Inquiry 10-010:
Bombardier DHC-8-311, ZK-NEB, landing without nose landing gear extended,
Woodbourne (Blenheim) Aerodrome, 30 September 2010

Final Report

Aviation inquiry 10-010

Bombardier DHC-8-311, ZK-NEB

Landing without nose landing gear extended

Woodbourne (Blenheim) Aerodrome

30 September 2010

Approved for publication: September 2012

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

Commissioners

Chief Commissioner	John Marshall, QC
Deputy Chief Commissioner	Helen Cull, QC

Key Commission personnel

Chief Executive	Lois Hutchinson
Chief Investigator of Accidents	Captain Tim Burfoot
Investigator in Charge	Peter R Williams
General Counsel	Rama Rewi
Assessor	Pat Scotter

Email	inquiries@taic.org.nz
Web	www.taic.org.nz
Telephone	+64 4 473 3112 (24 hrs) or 0800 188 926
Fax	+ 64 4 499 1510
Address	Level 16, AXA Centre, 80 The Terrace, PO Box 10 323, Wellington 6143, New Zealand

Important notes

Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

Ownership of report

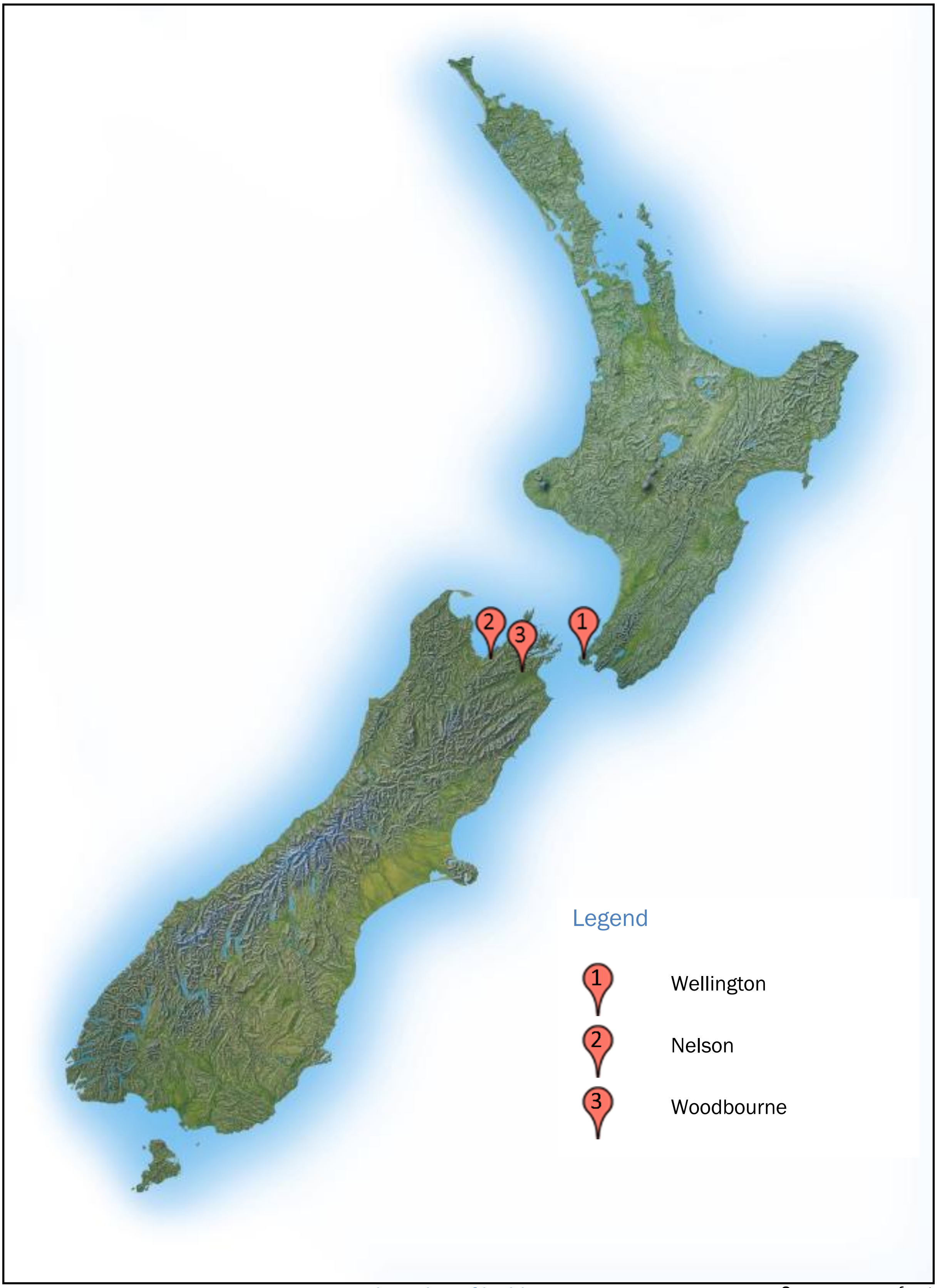
Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1980 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.

Bombardier DHC-8-311, ZK-NEB



Location of incident

Source: mapsof.net

Contents

Figures

Abbreviations

Commission	the Transport Accident Investigation Commission
CRM	crew resource management
Q300	the commercial name for the Bombardier model DHC-8-311 aeroplane
QRH	Quick Reference Handbook
UTC	co-ordinated universal time

Glossary

advisory indicators	lights that give the status of various systems
apron	that part of an aerodrome where aircraft are parked, loaded and unloaded, and some maintenance can be carried out
bleeding	a procedure to remove trapped air in fluid lines
cycle	one take-off and one landing
fines	visible, small metallic particles, usually the result of wear, such as iron filings
go-around	abandon a landing approach and climb away
micron	one-thousandth of a millimetre
Minimum Equipment List	lists those items that may be inoperative for flight. The operator combined this with a Discrepancy Procedures Guide, which listed any operational and maintenance conditions that were to be met for flight with a specific item inoperative
on-condition	a preventative maintenance process that allows for the expected deterioration of components by monitoring them for their continued compliance with standards. Continued satisfactory operation may be determined by inspection, operation or examination without detailed dismantling. The need for removal or replacement depends on the condition.
Quick Reference Handbook	a condensed version of the emergency and abnormal procedures and other data, taken from the aircraft flight manual, which is readily available to pilots
verification lights	lights, under the landing gear alternate extension door in the flight deck floor, that independently show whether the landing gear legs are locked down

Data summary

Aircraft particulars

Aircraft registration:	ZK-NEB
Type and serial number:	Bombardier Aerospace DHC-8-311, 615
Number and type of engines:	2 Pratt & Whitney Canada PW123 turbo-prop
Year of manufacture:	2005
Operator:	Air Nelson Limited
Type of flight:	scheduled air transport
Persons on board:	46
Pilot's licence:	airline transport pilot licence (aeroplane)
Pilot's age:	53
Pilot's total flying experience:	12 200 hours, including 1250 hours on type

Date and time	30 September 2010, 1706[1]
Location	Woodbourne Aerodrome latitude: 41°31.1´ south longitude: 173°52.2´ east
Injuries	nil
Damage	minor

[1] Times in this report are New Zealand Daylight Time (UTC + 13 hours) and expressed in the 24-hour format.

1. Executive summary

1.1. On 30 September 2010 a Bombardier DHC-8-311 aeroplane (often referred to as a Q300 or Dash 8) departed from Wellington International Airport on a scheduled flight to Nelson Aerodrome. The aeroplane diverted to Woodbourne Aerodrome (Blenheim) because of poor weather at Nelson. There were 2 pilots, one flight attendant and 43 passengers on board.

1.2. When the pilots moved the landing gear selector lever to DOWN, the left and right main landing gear legs extended normally, but the nose landing gear stopped before it had fully extended, probably because debris within the hydraulic fluid blocked a small orifice in the hydraulic ram (actuator) that extended and retracted the nose landing gear.

1.3. The primary system that indicated the status of the landing gear showed the pilots that the landing gear was "unsafe", that the nose landing gear was not down and locked, and that the nose landing gear forward doors were open.

1.4. The pilots began working through a checklist to troubleshoot the problem. The checklist directed them to an independent verification system designed to show whether the individual landing gear legs were locked down. That system showed the pilots 3 green lights, which verified that all the landing gear was down and locked, in spite of the other indications that the nose landing gear was not.

1.5. The pilots assumed that there was a fault in one of the landing gear sensors and continued the approach to land at Woodbourne in the expectation that all of the landing gear was locked down. On the final approach the landing gear warning horn sounded when the pilots began to configure the aeroplane for landing by selecting the wing flaps to 15 degrees. This warning horn was designed to alert the pilots that the landing gear was not safe. A short time later the ground proximity warning system also alerted the pilots that the landing gear was not locked down. The pilots ignored both of these warnings in the belief that they had been generated from a single sensor that they assumed was faulty and had given them the original unsafe nose landing gear indications.

1.6. When the aircraft touched down and the pilot lowered the nose, the nose landing gear was pushed into the wheel well and the aeroplane completed the landing roll skidding on the nose landing gear doors. Damage to the aeroplane was minimal and no-one was injured.

1.7. The Transport Accident Investigation Commission (Commission) found that other events involving the same nose landing gear in the weeks preceding this incident had probably been caused by the same condition that prevented the normal extension, debris within the hydraulic fluid, but that that condition had not been identified as the cause of those previous events. The Commission also found that the primary landing gear indication system had shown correctly that the nose landing gear was not locked down, but the pilots had been misled by the verification system. The verification system was found to be unreliable. The Commission found that the pilots ought to have heeded the aural warnings, which sounded on the final approach, and should have abandoned that landing attempt until the actual position of the nose landing gear had been determined. Additional findings related to crew resource management (CRM).

1.8. The operator, Air Nelson Limited, and the aeroplane manufacturer, Bombardier, took a number of safety actions to address issues raised in this report. However, one safety issue had not been resolved, so the Commission made a recommendation to the Director of the New Zealand Civil Aviation Authority to work with the Canadian authorities to require the manufacturer to improve the reliability of the landing gear verification system.

1.9. Key lessons arising from this inquiry were:

- when critical systems begin intermittently to malfunction or behave abnormally, this is often a precursor to total failure. For this reason the diagnosis of these problems should be exhaustive and multifaceted

- the more a pilot knows about aircraft systems, the better armed they will be to deal with emergency and abnormal situations.
- aircraft warning systems are designed to alert pilots to abnormal conditions. Alerts should not be dismissed without considering all other available information
- pilots must retain sufficient knowledge of aircraft systems to deal with situations not anticipated by Quick Reference Handbooks.

2. Conduct of the inquiry

2.1. At 1730 on 30 September 2010, the Civil Aviation Authority notified the Commission of the incident. The Commission opened an inquiry under section 13 of the Transport Accident Investigation Commission Act 1990.

2.2. The Commission approved the removal of the aeroplane from the runway before its investigator in charge arrived on site the next morning. Following an initial examination of the aeroplane at Woodbourne, it was flown to the operator's maintenance and operational base at Nelson Aerodrome on 1 October 2010.

2.3. A field service representative of the manufacturer was based at the operator's base at the time and provided direct assistance to the inquiry.

2.4. On 5 October 2010 the Australian Transport Safety Bureau appointed an Accredited Representative to assist the Commission, as provided for by Annex 13 to the Convention on International Civil Aviation. On 7 October the cockpit voice recorder was taken to the Bureau's laboratory in Canberra and the content downloaded and protected in accordance with Australian legislation.[2] The involved pilots later assisted the Commission to prepare a transcript of the recording.

2.5. On 13 October 2010 the Transportation Safety Board of Canada appointed an Accredited Representative who assisted the inquiry by supervising the examination of nose landing gear components that had been returned under quarantine to the aeroplane manufacturer. A specialist examination of the components was conducted at the facilities of the component manufacturers in Canada.

2.6. On 14 March 2011 the National Transportation Safety Board of the United States appointed an Accredited Representative who arranged the supervision of a specialist examination of some components that, under United States law, could only be examined at the manufacturers' facilities in the United States.[3]

2.7. In April 2011 the Defence Technology Agency of the New Zealand Defence Force analysed hydraulic fluid samples and some landing gear components for the Commission.

2.8. The following processes also took place during the inquiry:

- interviews with the crew members and discussions with operational and maintenance personnel from the operator
- an analysis of the recorded flight data
- comparisons with nose landing gear operations on other aeroplanes in the operator's fleet
- discussions and correspondence with the aeroplane and component manufacturers' representatives in New Zealand and elsewhere
- discussions with representatives of the Civil Aviation Authority and Transport Canada
- reviews of the safety occurrence databases in New Zealand, Australia, Canada and the United Kingdom for relevant occurrences.

2.9. The Commission acknowledges the assistance of the Defence Technology Agency, the Australian Transport Safety Bureau, the Transportation Safety Board of Canada, the United States' National Transportation Safety Board, and the aeroplane and component manufacturers in this inquiry.

2.10. On 28 June 2012 the Commission approved a draft final report for circulation to interested persons for their comment. Submissions were received from both pilots, Air Nelson, Bombardier Aerospace, the Civil Aviation Authority, the Australian Transport Safety Bureau and the Transportation Safety Board of Canada on behalf of Transport Canada and Messier-Dowty

[2] Transport Safety Investigation Act 2003.
[3] International Traffic In Arms Regulations, as prescribed by the Arms Export Control Act (22 USC 2778).

