Bombardier DHC 8 Propeller Overspeeds

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Background information

- The Bombardier DHC 8- 100 to 300 series aircraft have had numerous propeller overspeed events dating back many years.

- Some of those events have led to serious incidents, engine failures and one catastrophic accident.

- Both presenters have assisted or conducted investigations into some of the events mentioned.

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Background information

- Both presenters collaborated on behalf of their organisations to assist the Accident Investigation Commission of PNG with their investigation into the P2-MCJ, DHC 8-103 double propeller overspeed fatal accident on 13 October 2011.

- This presentation will describe the DHC 8 propeller speed control system, the propeller overspeed events, the design issues and the proposed design issue rectifications.

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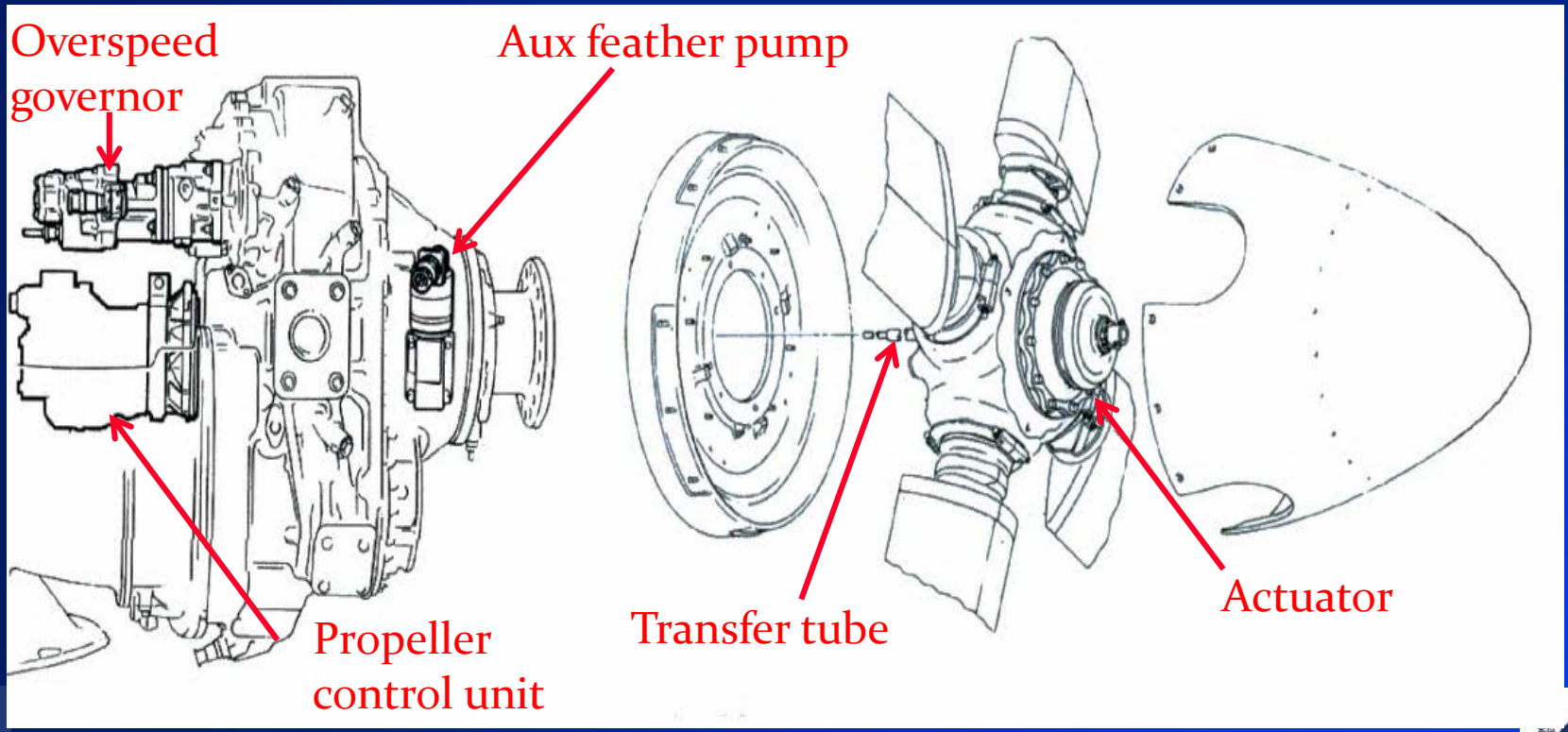
Propeller system design

- Each propeller system consists of a four blade propeller assembly, an actuator, a propeller control unit (PCU) an overspeed governor and pump, a transfer tube and an Aux feather pump.



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Propeller overspeed protection

- In normal flight operation between flight idle and full power the PCU controls and maintains the propeller speed between 900 rpm and 1200 rpm through its governor.

- In the event that the PCU does not govern the propeller to the set speed the overspeed governor will sense the overspeed condition (anywhere from 103-108% NP) and will increase the blade angle to reduce the propeller speed.

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Propeller overspeed protection

- The finer the propeller pitch angle, the faster the propeller will operate, so increasing pitch will slow the propeller down because it is taking a bigger bite out of the air.

- The system also incorporates a third layer of protection with the Beta Backup system logic which drives the propeller towards feather if it senses the blade angle is below flight idle with the power levers above the flight idle gate.

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Ground Beta

- Ground beta range for most turbo propeller engines is the range designed for use when taxing an aircraft on the ground, or slowing an aircraft down after landing by controlling the propeller pitch directly from power lever position.
- When in the ground beta range all propeller governing and propeller overspeed protection systems are inhibited.
- This is an intended design feature to allow complete control of the propellers pitch angle through the power levers when the aircraft is on the ground.

