Inquiry 11-002:
Bombardier DHC-8-311, ZK-NEQ, landing without nose landing gear extended
Woodbourne (Blenheim) Aerodrome, 9 February 2011

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

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Final Report

Aviation inquiry 11-002

Bombardier DHC-8-311, ZK-NEQ

Landing without nose landing gear extended

Woodbourne (Blenheim) Aerodrome

9 February 2011

Approved for publication: December 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.

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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

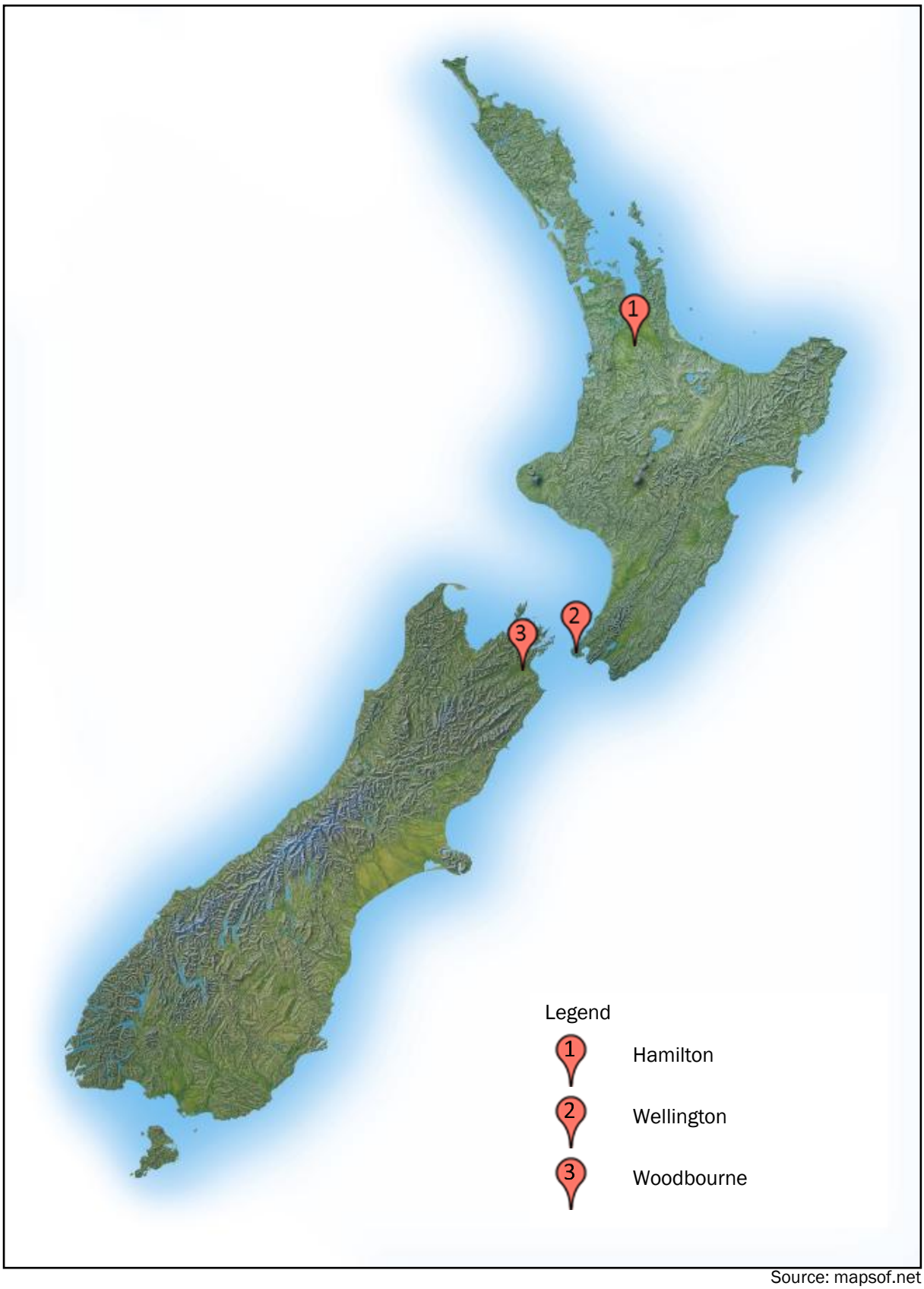
Citations and referencing

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-NEQ landing at Woodbourne Aerodrome, 9 February 2011



Source: mapsof.net

Location of accident

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Abbreviations

Annex 13	Annex 13 to the Convention on International Civil Aviation
Commission	Transport Accident Investigation Commission
inhibit switch	Landing Gear Down Select Inhibit Switch
kg	kilogram(s)
Q300	commercial name for the Bombardier model DHC-8-311 aeroplane
QRH	Quick Reference Handbook
UTC	co-ordinated universal time