INC. The flight attendant, the Defence Technology Agency and the National Transportation Safety Board replied without commenting on the draft report.

2.11. All submissions were considered when preparing this final report. On 26 September 2012 the Commission approved the final report for publication.

3. Factual information

3.1. History of the flight

3.1.1. At 1507 on 30 September 2010, a Bombardier Q300 aeroplane departed Wellington International Airport on a scheduled air transport flight to Nelson Aerodrome. The aeroplane was registered ZK-NEB and operated by Air Nelson (the operator). On board were 2 pilots, one flight attendant and 43 passengers.

3.1.2. After 2 unsuccessful approaches at Nelson because of poor weather, the flight diverted to Woodbourne Aerodrome, near Blenheim. The planned alternate aerodrome had been Christchurch, but the captain decided that conditions at Woodbourne were suitable.

3.1.3. At Woodbourne, a long, straight-in visual approach was flown to runway 24.[4] After the landing gear had been selected DOWN, lights (advisory indicators) on the centre instrument panel indicated that only the main landing gear had locked down (see Figure 1). The red "gear unsafe" light and the amber "door open" light for the nose landing gear were illuminated. The amber light in the landing gear selector lever handle was also illuminated, indicating that not all of the landing gear was in the position selected. No other caution lights were illuminated.

3.1.4. The captain commenced a go-around and entered the aerodrome circuit while the pilots assessed the situation. They advised the air traffic controller (the controller) that they had "a gear malfunction" and requested a "Local Standby" of emergency services.[5] They did not inform the flight attendant of the reason for the go-around or give her any further information during the remainder of the flight.[6]

3.1.5. The landing gear selector lever was left in the DOWN position and the captain directed the first officer to begin the "Landing gear fails to extend" checklist in the operator's customised QRH (see Appendix 1).

3.1.6. One item in the checklist was to check the verification lights that were located under the landing gear alternate extension door (flap) in the flight deck floor (see Figure 2). As the first officer was about to perform this step, the captain said to him, "You will find it's not the problem". The captain meant that he was not expecting the light for the nose landing gear to illuminate and that he expected that they would have to carry out the alternate landing gear extension procedure.

3.1.7. However, the 3 verification lights (one for each landing gear leg) illuminated green when checked. The captain, not expecting to see the light for the nose landing gear illuminated, twice interrupted the first officer's reading of the checklist, saying that not all of the landing gear legs were locked down. The first officer continued reading from the QRH, which stated in part:

> If either the "Landing gear down and locked advisory light" or the "Landing gear down verification light" is on, the gear is down and locked.
>
> Is at least one green light illuminated for each Gear Leg position?
>
> YES – The gear is down and safe.
>
> NO – carry out an Alternate Gear Extension.

---

[4] The runway designation is the magnetic heading to the nearest 10 degrees.

[5] The declaration of a "Local Standby" means the aircraft has some defect, but a safe landing is expected. The air traffic services unit is responsible for alerting emergency services. Those services based on the aerodrome will be brought to a state of readiness. Off-airport services are notified, but would not normally respond (AIP New Zealand, p.ENR 1.15-12).

[6] Communications between the crew members and with air traffic control, and flight deck sounds, were obtained from the cockpit voice recorder.

Figure 1
Q300 flight deck, centre instrument panel

3.1.8. Even though they now had 3 green lights, the first officer asked whether they should fly by the control tower to allow the controller to check the landing gear position visually.[7] The captain declined to do this, saying, "A green is a green". They informed the controller that the landing gear was now down, and were then cleared to land. While on the downwind leg of the circuit, the captain asked to check the verification lights again, and both pilots saw 3 green lights.

3.1.9. When the Q300 flew past the tower on the go-around, the controller was on the telephone advising adjacent air traffic control sectors of the situation and arranging the aerodrome emergency response. The controller was also co-ordinating a following arrival, so he did not look up to check the position of the landing gear. When the Q300 was on final approach the second time, he used binoculars to check the landing gear and at that distance it appeared to be down.

3.1.10. When the first officer selected the wing flaps to 15 degrees, the landing gear warning horn sounded.[8] The horn sounds if the flaps are set to 15 degrees or more and any landing gear leg is not down and locked. The captain was about to suggest that the circuit breaker that provided power to the horn could be pulled, but the first officer suggested that he disregard the horn as the aeroplane was now only 600 feet above the ground. The horn continued to sound until after the landing.

[7] An external observer could have reported the landing gear position, but could not categorically confirm that the landing gear was locked down.
[8] Flight parameters were obtained from the flight data recorder. See paragraph 3.2.5.

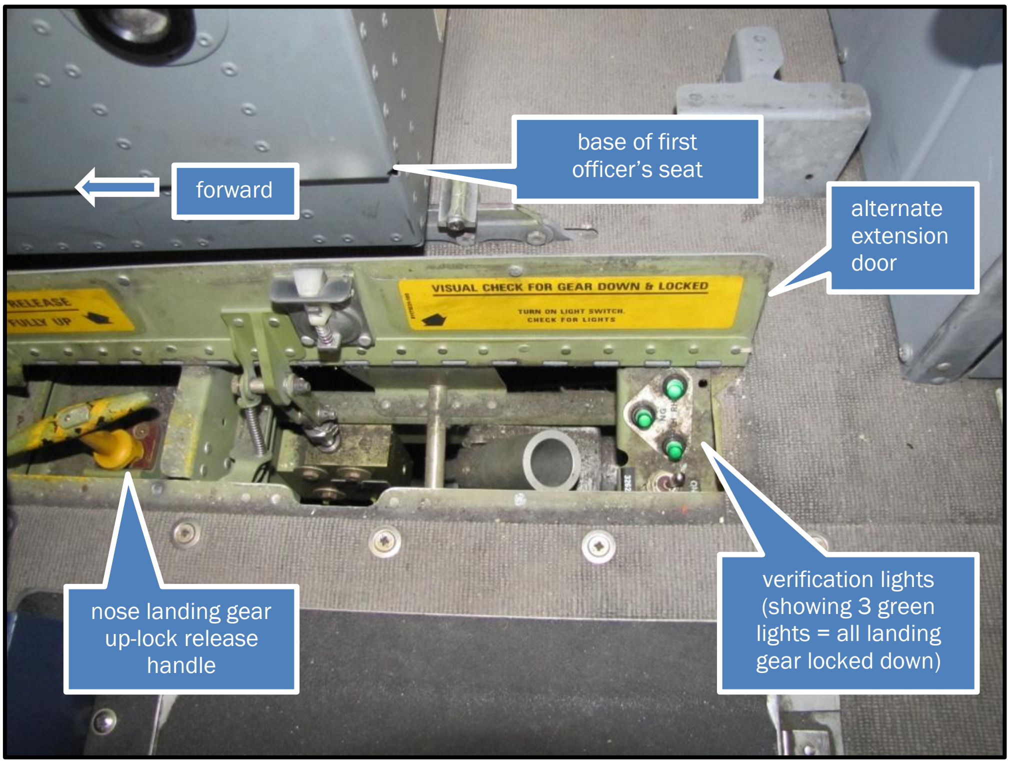


Figure 2
Nose landing gear up-lock release handle and verification lights

3.1.11. At about 200 feet above ground, after the pilots had selected the wing flaps to 35 degrees for landing, the ground proximity warning system voice alert, "Too low gear", sounded.[9] This alert warns of unsafe terrain clearance when one or more landing gear legs are retracted. The first officer quickly said, "Don't worry about it. Too late", meaning they were about to land so it was too late to be looking for the circuit breaker to silence the alert. The captain made no comment. The first officer said later that, as the runway was in sight, there had been no risk of a collision with terrain, but he had felt uneasy. This alert also continued until after the landing.

3.1.12. Both pilots said the aural warnings were a distraction during the final approach, but because they had 3 green verification lights they were confident that all of the landing gear was down. They each suspected that the advisory indicators and aural warnings were caused by a single defective proximity sensor that senses the nose landing gear position, so they reasoned that as the verification lights showed that the nose landing gear was locked down, the aural warnings could be ignored.

3.1.13. The flight attendant heard and recognised the sound of the landing gear warning horn. She also heard the "Too low gear" alert. She had heard the same voice alerts on other flights, but they had always been silenced quickly. When the "too low gear" alert continued, she looked from her seat to see that the left main landing gear was down and asked a passenger to check the right main landing gear. As both main landing gear legs appeared to be locked down, she felt that all she could do was reassure some passengers who had heard the warnings that everything was all right, although she remained puzzled by the alerts.

3.1.14. At 1710 the aeroplane landed on runway 24. After the main landing gear had touched down and the captain went to lower the nose, he realised that the nose was going lower than normal and that the nose landing gear might not be extended. He progressively applied full aft elevator to cushion the nose touchdown and commenced wheel braking. The high wing design of the Q300 is such that the propellers do not contact the ground when the aeroplane is landed without the nose landing gear locked down, if the wings are kept level.

[9] The aeroplane was equipped with the Enhanced Ground Proximity Warning System, which includes the "basic" ground proximity warning modes, of which one is the mode referred to.

3.1.15. The flight attendant heard unusual scraping noises during the landing, but she got no sense that the landing might not be under control. At no stage did she feel a need to instruct passengers to keep their heads down or that an emergency evacuation might follow. She did not think that the floor angle after landing, which was 3 degrees nose down, was particularly unusual.

3.1.16. The controller watched the landing and thought that the nose landing gear was collapsing after the aeroplane landed. He immediately cleared the assembled aerodrome emergency vehicles, which had responded to the Local Standby request, onto the runway.

3.1.17. The captain chose not to initiate an emergency ground evacuation, but instructed the first officer to shut down the engines and then made the cabin announcement, "Remain seated". The pilots then switched off all electrical power, which silenced the aural warnings.

3.1.18. After the engines had been shut down the captain went into the cabin, briefly explained what had happened and directed the flight attendant to disembark the passengers immediately. No-one was injured and there was no fire.

3.2. Aircraft information

3.2.1. The Q300, or model DHC-8-311, is a Bombardier Aerospace development of the de Havilland Canada model commonly called the "Dash 8". It is a high-wing, pressurised aeroplane powered by 2 turbo-prop engines. The aeroplane has a crew of 2 pilots and, typically, one flight attendant and seats for 50 passengers. The type certification authority for the Q300 is Transport Canada.

3.2.2. The operator had a fleet of 23 Q300 aeroplanes that had entered service between July 2005 and June 2009. At the time of the incident Bombardier had a service representative based with the operator. ZK-NEB had been manufactured in October 2005 and entered service with the operator in November that year. At the time of the incident it had accrued 10 969 flight hours and 13 340 cycles.

3.2.3. According to the operator's records, the aeroplane had been maintained in accordance with the approved maintenance programme. The previous scheduled maintenance had been a "3A" check that was completed on 29 September 2010.[10] During a 3A check, the entire nose landing gear assembly is visually inspected and lubricated, and the nose landing gear doors are checked for full and free movement. The steering assembly is also inspected, lubricated and operated. The next annual maintenance review was due on 8 October 2010.

3.2.4. On 30 September 2010 the only deferred maintenance was rectification of an inoperative stick-pusher.[11] Deferment of that task was permitted and it did not affect the incident.

3.2.5. The aeroplane was fitted with a Honeywell solid-state flight data recorder. Data relevant to the incident flight was downloaded at the operator's maintenance base and analysed for the Commission by the Transportation Safety Board of Canada.

3.2.6. A Honeywell solid-state cockpit voice recorder with a 2-hour recording duration was also fitted. The recorder was taken to the Australian Transport Safety Bureau in Canberra where the incident flight recording was downloaded. The 2 pilots assisted the Commission in confirming the transcript of the recording.

[10] An A check is carried out every 500 flight hours.

[11] The (control column) "stick-pusher" is a component of the stall warning system.

Hydraulic system

3.2.7. Hydraulic power to operate various items is provided by 2 independent systems. The #2 hydraulic system powers the landing gear and nose wheel steering. Filters in the pressure and return lines remove foreign debris from the hydraulic fluid. The fluid is usually analysed once a year by drawing samples from the low point of each reservoir.[12]

Landing gear description and operation

3.2.8. The Q300 has a retractable, tricycle landing gear. The nose landing gear retracts forward into the fuselage nose. Figure 3 shows some of the nose landing gear components referred to in this report.

3.2.9. The landing gear operation is controlled by moving the landing gear selector lever on the centre instrument panel to the UP or DOWN position. This sends an electrical signal to the appropriate solenoid of the landing gear selector valve, which pressurises the hydraulic lines to the landing gear.

3.2.10. The nose landing gear is enclosed by 2 sets of doors when retracted. The forward doors are operated hydraulically and the rear doors are mechanically linked to the landing gear leg. When the landing gear selector lever is moved to DOWN, hydraulic pressure is applied simultaneously to:

- the door actuator, to open the forward doors
- the drag strut actuator, to release the up-lock
- the nose landing gear extend/retract actuator.

3.2.11. Electrically controlled and mechanical sequence valves ensure that the components move in the correct order. Once the nose landing gear is locked down, the forward doors close, but the rear doors remain open.