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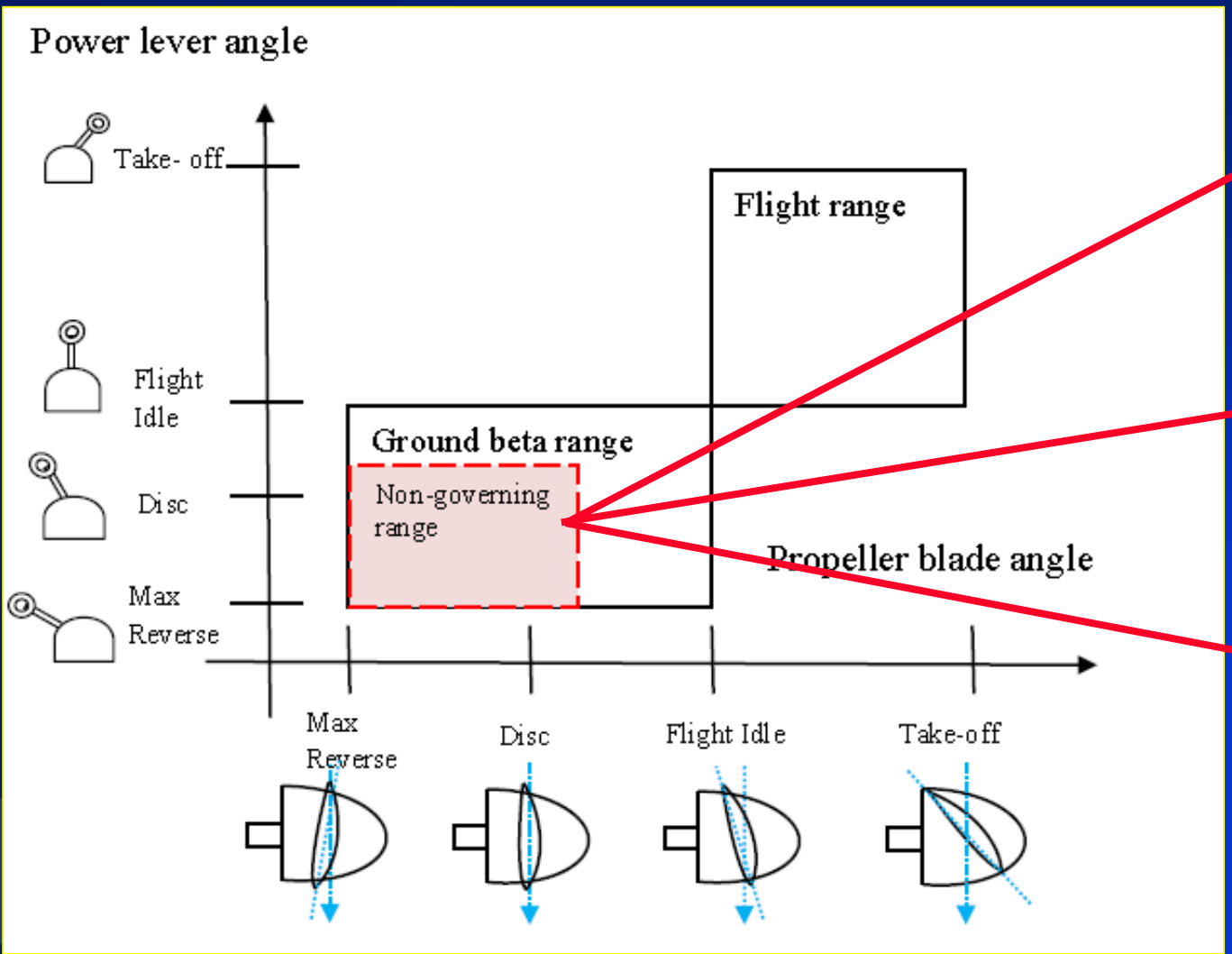
Propeller governing operation



Propeller Control Unit Governing

Propeller Overspeed Governor Protection

Beta Backup System Protection

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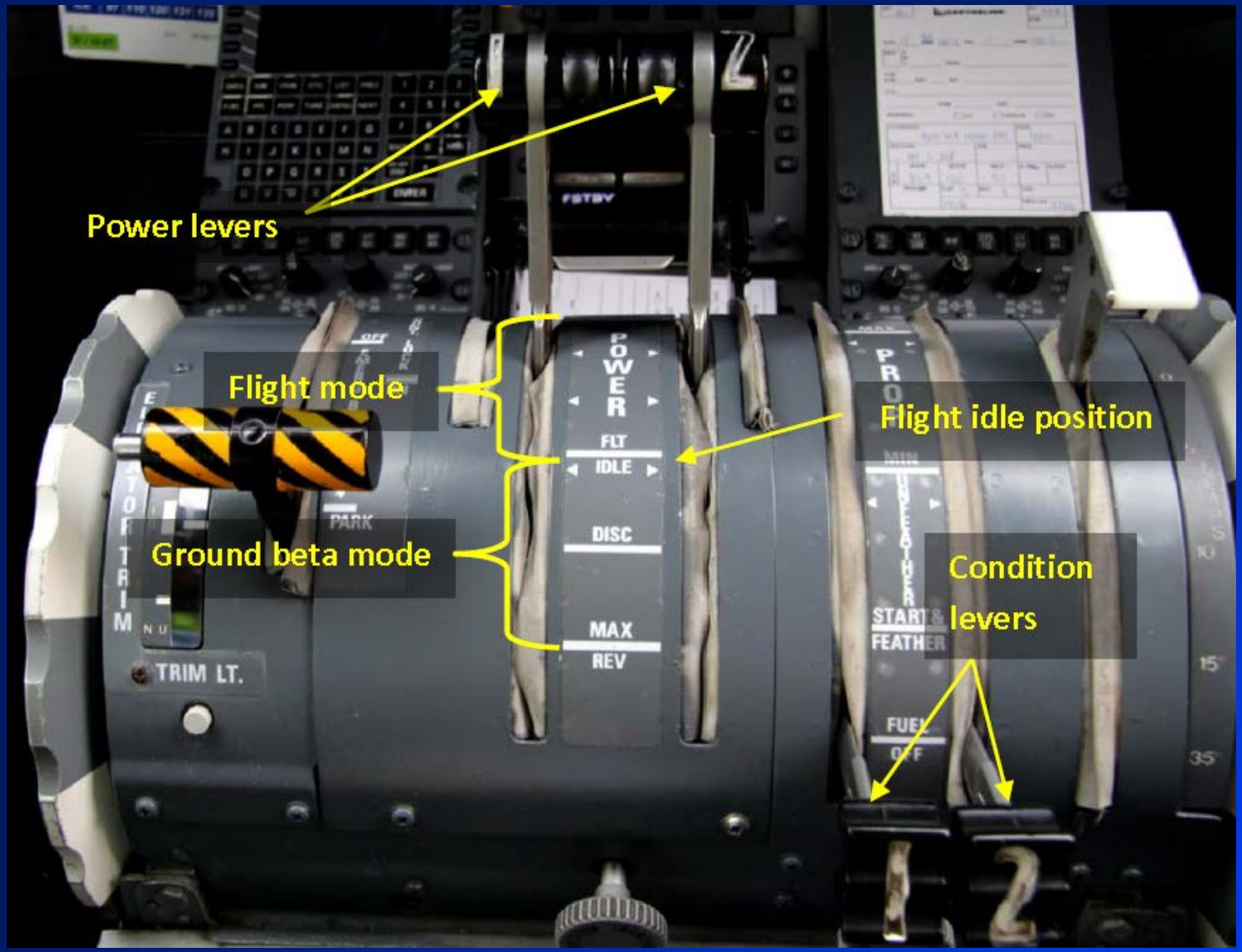
Power lever quadrant



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Flight idle gate triggers

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Propeller overspeed explained

- Three elements required
  - High aircraft forward speed
  - Lifting of the gate release triggers (for whatever reason)
  - Power levers 13 degrees below flight idle

When the power levers are move to a position of 13 degrees below flight idle all governing and overspeed functions are inhibited. Coupled with a high airspeed the propeller will be driven by the airflow much like a windmill, overspeeding propeller.

