guidance applicable to the emergency in which the crew of MCJ found themselves. This was primarily contained in the Policy and Procedures Manual and the DHC-8 Flight Crew Operating manual (FCOM).

The sections of these documents most relevant to the accident involving MCJ are reproduced in Appendix 5.3. A brief summary is provided here.

Policy and Procedures Manual

The Policy and Procedures Manual explained

- the requirement to comply with Standard Operating Procedures (SOPs) and the way the two flight crew members were to interact in accordance with coordinated crew procedures, including the sharing of pilot duties
- the use of checklists, including abnormal and emergency checklists, and use of the QRH
- crew discipline and the requirement to operate according to procedures, including the following quotation

> "Discipline is the foundation of airmanship. With it, a crew member can safely and systematically build towards excellence. Without it, we cannot hope to mature towards our full potential as crew members or aviation organizations. In fact, without a solid foundation of flight discipline, we are always on thin ice, consistently flirting with tragedy. Failures of flight discipline can, in a single instant, overcome years of skill development, in depth systems knowledge and thousands of hours of experience. Without discipline, none of these attributes can protect us against a sudden loss of judgment."

- use of emergency phraseology
- response to emergency situations and the assignment of duties during an emergency
- use of emergency/abnormal QRH checklists
- actioning emergency/abnormal QRH checklists
- flight path control during emergency/abnormal situations
- identification and confirmation of failed engines
- in-flight fire or smoke
- emergency landings.

DHC-8 Flight Crew Operating manual (FCOM)

The FCOM was comprised of chapters on aircraft limitations, abnormal procedures, aircraft performance, normal procedures, weight and balance, flight planning, and use of the oxygen system. This included

- detailed descriptions of the flight crew response required in specified abnormal/emergency situations (with the applicable checklists reproduced in the QRH)
- company requirements for aircraft speed management on descent, and guidance on descent profiles
- forced landing procedures.

1.17.4 Quick Reference Handbook (QRH)

An aircraft Quick Reference Handbook (QRH) contains approved emergency and abnormal procedures and other information such as certain performance charts, ditching information, etc. An easily-accessible copy is available in the cockpit for each pilot. The operator reported that, at the time of the accident, it used the DHC-8 QRH published by Bombardier. The Bombardier DHC-8 QRH procedures current at the time of the accident for propeller overspeed, engine fail/fire/shutdown in flight, fuselage fire or smoke, emergency landing (both engines operating), and forced landing (both engines inoperative) are given in Appendix 5.4.

The QRH Preface included the following advice to pilots.

> Pilots must be aware that checklists cannot be created for all conceivable situations and are not intended to preclude good judgement. In some cases deviation from the checklists may, at the discretion of the Pilot-in-Command, be necessary. Under all circumstances, the first priority is to maintain safety of the airplane for the duration of the flight.

1.17.5 QRH checklists and the use of flaps during forced landings

The QRH checklist *Forced landing (both engines inoperative)* begins as follows.

> - Airspeed.. 1.3 Vs
>
> ***Note:*** *With flap 0, landing gear retracted, propellers feathered and zero wind, 2.5 nautical miles can be travelled for every 1000 feet of altitude loss.*
>
> *All hydraulic, pneumatic and non-essential electrical services will be inoperative.*

This checklist does not consider any flap setting other than flap 0. This is because if both engines fail when the flaps are retracted, the flight crew cannot extend the flaps (because “All hydraulic, pneumatic and non-essential electrical services will be inoperative”). In other words, the checklist is predicated on the non-availability of the hydraulic system needed to extend the flaps, rather than the desirability of landing with flaps 0 during a forced landing.

The QRH checklist *Forced landing (both engines operating)* includes the following.

> **Landing considerations**
>
> - Flap 35

In the case of a forced landing when the hydraulic services needed to extend the flaps are available, the manufacturer’s QRH advises the use of flaps.

1.18 ADDITIONAL INFORMATION

1.18.1 Flight crew response to an in-flight emergency

Pilots are trained to respond promptly to emergency and abnormal situations by actioning specific, predetermined procedures. Each procedure is carefully designed so the flight crew deals with and rectifies an abnormal/emergency situation in a particular way, avoiding ad hoc actions. Recurrent training is intended to prepare flight crew to transition directly from the recognition and confirmation of an abnormal/emergency situation into the action sequence designed for that situation. Many abnormal/emergency procedures involve initial ‘Phase 1 memory items’, which flight crew must be able to action from memory, followed by ‘Phase 2’ items in which the Phase 1 actions already carried out are checked against the QRH, and Phase 2 items are read aloud from the QRH and actioned.

Responding to an emergency in the manner described above – i.e. promptly actioning predetermined, situation-specific procedures that have been practiced during training – increases the flight crew’s ability to gain control of the situation and manage the flight to a safe conclusion.

No two abnormal/emergency situations are exactly alike. However, the broad expectation in a multi-crew environment is that the flight crew will first ensure the aircraft remains in controlled flight, then identify and confirm the nature of problem, and carry out any Phase 1 actions from memory. If time permits, they will access the QRH to check their Phase 1 actions, and read and carry out any Phase 2 actions. Once the situation has been dealt with in this way, they will work together to determine what aircraft systems are operating, assess their options, carry out any further QRH or normal checklists, advise ATC, and brief other crew and passengers as required. Implementing such a sequence of actions successfully in a genuine emergency depends on the interaction of multiple different factors, for example: the correct execution of normal and abnormal procedures learned and practiced during training, good coordination with other crew members, aircraft systems knowledge, judgment derived from flying experience, remaining calm enough to function and think effectively, etc.

1.18.2 Rate of descent before the propeller overspeeds

The operator’s DHC-8 standard operating procedures (SOPs) (see Appendix 5.3) stated that the aircraft should be descended at 2,000 ft per minute on a 2x descent profile. In the 30 seconds before the V_{MO} overspeed warning sounded, MCJ’s rate of descent was increasing from approximately 2,200 to approximately 4,200 ft per minute (Figure 49).

1.18.3 MCJ flight crew actions following the onset of the emergency

Following the onset of the emergency and the flight crew’s initial shock, the First Officer quickly identified the double propeller overspeed and informed the Pilot-in-

Command. Shortly after the propeller overspeed noise had ceased, the flight crew identified that they had no engine power.

The aircraft descended with the left propeller windmilling. The rate of descent increased erratically from about 1,500 ft per minute passing 10,090 ft when the overspeeds occurred, to over 6,000 ft per minute as the aircraft passed through 4,880 ft AMSL (Figure 49). The rate of descent subsequently decreased until impact. The Pilot-in-Command stated that prior to the propeller overspeeds he had been attempting to descend below a layer of cloud in order to remain visual, and he thought that he had persisted with this mental objective after the overspeeds occurred. He said that he had had ‘control problems’ after the overspeeds occurred. This would in part have been because of the windmilling left propeller. In addition, although the aircraft was certified for operation with the yaw damper inoperative, and is fully controllable with the rudder control unmodified by input from the yaw damper, the lack of the yaw damper would have made the rudder more sensitive to control inputs, leading to a tendency to over-control the rudder.

The Pilot-in-Command stated they had not actioned an emergency procedure because there was no procedure for double propeller overspeed. The First Officer said he had been about to begin the propeller overspeed Phase 1 memory items when the smoke event occurred, changing his focus from the propeller overspeed checklist to the smoke checklist.

Moments after the flight crew realised they had no useable engine power, the Pilot-in-Command directed the First Officer to contact Madang Tower and the First Officer began a radio exchange which occupied him for 63 seconds, or 30 % of the time remaining to impact, during which time the aircraft descended 4,370 ft and the First Officer was unavailable for any other activity in coordination with the Pilot-in-Command.

The flight crew’s initial intention appears to have been to ditch the aircraft in the sea although there was no direct discussion between them of ditching: the First Officer told Madang Tower they would ‘probably’ ditch, after which the Pilot-in-Command told the First Officer to brief the Flight Attendant that they would be ditching. Shortly after telling the First Officer to brief the Flight Attendant for a ditching, the Pilot-in-Command decided to make a forced-landing on land instead. Following a brief discussion, the flight crew agreed to force-land in the bed of the Guabe River.

Table 3: Principal events and flight crew actions following the onset of the emergency

Time to end of recording (mm:ss)	Altitude (feet)	Events and crew actions
-04:24	10,500	V_{MO} OVERSPEED WARNING SOUNDS
-04:18	10,090	DOUBLE PROPELLER OVERSPEED BEGINS, LASTING APPROX 38 SECONDS
		SMOKE EVENT IN COCKPIT AND CABIN
-04:07	9,410	F/O identifies double propeller overspeed.
-03:54	8,980	No. 2 PROPELLER AUTOFEATHERED, No. 1 PROPELLER WINDMILLING
-03:41	8,350	PROPELLER OVERSPEED NOISE STOPS
-03:32	7,980	Crew recognition of complete loss of useable engine power.
-03:27	7,730	PIC directs F/O to contact Madang Tower.
-03:25	7,620	Prolonged (1 min 3 sec) F/O radio exchange with Madang Tower begins: MAYDAY call, then discussion of the crew's intentions including 'probable' intention to ditch, then transmission of the aircraft's GPS coordinates (ends -02:22).
-02:47	4,880	AIRCRAFT EXCEEDS 6,000 FPM RATE OF DESCENT V_{MO} OVERSPEED WARNING SOUNDS AGAIN
-02:22	3,250	F/O radio exchange with Madang Tower finishes.
-02:16	3,160	PIC tells the F/O to call the F/A to the cockpit to brief him they are going to ditch.
-02:08	2,950	PIC decides to make a forced-landing on land, instead of ditching. Then, after a brief discussion, the crew decide to force-land in the bed of the Guabe River.
-01:35	1,600	F/O transmits intention to force-land in a river bed to Madang Tower.
-01:16	1,230	F/O asks the PIC if he would like him [the F/O] to shut both engines down.
-01:14	1,190	PIC directs F/O to shut 'everything' down.
-01:12	1,140	F/O shuts both engines down. No. 1 PROPELLER FEATHERS No. 1 HYDRAULIC PUMP STOPS OPERATING No. 1 AC GENERATOR STOPS; AC POWER LOST No. 1 + No. 2 DC GENERATORS DROP OFF LINE; DC POWER AVAILABLE FROM BATTERIES (LIMITED ELECTRICAL SYSTEMS AVAILABLE)
-00:56	660	PIC directs F/O to give Madang Tower their coordinates (this was not possible because the GPS was no longer powered).
-00:14	240	PIC and F/O make public announcement "Brace, brace, brace".
-00:01	180	AIRCRAFT IMPACTS TERRAIN AT 114 knots, GEAR UP, FLAPS 0
00:00	180	[SILENCE ON CVR]

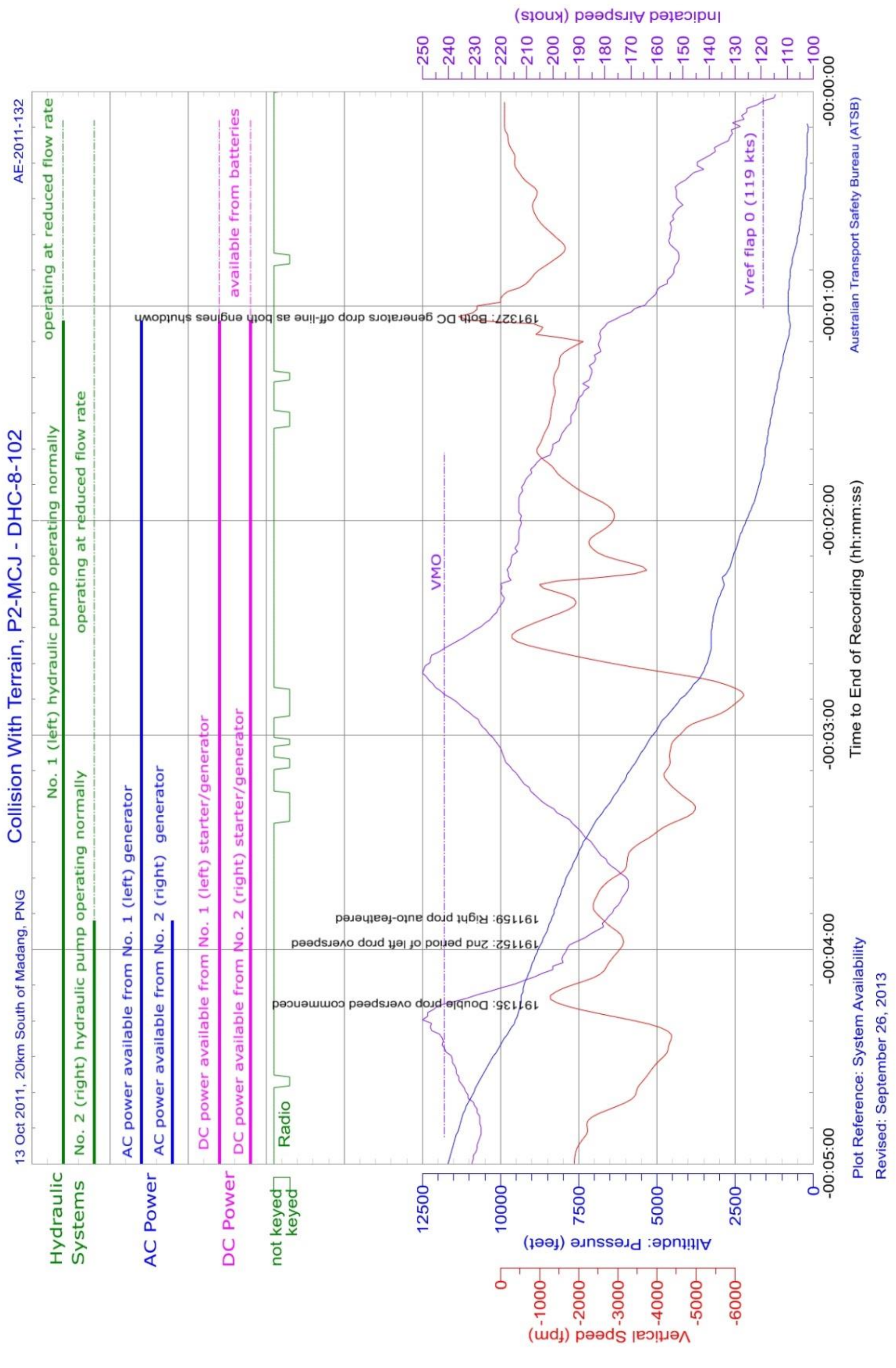

Figure 49: Rate of descent and availability of systems following the overspeed event[14]

After telling Madang Tower they planned to land in the river bed, the First Officer asked if the Pilot-in-Command would like both engines shut down and the Pilot-in-

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[14] The traces for hydraulic systems, AC power, and DC power were not recorded parameters. They were derived from analysis of engine operation.