3.2.12. The nose landing gear actuator has a dual-acting steel piston that slides inside an aluminium alloy cylinder. The piston head has a black elastomer inverted "T"- seal, with a black Teflon back-up ring on either side.[13,14] Hydraulic fluid is directed through a restrictor to either the "up" or "down" port of the actuator. Figure 4 is a simplified "exploded" view of the nose landing gear extend/retract actuator.

3.2.13. Nose landing gear actuators are subject to "on-condition" maintenance and can be repaired or overhauled by approved organisations only. Air Nelson did not hold the required approvals for working on the actuators, so they were sent to an approved organisation for repair and overhaul. Therefore, Air Nelson staff did not know the usual condition of piston seals and rings when they were replaced. The actuators sent previously by Air Nelson for repair had been replaced primarily because of mechanical defects, such as loose rod ends.

3.2.14. A Proximity Switch Electronics Unit monitors a number of functions, including the positions of the landing gear doors, the landing gear up-locks and down-locks, the engine power levers and the wing flaps selector lever. The Unit controls the operating sequence of landing gear doors and hydraulic actuators, and activates the landing gear warning horn. The Terrain Awareness and Warning System also receives information about the position of wing flaps and landing gear from the Unit.[15]

---

[12] The fluid type used was Skydrol.

[13] The seal set was manufactured by Greene Tweed Aerospace Engineering and consisted of the seal, part number 7215MT-952, and 2 back-up rings, part number 7215MT-P3.

[14] Teflon is the DuPont Co. brand name for a polytetrafluoroethylene product. This material is well known for its low-friction, non-stick, non-wetting properties.

[15] See paragraphs 3.1.10 and 3.1.11.

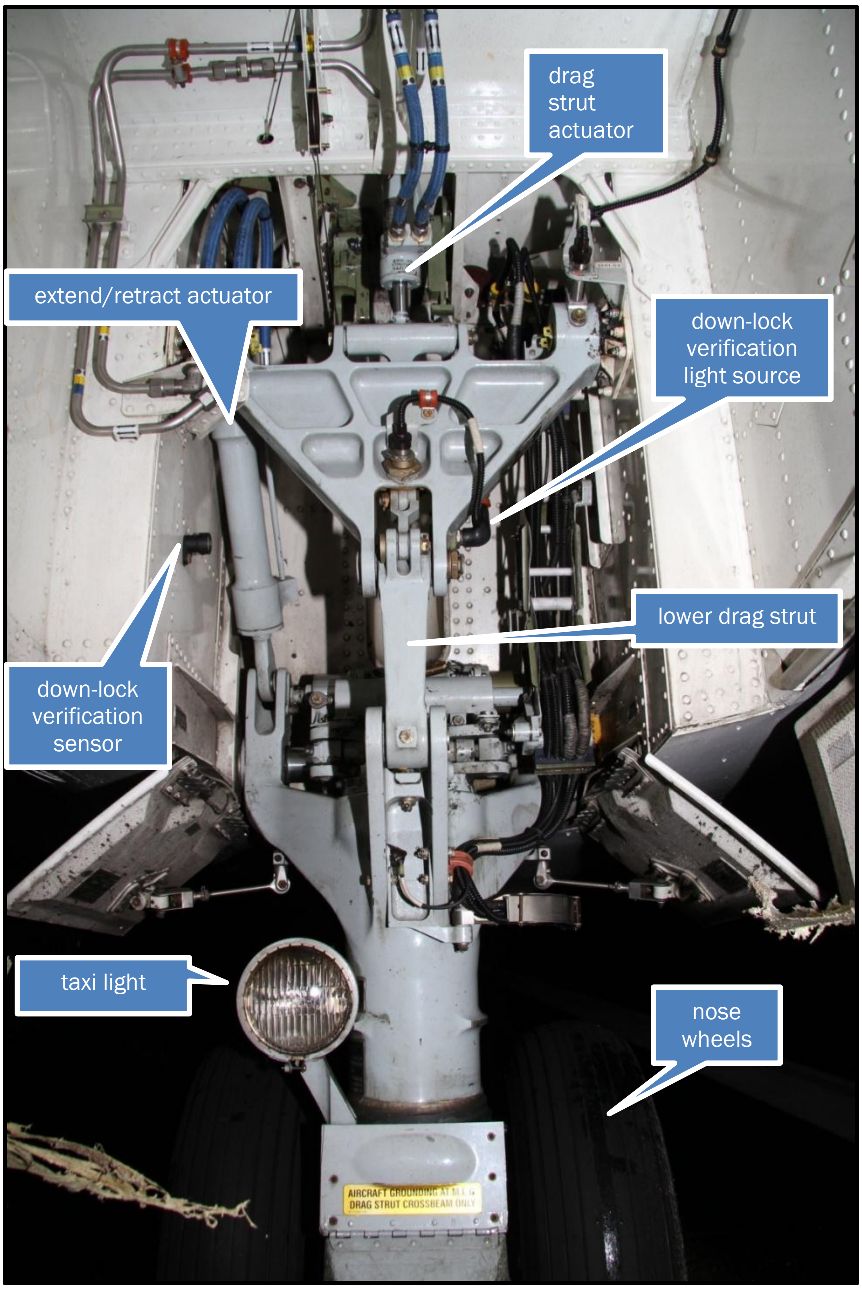


Figure 3
Q300 nose landing gear

3.2.15. When the landing gear is locked down, the Unit signals the respective green "gear down" advisory lights above the landing gear selector lever to illuminate and the red "gear unsafe" lights to extinguish. The hydraulically operated landing gear doors are then signalled to close, and once they have closed the amber "door open" lights extinguish. If the position of any of the landing gear legs does not match the position of the landing gear selector lever, the amber light in the lever handle and the appropriate red "gear unsafe" light on the advisory panel illuminate.

3.2.16. Two separate down-lock proximity sensors in the nose landing gear must agree before the Proximity Switch Electronics Unit logic determines that the leg is locked down. Therefore, one faulty nose landing gear down-lock sensor can cause the Proximity Switch Electronics Unit to determine that the nose landing gear is not locked down. The Electronics Unit determines the status of the landing gear and sends the appropriate signal: to illuminate the advisory lights above the landing gear selector lever; to the landing gear warning horn; and to the ground proximity warning system.

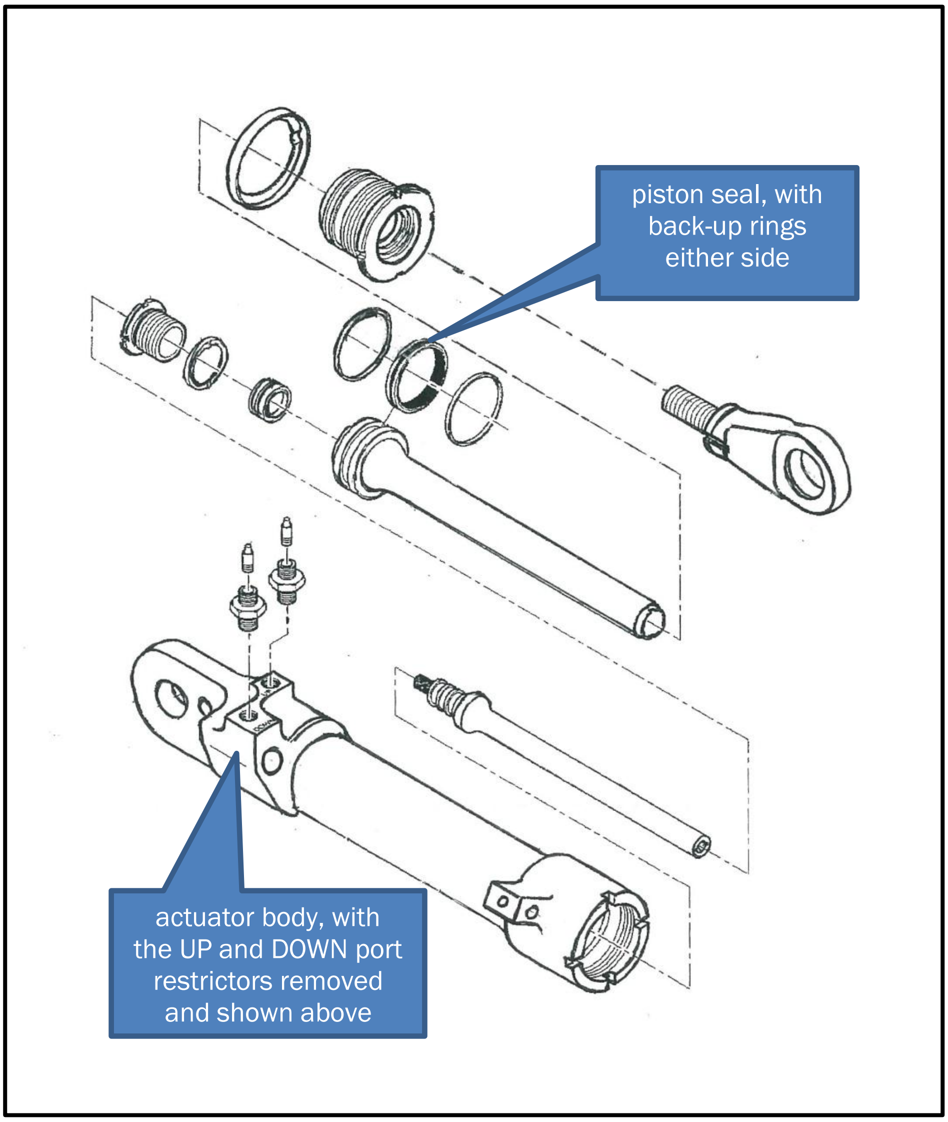


Figure 4
Nose landing gear actuator

(figure adapted from Messier-Dowty Component Maintenance Manual)

3.2.17. A taxi light is mounted on the right of the nose landing gear strut.[16] The operator's normal procedure was for it to be switched on immediately after the landing gear selector lever had been put to DOWN. The light would then be on before the nose landing gear had fully extended.

Down-lock verification system

3.2.18. The down-lock verification system provides an independent confirmation that the landing gear is locked down. For the nose landing gear, a directional light is attached above the left side of the drag strut (see Figure 5). The light is activated by the switch under the alternate extension door in the flight deck floor. If the nose landing gear down-lock is engaged, the light shines through a small hole in the down-lock link at the rear of the strut and falls onto a photo-transistor sensor on the opposite wall of the wheel well. The sensor then activates the forward green light in the floor compartment. If the nose landing gear is not locked down, the light path is blocked and the light should not illuminate.

[16] The taxi light was originally mounted externally on the nose cone and moved to the nose landing gear strut on aeroplanes manufactured after serial number 320.

3.2.19. The main landing gear down-lock verification is similar. The electronic controls for the verification system are located in the cabin and are therefore protected from moisture. The Minimum Equipment List allows flight with the nose landing gear verification light inoperative but not the lights for the main landing gear.

3.2.20. A Bombardier service letter[17] that explained the primary (advisory) and alternate (verification) means of indicating the down and locked position of the landing gear included the following, under the heading "Operator Action":

> *Upon completion of a normal extension sequence, if one or more of the three gear 'safe' lights are not on, or if one or more of the three gear 'unsafe' lights illuminate, the Alternate Downlock Indication must be consulted for landing gear status verification.*
>
> *... illumination of the appropriate gear locked down (green) by either the primary or alternate indication system is confirmation that the landing gear is down and locked.*

Alternate landing gear extension

3.2.21. If the landing gear does not extend with the normal system, an alternate method can be used (see Appendix). The alternate landing gear extension controls are:

- the main landing gear up-lock release handle behind the alternate *release* door in the flight deck ceiling above the co-pilot's seat
- the nose landing gear up-lock release handle under the alternate *extension* door (flap) in the floor by the co-pilot's seat (see Figure 2).

3.2.22. By opening the overhead door to access the main landing gear alternate release handle, a mechanical connection activates a bypass valve that connects the pressure and return lines of the landing gear hydraulic system. The landing gear up-lock release handles are attached to the up-locks by cables. When the handles are pulled, the landing gear legs should then lower freely.

Non-normal and emergency checklists

3.2.23. A QRH provides abbreviated information taken from the approved aircraft flight manual. It is intended to assist pilots to verify that the proper flight manual actions have been carried out when dealing with non-normal and emergency situations. The preface to the Bombardier Q300 QRH was typical in stating (Bombardier, 2009, p.i, ii):

> *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 [aircraft flight manual], the [aircraft flight manual] 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...*
>
> *The Non-normal/Emergency checklist assumes that if an indicating light associated with a system is not illuminating, the integrity of the bulb is checked prior to referring to the checklist.*

[17] Bombardier DH8-SL-32-027, Primary and alternate gear downlock indication, 29 September 2008.