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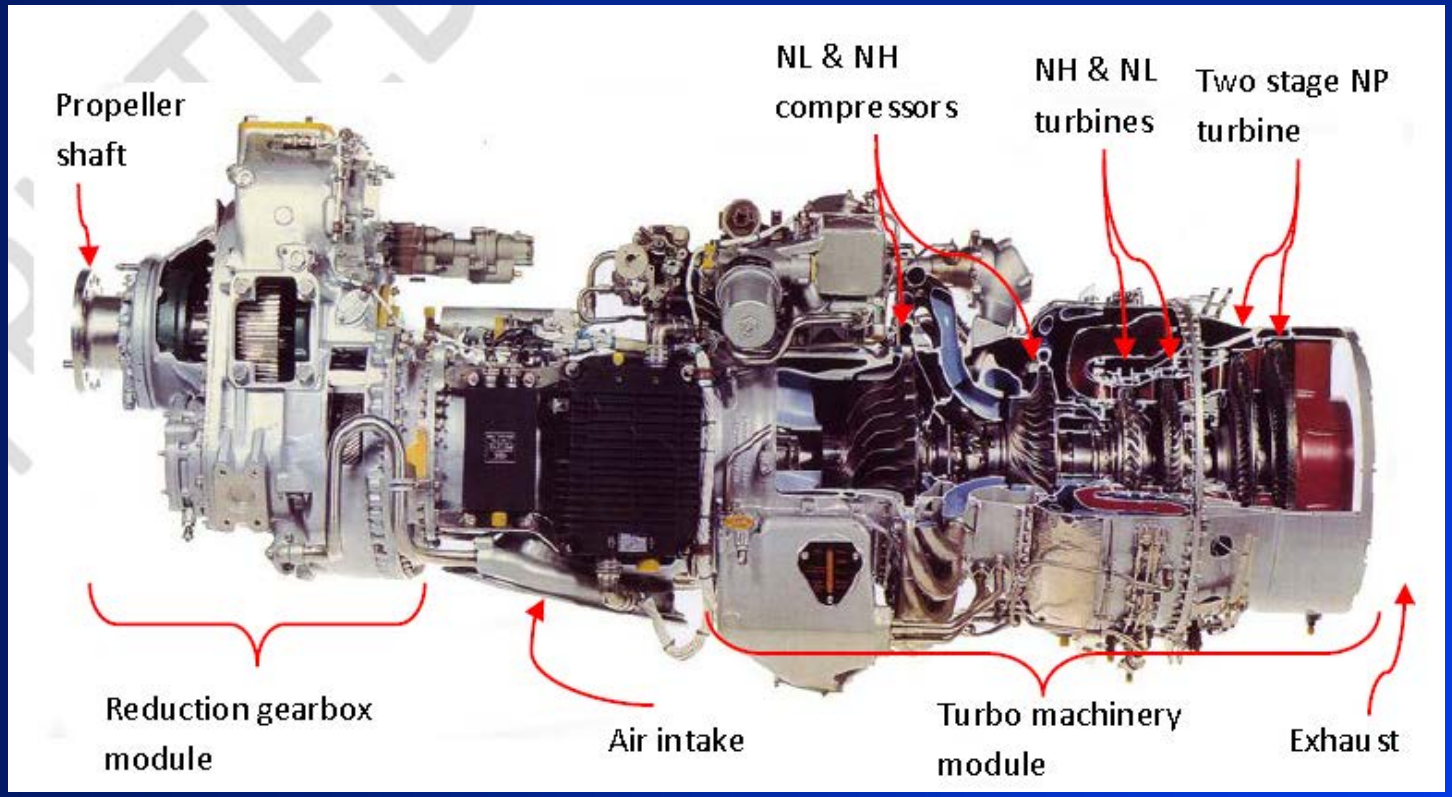
Engine failure

The propeller (NP) is connected through a drive shaft to the power turbine, it too will overspeed, eventually leading to engine failure.



Centrifugal twisting moment

- A force that increases with propeller speed
- Force applied to decrease the propeller pitch angle
- At about 1500 rpm the force is so great that it can not be overcome by the propeller actuator (pitch lock)
- Only a reduction in airspeed will reduce the propeller speed back into the controllable range.

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Certification Requirements DHC-8-100 to 300 In-flight Beta-range Protection

Background – In the early 1990s there were several accidents resulting from propellers going into ground beta range inflight. Notably, an EMB 120 crashed on 5 May 1991, killing all onboard, including a US Senator. There was an impetus to design better protections in attempts to avoid the possibility of ground beta range selection while airborne.

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Certification Requirements DHC-8-100 to 300 In-flight Beta-range Protection (Oct 2011)

Most of the World – The Power Levers cannot be moved below flight idle unless Flight Idle Gate Trigger raised.

In 1999, Transport Canada AD 99-18 was issued to require the additional protection of an aural warning “chirping”.

Link to Video of “chirping” vs gate triggers

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Certification Requirements DHC-8-100 to 300 In-flight Beta-range Protection (Oct 2011)

UK - Aircraft modified in accordance United Kingdom Civil Aviation Authority (U.K. CAA) Flight Idle Gate option Bombardier (de Havilland) Customer Request CR873SO8112, CR873CH00003 or CR873CH00005.

Flight Idle Gate Triggers cannot be raised until power levers are brought back to flight ide.

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Certification Requirements DHC-8-100 to 300 In-flight Beta-range Protection (Oct 2011)

USA – Beta Lockout System initially mandated the USA in accordance with FAA AD 2000-02-13 (incorporated Bombardier Service bulletin 8-76-24)

The Beta Lockout system does not prevent flight crews from moving the power levers below the flight idle gate in flight, but it prevents a propeller overspeed from such an action.

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Ground Beta Activation in-flight

- At Least 8 Occurrences, Likely More
- 1 April 1996 Air BC, DHC-8-100 Incident Canada
- 28 May 1996, DHC-8-400, Canada
- 1 May 2005 Widerøe, DHC-8-103 Accident, Norway
- 21 Feb 2006 Widerøe, DHC-8-103, **LN-WIE** Incident Norway
- 7 October 2008 DHC-8-100 Incident Chad, Africa
- 10 March 2010, DHC-8-400 (FADEC system)
- 2 November 2011, DHC-8-100 (beta lockout system)
- 6 December 2011 QantasLink, DHC-8-300 Incident Weipa, QLD

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1 May 2005, Widerøe, DHC-8-103 Accident, Hammerfest, Norway (AIBN SL Report 2009/22)

From the AIBN Report of LN-WIE "The Accident Investigation Board touched upon the topic of reversal in the air when a DHC-8-103 operated by Widerøe crashed during landing at Hammerfest airport on 1 May 2005 (SL Report 2009/22). During the approach, the crew heard something they likened to birds twittering without knowing what it meant. In retrospect, it became clear that this was the warning sound for pulling the Power Levers into the Beta-range. Although this did not have any bearing on the accident, the report made a safety recommendation to the effect that "*Widerøe should consider whether the pilots' knowledge and awareness of this system can be improved.*" (Safety recommendation SL No. 2009/27T)"

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LN-WIE investigation

aibn Accident Investigation Board Norway

Issued June 2012

REPORT SL 2012/05

REPORT ON SERIOUS INCIDENT DURING DESCENT TO SØRKJOSEN AIRPORT, NORWAY ON 21 FEBRUARY 2006 WITH BOMBARDIER DHC-8-103, LN-WIE OPERATED BY WIDEREØES FLYVESELSKAP AS

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History of Flight

- Widerøe flight WIF922 from Tromsø to Sørkjosen airport encountered heavy turbulence during the descent.
- Near the max allowable airspeed, the Commander reduced engine power by pulling both Power Levers back towards the lowest possible power setting when the aircraft is airborne (Flight Idle).
- Unintentionally, both Power Levers ended up aft of the flight idle gate.

History of Flight - continued

- As a result both propellers oversped, reaching uncontrollably high rotation speeds.
- The right engine was severely damaged and it was difficult to control of the aircraft.
- The crew shutdown the right engine and were able to use the left engine.
- The crew decided to return to Tromsø where they performed a single engine landing

History of Flight - continued

- During the event, the highest bank angle was 58° to the right and the nose pitched down to about 20°.
- The event commenced at an altitude of 8,870 feet and the loss of altitude was 760 feet.
- It was not possible to establish how far back the power levers went before the Commander instinctively pushed them forward again as he realised something was seriously wrong.