Command directed him to shut ‘everything’ down. The First Officer shut down both engines 72 seconds before impact, passing 1,140 ft AMSL, causing the No. 1 propeller to feather, the No. 1 AC generator to go offline, both DC generators to drop offline, and cutting electrical power to the No. 1 hydraulic pump which then stopped operating normally. There had been no discussion of the use of the flaps or landing gear prior to this, although the flaps could have been extended until the engines were shut down. The landing gear could have been extended at any time until impact.

The Pilot-in-Command directed the First Officer to give their position coordinates to Madang Tower but this was no longer possible because the GPS was not powered. During the final 45 seconds of flight there was no verbal communication between the flight crew.

About 10 seconds before impact, both pilots transmitted the “Brace” command over the PA system to the cabin. The initial impact occurred at 114 knots with the landing gear and flaps retracted. This was between the V_{REF} flap 0 speed (120 knots) and the V_{REF} flap 35 speed (89 knots), and was 25 knots faster than could have been achieved with flap 35.

1.18.4 The effects of stress on performance

Stress can lead to errors and poor performance[15]. For example, stress can affect attention, memory, and decision making. It can result in perceptual and cognitive narrowing, where attention and decision making are focussed on a restricted range of information and tasks. Attention may become focussed on one source of information to the neglect of other sources of information, resulting in ‘tunnel vision’. This can result in a loss of situational awareness and poor decision making. Pilots may restrict their scanning of information and jump to premature conclusions. Under high levels of stress scanning patterns may become chaotic.

Stress can also lead to task shedding. Some operations may be ignored because of cognitive overload, or the pilot may take shortcuts in an attempt to deal with all the tasks required in a limited time. This can result in the neglect of crucial matters while time may be spent on tasks of lesser importance. Under stress, a pilot may act as though there is greater time pressure than is actually the case.

Decisions that require a choice from among more than one option are particularly vulnerable to the effects of stress. In contrast, decisions that can be made on the basis of standard operating procedures or based on the pilot’s past experience are less likely to be affected by stress.

1.18.5 Propeller overspeed occurrences involving other DHC-8 aircraft and other turbopropeller aircraft types

Information on propeller overspeed occurrences involving other DHC-8 aircraft is given at Appendix 5.1 and involving other turbopropeller aircraft types at Appendix 5.2.

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[15] Stokes A & Kite K (1994). “Flight stress: Stress, fatigue, and performance in aviation.” Avebury: Hants, UK.

2 ANALYSIS

2.1 Introduction

During the occurrence, P2-MCJ (MCJ) was being hand-flown on a steep descent with the propellers governed to 900 revolutions per minute (RPM). The aircraft's rate of descent increased to 4,200 ft per minute and its airspeed was allowed to increase at the same time, reaching the maximum operating speed V_{MO} and causing the V_{MO} overspeed warning to sound in the cockpit. The First Officer recalled that the Pilot-in-Command then pulled the power levers back "quite quickly". Shortly afterwards, both propellers underwent significant simultaneous overspeeds which lead to engine damage, a complete loss of forward thrust, and an off-field forced landing accident. The engine damage led to smoke entering the cockpit and cabin through the bleed air system, although there was no evidence of any pre-impact fire.

With the exception of the beta warning horn, the right propeller control unit, and the yaw damper, the investigation identified no pre-existing problems with the aircraft that may have contributed to the accident.

Once the overspeed had occurred, the flight crew handled the situation without recourse to standard emergency procedures and checklists. One consequence was that the time between the onset of the emergency and the forced landing was significantly shortened because the left propeller remained unfeathered until 72 seconds before impact, creating very significant drag and increasing the rate of descent. It should also be noted that the other principal contributor to the high rate of descent was the excessive speed at the aircraft was flown at after the double propeller overspeed. This meant that the flight crew had less time to deal with the situation than if the descent had been slower; the time from the onset of the emergency to impact could have been increased from approximately four to approximately 10 minutes. Flaps and landing gear were available but were not extended by the flight crew, although their use would have reduced the speed and severity of the impact.

Several similar propeller overspeed events have occurred in other DHC-8 aircraft that did not have a beta lockout mechanism fitted. These all had factors in common such as the aircraft being on descent, high airspeed, and power levers moved below the flight idle gate.

At the time of the accident, DHC-8 aircraft outside the USA were not required to have a beta lockout mechanism.

Two principal hypotheses to account for the propeller overspeeds were considered. The first was that the power levers were at or above flight idle and the aircraft had some type of mechanical failure. The second was that the power levers were moved to a position below the flight idle gate during flight, resulting in loss of propeller governing function. These are discussed below.

2.2 Mechanical failure

The possibility of mechanical failure or failures was explored in great detail during this investigation. The design of the propeller control systems meant that for there to be a propeller overspeed with the power levers above flight idle, three independent propeller control systems needed to malfunction: the propeller control unit (PCU), the overspeed governor and its pump, and the beta backup system.

The right PCU and overspeed governor were destroyed and therefore could not be examined. The remaining components of the right propeller system were inspected and no pre-impact defects were identified. The entire left propeller system was available for examination. The left PCU could not be tested functionally but it was disassembled and inspected and no pre-impact defects were identified. The left overspeed governor and pump assembly was tested functionally and no defects were identified. The remaining components of the left propeller system were inspected with no pre-impact defects identified. The investigation found no evidence of any mechanical failure in the propeller control systems.

The fact that both propellers oversped simultaneously greatly decreased the likelihood that mechanical malfunction led to the occurrence. This is because both propellers had completely independent control systems and for mechanical failure to underlie the simultaneous overspeeding of both propellers, wholly independent systems on each side of the aircraft needed to malfunction at the same time. Because of this, and in the absence of any evidence of propeller system failure, mechanical failure was discounted as an explanation for the double propeller overspeed.

2.3 Power levers below the flight idle gate during flight

Two conditions must have existed for the double propeller overspeed to be the result of movement of the power levers behind the flight idle gate during flight: (1) the Pilot-in-Command must have moved the power levers rearwards and (2) he must have raised the flight idle release gate trigger(s) to allow the power levers to move behind the flight idle gate into the ground beta range.

First, it is known that the Pilot-in-Command moved the power levers rearward in response to the V_{MO} overspeed warning. Both pilots recalled this in interviews after the accident.

Second, just before the propeller overspeeds began there was an audible click on the CVR recording (Figure 14) consistent with the flight idle gate release triggers being raised. It is possible the click could have been produced in some other way, however, given the fact that the double propeller overspeed occurred moments later, the click occurred at exactly the time it would be expected if it were the sound of the triggers being raised (but see footnote to section 1.11.8 *FDR and CVR recordings prior to and during propeller overspeeds*).

The manufacturer interpreted a very small reduction in the right engine FDR-recorded N_H as an indication that the right power lever may have been moved below the flight idle gate for four to five seconds before the propeller overspeeds occurred. For this to have happened, one or both flight idle release gate triggers would have had to be lifted before the right power lever could pass behind the gate. This interpretation is not consistent with the distinct click, recorded on the CVR, just before the propeller overspeeds began. The timing of the click was consistent with the triggers being lifted shortly before the overspeeds began, suggesting the power levers were at or forward of the flight idle gate before the click occurred.

The fact that the beta warning horn was recorded by the CVR is important evidence that the Pilot-in-Command did lift the flight idle release gate triggers, fulfilling an essential precondition for the power levers to move behind the flight idle gate. Although the beta warning horn malfunctioned and did not begin to sound until after the propeller overspeeds had commenced, it did sound. This indicated that one or both triggers were lifted.

The V_{MO} overspeed warning took both pilots by surprise. The strongest evidence for this comes from the CVR, which indicated that neither pilot noticed the aircraft's speed approaching V_{MO}. The Pilot-in-Command recalled he was mainly looking outside the cockpit prior to the V_{MO} overspeed warning. This was because his attention was focussed on keeping the aircraft clear of cloud. The element of surprise meant that the Pilot-in-Command's reaction to the V_{MO} overspeed warning was probably more spontaneous and less considered than it would have been if his attention had been more focussed inside the cockpit and he had been more aware of the aircraft's speed.

Pilots use the flight idle gate release triggers during each landing to move the power levers into the ground beta range in order to slow the aircraft. This is a routine, skill-based action. In some cases, particularly when an individual is under high workload or distracted, skill-based actions may be confused with other actions, particularly those that share similar features[16]. Such errors are commonly known as 'slips'. It is conceivable that under unusual flight conditions, high workload, or when distracted, the action of slowing an aircraft in flight by pulling back on the power levers could be confused with the action of slowing the aircraft on the ground, which also involves a rearwards movement of the power levers. In this way, the flight idle gate release triggers might be raised in flight during rearwards movement of the power levers.

In the absence of any identifiable mechanical component failures, movement of the power levers behind the flight idle gate by the Pilot-in-Command is considered to be the only plausible explanation for the simultaneous double propeller overspeed in MCJ.

There was no evidence from the CVR that indicated any premeditation of the power lever movement by either pilot. The CVR evidence from the period after the double propeller overspeeds began was characterised by surprise and confusion on the part of the crew, which suggests that neither pilot realised what the Pilot-in-Command had done. Although it is not possible to exclude alternative explanations completely, the evidence suggests the Pilot-in-Command reacted spontaneously to the V_{MO} overspeed warning; the action of moving the power levers below the flight idle gate was probably unintentional.

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[16] Reason, J 1990, *Human Error,* Cambridge University Press.

2.4 Consequences of the loss of propeller speed control

As a consequence of the inhibition of the propeller speed control and overspeed protection systems in MCJ, all propeller speed control was lost. This meant the propellers were driven by the airflow like the vanes of a windmill, resulting in the propeller RPM limits being significantly exceeded, a condition exacerbated by the aircraft's high speed. With the propellers back-driving the engines, the power turbines oversped and the left engine failed.

The right propeller underwent an uncommanded feather because of a malfunction in the PCU beta switch system. However, expert knowledge of the propeller control system – beyond that which any pilot could be expected to possess – would have been needed to unfeather the right propeller and the right engine could not therefore be used for forward thrust. The left engine had shut down due to internal damage, so a forced landing without power was inevitable. Although it could not be used for forward thrust, the left engine was still powering the left hydraulic system and the left AC generator was producing AC electrical power.

The propeller blade tips exceeded the speed of sound. The CVR recording showed that the flight crew had great difficulty communicating above the very loud noise. The propeller noise also masked the intermittent sound of the beta warning horn.

Once the propeller overspeeds had reached their peaks, over 60 % above their maximum RPM, advancing the power levers into the governing range may not have returned the propellers to governing speed. This was due to centrifugal twisting moment forces being greater than the propeller control force required to change the pitch of the propeller blades. The propellers gradually slowed to a point where they could be controlled due to the decrease in forward airspeed, and the left propeller returned to a governing speed of 900 RPM momentarily before over-speeding a second time. This may have been due to the left power lever being moved into, then out of, the governing range; the power levers did not need to be advanced forward of the flight idle gate for this to occur because the governing range extends to 13 degrees below the flight idle gate.

2.5 Beta warning horn

In 1999 the manufacturer recommended and Transport Canada mandated the installation of a beta warning horn on the DHC-8 to alert pilots whenever the flight idle gate release triggers were lifted in flight. This reduced the risk of inadvertent movement of the power levers below the flight idle gate during flight. Audible warnings can be very effective, although research has shown they are not always heard or comprehended in sufficient time for an effective response to be made, particularly in times of high workload or distraction[17].