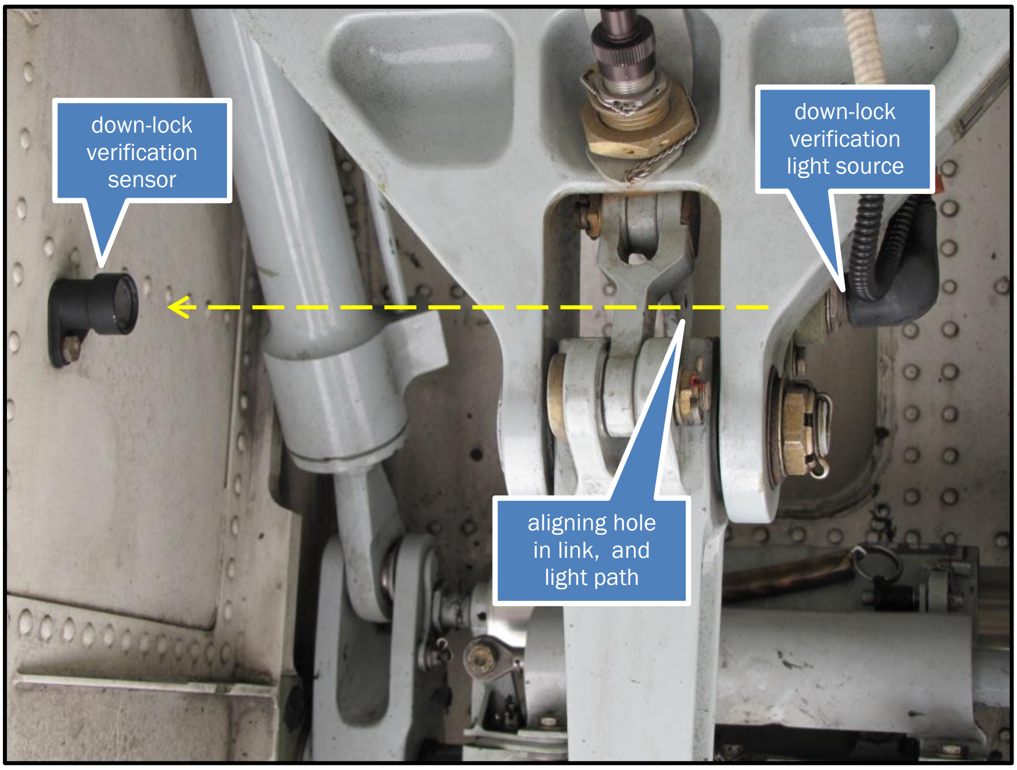


Figure 5
Down-lock verification system

3.2.24. The Bombardier flight manual and QRH had an "Alternate gear extension" procedure to use in the event the landing gear did not extend normally.

3.2.25. Air Nelson published its own QRH, which had an additional procedure for "Landing gear fails to extend". This procedure began by checking that the flight deck had been correctly configured for normal extension of the landing gear before directing the pilots to perform the alternate gear extension procedure. Part of this additional procedure directed the pilots to check the status of the down-lock verification lights. Air Nelson said that this procedure had been developed as a result of Bombardier's service letter.[18] If, for example, the pilots had not seen 3 green verification lights, Air Nelson's additional procedure would then have led to the same alternate gear extension procedure as in the Bombardier QRH.

3.2.26. The pilots had covered the "Landing gear fails to extend" and "Alternate gear extension" procedures in the flight simulator phase of their Q300 conversion training. The alternate landing gear extension actions are performed by the pilot who sits in the right seat (normally a first officer). The captain had completed his conversion training flying from the left seat, but had also operated as a training captain on the Q300 in the right seat and was familiar with the procedure.

3.2.27. The manufacturer stated that the Q300 "can safely land with the nose [landing] gear retracted" and with all of the landing gear retracted.[19] The operator's QRH recommended that pilots only consider an emergency evacuation for a landing with one main landing gear leg retracted, because that configuration presented more risk.

3.3. Incident troubleshooting

3.3.1. On both approaches to Nelson the landing gear had operated normally, and it had been retracted while the flight was holding above Nelson between the approaches. The aeroplane had been in cloud for most of the incident flight, but the pilots had not seen any airframe icing. Therefore icing was discounted as a cause of the nose landing gear not extending.

---

[18] See paragraph 3.2.20.
[19] Bombardier Service Letter DH8-SL-32-030A, 21 April 2011.

3.3.2. After the aeroplane nose was lifted by crane, the nose landing gear extended under its own weight and was pushed rearwards into the locked down position. The wheels were at a slight angle, but there was no sign that mechanical binding or an obstruction had prevented normal extension. The damage was confined to the forward nose landing gear doors and the surrounding skin, and a radio antenna on the lower fuselage (see Figure 6). The aeroplane was towed to the apron about 5 hours after landing.

3.3.3. The next day the nose landing gear was jacked clear of the ground. When the down-lock was released and the nose landing gear moved about 300 millimetres forwards in the direction of retraction, the verification lights again gave a false down-and-locked indication for the nose landing gear. The taxi light was off for this test, but it was carried out in bright sunlight on a light-coloured apron.

3.3.4. Later the same day the aeroplane was flown with the landing gear down to the operator's base at Nelson. There it was placed on jacks in a hangar and connected to a ground rig. The ground rig is used to pressurise the hydraulic systems without starting the engines, to enable landing gear retractions and extensions, and for other hydraulic system maintenance.

3.3.5. Many satisfactory extension-retraction cycles of the landing gear were undertaken using the normal system, but after a while the nose landing gear movement became slow and variable. On some occasions the nose landing gear stopped when only half-extended, and on others it paused during extension.

Figure 6
Damage to ZK-NEB

(photograph courtesy of Royal New Zealand Air Force)

3.3.6. The nose landing gear actuator, drag strut actuator and landing gear selector valve were removed for further inspection. The nose wheel steering manifold assembly was also removed. An initial examination showed that the hydraulic fluid was contaminated with unidentified black specks. No contamination was found in the similar components of the main landing gear. The ground rig was eliminated as the source of the contamination.

3.3.7. After the hydraulic lines were cleaned, the nose landing gear was reinstalled (apart from the forward doors) using replacement components. Extension and retraction tests were then carried out with no further faults found.

3.3.8. The operator analysed hydraulic fluid samples from each aeroplane annually. The most recent samples from ZK-NEB had been taken on 4 September 2010, 16 days before the incident. The analysis report stated the fluid was "in good condition".

Other incidents

3.3.9. A month before this incident a flight crew wrote in the maintenance log for ZK-NEB that after selecting the landing gear UP, the position indicators showed that the nose landing gear had not retracted. The pilots extended the landing gear and retracted it again, after which correct indications were obtained. The landing gear operation remained normal for the rest of that day, so no further maintenance action was taken.

3.3.10. On 10 September 2010, 20 days before this incident, a flight crew reported that the nose landing gear on ZK-NEB was very slow to retract after 2 take-offs, with the position indicators showing that the nose landing gear doors had not closed. At the operator's base, a series of landing gear retractions and extensions was carried out and a defect was confirmed, although it was described as "mainly slow and inconsistent extensions". The maintenance team replaced the nose landing gear door solenoid sequence valve, but the defect remained. The nose landing gear door mechanical sequence valve was then replaced and the nose landing gear actuator bled of air. After 30 successful retract-extend cycles, the nose landing gear operation was considered satisfactory and the aeroplane was returned to service.

3.3.11. In 1995 a different New Zealand airline had to use the alternate procedure to extend the nose landing gear on a Dash 8-100 aeroplane, which landed uneventfully.[20] Whether an attempt was made to cycle the landing gear is not known. The Dash 8-100 preceded the Q300, but the nose landing gear actuators were the same part. The defect was caused by pieces of the actuator seal restricting the hydraulic fluid flow through one of the actuator orifices. The cause of the seal failure was not determined.

3.3.12. On 12 March 2012 the flight crew of a Dash 8-100 aeroplane operated in Papua New Guinea carried out an alternate extension of the landing gear following a loss of #2 hydraulic system pressure.[21] The nose landing gear did not extend initially. However, the verification light indicated that the nose landing gear was locked down, even though an air traffic controller confirmed that it was retracted and the doors were closed. The verification system used in the Dash 8-100 uses a fibre-optic path from the light sensor to the down-lock green light, and the taxi light is located above the aeroplane nose, outside the nose wheel well. This incident was still under investigation when this report was published.

3.4. Tests and defect rectification

Down-lock verification system

3.4.1. The complete verification system from ZK-NEB was tested for the Commission by the Transportation Safety Board of Canada. The general condition and proper construction of the assembly were found to be satisfactory. All tests, including the circuit performance with the sensor immersed in water, were satisfactory. The Transportation Safety Board reported that:

> *the most likely cause of the [false down and locked indication] was a light source producing sufficient ambient light to activate the circuit. Tests conducted by Bombardier seem to indicate that the most likely source of light was the taxi light which is located on the nose [landing] gear.*

3.4.2. Bombardier had conducted its own tests, which revealed that false nose landing gear down-lock indications could occur if the taxi light was switched on during landing gear extension.

---

[20] Civil Aviation Authority occurrence number 95/3752.

[21] Information provided by the Papua New Guinea airline.

The tests showed that as the nose landing gear was extending, the verification light in the cockpit illuminated as the taxi light passed level with the top of the light sensor in the nose wheel well, extinguished again once the gear had made about two-thirds of its travel, then illuminated again once the nose landing gear was down and locked (as it was designed to do). That finding was confirmed in tests conducted by the Commission.

3.4.3. Bombardier said that this problem had not been foreseen when it moved the taxi light from above the nose cone, where it had been fitted on earlier models of the Dash 8, to the nose landing gear strut on the Q300. The flight manual and QRH were later amended to require the taxi light to be switched off before checking the verification lights.

3.4.4. During the troubleshooting of this incident, false down-and-locked indications were seen for the right main landing gear as well. The electrical connectors were cleaned and treated with a water repellent, but the defect recurred. A chafed wire was found to have been the cause.

3.4.5. On 14 November 2010 the operator added daily in-flight checks of the verification system to supplement the daily ground checks it already performed. During 2011 the operator had 7 reports of false landing gear position indications in flight. None involved the nose landing gear, but in one case the indications for both main landing gear legs were false. Flight in moist conditions was a common factor. In each case the defect was rectified by cleaning the sensors and connectors and applying a water repellent. The aeroplane maintenance manual already contained advice on this issue.

Landing gear selector valve

3.4.6. The landing gear selector valve was examined by the manufacturer, Eaton Aerospace, under the supervision of an investigator from the United States National Transportation Safety Board on behalf of the Commission. The valve passed all but one functional test, with one internal leakage test just outside tolerance. The investigating group considered that the result was consistent with an in-service part and had not affected the valve's functionality.

3.4.7. The valve was disassembled and no anomaly was found. The remaining hydraulic fluid in the valve was assessed as Class 10, which did not meet the fluid cleanliness standard of Class 8 or lower.[22]

Nose landing gear actuator, drag strut actuator and steering manifold

3.4.8. The nose landing gear actuator, drag strut actuator and the nose wheel steering manifold were examined by their manufacturer, Messier-Dowty, under the supervision of the Transportation Safety Board of Canada on behalf of the Commission. No defects were found with the drag strut actuator or the steering manifold.[23]

3.4.9. According to Messier-Dowty, the nose landing gear actuator had not been disassembled previously and the seals were those installed at manufacture in 2003. At the time of the incident the actuator had completed 13 340 cycles. The manufacturer estimated that the global fleet *mean* time between unscheduled removals was approximately 30 000 cycles.[24]

---

[22] The applicable standard was National Aerospace Standard 1638.

[23] Messier-Dowty report ESR00574-8, 11 February 2011.

[24] The number of cycles for the nose landing gear actuator would likely be slightly higher than this, because some extensions and retractions do not involve a landing, e.g. missed approaches, go-arounds and training.

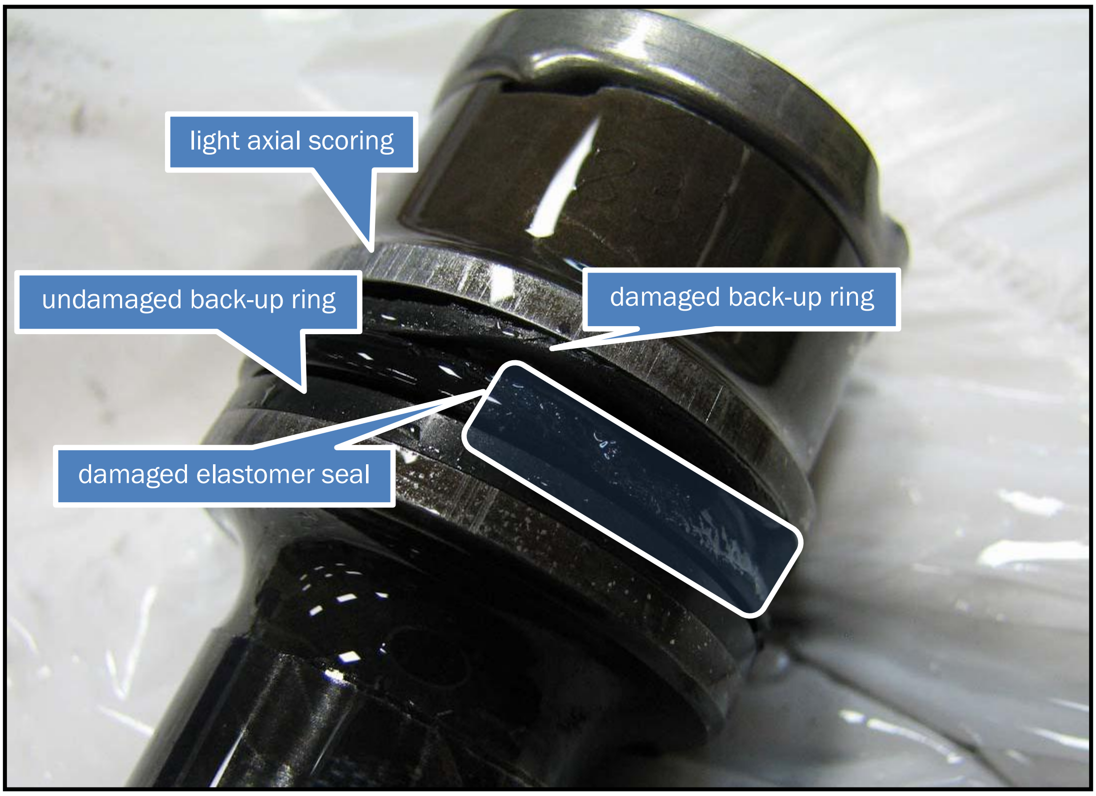


Figure 7
Nose landing gear actuator piston removed from ZK-NEB

3.4.10. The nose landing gear actuator could be fully extended and retracted by hand without excessive force or binding. However, on disassembly fluid contamination was noted and minor wear marks were seen on the piston head. Black debris was found on the inside of the UP restrictor. The dimensions of the actuator met production specifications. An analysis of residual fluid and debris determined that the hydraulic fluid was of the correct type and that the contaminants were a range of metals, predominantly aluminium, and a black, organic material with characteristics consistent with those of Teflon.