From Flight Recorders

- CVR was overwritten (left powered on ground).
- Engine power lever position not recorded.
- Airspeed was initially 225 kt, but increased significantly to 243 kt (**V_{NE}** is 242 kt) during the last 10 seconds before the propeller speed started to increase.
- Over a 4-second period, the vertical acceleration (g) varied from 1.0 through 0.2 to 2.0 and or a brief moment, it reached -1.07 g.

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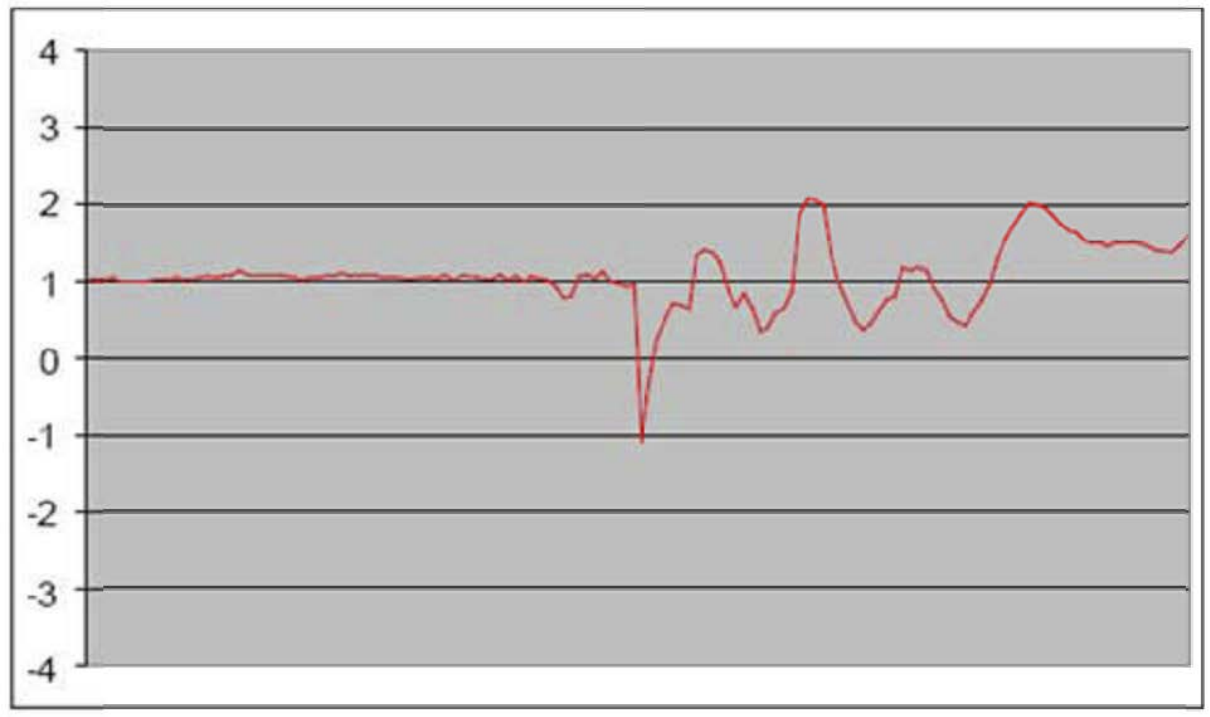
Vertical g in Turbulence

The lowest value of -1.07 g was recorded in the same second that the torque on the right engine fell from 42.6% to 6.1%.



Vertical acceleration (g) over a period of 20 Seconds

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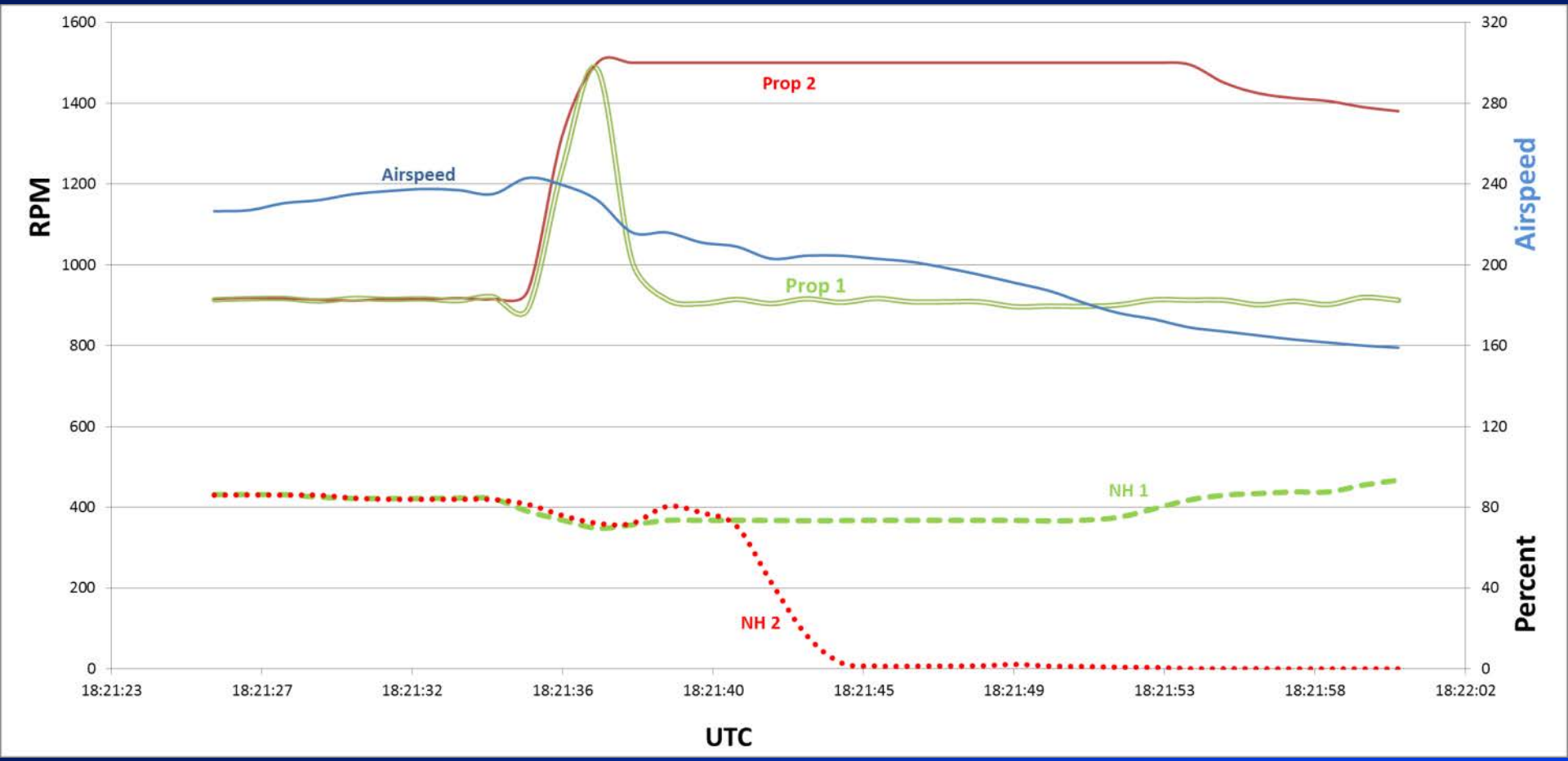
FDR Plot From EXCEL Data Provided by Norway