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[17] Rehman, N 1995, *Flightdeck crew alerting issues: An aviation Safety Reporting System analysis*, US Department of Transportation / Federal Aviation Administration Report DOT/FAA/CT-TN94/18.

Due to the malfunction of the beta warning horn in MCJ, the audible tone of the horn – which was a defence against in-flight raising of the power lever triggers – was absent. If the beta warning horn had functioned normally, the pilots may have recognised what was happening and taken appropriate action quickly enough to prevent the propeller overspeeds from damaging the engines. This is uncertain, however, because the Pilot-in-Command said afterwards that he was not sure he had ever heard the beta warning horn before the day of the accident. He may therefore not have realised what it signified even if it had sounded as soon as he lifted one or both the triggers.

After the accident, the aircraft manufacturer identified a problem with the beta warning horn functional test on one of its own corporate aircraft. The manufacturer issued a service bulletin with an updated test and a request for operators to provide further information. Five of the 91 aircraft covered by these responses were found to have faulty beta warning horn systems. The manufacturer identified worn micro-switch retaining brackets as the factor underlying this malfunction, and a further service bulletin was issued to rectify the problem. Because of the damage caused by the impact and post-impact fire, it was not possible to determine why the beta warning horn in MCJ malfunctioned on the accident flight.

2.6 Power lever and propeller system design

The aircraft design included features to reduce the likelihood of inadvertent movement of the power levers below flight idle into the ground beta mode during flight, an action prohibited by the Aircraft Flight Manual. These included the flight idle gate, the release triggers which required a specific action (lifting the triggers) before the power levers could be moved past the flight idle gate, and the beta warning horn. Although these features significantly reduced the likelihood that flight crew would pull the power levers below flight idle during flight, they did not prevent it.

There have been several documented cases where flight crews have pulled the power levers behind the flight idle gate during flight, some of which occurred during turbulence when the pilot was gripping the power levers more tightly than usual. Although the likelihood of this occurring on any given flight is very low, the consequences may be catastrophic, as in the case of MCJ.

2.7 Propeller overspeed protection in DHC-8 aircraft

At the time of the occurrence, a significant number of DHC-8-100, -200, and -300 series aircraft in Papua New Guinea and other countries outside the United States did not have a beta lockout system installed to prevent propeller overspeed in the event that the power levers were moved into the ground beta range during flight, nor were they required to have a beta lockout system fitted. Only DHC-8 aircraft operating in the USA were required to have such a system.

2.8 Automated feathering of the right propeller

There was an uncommanded feathering of the right propeller shortly after the propeller overspeeds began. When the right power lever was moved rearward to a position less than 13 degrees below flight idle i.e. into the non-governing range, the right beta switch changed to the closed position when the propeller blade angle attained the actuation point (2.5 degrees below flight idle), as designed. Although it is not possible to identify when, it is likely that the right power lever was subsequently moved forward again into the governing range (i.e. above the 13-degrees-below-flight-idle position); when the power lever was moved forward to within 3 degrees (or more) of flight idle, the beta backup logic automatically feathered the propeller, as designed, because the beta switch remained stuck in the closed position (indicating propeller fine pitch). FDR data indicated the beta switch remained stuck in the closed position for the rest of the flight; this would have prevented the pilots from unfeathering the propeller, had they attempted to do so (they did not).

A beta switch stuck in the closed position is not a fault that could remain undetected during the course of normal operations because the propeller would feather immediately the power levers were moved from the ground range to flight range. Pilots routinely operate the power levers through these positions each time they taxi before takeoff so the right propeller beta switch could not have been stuck in the closed condition on MCJ before the accident flight. The beta switch probably stuck in the closed position as a consequence of the propeller overspeeds, perhaps because of propeller vibration.

Shortly before this report was finalised, the NTSB indicated to the AIC that, had the PCU still been in operation on an aircraft, it would have been subject to recall for issues directly related to beta switches sticking due to incorrect application of installation procedures at overhaul. It is possible that the quality control issue associated with that recall was implicated in some way in the feathering of MCJ’s right propeller, but extensive thermal damage to the right PCU precluded any examination and testing to determine the cause of the beta switch malfunction. The AIC was therefore unable to determine if the quality control issue contributed to the uncommanded feather of the right propeller or not.

Although the right engine remained undamaged after the propeller overspeed commenced, the uncommanded feather of the right propeller meant it could not be used for forward thrust. If the PCU had not malfunctioned and the propeller had returned to the governing range, the flight crew may have been able to use the right engine for forward thrust and a forced landing may not have been necessary. However, if the right propeller had not feathered and the engine power turbine had continued to be driven by an overspeeding propeller, it is possible the right engine would have failed in the same way as the left engine because of the forces exerted on the power turbine by the overspeeding propeller.

2.9 Aircraft systems

2.9.1 Landing gear and flaps

On the basis of FDR information and information provided by the manufacturer, the landing gear and the flaps were available for use after the propeller overspeeds occurred. The flaps remained available until the First Officer shut down the engines and feathered the left propeller 72 seconds before impact. The landing gear could have been extended at any time before impact.

2.9.2 Yaw damper and autopilot

MCJ had an unserviceable yaw damper at the time of the accident. It was permissible to fly the aircraft with an unserviceable yaw damper, but it meant that the autopilot could not be used. The Pilot-in-Command was therefore hand-flying the aircraft on the steep descent into Madang during which neither pilot noticed the aircraft accelerating to its maximum operating speed V_{MO}. It was the exceedance of V_{MO} that caused the V_{MO} overspeed warning to sound and prompted the Pilot-in-Command to make a rearward movement of the power levers. If the autopilot had been in use it would have decreased the Pilot-in-Command's workload and stabilised the rate of descent (at whatever vertical speed was set by the flight crew). This might have made it more likely that the aircraft either would not have reached V_{MO} at all or that its acceleration towards V_{MO} would have been noticed, and corrected, by the flight crew. This would have removed what appears to have been the catalyst – the V_{MO} overspeed warning – for the Pilot-in-Command's rearward movement of the power levers behind the flight idle gate.

2.10 High rate of descent and high airspeed before the propeller overspeeds

In the 30 seconds prior to the V_{MO} overspeed warning, the aircraft's rate of descent was increasing from approximately 2,200 to 4,200 ft per minute. This was a significantly higher rate of descent than required to maintain the 2x profile and a significant departure from the operator's standard operating procedures (SOPs). The aircraft's airspeed increased concurrently with the increase in the rate of descent, from approximately 230 knots to 250 knots, until V_{MO} was reached and the V_{MO} overspeed warning sounded. The Pilot-in-Command was hand-flying the aircraft due to the yaw damper unserviceability, but he could nevertheless have maintained a rate of descent at or close to 2,000 ft per minute in accordance with the operator's SOPs. Had he done so, it is possible that the aircraft would not have reached V_{MO}, the V_{MO} overspeed warning would not have sounded, and he may therefore not have pulled the power levers rearwards in the way that he did prior to the propeller overspeeds.

On the descent, the propeller speed had not been increased from 900 RPM (which was their setting during the cruise). If the propeller RPM had been increased by the flight crew in the period between top of descent and the propeller overspeeds, the increased drag from the propeller discs would have led to a slower airspeed. The Pilot-in-Command stated after the accident that he had been about to ask the First

Officer to increase the propeller speed to 1,050 RPM just before the V_{MO} overspeed warning sounded. Had he done so sooner, it would have lessened the effect the high rate of descent had on the aircraft's airspeed.

2.11 Flight crew response to the emergency

2.11.1 Stress

When both propellers oversped, the crew were suddenly faced with an unexpected and confusing situation with high risk consequences. The stress they faced was exacerbated by the deafening noise and the appearance of smoke in the cockpit. The high stress of the situation had the potential to affect the crew's performance in a number of ways, including reducing the effectiveness of their ability to assimilate and analyse information, and their decision making.

Because of the inherent limitations of human performance in high stress and time-limited situations, crews are trained to respond to abnormal and emergency situations by carrying out predetermined actions to identify and respond to specific events. In effect, they implement 'pre-packaged' decisions that are based on prior operating knowledge and experience, and encoded in standard procedures.

Following the double propeller overspeed, the crew of MCJ did not follow any sequence of standard emergency response procedures, such as actioning Phase 1 items or QRH procedures. This decreased the likelihood of them dealing effectively with a very difficult and challenging emergency situation. As a result, the crew did not feather the windmilling left propeller until the First Officer was told to 'shut everything down' by the Pilot-in-Command 3 minutes and 6 seconds after the overspeeds began. The windmilling propeller had the effect of increasing the aircraft's rate of descent, as well as adding to aircraft controllability problems.

One reason given by the crew for not actioning any formal emergency response procedures was that there was insufficient time to carry out such actions. However, the time from the initial propeller overspeed to the forced landing was 4 minutes 18 seconds. The flight crew's perception of time during the emergency may have been affected by stress.

2.11.2 No use of emergency procedures

If the flight crew had used the DHC-8 emergency procedures for propeller overspeed, engine failure, and forced landing, it may have altered the final outcome of the occurrence. In common with the manufacturer's other abnormal and emergency procedures, these procedures were designed for flight crew to deal with the emergencies without recourse to ad hoc actions.

Why the flight crew did not respond with standard emergency procedures is not clear. They said afterwards there had been insufficient time. It is possible they were overwhelmed and this somehow prevented them from putting into effect the procedures and methods they had been trained to use in such circumstances.

On the basis that the flight crew responded in an ad hoc manner to the emergency, it appeared that the operator’s training system had been ineffective in inculcating into those pilots the company’s prescribed responses to emergencies.

There was no evidence that either pilot had completed the propeller overspeed drill during their simulator training or simulator checks. It is therefore possible that they had never demonstrated this procedure to a check captain. With respect to the propeller overspeed emergency drill, the operator’s training system had not taken advantage of the opportunity provided by the simulator environment to practise this drill in a realistic manner.

2.11.3 Airspeed and high rate of descent after the propeller overspeeds

The rate of descent was greatly influenced by the windmilling left propeller which was creating very significant aerodynamic drag. This drag significantly increased the rate of descent and shortened the time to impact. Actioning the Phase 1 items for propeller overspeed and engine failure would have feathered the left propeller and slowed the descent, giving the pilots more time to deal with the situation.

2.11.4 Long radio exchange

Shortly after the flight crew identified the double propeller overspeed, the Pilot-in-Command directed the First Officer to contact Madang Tower and tell them what had happened. The First Officer became engaged in a long radio exchange with Madang Tower which lasted 63 seconds or 30 % of the time remaining to impact, beginning with a mayday call and developing into a discussion of the situation and the intentions of the flight crew, and the aircraft’s GPS coordinates. During the radio exchange, while the aircraft descended 4,460 ft, the First Officer’s attention was fully engaged and he was therefore unavailable to coordinate with the Pilot-in-Command to manage the situation. The Pilot-in-Command interjected instructions to the First Officer during the radio exchange, suggesting that instead of delegating this task to the First Officer the Pilot-in-Command’s attention remained at least partly focussed on it also.

Although making a mayday call was required, the lengthy radio exchange did not improve the outcome of the occurrence and the flight crew’s attention and time would probably have been better employed in determining their options, configuring the aircraft, and managing the descent and approach.

2.11.5 Aircraft configuration and approach to land

The Pilot-in-Command said that he had difficulty controlling the aircraft after the propeller overspeeds. This was due to the asymmetric forces created by the left propeller windmilling while the right propeller was feathered.

The flight crew could have extended the landing gear and flaps if they had elected to do so before the First Officer shut down the left engine 1,140 ft AMSL 72 seconds before impact. Although extending the landing gear would have been inappropriate for ditching in the sea, the decision to make a forced landing on land in the river bed (rather than in the sea) was made passing 2,950 ft, 2 minutes and 8 seconds before impact.

Extending the landing gear and flaps would have resulted in a much lower speed at impact and, consequently, smaller deceleration forces. Although it is not possible to say how this would have altered the outcome, lower speed and smaller deceleration forces at impact would, others thing being equal, have made it easier for the flight crew to make the approach to land and resulted in less damage to the aircraft during the impact sequence. The impact would also have been less physically traumatic for the occupants of the aircraft.

Without knowing the exact nature of the surface they would be landing on it would have been difficult for the crew to assess whether or not it was suitable for landing with the gear extended. This was, however, at least partly a consequence of the short time between the double propeller overspeeds and the forced landing, in turn a consequence of the way the flight crew managed the aircraft during the emergency.

2.11.6 Gliding distance and time before impact

This section is not intended to imply that the flight crew should have attempted to glide towards Madang. Instead, it examines what may have been possible given the height at which the propeller overspeeds occurred, and how long the aircraft could have remained airborne if the flight crew had managed the situation differently.

The Aircraft Flight Manual and the QRH checklist for forced landing with both engines inoperative both stated that at 1.3 V_S with flap 0, landing gear retracted, propellers feathered, and in nil wind the aircraft would travel 2.5 nautical miles (4.6 km) for every 1,000 ft of altitude lost. At MCJ's estimated weight of approximately 14,600 kg at impact, the 1.3 V_S speed was 120 knots with flap 0.