Glossary

cycle	one take-off and one landing
detent	a notch, or catch, by the release of which machinery (e.g. a lever) is allowed to move
fidelity	the accuracy of a flight simulator in representing the layout of an aircraft's flight deck, its aerodynamic and engine performance, the flight controls and forces, and aircraft systems
go-around	to abandon a landing approach and climb away
Minimum Equipment List	lists those items that may be inoperative for flight, and any operational or maintenance conditions that must be met for flight with a specific item inoperative
Quick Reference Handbook	a condensed version of the emergency and non-normal procedures and other data, taken from the aircraft flight manual, which is readily available to the pilots
verification lights	lights, located 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-NEQ
Type and serial number:	Bombardier Aerospace DHC-8-311, 636
Number and type of engines:	2 Pratt & Whitney Canada PW123 turbo-propeller
Year of manufacture:	2007
Operator:	Air Nelson Limited
Type of flight:	scheduled air transport
Persons on board:	44
Pilots' licences:	airline transport pilot licence (aeroplane), both pilots
Pilots' ages:	captain 34, first officer 23
Pilots' total flying experience:	captain: 5549 hours, including 2309 hours on type
	first officer: 2243 hours, including 1315 hours on type
Date and time	9 February 2011, 1440[1]
Location	Woodbourne Aerodrome latitude: 41° 31.1´ south longitude: 173° 52.2´ east
Injuries	nil
Damage	minor

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

1. Executive summary

1.1. On 9 February 2011 a Bombardier DHC-8-311 aeroplane (known as a "Q300") operated by Air Nelson Limited departed from Hamilton Aerodrome on a scheduled flight to Wellington Aerodrome. On board were 2 pilots, a flight attendant and 41 passengers.

1.2. Prior to taking off from Hamilton, the nosewheel steering malfunctioned because an "inhibit switch" in the cockpit was faulty. The faulty switch caused a loss of hydraulic pressure to the nosewheel steering. The nosewheel steering system was considered non-essential, so in accordance with the approved Minimum Equipment List, the aeroplane departed Hamilton with the system inoperative. The trip towards Wellington was uneventful.

1.3. The nosewheel steering hydraulic power came from the extend side of the landing gear hydraulic system. On the approach to Wellington, none of the landing gear extended when it was selected down. The pilots carried out a go-around to give them time to perform the relevant procedures provided in a Quick Reference Handbook (QRH). The Q300 was fitted with an alternative system for lowering the landing gear when the normal system failed. The "Alternate Gear Extension" procedure succeeded in getting the main landing gear to extend, but not the nose landing gear.[2] That remained locked in its retracted position.

1.4. There was nothing mechanically wrong with the alternate landing gear extension system. The nose landing gear did not extend because the pilots did not pull hard enough on the handle that should have released the uplock. If the uplock had released, the nose landing gear would have lowered under gravity and locked down.

1.5. The pilots decided to divert to Woodbourne Aerodrome and to land with the nose landing gear retracted. No-one was injured in the landing. The damage to the aeroplane was confined to the area around the nose landing gear and the lower forward fuselage.

1.6. The Minimum Equipment List appeared to have considered the operational consequences only of allowing a Q300 to depart with inoperative nosewheel steering. The link between a failure of the nosewheel steering and a potential failure in the hydraulic system, which would affect the landing gear, did not appear to have been considered. The manufacturer has since amended the Minimum Equipment List to require a check of the hydraulic system pressure before allowing a departure with the nosewheel steering inoperative.

1.7. The operator's pilots were not made aware through their training of how hard one had to pull the handle to release the nose landing gear uplock. A much lesser pull was required when practising the procedure in the operator's flight simulator and the Alternate Gear Extension procedure did not, at the time, give any guidance as to the force required.

1.8. Air Nelson modified its flight simulator so that the forces were more typical of those found on the actual aeroplane, and provided its pilots with more technical information on the Alternate Gear Extension procedure. The aeroplane manufacturer provided all operators of the Q300 with a more comprehensive description of the Alternate Gear Extension procedure and provided options for pilots to consider should the procedure be unsuccessful.

1.9. A recommendation was made to the Director of Civil Aviation that he liaise with Transport Canada to make other National Aviation Authorities aware of this incident and of the desirability of flight simulators closely representing the actual forces required for an alternate landing gear extension.

1.10. Although not contributory to the accident, the report discusses the design of checklists and how they can lead to pilots making errors or missing important items during times of high workload. The Transport Accident Investigation Commission (the Commission) had commented on this issue in a previous inquiry. A recommendation was made to the Director of Civil Aviation regarding the format of QRHs.

[2] Although 'alternative' is the more correct word, the industry-accepted 'alternate' is used in this report.

1.11. The Commission made findings about the cause of the nosewheel steering and landing gear extension failures, about crew training in alternative procedures, and the importance of having well designed QRHs.