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Propeller RPM From FDR

- The RPM on the right propeller rose from 911 to above the highest recordable value of 1,500 over the course of 7 seconds.
- The right propeller RPM was above 1500 for about 18 seconds.
- During the same period, the RPM for the left propeller rose from 916 to the highest recorded value of 1,483.
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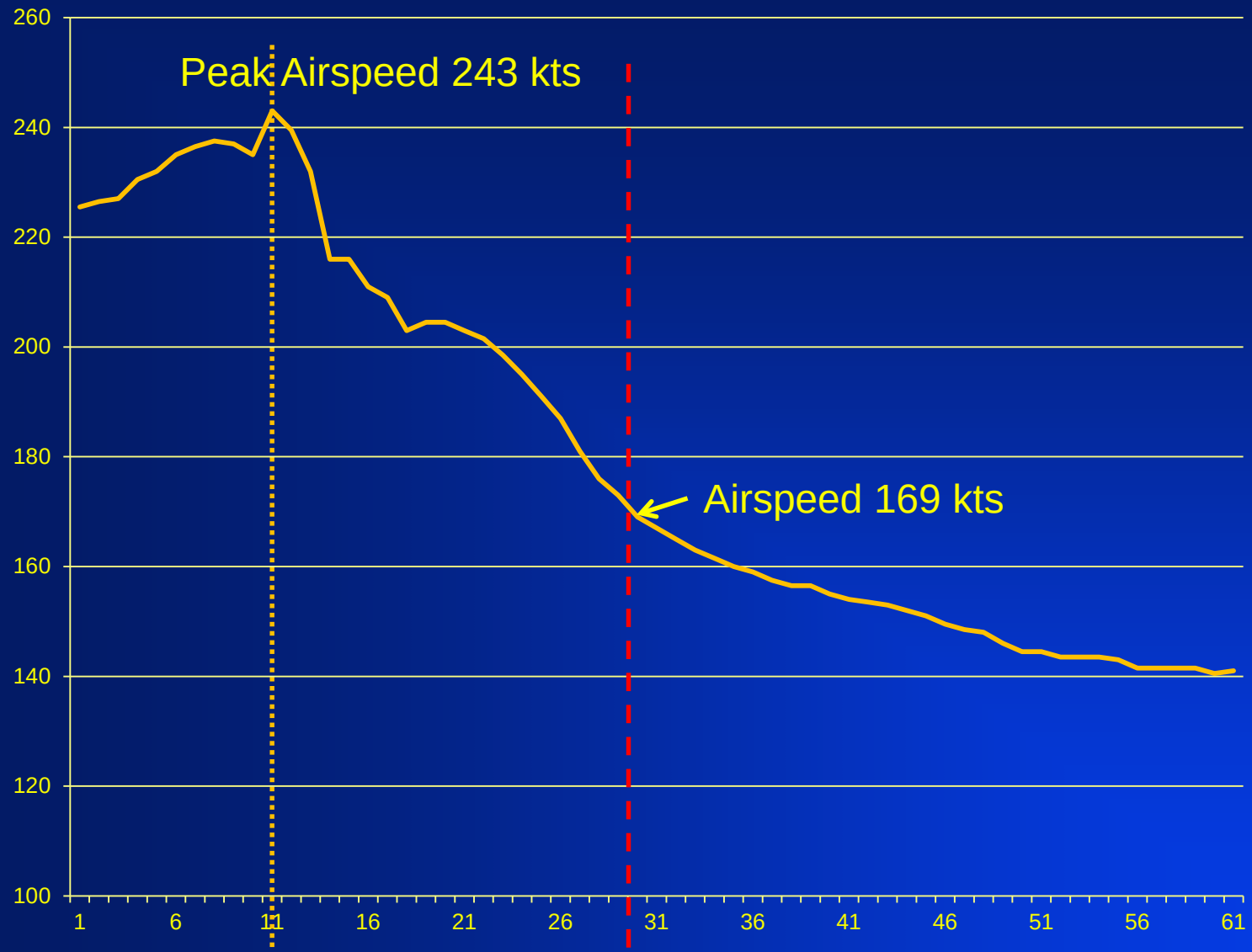
LN-WIE investigation



FDR - Airspeed

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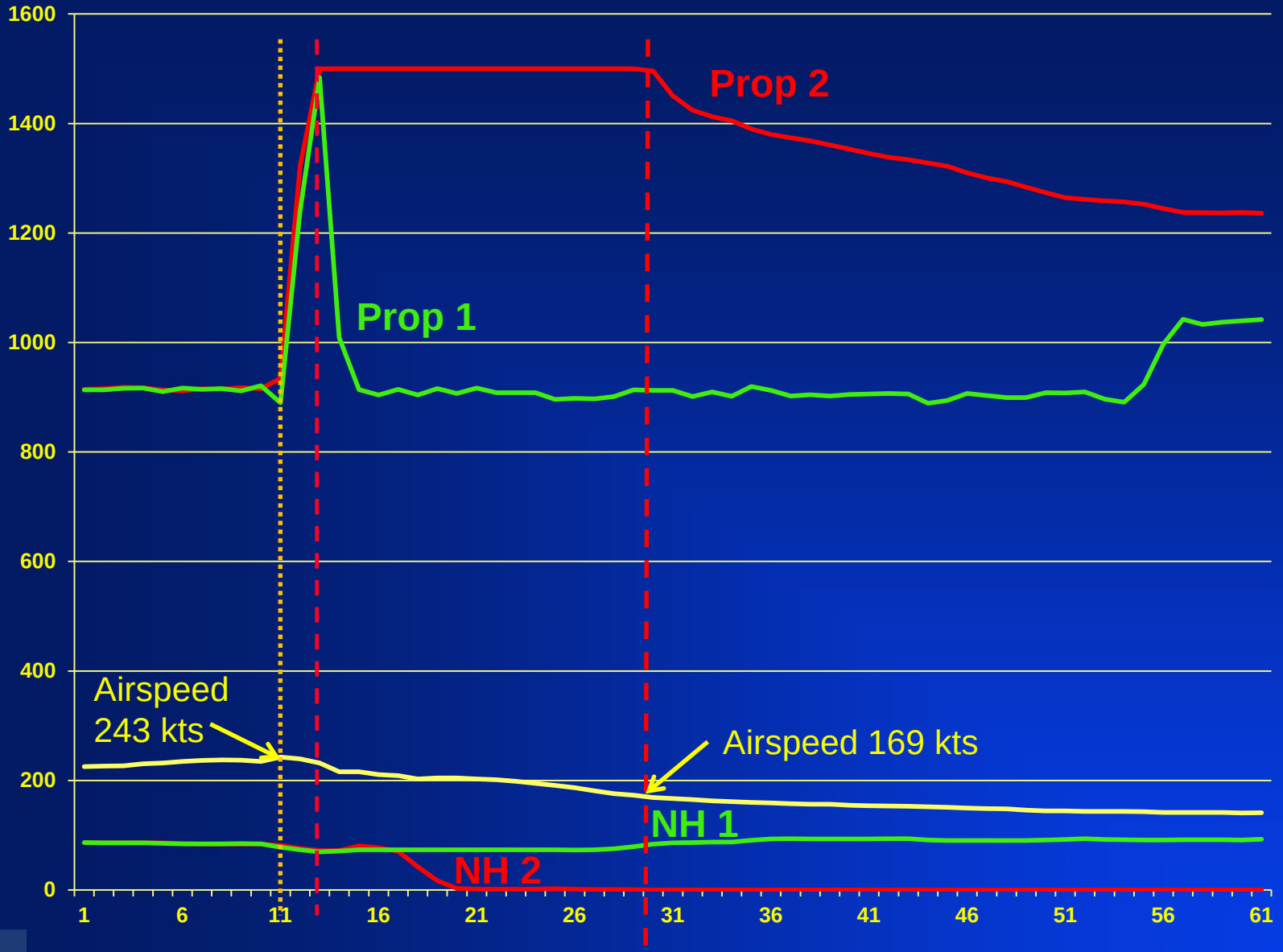
LN-WIE investigation