To calculate how long MCJ could have remained airborne and far it might have travelled if the flight crew had feathered the left propeller and flown the aircraft at 120 knots, the time between the onset of the emergency and the configuration of the aircraft at 120 knots with both propellers feathered must be estimated.

Timing of the commencement of pilot action in an emergency is subjective. As a rule-of-thumb, the manufacturer estimated that identification of each abnormal situation would take one second and that each of the required pilot actions in the emergency procedure would take one second. On this basis, and if they were treated as separate failures, the time taken to deal with each propeller overspeed, including engine shutdown, would be from 20 to 30 seconds. MCJ could therefore have been in the flap 0, 1.3 V_S glide configuration approximately one minute from the start of the first propeller overspeed emergency procedure.

If we assume the aircraft had been slowed – as required by the propeller overspeed emergency procedure – and was on-speed at 120 knots by 7,500 ft AMSL, this would have allowed it to remain airborne for over nine minutes and to glide 18.9 nautical miles or 35 km. (As it was, MCJ impacted the ground 4 minutes 18 seconds after the propeller overspeeds began.)

MCJ impacted the ground approximately 3 minutes 20 seconds after passing 7,500 ft

AMSL, so prompt execution of the applicable emergency procedures would probably have given the flight crew approximately six minutes longer to prepare for the forced landing.

When the propeller overspeeds occurred, the aircraft was at 10,090 ft AMSL 34 km south south east of Madang aerodrome. If we estimate it might have travelled two nautical miles towards Madang while losing 2,500 ft during the time the flight crew executed the emergency procedures and configured the aircraft to fly at 1.3 V_S, it would have been approximately 17 nautical miles or approximately 31.5 km from Madang aerodrome by 7,500 ft AMSL. Prompt execution of the applicable emergency procedures would therefore have probably allowed the flight crew to glide to, or close to, Madang aerodrome, had they been able to see it. However, the flight crew could not see Madang and were also aware of a storm in the vicinity of the aerodrome.

2.11.7 Summary of flight crew response to the emergency

In summary, the aircraft’s degraded controllability and the high rate of descent/short time to impact were at least partly attributable to the fact that the flight crew did not use the standard emergency procedures early on.

While it is not possible to determine exactly what would have happened if the flight crew had had more time to deal with the situation, it is reasonable to suppose it may have positively affected their ability to assess and manage the situation in a systematic manner.

3 FINDINGS

From the evidence available, the following findings are made with respect to the double propeller overspeed 35 km south south east of Madang on 13 October 2011 involving a Bombardier Inc. DHC-8-103 aircraft, registered P2-MCJ. They should not be read as apportioning blame or liability to any organisation or individual.

Contributing safety factors

- The Pilot-in-Command moved the power levers rearwards below the flight idle gate shortly after the V_{MO} overspeed warning sounded. This means that the release triggers were lifted during the throttle movement.
- The power levers were moved further behind the flight idle gate leading to ground beta operation in flight, loss of propeller speed control, double propeller overspeed, and loss of usable forward thrust, necessitating an off-field landing.
- A significant number of DHC-8-100, -200, and -300 series aircraft worldwide did not have a means of preventing movement of the power levers below the flight idle gate in flight, or a means to prevent such movement resulting in a loss of propeller speed control.

Other safety factors

- Prior to the V_{MO} overspeed warning, the Pilot-in-Command allowed the rate of descent to increase to 4,200 ft per minute and the airspeed to increase to V_{MO}.
- The beta warning horn malfunctioned and did not sound immediately when one or both of the flight idle gate release triggers were lifted. When the beta warning horn did sound, it did so intermittently and only after the double propeller overspeed had commenced. The sound of the beta warning horn was masked by the noise of the propeller overspeeds.
- There was an uncommanded feathering of the right propeller after the overspeed commenced due to a malfunction within the propeller control beta backup system during the initial stages of the propeller overspeed.
- The right propeller control unit (PCU) fitted to MCJ was last overhauled at an approved overhaul facility which had a quality escape issue involving incorrect application of beta switch reassembly procedures, after a service bulletin modification. The quality escape led to an uncommanded feather incident in an aircraft in the United States due to a beta switch which stuck closed.
- Due to the quality escape, numerous PCU’s were recalled by the overhaul facility for rectification. The right PCU fitted to MCJ was identified as one of the units that may have been affected by the quality escape and would have been subject to recall had it still been in service.
- The FDR data indicated that the right PCU fitted to MCJ had an uncommanded feather, most likely due to a beta switch stuck in the closed position, induced by the propeller overspeed. It was not possible to confirm if the overhaul facility

quality escape issue contributed to the beta switch sticking closed, because the PCU was destroyed by the post-impact fire.

- The landing gear and flaps remained retracted during the off-field landing. This led to a higher landing speed than could have been achieved if the gear and flaps had been extended, and increased the impact forces on the airframe and its occupants.
- No DHC-8 emergency procedures or checklists were used by the flight crew after the emergency began.
- The left propeller was not feathered by the flight crew after the engine failed.
- The investigation identified several occurrences where a DHC-8 pilot inadvertently moved one or both power levers behind the flight idle gate in flight, leading to a loss of propeller speed control. Collectively, those events indicated a systemic design issue with the integration of the propeller control system and the aircraft.

Other key findings

- The flaps and landing gear were available for use after the propeller overspeeds and the engine damage had occurred.
- There was no regulatory requirement to fit the beta lockout system to any DHC-8 aircraft outside the USA at the time of the accident.
- The autopilot could not be used during the accident flight.
- The operator’s checking and training system did not require the flight crew to have demonstrated the propeller overspeed emergency procedure in the simulator.
- After the accident, the aircraft manufacturer identified a problem in the beta warning horn system that may have led to failures not being identified during regular and periodic tests of the system.

Safety issues

- A significant number of DHC-8-100, -200, and -300 series aircraft did not have a means of preventing movement – whether intentional or unintentional – of the power levers below the flight idle gate in flight, nor a means to prevent such movement resulting in a loss of propeller speed control.
- The aircraft manufacturer identified a problem in the beta warning horn system that left the system susceptible to failures that may not have been identified during regular and periodic tests of the system.
- After the accident, the facility that overhauled the propeller control unit (PCU) installed on MCJ (as the aircraft’s right hand PCU at the time of the accident) identified a quality escape relating to the use of incorrect reassembly procedures for the installation of the beta switch within the propeller control unit. The quality escape may have led to uncommanded fearing of the right propeller.

4 SAFETY ACTIONS

4.1 SAFETY ACTIONS

The following safety actions have been taken by the manufacturer, Transport Canada, the Civil Aviation Safety Authority PNG, the operator, and Pacific Propeller International in response to the accident involving P2-MCJ.

4.1.1 Bombardier Inc. and Transport Canada

Safety issue

A significant number of DHC-8-100, -200 and -300 series aircraft did not have a means of preventing movement – whether intentional or unintentional – of the power levers below the flight idle gate in flight, nor a means to prevent such movement resulting in a loss of propeller speed control.

On 19 June 2012 the manufacturer issued an All Operator Message, No. 994, which stated that

> Despite incorporation of the beta warning horn modification, incidents continue to occur in which the power levers are selected aft of the flight idle gate, into the beta range during flight. As a result, Transport Canada has indicated their intention to issue an Airworthiness Directive to mandate incorporation of a beta lockout modification for all aircraft that do not already have one installed. Bombardier has conducted an internal review of the existing engineering for the FAA approved installation and will be revising the engineering to cover all aircraft configurations in service and to introduce modification kits.

On 13 September 2012 the manufacturer issued Service Bulletin (SB) 8-11-115, which recommended the fitment of a warning placard in the cockpit that stated

> Positioning of the power levers below the flight idle stop during flight is prohibited. Such positioning may lead to loss of airplane control, or may result in an engine overspeed condition and consequent loss of engine power.

SB 8-11-115 was mandated by Transport Canada AD CF-2012-33 which stated

> Corrective action: within 400 flight hours or 60 days, whichever occurs first from the effective date of this AD.

On 5 June 2013 Transport Canada issued an AD CF-2013-15 “In-flight operation of propeller in Beta range” that stated

> There have been a number of reported incidents, where the flight crews have operated the propellers in Ground Beta range during flight on DHC-8-100/200/300 aeroplanes. In-flight Beta range operation of the propeller can and has resulted in over-speeding of the propeller(s). This condition not only can cause the associated engine to fail, but the high drag

> resulting from the over-speeding propeller can adversely affect the controllability of the aeroplane.
>
> Notwithstanding the fact that affected models of DHC-8 aeroplanes are equipped with a Beta warning (horn) system as mandated by Transport Canada AD CF-99-18, to alert the flight crew of impending Ground Beta range operation during flight, the existing system design does not prevent propeller operation in Beta range during flight.
>
> In order to prevent the operation of propellers in Ground Beta range during flight on the affected aeroplanes, Bombardier Inc. has issued Service Bulletin (SB) 8-76-35 to install new electrical circuits (Beta Lockout System) that are designed to prevent the propellers from entering the Beta range of operation during flight. This AD is issued to mandate compliance with SB 8-76-35 to install a Beta Lockout system on all affected aeroplanes.

SB 8-76-35 was mandated by Transport Canada AD CF-2013-15 for fitment within 6,000 hours air time or 3 years, whichever occurred first, from 19 June 2013 (the effective date of AD CF-2013-15).

Safety issue

The aircraft manufacturer identified a problem in the beta warning horn system that left the system susceptible to failures that may not have been identified during regular and periodic tests.

On 5 January 2012, Transport Canada issued an AD CF-2012-01 “Beta Warning Horn System Failure” that stated:

> Recently, on a DHC-8 Series 200 aeroplane, the Beta Warning Horn (Mod 8/2852) was found to be inoperative with the power levers positioned below FLIGHT IDLE. The cause of the malfunction was determined to be the Beta Warning micro-switch gap exceeding the adjustment tolerances. The investigation indicated that the operational test of the Beta Warning Horn system as per the existing Aircraft Maintenance Manual (AMM) procedures and the frequency of the related Certification Maintenance Requirements (CMR) task may not effectively identify the subject dormant failure.
>
> Considering that the subject Beta Warning Horn system installation was mandated by Airworthiness Directive (AD) CF-99-18 to provide an additional means of warning the flight crew against the inadvertent selection of ground Beta and to deter the unlikely intentional movement of the power lever aft of the flight idle gate during flight, any malfunction or non availability of the subject Beta Warning Horn in flight can potentially result in an unsafe condition.
>
> In order to help mitigate this potentially unsafe condition, Bombardier has issued Alert Service Bulletin (SB) A8-31-29 Rev. “B”, requiring an operational test of the Beta Warning System in accordance with the enhanced test procedures, as introduced through AMM Temporary revisions; TR31-010 (DHC-8 Series 100), TR31-015 (DHC-8 Series 200) and TR31-018 (DHC-8 Series 300). This AD is issued to mandate compliance with the Bombardier Alert SB A8-31-29 Rev. “A” requirements and the requirement

> for a repetitive Operational Test of the Beta Warning Horn system on the affected aeroplanes.

AD CF-2012-01 was effective from 16 January 2012 and Transport Canada mandated that within 50 hours air time or 10 days, whichever came first, operators should

> 1. ... perform an operational test of the Beta Warning Horn system and complete all required actions including the operational test findings, in accordance with the Bombardier SB Number A8-31-29 Rev. “B” dated 22 December 2011 ...
>
> 2. From the date of compliance with Part 1 above, repeat the operational test of the Beta Warning Horn system at intervals not to exceed 50 air time hours, in accordance with Bombardier SB A8-31-29 Rev. “B” ...

To address the root cause of the Beta Warning Horn micro switch failure, in March 2013 Transport Canada revised AD CF-2012-01R1 for compliance with SB 8-76-33 to replace the Beta Horn microswitch bracket within 6,000 hours or 36 months, whichever occurs first. Compliance with AD CF-2012-01R1 negates the repeat operational test requirements per the original issue of AD CF-2012-01 and is therefore a terminating action for the requirements of AD CF-2012-01.

4.1.2 Civil Aviation Safety Authority (CASA PNG)

On 13 October 2011, CASA PNG grounded the operator’s DHC-8 fleet for up to 10 days.

Safety issue

A significant number of DHC-8-100, -200, and -300 series aircraft did not have a means of preventing movement – whether intentional or unintentional – of the power levers below the flight idle gate in flight, nor a means to prevent such movement resulting in a loss of propeller speed control.

Safety issue

The aircraft manufacturer identified a problem in the beta warning horn system that left the system susceptible to failures that may not have been identified during regular and periodic tests.

On 4 November 2011, CASA PNG issued the following Airworthiness Directive.

> **PNG AD/DHC8/22: In-flight selection of ground beta – inspection/protection**
>
> **Issue 2 (a): 04/11/11**
>
> **Applicability:**
>
> (a) Applies to Bombardier Inc. (formerly de Havilland) DHC-8 Series 100, 200 and 300 aircraft, certificated in any category, except those aircraft incorporating the FAA Beta lock-out system per the latest revision of FAA AD 2005-13-35.