3.4.11. The piston seal and one of the seal back-up rings had damage that the manufacturer considered rare (see Figure 7). An analysis indicated that the seals and back-up rings were genuine parts and had been fitted in the correct order. Messier-Dowty stated that nose landing gear actuators had seldom leaked fluid or sustained seal damage like that found in this actuator, and their specifications had not been changed.

3.4.12. The Messier-Dowty report concluded that the seal deterioration and contamination were the result of hydraulic system contamination. It did not specifically address the cause of the actuator failing to extend the nose landing gear, but implied that a particle of contaminant had blocked an integral port and prevented proper actuator operation.

3.4.13. Sections of the seal and the damaged ring were sent by Messier-Dowty to the seal supplier and the Transportation Safety Board of Canada for further examination. These examinations found that the seal and back-up rings were genuine parts and had been installed in the correct order. The seal supplier concluded that the seal damage was a form of material fatigue known as “pock marking”, in which the first material to be damaged is carried away in the fluid and the uneven hydraulic pressures lead to accelerated damage to more material. Ultimately, a pock-marked seal will fail completely. The seal manufacturer, noting the light scoring on the piston head and metal fines on the seal remnants, concluded that “hardware environment factors” had caused the seal damage. The seal manufacturer did not consider the event systemic, in part because of the history of successful operation across the Dash 8 fleet.

3.4.14. The Transportation Safety Board of Canada laboratory identified the presence of particles of a "7xxx-series aluminium alloy" on the seal.[25] The report noted that the nose landing gear actuator cylinder was 7075 alloy and that "the composition of most metal particles found on the back-up ring … is consistent with the major elements specified for this alloy".[26] The report concluded that:

- no signs of incorrect seal and/or back-up rings having been used in the hydraulic system of the occurrence aircraft could be established. Materials of the occurrence parts matched materials of exemplar parts

- signs of wear or mechanical damage were observed on the occurrence parts

- the organic material deposits on the filters from hydraulic system tests were likely debris from the seal and back-up rings

- metal contamination, primarily with aluminium alloy particles, was found on the occurrence parts. These particles were probably a result of wear of hydraulic system components made of aluminium alloy.

3.4.15. The Transportation Safety Board of Canada also analysed 22 hydraulic fluid "patch" samples taken from various points in the hydraulic system of ZK-NEB, including the #2 hydraulic system pressure and return filters and residual fluid from the nose landing gear actuator. Using various spectroscopy techniques, the laboratory identified a range of contaminants ranging from sub-micron to sub-millimetre in size, many of them non-metallic. The analysis focused on the metallic particles and concluded that:

- microscopic metal-containing particles with chemical compositions generally consistent with metallic materials employed in aircraft construction were observed on the filters

- a comparison filter [from another of the operator's aeroplanes with a similar time in service] was in all aspects very similar to the corresponding test filter (#2 return) from the occurrence hydraulic system

- it was not possible to determine the specific origins of the particles with the information provided for the examination.[27]

3.4.16. As the nose landing gear actuator had been considered the likely defective component from the outset, the actuators from 2 other aeroplanes with similar times in service had been sent to Bombardier for comparison. The cylinder of one of these actuators was scored beyond limits, but the other actuator was serviceable.

3.4.17. These findings became known at about the time of another incident of a Q300 landing without its nose landing gear extended.[28] The operator then examined all nose landing gear actuators that had more than 10 000 hours in service. In nearly all cases, metal fines were found on the seals of the actuators, and some had seal damage or wear, but not to the extent of that seen on the actuator from ZK-NEB.

[25] Alloys of different composition have different identification numbers. The 7000 series of alloys is commonly used in aircraft and aircraft component manufacturing.
[26] Transportation Safety Board of Canada, Engineering report LP176/2010, Nose gear actuator ring examination, 20 January 2011.
[27] Transportation Safety Board of Canada, Engineering report LP155/2010, Analysis of hydraulic fluid samples, 9 December 2010.
[28] This incident, involving ZK-NEQ, was investigated by the Commission (report 11-002, still under investigation).

Subsequent incident

3.4.18. On 16 March 2011 hydraulic fluid samples that had been taken earlier from the #2 hydraulic system of ZK-NEB were found to be contaminated with "a fine black sludge". The nose landing gear actuator (which had been installed after the 2010 incident), the nose wheel steering actuator and the nose landing gear door actuator were replaced. An inspection confirmed that the #2 hydraulic system reservoir was not contaminated, but the #2 system fluid was replaced. Fluid samples taken subsequently have been clean.

3.4.19. The removed nose landing gear actuator was examined and found to be in a satisfactory condition, but there was some evidence of contamination in the steering actuator. This contained a small piece from the actuator transfer tube seal back-up ring, which appeared to have been nicked during installation.

3.4.20. The nose landing gear door actuator was examined by its manufacturer, which found that the aluminium cylinder was worn beyond limits and the white Teflon piston seal back-up rings were excessively worn (see Figure 8). The door actuator had been installed as a new item when ZK-NEB was manufactured. Bombardier advised that between August 2005 and February 2011 the world Q300 fleet mean time between unscheduled removals of the door actuator was 49 134 flight hours.

3.4.21. The operator removed the door actuators from 5 aeroplanes, based on their hours in service and higher, although acceptable, levels of hydraulic fluid contamination. Four actuators had cylinder wear that was outside limits and the seals of 2 had major damage. The aeroplane manufacturer and operator continue to examine causes of the high wear rate. In the interim, the operator has instituted a finite life for the nose landing gear door actuators.

3.4.22. In April 2011 the Defence Technology Agency conducted further tests for the Commission on the fluid samples and the nose landing gear actuator seals. The Agency's analysis methods included the use of electron microscopy and X-ray spectroscopy microanalysis of the seals and hydraulic fluid samples to determine the alloy composition of metal contaminants.

3.4.23. The Defence Technology Agency's report on these analyses included reference to the following:[29]

- fluid samples from the #2 hydraulic system reservoir were considered reasonably clean, compared with the appropriate standard[30]

- the 'black particulate material', evident in samples taken from the #2 system pressure and return filters and the right engine-driven hydraulic pump case drain contained a polymer that might have been from the rubber used in the piston seal, but a definitive match could not be confirmed

- the Agency was unable to make any specific categorisation of the particulate contaminants present in the samples. However, 'in general terms, the 2 predominant types … were organic (carbonaceous and/or fluorine) and aluminium-based (similar to 7000 series alloys)'. The majority of the organic debris was likely from the seals and back-up rings. The report noted that the aluminium-based debris may be consistent with wear and damage to the [nose landing gear] actuator cylinder.

3.4.24. The report concluded that a range of metallic contaminants had been identified, with aluminium-based debris predominant in some samples. Organic debris was "likely to have been consistent with" the nose landing gear actuator piston seal and back-up ring component materials.

---

[29] Defence Technology Agency, Technical Memorandum C1199, 9 May 2011.

[30] This was the Society of Automotive Engineers' standard AS4059E class 7, equivalent to the National Aerospace Standard 1638 class 7.

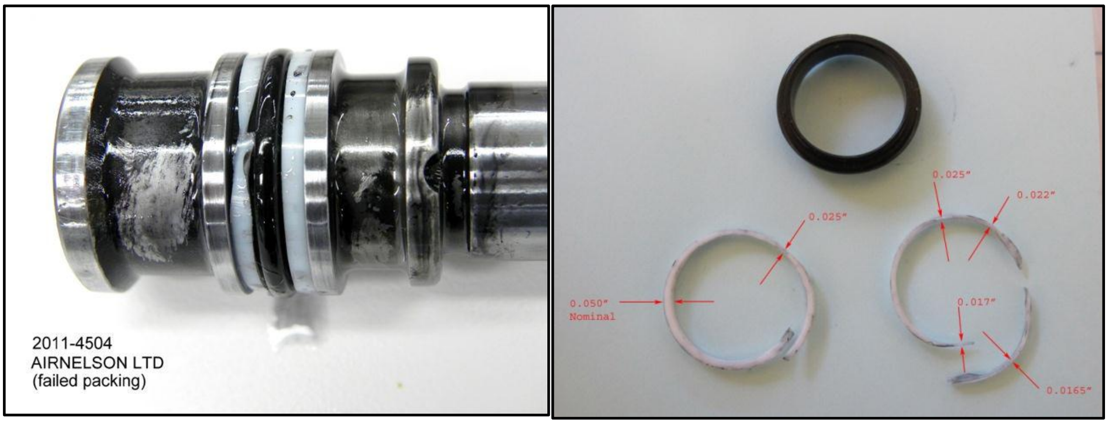


Figure 8
Nose landing gear door actuator from ZK-NEB:
damaged seals in place (left) and removed (right)

3.5. Aerodrome information and air traffic control

3.5.1. Woodbourne Aerodrome is located about 6 kilometres west of Blenheim city in a broad river valley. There is an unobstructed approach to the single, sealed runway and the right-hand circuit for runway 24 is comfortably clear of terrain for a Q300-size aeroplane.

3.5.2. The sole air traffic controller on duty had more than 35 years' experience and had been controlling at Woodbourne since late 2001. On previous occasions he had visually checked the landing gear of aeroplanes when the pilots had doubts about its position.

3.6. Personnel information

3.6.1. The captain, who was the pilot flying the sector to Nelson, had flown the previous 2 sectors in ZK-NEB, but with a different crew. The flight attendant had operated with the captain on the first sector that day then flown 2 sectors with another crew. The first officer had also operated 2 sectors with a different crew.

3.6.2. The captain had been hired by the operator in 1994 and obtained an airline transport pilot licence (aeroplane) in September 1996. He had obtained a Q300 aeroplane type rating in April 2007, but had been the Q300 fleet manager since March 2007. In that capacity he had represented the operator at customer seminars hosted by Bombardier. His total flight experience at the time of the incident was about 12 040 hours, of which about 1066 hours had been on the Q300. His previous flight crew competency and line checks had been on 14 September 2010. He held a valid Class 1 medical certificate endorsed with the requirement to have half spectacles readily available.

3.6.3. The captain had had more than 13 hours free of duty, and said he had had adequate sleep, before reporting for duty at 0620 on the day of the incident. He had operated one sector, then had a 3-hour break before operating 2 more sectors, followed by a short break prior to the incident flight. He said he had not felt tired when on the approach to Woodbourne. He had worked in the office for 8 hours a day on the 2 days prior to 30 September. He had had no duty on 27 September, having just returned from a meeting with Bombardier in Canada. He had flown about 90 hours in the previous 90 days, and 21 hours in the previous month.

3.6.4. The first officer had joined the operator in February 2009. He was one of 2 Royal New Zealand Air Force junior pilots seconded to the airline during a period of reduced flying in the Air Force. They did not have the minimum flight experience required by Civil Aviation Rules before commencing training as first officers, but had been granted an exemption by the Director of Civil Aviation on 12 December 2008.[31]

---

[31] Civil Aviation Rule 121.511(1) and (2), and Civil Aviation Authority Exemption 9/EXE/37 refer.

3.6.5. The first officer held a commercial pilot licence (aeroplane) issued in November 2008. He had obtained a Q300 type rating in March 2009 and his total flight experience at the time of the incident was about 1167 hours, about 780 hours of which had been on the Q300. His previous flight crew competency and simulator checks had been on 9 July 2010. He held a valid Class 1 medical certificate with no conditions, restrictions or endorsements.

3.6.6. The first officer had had more than 22 hours free of duty, and said he had had adequate sleep, before reporting for duty at 1015 on the day of the incident. He had operated 2 sectors with a different crew before the incident flight. He had had 10 hours of duty on 28-29 September, with the night of 28 September spent away from his home base. The 4 days before that had been free of duty, but included travel back from Australia. He had flown about 141 hours in the previous 90 days and 44 hours in the previous month.