FDR – Propellers, HP & Airspeed

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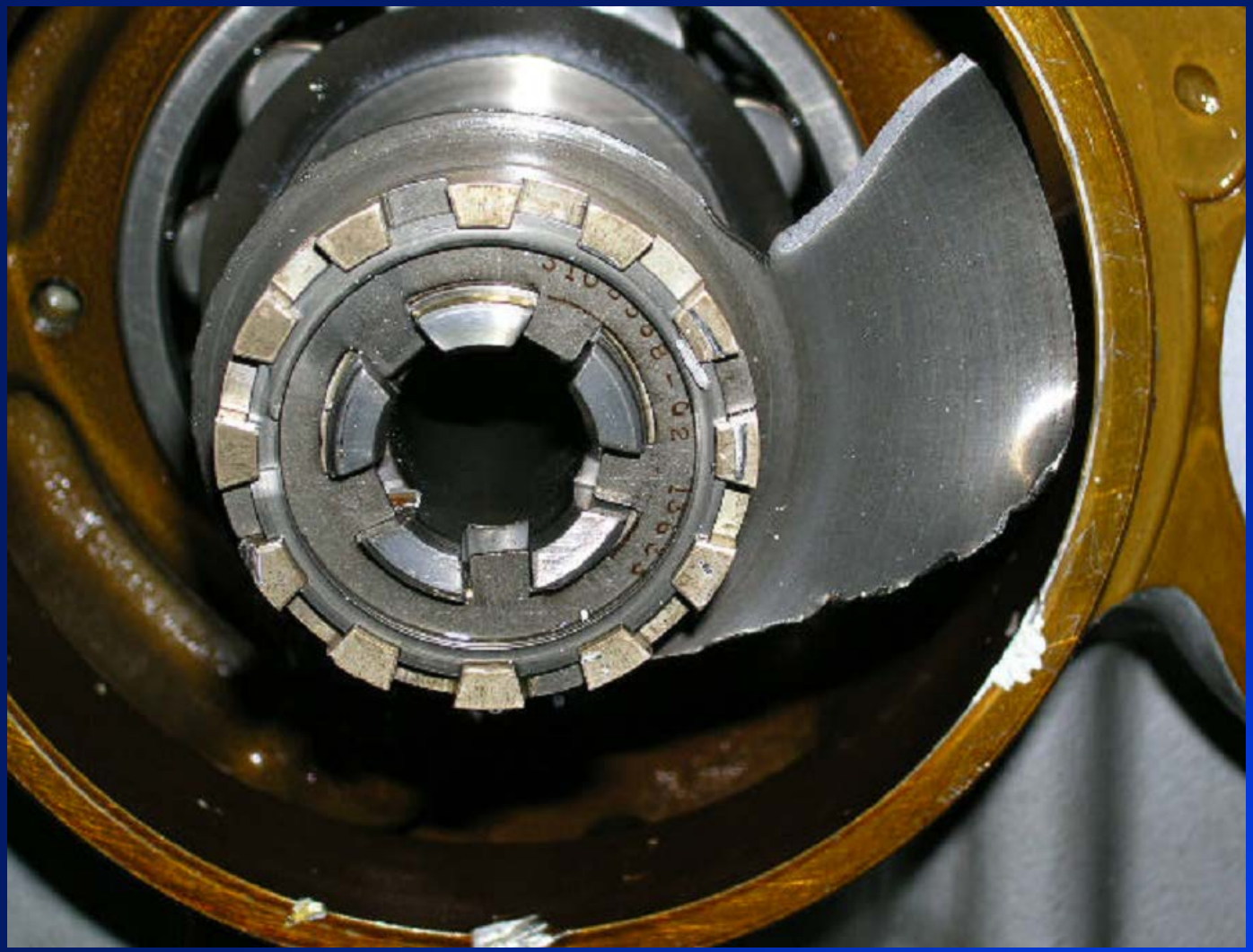
Engine 2 Damage



Torque Shaft Forward Web

Engine 2 Damage

Inlet Plenum

Engine 2 Damage

The low-pressure turbine shaft had separated and partially melted

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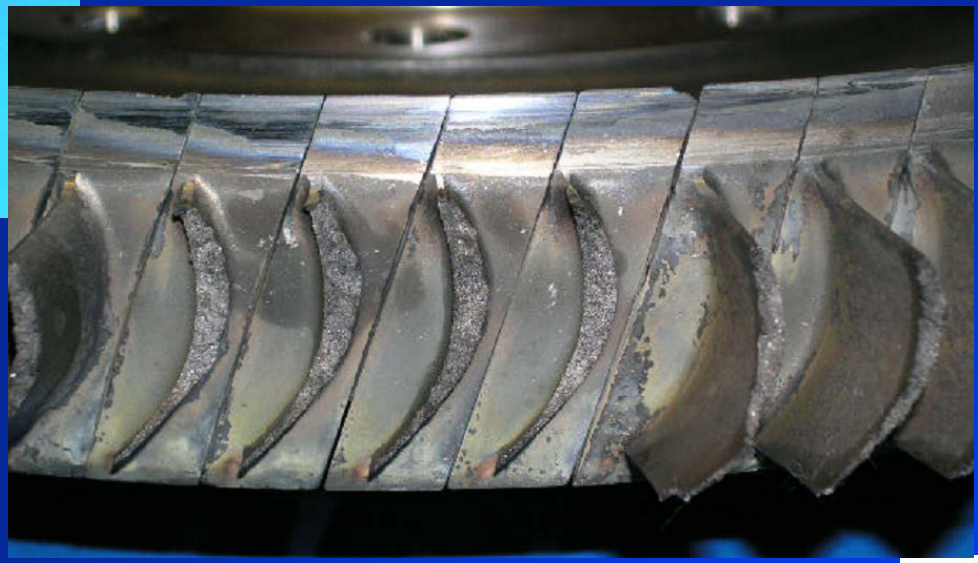
Engine 2 Damage

2nd Stage Power Turbine



Interim Recommendation by AIBN – 28 Feb 2007

"The AIBN that Bombardier evaluate all DHC-8 models with respect to inadvertent airborne reversing. All 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. Until a modification is implemented operators should be informed about the hazard in an appropriate way. (Interim safety recommendation 06/120-9)"

Response from Canada to Interim Recommendation

"Bombardier appreciates the opportunity to review and comment on the above referenced safety recommendation. We have thoroughly reviewed the existing power lever flight idle gate design and find that inadvertent airborne reversing is unlikely to occur. In our opinion, further modification to the installation is not necessary."