The operation of existing DHC-8 Series 100, 200 and 300 aircraft power levers requires a separate and distinct operation (pulling a trigger mechanism and overcoming the flight idle detent position) to prevent the unintentional operation of the power levers aft of the flight idle position. In addition, the DHC-8 Flight Manuals prohibit in-flight operation of the power levers aft of the flight idle position and clearly state[s] “Selecting the power levers below flight idle, while in flight, will cause propeller overspeed, possible engine failure and may result in loss of aircraft control.”

To provide an additional means of warning and deterring the flight crew against the unintentional operation of the power levers aft of the flight idle position, a beta warning horn installation per Bombardier (de Havilland) Service Bulletins (SB) 8-34-126, 8-76-15, 8-76-17/8-76-18 were mandated by Transport Canada Airworthiness Directive CF-99-18. If a flight idle trigger is raised while either power lever is at any position on the quadrant and the aircraft is above 20 feet, the warning horn will sound.

This AD requires revisions to certain Operator maintenance documentation to mandate several Bombardier (de Havilland) “optional” maintenance inspections. Several amendments to [the] Minimum Equipment List (MEL) are included.

This AD also requires all Operators to install a system that will prevent the selection of Beta range during flight.

Requirement:

(b) Before further flight and at intervals not exceeding 50 hours thereafter, accomplish the following in accordance with Bombardier (de Havilland) maintenance requirements document reference PSM 1-8-7 TC revision 19 or later Transport Canada approved revision:

1. An operational check of the beta warning horn.

2. An operational check of the beta-backup system.

3. An operational check of the propeller overspeed governors.

4. Install placard in a prominent location on the instrument panel of the cockpit that states:

“Positioning of the power levers below flight idle stop during flight is prohibited. Such action may lead to loss of aircraft control, or may result in an engine overspeed condition and consequent loss of engine power.”

(c) Within seven (7) days of the effective date of this AD – amend the DHC-8 Minimum Equipment List (MEL) in accordance with the requirements of this AD listed in the following table:

System affected	MMEL reference	MMEL category	Action required
AFCS Autopilot functions	22-1	C	Change to category A.
	22-1	C	(M) May be inoperative for two (2) flight sectors only, provided weather minimums or operating procedures are not dependent on its use.
	22-1	C	(M) Aircraft must not depart an airport where repairs or replacements can be accomplished.
Radio Altimeter System	34-2	A	Remove from MEL
Reverse Beta Warning Horn System	61-4	A	Remove from MEL

> (d) Within 120 days after 5 November 2011, install a system that will prevent the selection of Beta range during flight, in accordance with the latest revision of FAA AD 2005-13-35. Following accomplishment of that installation, all the requirements of paragraph (b) and (c) of this AD may be removed.
>
> **Compliance:**
>
> You are responsible for having the actions required by this AD performed within the compliance times specified, unless the actions have already been accomplished.
>
> **This AD is effective from 04 November 2011.**
>
> **Note:** This AD is based on the latest approved revision of FAA AD 2005-13-35.

On 4 April 2012, CASA PNG promulgated Issue 3 of PNG AD/DHC8/22, in which section (d) was amended from Issue (above) 2 to read

> (d) Within 120 days after 05 November, 2011, Operators are required to install the FAA Beta Lockout System (BLS) as per Bombardier (de Havilland) SB 8-76-24 (CR873CH00011). Following the accomplishment of this installation, the aircraft would be fully compliant with this AD and all the requirements of paragraphs (b) and (c) of this AD may be removed.
>
> **Compliance:**
>
> Operators are responsible for having the actions required by this AD performed within the compliance times specified, unless the actions have already been accomplished.

This AD is effective from 04 November 2011.

All DHC-8 aircraft registered in Papua New Guinea affected by AD/DHC8/22 are now compliant with the requirements of the AD.

On 24 October 2012, CASA PNG began a Special Purpose Audit of the operator leading to organisational restructuring and procedural changes to its Flight Operations, Maintenance, and Safety and Quality Management departments.

4.1.3 The operator, Airlines PNG

Between 16 and 21 October 2011, the operator, Airlines PNG, took the following safety actions.

Flight operations

Flight Standing Order (05/11) was issued amending flight crew Standard Operating Procedures as follows.

- Airspeed and power control. A maximum IAS of V_{MO} minus 30 knots shall apply on descent.
- Prior to descent, condition levers shall be set to 1,050 RPM and torque shall be set at 10 % until finals.
- One ignitor is to be on at all times until within the circuit area.
- Operation of power levers: the hand is to remain flat over the power levers and the fingers must not be near the flight idle release gate triggers when retarding the power levers.

All flight crew were given a briefing on propeller overspeed and the applicable Phase 1 memory items. The briefing also covered the propeller governing system, the company policy of maintaining positive torque on descent, and the beta warning horn system.

Flight Standing Order (06/11) was issued detailing new training procedures for all crew to be undertaken in the simulator covering propeller overspeed, propeller governor failure, and the applicable Phase 1 memory items.

Engineering

In accordance with CASA PNG AD/DHC8/22, a company Maintenance Alert was issued including the following checks to be undertaken on each company DHC-8 aircraft before it was returned to service.

- Beta warning horn check
- Operational check of the beta backup system
- Operational check of the overspeed governor

The Maintenance Alert included the following additional checks.

- Flight idle gate functional check
- Detailed visual inspection of the propeller
- Propeller oil level check
- Operational check of the propeller auxiliary feathering pump

In accordance with CASA PNG AD/DHC8/22, a placard was placed in the cockpit of all company DHC-8 aircraft which stated the following.

> “Warning | positioning the power levers below the flight idle stop during flight is prohibited. Such positioning may lead to loss of airplane control, or may result in an engine overspeed condition and consequent loss of engine power.”

Cockpit placard installed in the operator’s DHC-8 aircraft

On 24 October 2011 the operator ordered Service Bulletin (SB) kits (SB8-76-24) for all its DHC-8 aircraft. However, the requirement by CASA PNG for the beta lockout mechanism to be fitted within 120 days of 5 November 2011 could not be met due to supply constraints from the sole supplier of the N_P indicators needed for the modification. All operators of DHC-8 aircraft in PNG were forced to apply to CASA PNG for an extension to the AD compliance date. This was granted, with a requirement for the operators to inform CASA PNG of the SB kit delivery dates and the installation schedule. The operator of MCJ had installed the SB-8-76-24 kit on all its DHC-8 aircraft by 7 November 2012.

Maintenance planning

The operator modified its DHC-8 maintenance program to reduce the interval between the beta warning horn check and the beta backup system operational check from 500 hours (every A check) to 50 hours (every line check).

Minimum Equipment List (MEL)

The operator modified its DHC-8 Minimum Equipment List (MEL) in accordance with CASA PNG AD/DHC8/22 as follows.

System affected	MMEL reference	MMEL category	Action required	Action taken

AFCS Autopilot functions	22-1	C	Change to category A.	Changed to category A
	22-1	C	(M) May be inoperative for two (2) flight sectors only, provided weather minimums or operating procedures are not dependent on its use.	(M) b. May be inoperative for two (2) non-revenue sectors in VMC to bring aircraft to a Maintenance Base.
	22-1	C	(M) Aircraft must not depart an airport where repairs or replacements can be accomplished.	(M) c. Aircraft must not depart an airport where repairs or replacements can be accomplished
Radio Altimeter System	34-2	A	Remove from MEL	Removed from MEL
Reverse Beta Warning Horn System	61-4	A	Remove from MEL	Removed from MEL

After the SB8-76-24 beta lockout kits were installed on company aircraft, the operator amended its DHC-8 MEL to permit operation with the autopilot inoperative provided the standby elevator trim system operated normally and weather minimums were not dependent on use of the autopilot.

Return to service

On 28 October 2011, with the approval of CASA PNG, the operator re-commenced DHC-8 services on a reduced schedule for the first three weeks to minimise stress on the organisation. An operational return-to-service risk assessment was undertaken to ensure that all risks were identified and treated prior to restarting regular passenger transport (RPT) operations on the DHC-8 fleet.

4.1.4 The propeller control unit (PCU) overhaul facility, Pacific Propeller International, LLC

Safety issue

After the accident, the facility that overhauled the propeller control unit (PCU) installed on MCJ (as the aircraft's right hand PCU at the time of the accident) identified a quality escape relating to the use of incorrect reassembly procedures for the installation of the beta switch within the propeller control unit. The quality escape may lead to uncommanded fearing of the right propeller.

On 26 September 2013 the overhaul facility issued a recall notice for all propeller control units overhauled at its facility between September 2010 and September 2013.

On 10 October 2013 the Federal Aviation Administration (FAA) released a safety alert for operators (SAFO 13009) recommending the affected units be removed from service and sent to the overhaul facility for rectification.

On March 25, 2014 the overhaul facility extended the recall to all units overhauled between June 4 2001 and September 26, 2013.

At the time of writing this report the Federal Aviation Administration was in the process of amending the SAFO to include the extended recall of the affected PCU's.

5 APPENDICES

5.1 RELATED OCCURRENCES IN DHC-8 AIRCRAFT

The following information is reproduced with permission from the Australian Transport Safety Bureau (ATSB) report AO-2011-159.

1 April 1996, DHC-8-100, Canada

During descent at 245 knots indicated airspeed, both propellers simultaneously exceeded their maximum speed by more than 25 %. The overspeed condition resulted in the failure of the right engine power turbine section. It is believed that one of the pilots moved both power levers below the flight idle gate in flight during turbulence.

28 May 1996, DHC-8-300, Canada

The pilot reported that on descent he pulled the power levers into ground beta range and the propellers simultaneously exceeded their maximum RPM. Immediate reselection of the power levers above flight idle resulted in the propellers returning to the governing range.

21 February 2006, DHC-8-103, Norway

The Accident Investigation Board Norway (AIBN) concluded that the Pilot-in-Command inadvertently moved both power levers below the flight idle gate in flight during severe turbulence. There was a double propeller overspeed and subsequently one engine failed[18].

In February 2007, the AIBN issued an interim safety recommendation to the aircraft manufacturer that stated that ‘All [DHC-8] models that can be reversed unintentionally during pull back of power levers should be modified in such a manner that dangerous inadvertent airborne reversing is unlikely to happen…’. The aircraft manufacturer and Transport Canada did not adopt the recommendation. The manufacturer advised that they had ‘thoroughly reviewed the existing power lever flight idle gate design and find that inadvertent airborne reversing is unlikely to occur…’.

The AIBN released its final report in June 2012 and issued the following recommendation.

> The Accident Investigation Board Norway recommends that Transport Canada and EASA require the type certificate holder (Bombardier) to introduce measures to prevent propeller overspeed during unintended management of Power Levers.

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[18] The AIBN report is available at www.aibn.no/Aviation/Reports/2012-05-eng

7 October 2008, DHC-8-101, Chad

During descent, the aircraft exceeded its maximum airspeed, which was followed immediately by a right propeller overspeed and in-flight engine shutdown. The aircraft manufacturer advised that this event was likely to have been as a result of the crew moving the power levers below the flight idle gate in flight.

10 March 2010, DHC-8-400, Australia

During descent, the pilot flying noticed the aircraft speed increasing and he reduced power. That did not have the desired effect, so he disengaged the autopilot and pitched the nose of the aircraft up. He subsequently re-engaged the autopilot after which the nose pitched down and the speed increased rapidly. The pilot again disengaged the autopilot and ‘grabbed the power levers to reduce power’. As he did so, he inadvertently lifted the flight idle gate release triggers and moved the power levers into the ground beta range. He immediately realised what had occurred and advanced the power levers forward of the flight idle gate. There was no damage to the engines.

2 November 2011, DHC-8-100, Australia

The crew reported that while on the downwind leg in the circuit prior to landing, the Master Caution Light illuminated together with the No.1 and No. 2 ENG MANUAL caution lights, indicating that the engine electronic control units (ECUs) had reverted to manual control. According to the manufacturer, there is a latched ‘tell-tale’ that reverts the engine controls to manual, with associated caution lights, which can only be reset on the ground. This event required the circuit breaker to be reset before the ECUs would operate normally again, indicating that the flight idle gate release triggers had been lifted in flight and the power levers had been moved behind the flight idle gate. The operator’s investigation determined that the pilot flying may have inadvertently and momentarily lifted the triggers during turbulence.

A post-incident engineering inspection revealed that the beta warning horn was unserviceable at the time of the event. The aircraft was previously registered in the USA where a beta lockout system was fitted.

5.2 PROPELLER OVERSPEED OCCURRENCES INVOLVING OTHER TURBOPROPELLER AIRCRAFT TYPES

The following is reproduced with permission from the Australian Transport Safety Bureau (ATSB) report AO-2011-159.

Empresa Brasileira de Aeronáutica S.A. EMB-120

The EMB-120 is a twin turbopropeller aircraft with the same type of engine and propeller system as the DHC-8. The EMB-120 aircraft type had seven propeller overspeed events up to 1989 that were related to the inadvertent or intentional movement of the power levers below flight idle during flight.