3.6.7. The flight attendant had 5 years' experience with the operator. She had accrued a total flight time of about 2670 hours, of which about 2000 hours were on the Q300. In the 30 days prior to the incident she had accrued about 113 duty hours and 28 flight hours. Her previous flight attendant refresher course had been on 24 July 2010 and her previous line check had been on 27 July 2010.

3.7. Crew resource management

3.7.1. CRM has evolved since the 1970s from a concept for improving the efficiency and co-operation of flight deck crew only to a practice involving all flight crew and others outside an aircraft who directly affect the conduct or safety of the flight, such as air traffic controllers and maintenance personnel. The practice spread to other transport modes and activities and is now embedded as an essential skill for teams working in safety-critical operations.

3.7.2. The definition of CRM has changed as the theory and practice have evolved, but in an aviation context it is essentially "the effective use of all resources to achieve safe and efficient flight operations" (International Civil Aviation Organization, 1989, p.4). The resources contemplated being used include equipment, all of its features and the procedures that optimise its use; and people, whether on board as crew or not, and particularly their knowledge and ability to assist with problem-solving. In addition, the time available to resolve a problem or abnormal condition can be a useful resource.

3.7.3. The non-technical skills that enhance crew communication, co-operation and decision-making are essential components of CRM training courses. These courses impress upon trainees the nature of human error and how individual attitudes and behaviour affect crew performance and the safety of flight operations.

3.7.4. The operator's initial CRM training for pilots and flight attendants emphasised the team aspects of airline operations. Within 12 months of starting revenue flying, pilots and flight attendants attended a joint CRM training session that included, among other subjects, decision-making, abnormal situation management and crew communication. Pilots learnt the technical aspects of individual abnormal checklists during the relevant simulator and line training, and crew co-ordination and communication aspects formed "a large portion" of the joint refresher courses held for pilots and flight attendants every 2 years. CRM aspects that were more relevant to command were covered during a first officer's upgrade training.

3.7.5. Annual refresher training for flight attendants covered all of the subjects of their initial training and any special items. For 2010, a special item in the programme had been a presentation on ground accidents and unusual emergency evacuations after, for example, a landing gear failure to extend. The flight attendant had not been rostered to attend that refresher training prior to the incident. However, she and both pilots had completed refresher training in accordance with the operator's schedule.

3.7.6. The operator's standard procedure in the case of a prepared abnormal or emergency landing was for the aeroplane captain to brief the flight attendant. The briefing should cover the nature of the emergency, the captain's intentions, the time remaining and any special instructions, such as re-seating passengers to more favourable locations.

3.7.7. Flight attendants are taught to carry out a silent review before each take-off and landing in order to be primed to deal with unexpected occurrences. The review covers the aerodrome at which they are operating and its local environment, the need to be alert for anything unusual and the signals and commands for emergency situations, such as a ground evacuation.[32]

[32] Air Nelson, Flight Attendants' Procedures Manual, p.4-4-1

4. Analysis

4.1. The nose landing gear of the Q300 aeroplane did not fully extend when the pilots selected the landing gear down on approach to Woodbourne Aerodrome. The reasons for this are discussed below, but the nose landing gear not fully extending is not the main concern. The main concern is that the pilots thought it was down and locked when in fact it wasn't.

4.2. There are a number of reasons why the nose landing gear might fail to extend fully using the normal system, which is why aeroplanes are required to have an alternative means of extension. There are procedures and checklists to help the pilots to achieve this. However, in this case one of the systems for checking that the landing gear was down and locked was poorly designed and gave the crew a false indication that the nose landing gear was down and locked. The flight crew then continued the approach in the expectation of making a normal landing.

4.3. This report discusses the design of the verification system that falsely indicated that the nose landing gear was down and locked. It also discusses whether, if the indication system had not been faulty, the crew could have succeeded in extending the nose landing gear fully by alternative means.

4.4. The pilots were justified in believing the verification light that showed that the nose landing gear was down and locked. However, later in the approach the aeroplane systems gave them another 2 alerts that the landing gear was not safe. The report discusses the pilots' reactions to those additional warnings. The role of CRM in dealing with such incidents is also discussed.

Nose landing gear extend/retract actuator defect

4.5. The nose landing gear actuator most likely jammed because pieces of the damaged piston seal and its back-up rings had blocked at least one of the internal ports. After the landing gear selector lever had been placed to DOWN, the main landing gear locked down normally, showing that the electrical and hydraulic sub-systems worked correctly. The nose landing gear up-lock had released and the extend actuator had begun to extend the leg. If the UP port had then blocked, the fluid on that side of the dual-acting piston would have been prevented from returning to the reservoir, thereby creating a hydraulic lock that would have prevented further movement of the actuator.

4.6. The pieces of damaged seal were not the only contaminants found in the system. The analyses of the fluid by the Transport Safety Board of Canada and the Defence Technology Agency agreed broadly on the nature of the metallic particles, that their origin was most likely other components powered by the #2 hydraulic system, and that the organic compounds came from the seal and the back-up rings. Aluminium was the predominant metallic debris, but the aluminium cylinder of the nose landing gear actuator was not worn. Therefore the metal came from elsewhere in the nose landing gear system.

4.7. In March 2011 the nose landing gear door actuator cylinder was found to be worn beyond limits and to contain debris from its seal and back-up rings. That actuator had not been removed from ZK-NEB after the September 2010 incident, because the previous routine analyses of the hydraulic fluid had not caused concern for the condition of that or any other component.

4.8. The wear on the door actuator cylinder suggested that it was the source of much of the metal found on the extend/retract actuator and other components in ZK-NEB. A comparison with door actuators from other aeroplanes suggested this could be a fleet issue, which the manufacturer and operator are continuing to investigate. The Commission is recommending that the Director of Civil Aviation monitor the progress of those investigations and liaise with Transport Canada in order to produce acceptable corrective actions.

4.9. Hydraulic fluid samples from ZK-NEB analysed since the nose landing gear door actuator was replaced in March 2011 have been satisfactory.

4.10. A confounding issue during the investigation, especially after the incident in February 2011, was the presence of metal fines on the nose landing gear actuator piston seals. As Air Nelson had no experience of disassembling the actuators, it did not know whether the condition of an actuator that had performed 10 000 cycles was similar to that of one that had reached the average overhaul life of more than 30 000 cycles. However, Messier-Dowty and the various examinations indicated that metal fines were always present and a result of normal wear and tear.

4.11. The initiating cause of the seal damage was not conclusively determined. A manufacturing defect or incorrect seating of the seal during the assembly of the actuator cannot be excluded. Having been damaged, the seal would have been progressively eroded by normal hydraulic pressure fluctuations and by the larger metallic particles that contaminated the hydraulic fluid.

4.12. The nose landing gear extend/retract actuator has been a reliable component across the world-wide Q300 fleet. The damage to the seals found in this actuator is therefore considered to be unusual. For this reason the manufacturer has not amended its maintenance requirements for the actuator, and the Commission concurs with this decision.

4.13. In the 5 weeks before this incident, 2 nose landing gear defects on ZK-NEB were investigated and the aeroplane was released to service without any definite causes being found. The intermittent nature of these defects, particularly the retraction event, might now be recognised as symptomatic of fluid contamination or an actuator defect. Neither the nose landing gear actuator nor the door actuator was replaced.

4.14. Air Nelson amended its maintenance response to the contamination of the #2 hydraulic system to include replacement of the nose landing gear actuator and the nose landing gear door actuator, in addition to replacement of the filters and the #2 system fluid. Air Nelson also put a finite life on the nose landing gear door actuators, pending the outcome of the investigation referred to above.

4.15. The on-condition maintenance process should prevent the failure or degradation of a component from causing an operational incident by recognising the imminent or likely need to repair or replace the component before that happens. System redundancies and non-normal procedures cater for most sudden failures, but the on-condition process is not intended to be one of "fit until failure". Pilot reports of unusual system operation are as much a part of on-condition monitoring as obvious defects, such as a leaking seal.

4.16. The maintenance response to reported defects is usually straightforward when the causes of the defects are obvious. When the cause is not so obvious, or if the maintenance manual lacks specific guidance, troubleshooting will often follow the process of elimination of potential causes, which may mean the replacement of components. That process, particularly where there is an intermittent defect, may appear to remedy the defect, only for it to return later. For this reason, maintenance action might initially fail to identify the true cause of a defect.

Findings

The failure of the nose landing gear to extend fully was most likely caused by debris in the hydraulic fluid blocking orifices within the nose landing gear extend/retract hydraulic actuator. The debris probably came from damaged seals within the actuator.

The damage to the seals within the extend/retract hydraulic actuator could have initially been caused by a manufacturing defect in the seals or by an incorrect assembly technique. The damage may have been exacerbated by debris in the hydraulic fluid that originated from excessive wear in another actuator in the system, the one that opened and closed the forward nose landing gear doors.

Two instances of unusual operation of the nose landing gear had been reported in the 5 weeks prior to the failure to extend at Woodbourne. The cause of the earlier events was probably the same as that of the failure to extend.

Reason for the false down-lock verification

4.17. When the pilots moved the landing gear selector lever to DOWN on the approach to Woodbourne, the "Landing ear Inop" caution light did not illuminate, but the indicators on the landing gear panel told them that the nose landing gear was in an unsafe condition. The use of the "Landing gear fails to extend" procedure in the Air Nelson QRH was the appropriate action for the pilots to take. The procedure stated that if either the advisory indicator on the forward panel or the verification light under the alternate extension flap was green, the corresponding landing gear leg was down and locked. The 2 indication systems were independent of each other.

4.18. The text of the QRH removed any doubt for the pilots. It clearly stated that if either light was green, the relevant landing gear leg was down and locked. When the pilots saw the green verification light for all 3 landing gears, including the nose landing gear, the pilots had every right to believe the verification light, and halt the "Landing gear fails to extend" procedure.

4.19. The captain said that in his capacity as the airline's flight operations representative at Bombardier customer seminars, he had heard the saying "a green is a green" used to emphasise the dependability of the verification system. His comment that "a green is a green", made when he declined the first officer's suggestion to fly past the control tower and have the nose landing gear position checked by the controller, reflected his confidence in the verification system. Most other pilots would have concluded at that point that all of the landing gear was down. Notwithstanding that confidence, shortly afterwards he requested a second check of the verification light, and both pilots confirmed that it was still green.

4.20. Clearly, the nose landing gear down-lock verification had been false. That error was replicated the following day during ground checks. Laboratory testing confirmed that the verification sensor would be activated if the taxi light was ON before the nose landing gear had extended fully. The operator's normal procedure was to switch the taxi light ON immediately after the landing gear selector lever was put to DOWN. There was no reason to believe that the pilots on this flight had deviated from that procedure. Therefore it was almost certain that the taxi light had been ON when the verification lights were checked and that with the nose landing gear in the partially extended position, the bright taxi light caused the false indication.

4.21. The cause of the false indication the day after the incident, while the taxi light was OFF, was not determined, but it could have been that the sunshine reflected from the concrete apron was bright enough to activate the sensor that illuminated the green indicator light in the cockpit. The manufacturer had not recognised the possibility of stray light activating the sensor when the taxi light position was shifted from the external nose cone, where it had been on earlier Dash 8 models, to the nose landing gear strut. The manufacturer issued a service letter in April 2011 and added a note to the QRH to remind pilots to ensure that the taxi light was OFF when checking the verification lights.

4.22. The change to the QRH resolves the issue of stray light from the taxi light causing a false indication. However, the incident in New Guinea in March 2012, involving an aeroplane that did not have the taxi light on the nose landing gear strut, showed that there must be other causes for false indications. Air Nelson had identified at least 2 other causes: moisture ingress and the chafing of wires.

4.23. These defects and reports of occasional false in-flight verifications suggested that the reliability of the verification system for the Q300 (and Dash 8 series) did not warrant the trust placed in it by the manufacturer.

4.24. The Commission recommends that the Director of the New Zealand Civil Aviation Authority work with Transport Canada to require the manufacturer to improve the reliability and dependability of the landing gear down-lock verification system.

> **Findings**
>
> With the nose landing gear stuck in a partially extended position, light from the taxi light was likely detected by the sensor for the down-lock verification system, causing it to give a false green light.
>
> The false green light on the verification system misled the pilots of ZK-NEB into believing that the nose landing gear was fully down and locked.
>
> The verification system for checking if the landing gear is down and locked on the Dash 8 series of aircraft is not reliable enough for pilots to place total trust in it when trying to establish the status of the landing gear.

Other means of extending the nose landing gear

4.25. After the nose of ZK-NEB was lifted from the runway, the nose landing gear lowered under its own weight, which confirmed that the up-lock had released. The fact that the actuator then moved freely indicated that it was no longer jammed, possibly because the partly extended wheels had been forced back into the wheel well during the landing. That reverse actuator movement could have dislodged any debris in the actuator. With this possibility and the 1995 incident in mind, the Commission considered whether the nose landing gear might have been extended by another method.

4.26. The false down-lock indication caused the pilots, in accordance with the QRH, to stop the "Landing gear fails to extend" procedure. Therefore they had no reason to try the alternate extension procedure. However, it is probable that they would have tried that procedure if they had known (for example, from having asked the controller) that the nose landing gear, in spite of the verification light showing otherwise, was definitely not down.