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Safety Action by Widerøe

The company installed warning signs near the Power Levers of all their DHC-8-103 and DHC-8-311 aircraft in May/June 2006. Installation was based on Bombardier Service Bulletin 8-11-103.

Safety Action by Widerøe

Widerøe has modified its DHC-8-100 and DHC-8-300 aircraft in accordance with Bombardier Service Bulletin 8-76-28. The modification requires that the power levers be at flight idle before the flight idle gate triggers can activated. The so-called “UK Gate”

The Accident Investigation Board Norway (AIBN) made the following Safety Recommendation with the June 2012 release of the Report

Safety recommendation No. 2012/05T

This serious aircraft incident has shown that on the aircraft type DHC-8 it is possible to inadvertently pull the Power Levers back past Flight Idle while airborne. The consequences of this may include propeller overspeed, possible engine failure and loss of aircraft control.

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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13 October 2011
Airlines PNG Accident
Near Madang
Papua New Guinea (PNG)
DHC-8-103, P2-MCJ

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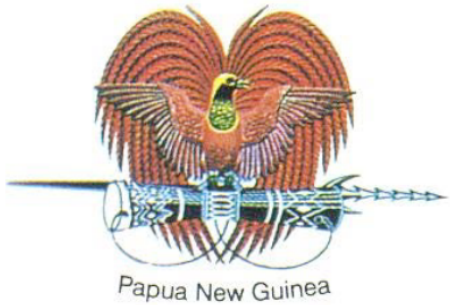
P2-MCJ investigation



ACCIDENT INVESTIGATION COMMISSION

AIRCRAFT ACCIDENT INVESTIGATION
PRELIMINARY REPORT
AIC-11-1010

Forced landing
P2-MCJ
Bombardier DHC- 8-103
33 km south east of Madang
13 October 2011

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International investigation

Accident Investigation Commission of PNG × 4 investigators assisted by:

- Australian Transport Safety Bureau × 4 investigators, plus assistance from Canberra
- PNG Civil Aviation Safety Authority × 2
- Airlines of PNG employees × 3
- Transportation Safety Board of Canada × 1
  - Bombardier × 2
  - Pratt & Whitney Canada × 1
  - Transport Canada (Regulator) × 1

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History of flight

- The DHC 8-103 aircraft was on a steep descent into Madang, PNG when the airspeed warning sounded.

- The PIC retarded the power levers, within seconds both propellers simultaneously exceeded their maximum RPM by 60%. The left engine failed shortly after that time and the right propeller had an uncommanded feather.

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History of flight (cont'd)

- With no forward thrust the PIC conducted an off field landing. The aircraft caught fire during the impact sequence and was destroyed by a significant fuel fed fire.

- Of the 32 people on-board only the flight crew, the cabin attendant and one passenger survived.

- The investigation is continuing, therefore the information able to be provided is limited to that of the preliminary report.

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Accident site

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Left engine

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Right engine

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Engine disassemblies

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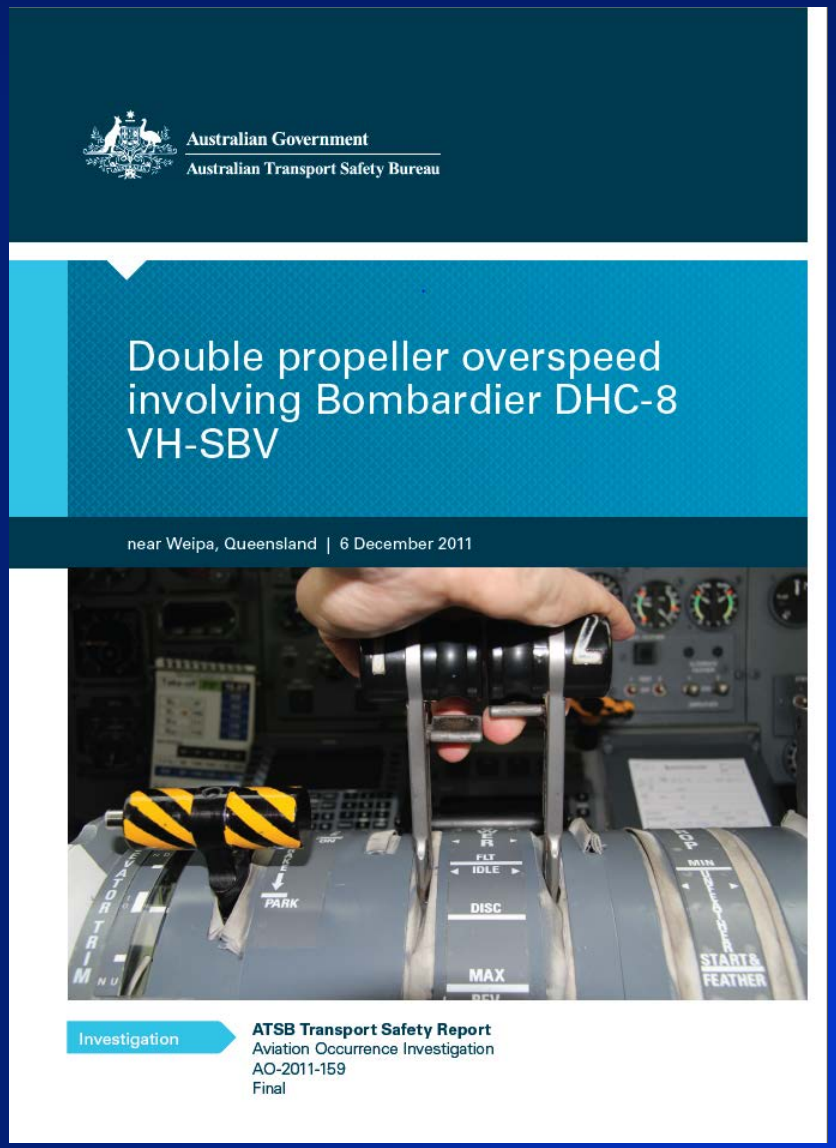
VH-SBV investigation



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History of flight

- During descent the power levers were inadvertently moved into the ground beta range due to turbulence, the pilot moved the power levers back above the flight idle gate within a second.
- During that time both propellers accelerated above their governed 900 RPM to 1275 RPM on the left engine and 1215 Rpm on the right engine.
- The trigger warning horn sounded during that event.