The manufacturer designed a flight idle lockout solenoid in 1990 to prevent propeller overspeed. The lockout solenoid was a mechanical means of preventing the selection of the ground beta range in flight. The modification was mandated by US Federal Aviation Administration (FAA) airworthiness directive (AD) 9017-12 and the modifications were applied to aircraft in other countries.

Since the installation of the lockout solenoid there has been only one reported propeller overspeed event that related to selection of the ground beta range in flight. In that occurrence (in 1992) the flight idle lockout system malfunctioned.

Fokker F27 MK 50 (Fokker 50)

The Fokker 50 is a twin turboprop aircraft with the same type of engine as the DHC-8 but a different propeller system. The engine and propeller system operated in a similar manner to the DHC-8 when the power levers were moved behind the flight idle gate in flight.

The Fokker 50 has a device that prevents the movement of the power levers below flight idle in flight. However, on two occasions this flight idle lockout system malfunctioned, causing accidents with multiple fatalities. Following the second accident in February 2004, the flight idle lockout system was modified and no further incidents or accidents have been reported.

Construcciones Aeronáuticas SA (CASA) C-212

The C-212 is a twin turboprop aircraft with a different engine and propeller system to that of the DHC-8. However, the engine and propeller system operated in a similar manner to the DHC-8 when the power levers were moved behind the flight idle gate during flight.

Initially, the C-212 did not have a system to prevent the power levers being moved below the flight idle gate in flight. Following an accident in 1987, the manufacturer designed and installed a mechanical lockout to prevent such events and the lockout was mandated by the FAA in AD 91-03-10.

A second accident occurred in 1992 when the mechanical lockout malfunctioned. Following that accident, the manufacturer introduced a requirement to functionally check the lockout system at regular intervals. No further occurrences have been reported.

S.A.A.B. Aircraft Corporation 340 (Saab 340)

The Saab 340 is a twin turboprop aircraft with a different engine and propeller system to the DHC-8; however, the engine and propeller system operated in a similar manner to that of the DHC-8 when the power levers were moved below flight idle in flight.

In 1994, there was an accident involving a Saab 340 in which intentional movement of the power levers below the flight idle gate in flight lead to a double propeller overspeed. The US National Transportation Safety Board (NTSB) report AAR-94-04 stated:

> …several serious incidents and accidents have occurred in the past that involved turbopropeller airplanes in which the propellers were moved into the beta range in flight. The causes of these occurrences involved several factors. In some cases, wear and poor maintenance of the triggers and flight idle stops allowed inadvertent movement of the power levers into beta. In other cases, intentional movement of the power levers into beta was involved. Lastly, there have been cases of inadvertent movement of the power levers into beta with a properly maintained and certified system.

Following this accident, the manufacturer designed a mechanical means of preventing the movement of the power levers below the flight idle position in flight. The installation was mandated in the USA by FAA AD 96-18-03 and the modifications were applied to aircraft in other countries. No other Saab 340 accidents relating to the selection of ground beta in flight have been reported since the modification.

5.3 PNG CIVIL AVIATION REGULATION (CAR) PART 61.37 RECENT FLIGHT EXPERIENCE

61.37 Recent flight experience

(a) **Airline transport pilot:** A person who holds an airline transport pilot licence must not act as pilot-in-command of an aircraft on an air operation that requires the pilot-in-command to hold an airline transport pilot licence unless, within the immediately preceding 90 days, –

(1) the person has carried out (as pilot-in-command of an aircraft or an approved synthetic flight trainer of the same type) not less than 3 take-offs and 3 landings; or

(2) the person has satisfactorily demonstrated to an appropriately authorised flight examiner continued competency in an aircraft of the same type; or

(3) the person has demonstrated to an appropriately qualified flight instructor competence in take-off and landing manoeuvres during the day in an aircraft of the same type; but

(4) one of the landings required by subparagraph (1) or (3) may be a monitored landing using the automatic landing facility of the autopilot.

5.4 OPERATOR’S MANUALS

Sections from the operator’s Policy and Procedures Manual relevant to the investigation are reproduced below.

> **5.17 Recency requirements**
>
> While the Operations Control has access to all required crew records, it remains the responsibility of crew members to ensure they are appropriately licensed and rated and meet all recency requirements for the duration of all flights undertaken.
>
> The recency requirements are specified in CAR Part 61.33 and these are summarised hereunder:
>
> Pilot in Command and First Officer
>
> - Successful completion of a flight proficiency test (including instrument proficiency) within the preceding 12 months. A Company Check Captain shall certify successful completion of the test in the pilot's log book.
> - Within the preceding 90 days, not less than 3 take-offs and 3 landings. The takeoffs and landings may also be accomplished in a zero flight time simulator of the same type as the aircraft. The successful completion of a proficiency test conducted by a Company Check Captain may be substituted for the foregoing take-off and landing recency.
> - Completed not less than 3 hours instrument time, of which at least 1 hour was instrument flight time or instrument time in a zero flight time simulator of the same aircraft type. The successful completion of an instrument rating proficiency test conducted by a Company Check Captain may be substituted for the 3 hours instrument time.
>
> **5.20 Compliance with the Company Exposition, the Operations Manual and Company Documents/Instructions**
>
> Staff compliance with the requirements of the Company Exposition Operations Manual and other documents and/or instructions is mandatory.
>
> Staff must ensure they are thoroughly familiar with the aspects of Company documentation applicable to their work activities.
>
> Ignorance of these requirements is no excuse and disciplinary action will result in the event of an unjustifiable breach.
>
> Failure to operate in compliance with the Company Exposition constitutes a contravention of CAR Part 119.101(2).
>
> **5.24 Precedence of the Aircraft Flight Manual**
>
> The Aircraft Flight Manual is an integral part of the Certificate of Airworthiness of the aircraft.
>
> The Pilot in Command is required by Part 91.109 to comply with requirements, instructions, procedures or limitations concerning the operation of the aircraft as set out in the Aircraft Flight Manual.
>
> In the unlikely event that the requirements of the Aircraft Flight Manual

conflict with the requirements of the Company Operations Manual, the requirements of the Aircraft Flight Manual shall take precedence, unless the Company has received Notice of no Technical Objection (or the equivalent) from the manufacturer.

7.2 Crew structure

The operation of an aircraft, like other machinery, involves the physical skills required to manipulate the aircraft and the knowledge to enable it to be operated safely and efficiently. The combination of two or more skilled persons as a crew, therefore, provides a pool of resources to operate the aircraft at a high level of safety and efficiency during all phases of operation. The effectiveness of the crew, or resource team, is dependent upon the manner in which they combine to operate together. The crew can only operate at peak efficiency if their thought process and physical activities are coordinated. The aim of this section is to specify those standard procedures which will maximise coordination and, therefore, efficiency and safety.

The coordinated crew procedures applicable to pilots are structured around the Pilot Flying (PF) and the Pilot Monitoring (PM) philosophy. This enhances the training benefit for First Officers by enabling them to gain considerable experience whilst operating aircraft as PF. The Pilot in Command always retains command of the aircraft. The First Officer will, however, have a large say in the operation of the aircraft. First Officers are expected to actively participate in the conduct of each and every flight.

Flight Attendants are also a vital, and integral part of the crew of the DHC 8 aircraft. The inclusion of the Flight Attendants as part of the resource team is essential for the safe, efficient and effective operation of the aircraft.

For the foregoing reasons, it is imperative that all crew members achieve and maintain a high standard of professional knowledge.

7.2 Sharing of pilot duties

The general concept of coordinated flight crew procedures is that the PF will fly the aircraft and coordinate the operation of the aircraft. The PM will monitor the flying and support the PF by carrying out the other activities associated with the operation, at the direction of the PF. At the direction of the PF, the activities of the PM would include :

- Radio communication
- Operation of ancillary controls and systems, eg, landing gear, flaps, pressurization
- Tuning and identification of radios and navigation aids
- Calling of checklists, and
- Administration functions

7.16 Checklists

Company aircraft are to be operated in accordance with the approved checklists at all phases of aircraft operation. Normal and emergency procedures checklists are in the aircraft QRH located in the cockpit of each aircraft. Those sections of the emergency procedures check lists highlighted by ruled borders, known as Phase One Checks, are to be committed to memory.

Checklists will be initiated at the direction of the PF. If the PM believes that a checklist has been overlooked the PM shall prompt the PF seeking a clarification of his/her requirements. Such prompting is required for any situation whether training, line operations or check flights.

After any checklist is completed, the PM should state " ------- checklist complete". This closes the loop after any checklist is initiated and maintains situational awareness during checklist phases.

If the checklist is interrupted at any time the PM should make a statement eg "Checklist interrupted”. The checklist is consequently required to be restarted from the beginning.

The checklist is exactly what it says, ie., a list against which to check that certain functions have been conducted. In other words, it is quite appropriate to conduct the action required in advance of conducting the checklist, then using the checklist to ensure that it is all done.

With the exception of an abnormal, before landing or before take-off checklist, it is NOT appropriate to commence a checklist phase unless it is intended to finish that phase without break.

The following terms and meanings are applicable to checklist usage:

- "Checked" - a system has been checked and is serviceable and within limitations.

- "Set" - where the setting of a control, switch, etc is optional and is set as required for the circumstance/condition.

Where a switch, control, etc., is required to be in a specific position, that position shall be the response to the checklist call related to that switch, control etc.

The challenge response technique involves the coordinated actioning of a checklist by two or more crew members. One pilot calls the checklist challenge (CHALLENGING pilot) and the OTHER pilot responds (RESPONDING pilot), except that some items require a response from BOTH pilots.

When actioning a checklist, the following procedures apply.

Challenging Pilot

- Is the pilot monitoring

- Calls the challenge

- Confirms that the correct response is given by the RESPONDING pilot

- Confirms that the item has been correctly actioned

- Responds ONLY to a checklist item requiring a response by both pilots

- ONLY then moves to and calls the next checklist challenge.

Responding Pilot

- Is the pilot flying (or taxiing) the aircraft

- Checks that the item has been correctly actioned

- Responds to the challenge.

NOTE : The challenging pilot is required to recall the challenge if an incorrect response is given to a checklist item.

A useful way to enhance the effectiveness of challenge and response is to **SAY, LOOK** and **TOUCH.**

Saying each item out aloud stimulates the sense of hearing and helps focus attention.

Looking at each item to be checked helps ensure that variation between the checklist instruction and the control position or instrument reading will be apparent.

Touching further focuses attention by involving yet another of the senses. The responding pilot should touch the item whether or not he/she is operating the item and then give the proper response.

10.5 Emergency phraseology

In the event of an emergency, standard emergency phraseology must be used. This is very important as it draws the attention of ATC and other aircraft to the problem and facilitates assistance. Procedures and phraseology are outlined in the Jeppesen Airway Manual, Emergency and the AIP.

12.1 [Emergencies] General

An emergency is an occasion when the aircraft and its crew and passengers are subject to grave and imminent danger.

An abnormal situation is an occasion in which the aircraft cannot be operated in the normal manner.

Information concerning communication procedures during an emergency is outlined at Section 10, "Communications", of this Manual.

Following any emergency or abnormal situation, the Pilot in Command may consider commercial and engineering aspects only if he/she is satisfied all safety requirements have been met.

Emergency and abnormal procedures shall be followed in the order set out in the applicable Flight Crew Operating Manual unless there is a sound and justifiable reason for the Pilot in Command to vary the procedure.

Emergency procedures shall not be initiated without the approval or direction of the Pilot in Command. If the Pilot in Command is absent from the flight deck, or incapacitated, the First Officer has the responsibility for initiating emergency procedures.

- All abnormal/emergency checklists and briefings shall be completed before starting an approach.

- Simulation of an engine fire by the use of the fire test circuit is not permitted during normal revenue operations.

12.6 Assignment of Duties during an Emergency

During an emergency, all duties shall be performed as outlined in the type Flight Crew Operating Manual, and/or the Flight Attendant Manual, as appropriate.

12.10 Use of Emergency / Abnormal Checklist (QRH)

The aircraft Emergency/Abnormal Checklist or Quick Reference Handbook (QRH) shall be used during the actioning of any emergency or abnormal occurrence.

12.11 Action of Emergency / Abnormal Checklist (QRH)

To enable the pilot flying the aircraft to concentrate on this critical task during an emergency or abnormal occurrence, the procedure for actioning Emergency/Abnormal Checklists involves a different technique to that used with normal checklists.

Phase One Checks are critical memory recall items, which shall be actioned in the following manner:

- The PF will direct the PM to action the applicable checklist

- The PM will call each checklist item and response

Where an engine control or switch is involved, the PM will place his/her hand on the applicable control or switch.

- The PF will confirm the correct selection of an engine or switch by the PNF and then call "CONFIRMED".

- The PNF will ACTION the checklist item.

WARNING : No engine control or switch may be moved in accordance with the specified action UNTIL the correct selection of that control or switch has been confirmed by the PF.

NOTE : Some Phase One checklist items require action by the PF, or both pilots. This includes the actioning of switches, etc., which are not readily accessible to the PM. These checklist items must be actioned in an appropriate manner.