4.27. During an alternate extension procedure, hydraulic pressure is equalised within the landing gear system. Whether simply depressurising the hydraulic system would allow any debris to dislodge from the "retract" (up) restrictor would depend on the size of the debris and how solidly it was entrapped there. The debris was likely to have been forced into the orifice of the restrictor under hydraulic pressure as the nose landing gear tried to extend. It is unlikely therefore that the debris would simply have fallen out when the hydraulic pressure was removed.

4.28. For the alternate extension procedure to have succeeded, the debris would have to have dislodged, or as discussed earlier, been forced out by hydraulic fluid flowing through the restrictor in the opposite direction. If the pilots had not been given 3 green verification lights, they would have gone straight to the alternate extension procedure. There would therefore have been no opportunity for such a reverse flow of hydraulic fluid through the restrictor. For this reason it is unlikely that the alternate extension procedure would have succeeded in extending the nose landing gear in this case.

4.29. The troubleshooting and the 2 earlier events had shown that the defect was intermittent. The nose landing gear moved in the retract direction when the nose wheels were pushed back into the wheel well during the landing. Therefore cycling the landing gear up and then down again could have dislodged any debris caught in the actuator and allowed the nose landing gear to lock down. However, the QRH did not at that time provide for the landing gear to be cycled.

4.30. Air Nelson confirmed that its training followed the manufacturer's advice that the landing gear selector lever should not be moved following an unexpected landing gear condition, unless the QRH directed otherwise. The reason given for this was that if the gear stops in an unsafe condition, one reason could be that the sequence of doors opening, landing gear extending and doors closing again is disrupted. Cycling the landing gear in this case could cause damage such as driving the wheels into out-of-sequence landing gear doors. Therefore the pilots' decision not to cycle the landing gear selector lever was appropriate.

4.31. Since then the manufacturer has issued a service letter that discusses resetting the alternate extension system, if it has been used without success, and situations when cycling the landing gear might be an option. Such an action would be a last resort and at the captain's discretion.

4.32. Cycling the landing gear might be prudent for a situation where only one side of the main landing gear is down and locked, because there is a higher risk of an unsuccessful landing with that configuration. In that case the captain has nothing to lose by cycling the landing gear. If, however, both sides of the landing gear are down and locked and the nose landing gear is not, as in this case, the captain would need to consider whether cycling the landing gear could exacerbate the problem. The captain would have to choose between landing with only the nose landing gear retracted, or cycling the landing gear and potentially encountering a problem with the main landing gear as well or instead.

Findings

Had the pilots known that the nose landing gear was not down and locked and then tried the alternate extension procedure, that action would have been unlikely to succeed because debris would probably still have been blocking the restrictor within the hydraulic actuator.

Assuming that the reason for the nose landing gear not fully extending was debris in the hydraulic fluid, it is possible that cycling the landing gear up and down again would have succeeded in getting all of the landing gear down and locked. However, that action was not recommended by the aeroplane manufacturer at the time.

The pilots' responses to the aural warnings

4.33. The verification light indicated to the pilots that the nose landing gear was down and locked, and that conclusion was reinforced by the text in the QRH. As the verification system was independent of the proximity sensors and relied simply on having an unobstructed light beam, the green light also strongly suggested that the advisory light on the landing gear panel must be wrong. Both pilots said they therefore assumed that the landing gear status, as determined by the proximity sensor logic and used by other systems, was wrong. This led them to disregard the landing gear warning horn and the ground proximity warning system alert that sounded shortly before landing.

4.34. The captain said he had expected the aural warnings, but he omitted to forewarn the first officer. Although each pilot said he had decided that the aural warnings were false, neither clearly stated this to the other. Warnings, especially ground proximity system warnings, should not be ignored without the involved pilots agreeing that the proposed action will be acceptable. By not doing so, the pilots have no opportunity to express any doubt and resolve it.

4.35. The first officer later added that, as the runway was in sight, there had been no risk of a collision with terrain. That explanation suggested he had not interpreted correctly the cause of the active ground proximity warning mode. The alert "Too low gear" refers to the aeroplane not being in the correct configuration for landing, rather than an impending collision with the ground as such. His further comment that he had been confident yet uneasy at the same time suggested that he may have been hasty in his response to the warnings.

4.36. The Proximity Switch Electronics Unit determines that the nose landing gear is locked down when both down-lock sensors signal that condition. One faulty nose landing gear down-lock sensor could cause the Proximity Switch Electronics Unit to determine that the nose landing gear is not locked down, and therefore the nose landing gear "unsafe" and "doors open" lights would remain illuminated. These were the indications seen in this incident. Because the green verification light showed (falsely) that the nose landing gear was locked down, the pilots reasoned that a faulty sensor was the cause.

4.37. A configuration warning, such as "too low gear", is not considered by the system manufacturer to be a *hard* warning, like "Terrain! Pull up!", which requires a mandatory, immediate escape manoeuvre. The normal response for a pilot is to correct the condition causing the alert; namely, extend the landing gear. However, by design these alerts occur late in an approach and as there will be little time or height available, the best response is invariably to go around and, when at a safe height, to review the situation.

4.38. The pilots said that they had had enough fuel to go around again. Had they done so, one would expect that they would have asked the controller to report the nose landing gear position, as the first officer had earlier suggested they do.

4.39. Had the controller said that the nose landing gear did not appear to be down, the pilots would have realised that the aural warnings were genuine. It would then have been logical for them to disregard the (false) green verification lights and go back to the "Landing gear fails to extend" checklist. This would have directed them to perform the alternate extension procedure. However, as mentioned above, that procedure would have been unlikely to succeed in this case, because the actuator was jammed.

4.40. A fly-by cannot confirm absolutely that a landing gear leg is locked down, especially at night, but an observer can report the landing gear appearance. In the case of the nose landing gear on the Q300, if the wheels appear down and the forward doors are closed, that is useful information, because the Proximity Switch Electronics Unit must sense that the landing gear is down and locked before it will signal the doors to close.

4.41. The pilots could have sought technical advice from the operator and likely would have done so had they gone around in response to the aural warnings. If it had been confirmed that the nose landing gear was not locked down, the checklist would have led the pilots to silence the potentially distracting warnings and they would have instructed the flight attendant to prepare the cabin for an emergency landing.

4.42. The operator later clarified the action it expected its pilots to take, including making use of an external observer, when there was a disagreement between landing gear position indications.

4.43. The pilots' CRM training covered general problem-solving techniques, but in this case they did not use all of the available resources, in particular the use of external observers and taking action that would give them more time. The flight attendant demonstrated her alertness and initiative by checking that the main landing gear was down when she heard the warnings. However, she had not been told of the earlier abnormal gear indication and her training told her not to interrupt the pilots at a late stage in the approach, especially if only to tell them that the main landing gear looked normal.

Findings

The aural warnings that not all of the landing gear was locked down were genuine warnings. Pilots must respect warnings. In this case, the pilots should have responded by performing a go-around, which would have given them more time to consider the situation.

The pilots did not use all of the available resources to confirm the nose landing gear position. If they had asked the controller to confirm the status of the nose landing gear, it is likely that they would have taken further action in an attempt to get the nose landing gear locked down.

Other crew resource management issues

4.44. The following further examples of crew interaction are discussed as lessons for the better handling of abnormal situations:

- the lack of information to the flight attendant
- the carrying out of the QRH checklist.

Informing the flight attendant

4.45. Flight attendants are on board aircraft primarily for the safety of passengers. The operator's CRM training emphasised the communication and co-ordination that should occur between the flight deck and flight attendant so that all of the crew are properly informed of any matter that might affect the safety of the aeroplane and those on board, or affect the discharge of their respective duties. Communication with flight attendants is particularly important for those who work alone in the cabin, as with this operator.

4.46. The training for flight attendants includes the preparation of the cabin and the advice to give passengers in the event that an emergency or abnormal landing is anticipated and the emergency evacuation of the aeroplane after landing. The operator required its flight attendants to carry out a silent self-brief before every take-off and landing so that they would be better prepared for unexpected emergencies.

4.47. A go-around from a landing approach is not common, but this flight attendant had been on board flights when this had occurred. The captain did not advise her of the reason for the go-around, because soon afterwards he believed there was no problem and a normal landing would follow. However, the Commission thinks he ought to have done this. It would have taken just half a minute to explain the situation to her. Under most circumstances that could be done using the public address system, thereby informing the passengers at the same time. Being less accustomed than flight attendants to go-arounds, some passengers could be anxious, and information can dispel anxiety.

4.48. Had this experienced flight attendant known what had led to the go-around, she might have considered abnormal landing conditions and her silent self-brief could have been more pertinent. Even though she was unconcerned by the continuing aural warnings, with knowledge of what had happened she would have been better primed for action had the landing been less favourable. Then she would have been justified in commanding the passengers "Head down, stay down" at the first sound and sign that the landing was not, in fact, normal.

> **Finding**
>
> The captain should have explained to the flight attendant the reason for the go-around, even though he believed that the situation had been resolved. The flight attendant would have been better prepared should the landing have been less favourable.

The carrying out of the QRH checklist

4.49. Through his company appointment and participation in the manufacturer's seminars, the captain had considerable knowledge of the global Q300 operational experience, abnormal landing gear conditions, and the development of QRH checklists. When the first officer advised him that the nose landing gear appeared to be not down, the captain anticipated that they would have to perform the alternate extension procedure.

4.50. Perhaps it was this anticipation that led the captain to interrupt the first officer's reading of the QRH checklist. In a couple of instances, the captain pre-empted the first officer's responses, but between them all of the checklist items were covered.

4.51. The captain's comment while the first officer was checking the verification lights that they were "not the problem" suggested a predetermination of the problem and interfered with the proper following of the checklist. The first officer took the comment to mean that he would see 3 verification lights, meaning all of the landing gear was down. When he did see 3 green verification lights, that indicated to him that the nose landing gear advisory lights on the instrument panel were wrong. The false verification lights supported the first officer's interpretation of the captain's comment and probably influenced his later belief that the aural warnings were false.

4.52. However, the captain's explanation was he did *not* expect to see a green verification light for the nose landing gear and he expected that an alternate extension would follow. Having interrupted the first officer's checklist responses, the captain was then surprised by hearing there were 3 green lights and he twice asked the first officer to confirm that. The captain later asked for the verification lights to be checked once more before they landed.

4.53. Unvoiced assumptions and doubts when faced with a problem are the antithesis of good crew communication and problem-solving. Interrupting the reading of a checklist, especially one from the QRH, breaks the flow of the checklist, and can lead to items being missed, misunderstood or having to be repeated. Even if a captain has a well-founded expectation of what will eventuate, the non-flying pilot should be allowed to read a QRH checklist fully and without interruption.

Finding

The captain's predetermination of what was going to be required to get the landing gear down and locked interfered with the proper following of the QRH checklist; nevertheless, all of the items were covered.

5. Findings

5.1. The failure of the nose landing gear to extend fully was most likely caused by debris in the hydraulic fluid blocking orifices within the nose landing gear extend/retract hydraulic actuator. The debris probably came from damaged seals within the actuator.

5.2. The damage to the seals within the extend/retract hydraulic actuator could have initially been caused by a manufacturing defect in the seals or by an incorrect assembly technique. The damage may have been exacerbated by debris in the hydraulic fluid that originated from excessive wear in another actuator in the system, the one that opened and closed the forward nose landing gear doors.

5.3. Two instances of unusual operation of the nose landing gear had been reported in the 5 weeks prior to the failure to extend at Woodbourne. The cause of the earlier events was probably the same as that for the failure to fully extend.

5.4. With the nose landing gear stuck in a partially extended position, light from the taxi light was likely detected by the sensor for the down-lock verification system, causing it to give a false green light.

5.5. The false green light on the verification system misled the pilots of ZK-NEB into believing that the nose landing gear was fully down and locked.

5.6. The verification system for checking if the landing gear is down and locked on the Dash 8 series of aircraft is not reliable enough for pilots to place total trust in it when trying to establish the status of the landing gear.

5.7. Had the pilots known that the nose landing gear was not down and locked and then tried the alternate extension procedure, that action would have been unlikely to succeed because debris would still have been blocking the restrictor within the hydraulic actuator.

5.8. Assuming that the reason for the nose landing gear not fully extending was debris in the hydraulic fluid, it is possible that cycling the landing gear up and down again would have succeeded in getting all of the landing gear down and locked. However, that action was not recommended by the aeroplane manufacturer at the time.

5.9. The aural warnings that not all of the landing gear was locked down were genuine warnings. Pilots must respect warnings. In this case, the pilots should have responded by performing a go-around, which would have given them more time to consider the situation.

5.10. The pilots did not use all of the available resources to confirm the nose landing gear position. If they had asked the controller to confirm the status of the nose landing gear, it is likely that they would have taken further action in an attempt to get the nose landing gear locked down.

5.11. The captain should have explained to the flight attendant the reason for the go-around, even though he believed that the situation had been resolved. The flight attendant would have been better prepared should the landing have been less favourable.

5.12. The captain's predetermination of what was going to be required to get the landing gear down and locked interfered with the proper following of the QRH checklist; nevertheless, all of the items were covered.

6. Key lessons

6.1. When critical systems begin intermittently to malfunction or behave abnormally, this is often a precursor to total failure. For this reason the diagnosis of these problems should be exhaustive and multifaceted.