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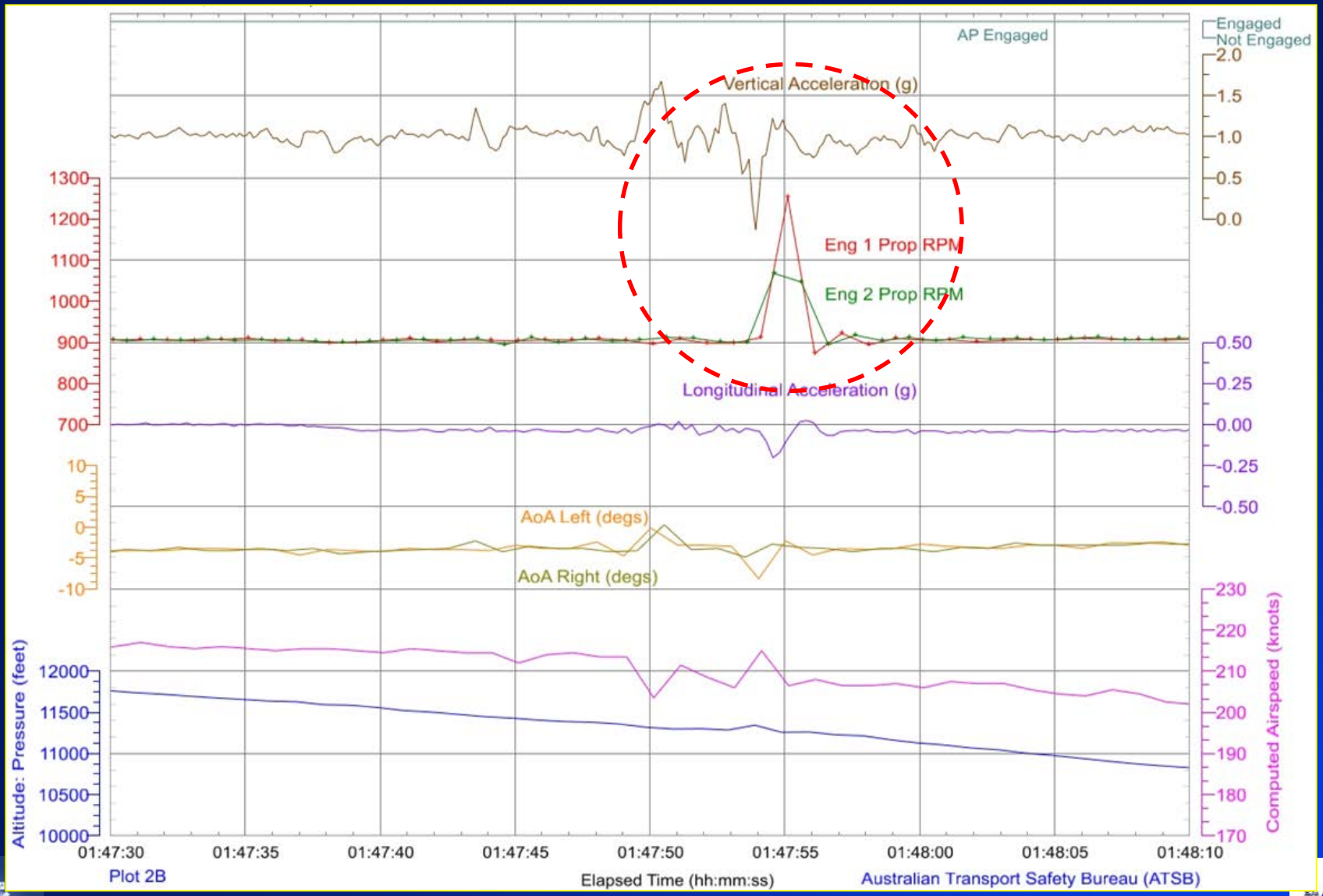
FDR data



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Intentional or Unintentional?

- None of the occurrences that were investigated identified that the movement of the power levers was an intentional act on the part of the pilot!

- This information coupled with the propeller system design issue meant that a significant systemic safety issue existed within the DHC 8 100 – 300 series aircraft worldwide.

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Safety action

Since the 13 October 2011 Airlines PNG Fatal DHC-8-103 accident near Madang, Papua New Guinea and the other incidents in Australia safety action has been taken to mitigate the risk of propeller overspeed and the resultant high probability of engine failure for DHC-8-100 to 300 aircraft.

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Beta Warning Horn

There were two main areas of concern.

- Crew Awareness
- Reliability and effectivness of the Beta Warning Horn System

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Beta Warning Horn Awareness

- In the case of the Widerøe and QantasLink incidents it was clear that the pilots were not acutely aware of the beta warning horn sound due to lack of exposure to it.
- Widerøe and QantasLink have taken steps to rectify that issue.
- The ATSB provided the beta warning horn sound on the VH-SBV investigation page on its web site and also spoke to all Australian operators about the issue.

Beta Warning Horn Reliability

- During an on-ground Beta Warning Horn (BWH) system check conducted in the wake of an in-flight Beta range operation incident on a DHC-8 Series 200 aeroplane, it was discovered that the BWH system failed to activate when the Beta mode was triggered.

- Bombardier noted the problem on one of their own corporate aircraft.

Beta Warning Horn Reliability

Transport Canada AD 2012-01R1

- "An investigation by Bombardier had determined that the deformation of the flexible center console cover could cause the BWH system triggering microswitch to malfunction, resulting in dormant failure of the BWH system. To mitigate the safety risk by minimizing the risk exposure period, AD CF-2012-01 was issued on 05 January 2012 to mandate a 50 hours periodic operational test of the BWH system functionality."

Beta Warning Horn Reliability

Transport Canada AD 2012-01R1

- "To address the root cause of the subject problem, Bombardier has issued Service Bulletin (SB) 8-76-33 that modifies the BWH microswitch installation by replacing the BWH microswitch attachment bracket with a new, more robust bracket that is not affected by deformation of the center console cover…."

Airworthiness Directive Issued by Papua New Guinea (PNG) 1:27/10/11

- Issued by CASA PNG in November 2011 in response to the 13 Oct 2011 Accident.
- Effective 27 October 2011

(a) Applies to any PNG registered DHC-8 series 100, 200 and 300 aircraft not equipped with the beta lockout system…

Papua New Guinea (PNG) AD 1:27/10/11

(b) Before further flight and at intervals not exceeding 50 hours thereafter, accomplish the following

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”.

Papua New Guinea (PNG) AD 1:27/10/11

(c) "…amend the DHC-8 Minimum Equipment List (MEL)…

Systems Affected

- Autopilot
- Radio Altimeter
- Beta Warning Horn System

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Papua New Guinea (PNG) AD 1:27/10/11

(d) Within 120 days after 27 October,2011, install a system that would prevent positioning of the power levers below the flight idle stop 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.

Transport Canada Response to AIBN Recommendation 2012/05T

"A risk assessment was carried out in the summer of 2012 by TC. As a result, TC has directed Bombardier (BA) to develop corrective action to prevent the operation of the propeller in the Beta range during flight. BA has proposed a Beta Lockout System similar to what is utilized for the FAA/US registered DHC-8 aircraft."

Transport Canada Response to AIBN Recommendation 2012/05T (cont'd)

"TC has accepted BA's proposed modification on the affected DHC-8 fleet of aircraft, and will mandate the modification by issuing a Canadian Airworthiness Directive in the first quarter of 2013.

In the interim, TC will be issuing an Airworthiness Directive to install a placard prohibiting the operation of the propeller in the Beta range during flight. The AD is scheduled to be released in the last quarter of 2012."

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Transport Canada AD CF-2012-33

- AD issued to mandate compliance with SB 8-11-115 requirements that a warning label be installed in the flight compartment to warn the crew against the operation of the propellers in Beta range during flight.

- Excludes aeroplanes with CR 873CH00011 (Service Bulletin 8-76-24) incorporated." (Beta Lockout System)

Recent Airworthiness Directives (ADs)

Transport Canada AD CF 2013-xx

- Description
- Description

- NOTE THIS IS THE EXPECTED AD FROM TRANSPORT CANADA MANDATING THE BETA LOCKOUT SYSTEM WORLD-WIDE

Questions?

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