Reconfirming Phase One Checks

At the appropriate time after actioning Phase One Checks, the Phase One Checks will be reconfirmed and the Phase Two Checks will be actioned. The procedure is:

- PM shall, at the appropriate time, access the Emergency/Abnormal Checklist (QRH)

- The PM will call each Phase One check AND response

- The PF will check the Phase One check has been correctly actioned and call "CONFIRMED"

- The PM, when satisfied the checklist item has been correctly actioned AND responded to by the PF, will call the next checklist item and response.

Actioning of Phase Two / Abnormal Checklist Items

- The actioning of Phase Two or Abnormal Checklist items is not time critical.

- These checklists should be reviewed by the PM before actioning, with particular attention paid to any notes, cautions or warnings.

- The Phase Two/Abnormal Checklist should be actioned, item by item, by the PM.

This involves :

– PM Calling the checklist item and response

– PM Actioning the checklist item, after confirmation from PF

NOTE : Some checklist items may need to be ACTIONED by the PF due to the location of the switch/control etc. In this instance the PF will action the item, then respond.

12.12 Flight Path Control During Emergency/Abnormal Situation

It is a normal reaction, whenever an abnormality develops during flight, pilots will concentrate on the reason for the abnormality and the subsequent corrective action. It is ABSOLUTELY ESSENTIAL, however, that one pilot continues to monitor the aircraft flight path.

Whenever an emergency or abnormal situation develops, the Pilot in Command shall identify who is to fly the aircraft during the actioning of the emergency/abnormal checks. The phrase "YOU FLY THE AIRCRAFT" or "I WILL FLY THE AIRCRAFT" shall be used.

The Pilot made responsible for flying the aircraft will ensure the aircraft is correctly navigated with particular attention paid to the maintenance of terrain clearance and separation from other aircraft.

Unless fuel critical, an instrument approach shall not be commenced until completion of the required checklist items.

If the approach has already started and an emergency or abnormal situation occurs requiring completion of checklist items, a go-around shall be initiated by 500 ft AAL unless fuel critical.

Pilots must maintain a positive awareness of the fuel status and endurance at all times.

If any pilot becomes uncertain of the situation of the aircraft or any confusion is experienced within the flight deck about the configuration, altitude, position or track of the aircraft or any other matter, the Pilot in Command shall immediately act to resolve the discrepancy, remove the confusion and restore the aircraft to a safe and stable flight condition. This may involve making a missed approach or other action as necessary.

The PF (as assigned above) shall:

– PRIMARILY Fly the aircraft

– SECONDARY Confirm checklist actions

It shall be the decision of the Pilot in Command as to who flies the aircraft in such circumstances. Bearing this in mind, the following Company guidance is given:

– When a problem arises at or above V1 during take-off, the preferred option is for the PF at the time of the occurrence to continue to fly the aircraft

– When a problem arises at other stages during a flight, the preferred option is for the First Officer to fly the aircraft whilst the Pilot in Command actions and manages the problem.

12.13 Identification and Confirmation of Failed Engine

Identification of a failed engine shall be primarily by at least 2 (two) engine "performance" gauges, et. Torque, ITT, N1, FF. The dead foot - dead engine principle may also be utilised to help identify the failed engine, although this method should not be solely relied upon as, under some circumstances, it can be misleading.

The PF shall identify the failed engine by these methods and it shall be confirmed by the PM.

The identification and confirmation of a failed engine shall be called as follows :

PF : "Engine failure - Engine failure No.1 confirm."

PM : "Engine failure No. 1 - confirmed."

The PF shall then call for the applicable Phase One Checks.

Hasty action shall be avoided and engine shutdown shall only be initiated after the malfunctioning engine is positively identified and confirmed.

12.26 In Flight Fire or Smoke - Cabin

In the event of smoke or fire in the cabin, the flight deck door, if fitted, shall be kept closed to minimise smoke intrusion to the flight deck.

The Flight Attendant shall communicate with the flight deck via the interphone in order to keep the flight deck door closed.

If flames are evident, the total contents of a BCF or Halon fire extinguisher shall be discharged and followed up, if necessary, with an H2O fire extinguisher.

Passenger oxygen masks should not be deployed when there is smoke in the passenger cabin unless the cabin altitude is above 14,000 ft.

12.34 Emergency Landings

The selection of an aerodrome for landing under emergency conditions may depend to a large degree on the level of urgency to commit the aircraft to a landing.

If the level of urgency dictates a more immediate emergency landing, an aerodrome not normally suitable may be considered provided it is deemed "acceptable" by the Pilot in Command. In this context an acceptable aerodrome is one on which the Pilot in Command considers a safe landing can be made.

When the level of urgency permits, the Pilot in Command shall give preference to conducting an emergency landing at an aerodrome which provides the most suitable emergency services.

When possible, the Pilot in Command shall conduct the approach and landing when operating under abnormal or emergency conditions.

If circumstances permit, all Emergency/Abnormal Checklists and briefing should be completed prior to commencement of the approach to land.

Sections from the DHC-8 Flight Crew Operating manual (FCOM) relevant to the occurrence involving MCJ are reproduced below.

CHAPTER 3 LIMITATIONS

3.5.1 Airspeed limitations

The airspeed limitations and associated definitions are as follows:

			KNOTS
1	Maximum Operating Speed (V_{MO}) This speed limit must not be deliberately exceeded in any regime of flight (climb cruise or descent) unless a higher speed is authorised for flight test or pilot training.	0 to 14000 ft	242

CHAPTER 5 ABNORMAL PROCEDURES

5.14 LANDING ABNORMALS

In a prepared abnormal landing, whether on land or water, the Flight Attendant will be responsible for preparation of the cabin.

Categories of Abnormal Landings

Landings performed due to an abnormal situation are categorized for the purpose of crew co-ordination. These categories do not vary Flight Manual procedures in any way but are to have relevance for the actions carried out by the Flight Attendant. The Flight Attendant is to be advised if a landing is to be carried out in one of the following categories:

a. **Ditching** A forced landing on water.

b. **Abnormal Landing** A landing at an airport when it is known, or considered possible, that the aircraft will be damaged when landing on a runway or surface approved or considered suitable for landing.

c. **Forced Landing** A landing made on any unprepared area away from an airport.

5.14.1.18 FORCED LANDING WITH BOTH ENGINES INOPERATIVE

After all attempts to achieve a successful airstart have failed, proceed as follows:

1. EGPWS CB-B3 Pulled
2. FLAP selector lever - 0º if possible
3. Airspeed – 1.3 Vs appropriate to weight and flap angle.

NOTE

With 0º flap, propellers feathered and landing gear retracted, under zero wind conditions, 2.5 nautical miles can be travel[led] for every 1000 ft of altitude lost. This distance will increase in a tailwind and decrease in a headwind.

4. CONDITION LEVERS – Off
5. ALTERNATE FEATHER – Feather (If required)
6. MAIN and AUX BATT switches – OFF
7. BATTERY MASTER switch – On

NOTE

The following services will be inoperative:

HYDRAULIC

Flap

Roll spoilers

Ground spoilers

Rudder

Anti-ski braking

Normal landing gear operation

Nosewheel steering

PNEUMATIC

Airframe de-icing

Pressurization

ELECTRIC

All variable frequency ac services

All non-essential dc services

see “Battery Essential Services” section for remaining essential services

8. PASSENGER SIGNS – On
9. EMERGENCY LIGHTS – On
10. ELT – On
11. SHOULDER HARNESSES – Lock
12. Flight Attendants and passengers – Advise of impending force[d] landing.

If the surface is appropriate

13. Landing gear – Extend by use of alternate extension procedure.

NOTE

1. Extending the landing gear will steepen the glide angle and decrease the horizontal glide distance.
2. Allow sufficient time for landing gear extension.

14. BATTERY MASTER switch – OFF prior to ground contact.

WARNING

Make the approach and landing into wind maintaining 1.3Vs until immediately prior into the flare. The flare should be commenced so as to achieve zero vertical velocity immediately prior to ground contact.

[9.] EMERG/PARK BRAKE lever – Operate after nosewheel contact, if appropriate.

[10.] Evacuate passengers and crew immediately after the aircraft has come to a halt.

NOTE

1. If the decision is made to land with the landing gear retracted, proceed as above, maintaining a nose up pitch attitude not exceeding 5º prior to ground contact to avoid a nose down slam on touchdown. Land into the wind if conditions permit.

[2.] If the above landing procedure is to be undertaken on a water surface, the landing gear must be left in the retracted position, and the aircraft should be brought into contact with the water as gradually as conditions permit while avoiding pitch attitudes in excess of 5º nose up.

CHAPTER 7 NORMAL PROCEDURES

7.17 Descent profiles

The subject of calculating descent profiles can be quite involved, and having said this should be kept as simple as possible, and will form a large portion of any Dash 8 line training and crew discussion. The following are just examples of the most common descent point calculations.

The normal descent profile is termed a ‘Three Times’ profile and this is based on the fact that the airplane will descend at Three miles horizontally for every thousand feet vertically, and the descent point is simply determined by multiplying the altitude by 3.

For example, if cruise altitude was 15 thousand feet, to determine the correct descent point, multiply 15 x 3 = 45 nm. The airplane should be descended at 1500 feet per minute, and just below V_{MO}. Adjustments to both power and rate of descent may be necessary to maintain the ‘profile’.

There will be many instances, where a standard 3 times profile is not acceptable, especially in situations of ‘steep’ DME or GPA arrival steps, or where an instrument approach is commenced at altitude, to allow for long outbound and inbound legs, airfield elevation, or in other instances, far too numerous to cover in this manual.

The other quite common profile, which is used in most cases to stay above steep arrival steps, is the ‘Two Times’ profile. The descent point is calculated by simply multiplying the cruise altitude by 2. Eg Altitude 15 thousand feet, multiply 15 x 2 = 30 nm. To maintain this profile, the airplane should be descended at 2000 feet per minute, with power and possibly ROD [rate of descent] adjustments as necessary.

Note

The altitude versus distance should be checked every thousand feet to avoid slipping under or over the correct profile, and adjustments will be made as required to maintain same.

8.4.3 Descent

No reduction in fuel flow shall be planned during descent. Normal descent procedure shall be type I high speed, unless turbulence dictates the use of type II, 180 intermediate speed procedure. Descent is normally made on a 3 x profile i.e. 3 x height = distance for top of descent. **Example** The distance on descent from 20,000 ft is = to 60 NM average speed on descent is = 270 kts. Rate of descent 1500 FPM.

For extended range purposes, based on descent from FL250 to 1000 ft, the designated speed is 230 kts.

Steeper descent profiles may be required due to terrain or DME/GPS arrival steps at some locations.

Note

With climb and descent profiles ‘distance’ is the track distance to be flown.

5.5 QUICK REFERENCE HANDBOOK EMERGENCY PROCEDURES

The operator stated that it used the manufacturer-recommended DHC-8 Quick reference Handbook (QRH) in its aircraft. The QRH emergency procedures relevant to the occurrence involving P2-MCJ are reproduced below.

- QRH Preface (page 1 only)
- Propeller overspeed
- Engine fail/fire/shutdown (in flight)
- Fuselage fire or smoke
- Emergency landing (both engines operating)
- Forced landing (both engines inoperative)

QRH PREFACE

PURPOSE

The Dash 8 Quick Reference Handbook (QRH) is designed to assist trained pilots to verify that the proper procedures have been carried out.

The QRH provides the flight crew with abbreviated information derived from the DOT Approved Airplane Flight Manual (AFM) to operate the airplane in most Normal and Non–normal/Emergency situations. It is the Operator's responsibility to ensure the checklists are applicable to their type of operation. In the event of an inconsistency between any checklist and the approved AFM, the AFM takes precedence.

Pilots must be aware that checklists cannot be created for all conceivable situations and are not intended to preclude good judgement. In some cases deviation from the checklists may, at the discretion of the Pilot–In–Command, be necessary. Under all circumstances, the first priority is to maintain safety of the airplane for the duration of the flight.

PRESENTATION

- Abbreviations do not have periods and are pluralized by an 's' in lower case (ECUs, RMIs, CBs).
- Revision bars located on the right hand margin of the page indicate changes incorporated in the latest revision.
- With some exceptions,only the most current modification status is reflected in the checks. (See Preface page iii for exceptions.)
  Operators are responsible for ensuring the checklists are applicable to the Mod status of their airplanes.
- With the exception of APU, TCAS and EFIS, options normally covered in AFM with Supplements are not addressed.

TERMINOLOGY

The following are terms unique to the QRH.

- Flap .... ___ set/ind
  This response is intended to include a particular ~~flap~~ setting.
- Altimeters .... set
  Set means check or set the pilot's, copilot's and standby altimeters.
- Bleed Air refers to the selector and the switch and will have a response such as: On / Max or On / Min.
- Bleed Selector refers only to the selector and will have a response of either Min or Max.

PROPELLER OVERSPEED

Above 400 ft AGL:

- Synchrophase . . . . Off
- Airspeed . . . . reduce toward minimum speed appropriate to flap configuration and flight conditions

Affected Engine:

- Power Lever . . . . Flight Idle
- Condition Lever . . . . Start/Feather
- Alternate Feather (if req'd) . . . . Fthr

IF propeller does not feather:

  – DO NOT SHUT DOWN ENGINE.
- Alternate Feather . . . . NORM
- Condition Levers . . . . MAX
- Power lever (affected engine) . . Advance. Do not exceed 1212 rpm
- Power lever (non affected engine) . . as required to maintain desired flight profile.
  – Land immediately at nearest suitable airport.