6.2. The more a pilot knows about aircraft systems, the better armed they will be to deal with emergency and abnormal situations.

6.3. Aircraft warning systems are designed to alert pilots to abnormal conditions. Alerts should not be dismissed without considering all other available information.

6.4. Pilots must retain sufficient knowledge of aircraft systems to deal with situations not anticipated by Quick Reference Handbooks.

7. Safety actions

General

7.1. The Commission classifies safety actions by 2 types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission that would otherwise have resulted in the Commission issuing a recommendation; and

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally have resulted in the Commission issuing a recommendation.

Safety actions that pre-empted issuing a recommendation

7.2. On 21 April 2011 Bombardier published Flight Operations Service Letter DH8-SL-32-030A "to remind Flight Crew of the appropriate procedures for operating the gear utilizing the normal or alternate extension systems". The service letter also addressed aspects of the second incident of a Q300 landing without the nose landing gear extended on 9 February 2011, and suggested "considerations for Flight Crew if confronted with an abnormal gear configuration, which cannot be rectified with the existing Aircraft Flight Manual (AFM) procedures established within the scope of certification requirements".

As well as repeating procedures and considerations already included in the aircraft flight manual and QRH, the service letter included the following:

- flight crew should check the serviceability of indication lights when an expected configuration was not observed
- cycling the gear as a step to achieve an all gear down-and-locked indication was not approved or recommended
- the alternate gear indication lights should be checked with the taxi light OFF.

However, although Bombardier did not approve or recommend cycling the landing gear, this service letter introduced the option, at the captain's sole discretion, of resetting the alternate extension system (if it had been used without success) and cycling the landing gear in a further attempt to get all of the landing gear down and locked.

7.3. In July 2011 Air Nelson amended its Q300 QRH to incorporate the above procedural changes and advice from Bombardier.

7.4. On 28 October 2011 Bombardier issued Service Bulletin SB-8-32-173, Landing Gear – Special Inspection and Rectification – Alternate Downlock Indication System applicable to most Dash 8 models including that operated by Air Nelson. The Bulletin stated the following:

> *Reason*
>
> *Problem: Potential for the landing gear alternate downlock indication system to provide a false 'down and locked' indication.*
>
> *Cause: In conjunction with a reported case of NLG [nose landing gear] collapse on landing, a review of the alternate downlock indicating system was carried out. The review has revealed that the system can provide a false 'down and locked' indication due to a wiring fault. This was not the cause of the reported NLG collapse.*
>
> *Solution: This Special Inspection and Rectification Bulletin provides a functional check procedure for the NLG and MLG [main landing gear] alternate indication phototransistors.*

All operators of the Dash 8 were advised by email of the bulletin, but the procedure was inadvertently described as being applicable to the 100 series only. When made aware of its applicability to its fleet, Air Nelson undertook the required inspections.

7.5. On 15 March 2012 Air Nelson issued an operational notice that required pilots to obtain a third-party report on the landing gear position in any future instance of a conflict between the landing gear position advisory lights and the verification lights. In the case of the main landing gear, that could be provided by the flight attendant. For the nose landing gear, a fly-by of a ground observer, for example an air traffic controller, was recommended.

7.6. On 7 May 2012 Bombardier advised that its Engineering group had identified the need to change the "alternate downlock indication system" and was working on a solution. A prototype of a new version had been successfully tested on the bench.

Safety actions addressing other issues

7.7. Air Nelson fitted better filters to its hydraulic ground rig and amended the rig operating procedures to further reduce the likelihood of hydraulic fluid contamination.

7.8. Air Nelson added cleaning of the nose landing gear lenses of the down-lock verification system as an A-check task. The cleaning of the lenses on the main landing gear legs was already an A-check task.

8. Recommendations

General

8.1. The Commission may issue or give notice of recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case, recommendations have been issued to the Civil Aviation Authority, with notice of these recommendations given to Transport Canada.

8.2. In the interests of transport safety it is important that these recommendations are implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations

8.3. On 28 June 2012 the Commission recommended to the Director of Civil Aviation that he urge Transport Canada to:

- note the instances of false verification of landing gear position reported for the Q300 and some related aeroplanes and the potential for a false indication to cause an accident
- require Bombardier Aerospace to take action to improve the reliability and dependability of the down-lock verification system. (027/12)

8.4. On 23 August 2012 the Director of Civil Aviation replied that he:

> *will accept the recommendation by co-ordinating with Transport Canada on the safety issues as outlined.*

8.5. On 28 August 2012 the Director General, Civil Aviation, of Transport Canada responded, in part:

> *Transport Canada Civil Aviation National Aircraft Certification, Continuing Airworthiness Corrective Action engineers are working with Bombardier with respect to this accident and the highlighted discrepancies. It has been identified that aircrew are not performing alternate gear extension and are relying solely on the secondary indication system. Consequently, Bombardier has re-evaluated their risk assessment and has implemented a Service Bulletin which requires an inspection to verify the operation and integrity of the alternate downlock indication system and AFM [Aircraft Flight Manual] and QRH revisions which require the use of the alternate landing gear extension procedure for any malfunction not covered by a specific procedure.*
>
> *The AFM Temporary Amendment has been issued and is found in Section 4 for each individual aircraft model type AFM… The accompanying QRH change is pending and is expected to appear in Revision 21 of the QRH.*

8.6. On 28 June 2012 the Commission recommended to the Director of Civil Aviation that he monitor the progress of the investigations by Air Nelson and Bombardier Aerospace into the causes of excessive wear in Q300 nose landing gear door actuators (part number 82910016-009) and liaise with Transport Canada in order to produce acceptable corrective actions. (028/12)

8.7. On 23 August 2012 the Director of Civil Aviation replied that he:

> *considers that provisions for monitoring are already in place under Rule 12, and this aspect will address future occurrences. The CAA will continue to work with Air Nelson in terms of monitoring the specific issue.*

9. Citations

Air Nelson. (2010). Q300 Quick Reference Handbook, rev. 19. Nelson.

Bombardier. (2009). PSM1-83-1B, Model 311, Dash 8, Quick Reference Handbook, Rev. 17, Toronto.

Civil Aviation Authority. (2010). Civil Aviation Rules Part 121, Air operations-large aircraft. Wellington.

International Civil Aviation Organization. (1989). Human factors digest No.2, Flight crew training: cockpit resource management (CRM) and line-oriented flight training (LOFT). International Civil Aviation Organization: Montreal.

Appendix 1: Procedures for abnormal gear conditions

Relevant excerpts from the operator's QRH that was current on 30 September 2010 follow.

LANDING GEAR FAILS TO EXTEND

Is the Landing Gear Inop Caution Light illuminated?

LDG GEAR INOP

YES

- Refer to Landing Gear Inop .... Below

NO

- Landing Gear Inhibit Switch .... NORM
- Landing Gear Alternate Release door........... Closed
- Landing Gear Alternate Extension door .... Closed

Landing Gear extends/indicates normally?

YES

— — — END — — —

NO

- Landing Gear Alternate Extension door .... Open
- Landing Gear
  Down Verification Light Switch .... On/Check/Off

Confirm gear is down and locked. If either the "Landing gear down and locked advisory light" or the "Landing gear down verification light" is on, the gear is down and locked.

Is at least one green light illuminated for each Gear Leg position?

YES

Landing Gear is down and safe.

- Landing Gear Alternate Extension door....... Close

— — — END — — —

NO

- Carry out an Alternate Gear Extension.. Page 14.4

LANDING GEAR INOP

LDG GEAR INOP

- Carry out an Alternate Gear Extension .... Page 14.4

APR 10 Air Nelson QRH AOL 12 Page 14.3

ALTERNATE GEAR EXTENSION

WARNING
Landing gear will not retract following this procedure

- Airspeed .... 140 KIAS (max)
- L/G Inhibit switch .... Inhibit
- Landing Gear selector..................................... Down
- Landing Gear Alternate Release door (above the right seat)...Open
- Main Gear Release handle .... Pull Fully Down
- Check Main Gear (Green) & Door (Amber) Lights ....On
- Landing Gear Alternate Extension door (on the floor)...Open

Note: If required hand pump until both main gear green lights illuminate.

- Nose Gear Release handle.................... Pull Fully Up
- Check Nose Gear (Green) & Door (Amber) Lights ....On

NOTE: If required, confirm gear is down and locked by activating the Landing Gear Down Verification lights switch located under the alternate extension door. If either the "Landing gear down and locked advisory light" or the "Landing gear down verification light" is on, the gear is down and locked.

Landing Gear is Down and Locked?

YES

- Anti-skid .... Test
- PTU...Check Off

CAUTION
Nose Wheel Steering is inoperative, taxi using differential braking and power.

Note: *Leave Landing Gear Alternate Release and Landing Gear Alternate Extension doors fully open and L/G Inhibit switch at Inhibit.*

Install Gear Pins as soon as possible after engine shut down.

— — — **END** — — —

NO

- Continued next page

Page 14.4 Air Nelson QRH AOL 12 APR 10

Landing Gear is not down and locked after an attempt at an Alternate Gear Extension.

Nose Gear UP or unsafe, Main Landing Gear Down:

YES

It is possible to safely land with the nose gear retracted. The propellers will not come in contact with the runway. Consider the following:

- Attempt to achieve an aft C of G through passenger re-seating.
- Select a runway with minimal crosswind.
- Touchdown offset from the runway centreline if runway equipped with a centreline lighting system.
- On touchdown, hold the nose just off the runway with the elevator. Prior to losing elevator control gently lower the nose to the runway.
- Should the nose wheel not be extended or collapse, maintain directional control with rudder until no longer effective at which point asymmetric braking can be used as required.
- Apply brakes or reverse thrust only after the nose wheel is on the ground and appears to be locked. If nose gear is not extended or collapses apply brakes only.
- Refer to the General Considerations......... page 14.8

NO

- **Continued next page**

All Gear Up Landing:

If the Alternate Gear Extension procedure has been completed, and it cannot be verified that both main gear are down and locked by the traditional means, the crew must make a decision to perform a landing with one main gear unsafe or opt for an all gear up landing if the landing gear can be retracted.

It is possible to safely land with all gear retracted. The geometry is such that the propellers should not come in contact with the runway with all gear retracted if it is possible to maintain the wings level throughout the landing.

Consider the following:

- Attempt to land on a runway with minimal crosswind.
- Touchdown offset from the runway centreline if runway equipped with a centreline lighting system.
- Refer to the General Considerations.............. Below

General considerations

- If practicable reduce landing weight through fuel burn
- Cabin .... Secure

— If possible ensure no passengers are seated in the plane of the propellers

- EGPWS CB - B3 (Left Rear CB Panel) .... Pull
- Emergency Lights ....On
- Auto/Man/Dump...Dump
- ELT...On
- Shoulder Harness ....Lock
- Ldg Gear Horn CB (E5—Left Main DC) .... Pull
- At 500ft AGL ....PA

  "Attention Attention Brace for impact"
- Plan to land with flap 35
- Fly the appropriate Vref for the landing weight

— — — END — — —

Page 14.8 Air Nelson QRH AOL 12 APR 10

Recent Aviation Occurrence Reports published by the Transport Accident Investigation Commission (most recent at top of list)

12-001	Interim Factual: Cameron Balloons A210 registration ZK-XXF, collision with power line and in-flight fire, 7 January 2012
10-009	Walter Fletcher FU24, ZK-EUF, loss of control on take-off and impact with terrain, Fox Glacier aerodrome, South Westland, 4 September 2010
10-007	Boeing 737-800, ZK-PBF and Boeing 737-800, VH-VXU airspace incident, near Queenstown Aerodrome, 20 June 2010
10-005	Cessna A152, ZK-NPL and Robinson R22 Beta, ZK-HIE near-collision. New Plymouth Aerodrome, 10 May 2010
10-003	Cessna C208 Caravan ZK-TZR engine fuel leak and forced landing, Nelson, 10 February 2010
10-006	Runway Incursion, Dunedin International Airport, 25 May 2010
10-001	Aerospatiale-Alenia ATR 72-212A, ZK-MCP and ZK-MCJ, severe turbulence encounters, about 50 nautical miles north of Christchurch, 30 December 2009
09-002	ZK-DGZ, Airborne XT-912, 9 February 2009, and commercial microlight aircraft operations
10-009	Interim Factual: Walter Fletcher FU24, ZK-EUF, loss of control on take-off and impact with terrain, Fox Glacier aerodrome, South Westland, 4 September 2010
10-008	Interim Factual: Cessna C152 ZK-JGB and Cessna C152 ZK-TOD, mid-air collision, near Feilding, Manawatu, 26 July 2010
09-007	Piper PA32-260, ZK-CNS, impact with ground following a loss of control after take-off, near Claris, Great Barrier Island, 29 September 2009
09-005	Cessna 182N ZK-FGZ and Bombardier DHC-8 Q311 ZK-NEF, loss of separation and near collision, Mercer, 40 km south of Auckland, 9 August 2009
08-007	Robinson Helicopter Company, R22 Alpha ZK-HXR, loss of control, Lake Wanaka, 1 November 2008

Price $38.00

ISSN 1179-9080 (Print)
ISSN 1179-9099 (Online)