IF propeller feathers:

- ENGINE FAIL / FIRE / SHUTDOWN

(page 5.14) . . . . accomplish

***Note**: Power and Power levers will be asymmetric.*

ENGINE FAIL/ FIRE/ SHUTDOWN
(In Flight)

Affected Engine:

- Power Lever .... Flight Idle
- Condition Lever .... Fuel Off
- Alternate Feather (if req'd) .... Feather
- Pull Fuel Off Handle .... Pull
- Tank Aux Pump .... Off

IF Fire:

- Extg switch (affected engine) .... Fwd Btl
  - If Fire Persists, Wait Up To 30 seconds:
- Extg switch (affected engine) .... Aft Btl

Warning: *When Autofeather is selected off, uptrim power is cancelled.*

Caution: *Propeller will unfeather if Autofeather is selected off before condition lever is selected to Fuel Off.*

- Autofeather .... Off
- Power Levers .... operate together as req'd
- Ignition:
  Operating Engine .... Manual (Auto)
  Affected Engine .... Off
- Bleed Air:
  Operating Engine .... as req'd
  Affected Engine .... Off
- Synchrophase .... Off
- Stby Hyd Press 1 and 2 .... On
- Tank Aux Pump (Operating Engine) .... On

– Transfer fuel as required to maintain fuel balance

No. 1 Engine is inoperative:

Landing Considerations:

Landing Distance Factor:

Flap 15 .... 1.36
Flap 35 .... 1.31

---------- END ----------

No. 2 Engine is inoperative:

– Prior to selecting Landing Gear Down:

- Manual PTU .... On
- Landing Gear .... Down/ 3 Green
- Manual PTU .... Off

Landing Considerations:

Landing Distance Factor:

Flap 15 .... 1.36
Flap 35 .... 1.31

---------- END ----------

MOD 8/2781 ONLY

FUSELAGE FIRE or SMOKE

- Oxygen Masks .... On/100% Emer
- Smoke Goggles .... On
- Mic Switch .... Mask
- Recirc Fans .... Off
- Emergency Lights .... On

– Land immediately at the nearest suitable airport if it cannot be visibly verified that the fire has been extinguished following fire suppression.

Note: *To prepare for and manage an immediate landing, the procedures given in the Unknown Source of Fire or Smoke section may be terminated prior to completion.*

Known Source of Fire or Smoke is known:

Yes

Flight Compartment Fire or Smoke:

– Extinguish fire with portable fire extinguishers.
- Cabin Alt Man knob . ..... Fully clockwise (INCR)

IF necessary to assist in removal of smoke:
- Fwd Outflow Valve .... Open

– Descend to below 14,000 ft as soon as possible.

- END -

Cabin Fire or Smoke:

– Extinguish fire with portable fire extinguishers.

Note: *If a pilot is required to fight the fire, protective breathing equipment must be donned prior to exiting the flight compartment.*

- Baggage Compartment Door .... Open

IF necessary to assist in removal of smoke:
- Auto/Man/Dump .... Dump

– Descend to below 14,000 ft as soon as possible.

- END -

Baggage Compartment Fire or Smoke

- SMOKE (Page 7.3) .... accomplish

- END -

No

Unknown Source of Fire or Smoke:

CONTINUED ON NEXT PAGE

No **Unknown Source of Fire or Smoke:**

Bleed Source or Air Conditioning Suspected

◆ **Yes**

- Bleed Air 1 .... Off

Wait up to 1 minute.

Improvement:

◆ **Yes**

- Leave selected switch in Off position.

- END -

No

- Bleed Air 1 .... On
- Bleed Air 2 .... Off

Wait up to 1 minute.

Improvement:

◆ **Yes**

- Leave selected switch in Off position.

- END -

No

- Bleed Air 1 and 2 .... Off

Wait up to 1 minute.

Improvement:

◆ **Yes**

- Leave selected switch in Off position.
  - Descend to below 14,000 ft as soon as possible.

- END -

No

- Bleed Air 1 and 2 .... On

No **Source of Fire or Smoke cannot be Identified:**

CONTINUED ON NEXT PAGE

FUSELAGE FIRE or SMOKE (cont'd)

No **Source of Fire or Smoke cannot be Identified:**

- DC Gen 1 and 2 .... Off
- AC Gen 1 and 2 .... Off
- Storm/Dome Lights .... Storm (if req'd)
- Main, & Aux Batteries .... Off
- Emergency Lights .... On then Off
- Land immediately at the nearest suitable airport.

IF Emergency Lights req'd:

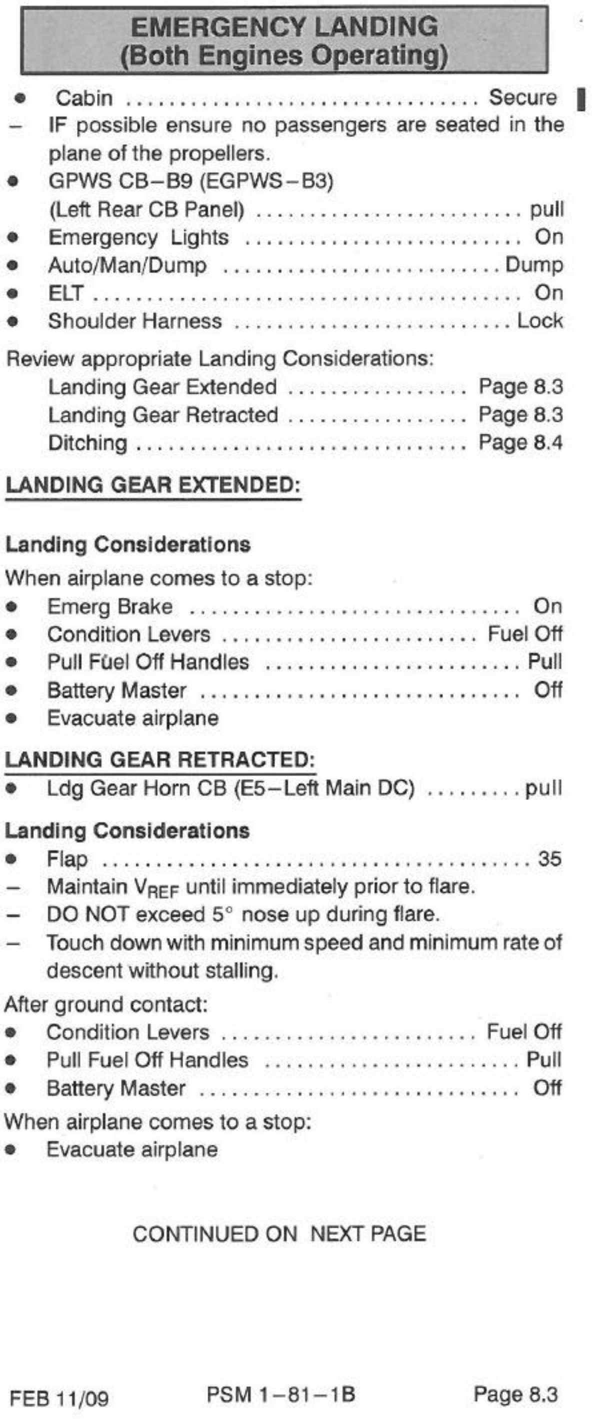
- Emergency Lights .... On

***Caution**: Battery duration for operation of essential services is 30 minutes.*

***Note**: Automatic control of cabin altitude is lost. Cabin differential pressure will increase until the safety outflow valve opens.*

- De - pressurize cabin, when below 14,000 ft:
- Auto/Man/Dump .... Man
- Man knob .... Fully clockwise (INCR)
- Fwd Outflow Valve .... Open

---------- **END** ----------



EMERGENCY LANDING (Both Engines Operating)

- Cabin .... Secure
  - IF possible ensure no passengers are seated in the plane of the propellers.
- GPWS CB–B9 (EGPWS–B3) (Left Rear CB Panel) .... pull
- Emergency Lights .... On
- Auto/Man/Dump .... Dump
- ELT .... On
- Shoulder Harness .... Lock

Review appropriate Landing Considerations:

Landing Gear Extended .... Page 8.3
Landing Gear Retracted .... Page 8.3
Ditching .... Page 8.4

LANDING GEAR EXTENDED:

Landing Considerations

When airplane comes to a stop:

- Emerg Brake .... On
- Condition Levers .... Fuel Off
- Pull Fuel Off Handles .... Pull
- Battery Master .... Off
- Evacuate airplane

LANDING GEAR RETRACTED:

- Ldg Gear Horn CB (E5–Left Main DC) .... pull

Landing Considerations

- Flap 35
  - Maintain V_{REF} until immediately prior to flare.
  - DO NOT exceed 5° nose up during flare.
  - Touch down with minimum speed and minimum rate of descent without stalling.

After ground contact:

- Condition Levers .... Fuel Off
- Pull Fuel Off Handles .... Pull
- Battery Master .... Off

When airplane comes to a stop:

- Evacuate airplane

CONTINUED ON NEXT PAGE

EMERGENCY LANDING (cont'd) (Both Engines Operating)

DITCHING

- Landing Gear .... Up
- Synchrophase .... Off
- Condition levers .... Max
- Bleed Air 1 and 2 .... Off
- Ldg Gear Horn CB (E5–Left Main DC) .... pull
- Flap 35

Landing Considerations

- In rolling swell surface conditions attempt to ditch along and parallel to the crests as much into wind as swell line permits. In other water surface conditions land into wind.
- Maintain V_{REF} until immediately prior to flare.
- Set rate of descent to 200 to 300 FPM.
- Commence flare to achieve zero vertical velocity immediately prior to water contact.
- Maintain pitch attitude of 10° nose up.
- Touchdown with minimum speed and minimum rate of descent without stalling.
- A transient nose–up pitching motion may result following touchdown. Overcorrection of this tendency could result in porpoising or nosing in.

After water contact:

- Condition Levers .... Fuel Off
- Pull Fuel Off Handles .... Pull
- Battery Master .... Off

When airplane comes to a stop:

- Evacuate Airplane

Warning: *DO NOT open the front door on the lower side.*

FORCED LANDING
(Both Engines Inoperative)

- Airspeed .... 1.3 Vs

Note: *With flap 0, landing gear retracted, propellers feathered and zero wind, 2.5 nautical miles can be travelled for every 1000 feet of altitude loss.*

All hydraulic, pneumatic and non−essential electrical services will be inoperative.

– Attempt engine airstart:
- Engine Airstart (page 5.8) .... accomplish

When all attempts to achieve a successful airstart have failed:

- Cabin .... Secure
- Main & Aux Batteries .... Off
- Passenger Signs .... On
- Emergency Lights .... On
- ELT .... On
- Shoulder Harness .... Lock

– Make the approach and landing into wind.
– Extending landing gear will steepen the glide angle and decrease the glide distance.

Review Appropriate Landing Considerations:
Landing Gear Extended .... Page 8.6
Landing Gear Retracted .... Page 8.6
Ditching .... Page 8.7

CONTINUED ON NEXT PAGE

FORCED LANDING (cont'd)
(Both Engines Inoperative)

LANDING GEAR EXTENDED:

Landing Considerations

IF the available surface is appropriate extend landing gear allowing sufficient time for alternate gear extension.

- Maintain 1.3 Vs until immediately prior to flare.
- Commence flare to achieve zero vertical velocity immediately prior to ground contact.
- Touchdown with minimum speed and minimum rate of descent without stalling.

● ALTERNATE LANDING GEAR EXTENSION (page 14.3) .... accomplish

Prior to touchdown:

● Battery Master .... Off

After touchdown:

● Emerg Brake .... apply intermittently

When airplane comes to a stop:

● Evacuate Airplane

LANDING GEAR RETRACTED:

Landing Considerations

- Maintain 1.3 Vs until immediately prior to flare.
- Commence flare to achieve zero vertical velocity immediately prior to ground contact.
- DO NOT exceed 6° nose up during flare.
- Touchdown with minimum speed and minimum rate of descent without stalling.

Prior to touchdown:

● Battery Master .... Off

When airplane comes to a stop:

● Evacuate Airplane

CONTINUED ON NEXT PAGE

FORCED LANDING (cont'd) (Both Engines Inoperative)

DITCHING:

Landing Considerations

- DO NOT select landing gear down.
- In rolling swell surface conditions attempt to ditch along and parallel to the crests as much into wind as swell line permits. In other water surface conditions land into wind.
- Maintain 1.3 Vs until immediately prior to flare.
- Commence flare to achieve zero vertical velocity immediately prior to water contact.
- Maintain pitch attitude of 10° nose up.
- Touchdown with minimum speed and minimum rate of descent without stalling.
- A transient nose–up pitching motion may result following touchdown. Overcorrection of this tendency could result in porpoising or nosing in.

After water contact:

- Battery Master .... Off

When airplane comes to a stop:

Warning: *DO NOT open the front door on the lower side.*

- Evacuate Airplane