1.12. The Commission also identified the following key lessons:

- in their simulator training pilots should be taught how to perform emergency and non-normal procedures as robustly and rigorously as if the procedures were being performed on the actual aircraft
- pilots should be informed of flight simulator characteristics that differ from those in the aircraft to ensure that pilots are not misled during actual flight operations
- QRHs should be designed to minimise the potential for error as they are used by pilots during times of high workload and, potentially, high stress when dealing with emergencies.

2. Conduct of the inquiry

2.1. On 9 February 2011 Air Nelson Limited (the operator) advised the Commission of the accident soon after it had happened. The Civil Aviation Authority of New Zealand notified the Commission very soon afterwards in accordance with section 27 of the Civil Aviation Act 1990. Although the circumstances appeared similar to those of an incident then under investigation by the Commission (inquiry 10-010), a separate inquiry was opened under section 12 of the Transport Accident Investigation Commission Act 1990.

2.2. The Commission gave permission for the aeroplane to be removed from the runway before the investigator in charge arrived on site early the next day. Following an initial examination of the aeroplane, the inquiry shifted to the operator's maintenance and operational base at Nelson Aerodrome. The aeroplane was flown to Nelson on 10 February 2011 for troubleshooting of the defect and repair of the damage.

2.3. A field service representative of Bombardier Aerospace, the manufacturer, was based at Nelson at the time and provided assistance throughout the inquiry.

2.4. On 10 February 2011 the Transportation Safety Board of Canada, the State of Manufacture, appointed an Accredited Representative in accordance with section 5.18 of Annex 13 to the International Convention on Civil Aviation (Annex 13). The Accredited Representative assisted the Commission by supervising the examination of landing gear system components that had been returned under quarantine to the aeroplane manufacturer. Specialist examinations of the components were conducted at the facilities of the component manufacturers in Canada.

2.5. On 15 February 2011 the cockpit voice recorder was taken to the Australian Transport Safety Bureau laboratory in Canberra for download. The Bureau appointed an Accredited Representative to assist the Commission, as provided for in section 5.23 of Annex 13. The downloaded information was protected in accordance with Australian legislation.[3] The 2 pilots assisted with the transcript of the recording. A further cockpit recording, taken during an alternate landing gear extension in another Q300, was analysed by the Bureau to help determine whether the nose landing gear uplock had released on the accident flight.

2.6. On 14 March 2011 the National Transportation Safety Board of the United States appointed an Accredited Representative, as provided for in section 5.23 of Annex 13, who arranged the supervision of a specialist examination of components at the manufacturers' facilities in the United States. This was a consequence of United States legislation.[4]

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

- interviews of the crew members and discussions with operational and maintenance personnel from Air Nelson
- analysis of the recorded flight data
- examination of the landing gear operation on other Q300 aeroplanes
- discussions and correspondence with the aeroplane and component manufacturers' representatives
- discussions with representatives of the Civil Aviation Authority
- reviews of the safety occurrence databases in New Zealand, Australia, Canada and the United Kingdom for relevant occurrences.

2.8. The Commission acknowledges the assistance of the Australian Transport Safety Bureau, the Transportation Safety Board of Canada and the National Transportation Safety Board.

2.9. On 29 August 2012 the Commission approved the draft report for circulation to Interested Persons for comment. Submissions were received from the 2 pilots, Air Nelson, Bombardier Aerospace, the Civil Aviation Authority and the Australian Transport Safety Bureau. The Transportation Safety Board of Canada had no comment. Neither did Transport Canada

[3] Transport Safety Investigation Act 2003.

[4] International Traffic In Arms Regulations, as prescribed by the Arms Export Control Act (22 USC 2778).

initially but, together with the Civil Aviation Safety Authority of Australia, it responded to a later request by the Commission regarding flight simulator certification requirements.

2.10. The submissions were considered by the Commission before this final report was approved on 12 December 2012 for publication.

3. Factual information

3.1. History of the flight

3.1.1. The aeroplane involved in this accident was a Bombardier DHC-8-311 aeroplane, known as a Q300. It was registered ZK-NEQ and operated by Air Nelson. At 1235 on 9 February 2011 the aeroplane taxied for departure from Hamilton Aerodrome on a scheduled air transport flight to Wellington Aerodrome. On board were 2 pilots, one flight attendant and 41 passengers.

3.1.2. While taxiing for departure, the nosewheel steering did not respond to the captain's hand control and the NOSE STEERING caution light illuminated. The captain centred the hand control and cycled the system switch off then back on, which initially extinguished the light, but the fault remained. The pilots then confirmed that they had carried out the actions required by the operator's QRH (see Appendix).

3.1.3. They also referred to the Minimum Equipment List[5] and confirmed that further flight was permitted with the steering system inoperative. The Minimum Equipment List included an operational limit of 20 knots of crosswind for take-off and landing, which could be met on that sector, and a maintenance requirement to remove the electrical power for the steering system, which the pilots did by pulling the appropriate circuit breakers.

3.1.4. The pilots considered that the defect was minor and would be attended to by an engineer after they arrived at Wellington. Therefore they did not inform the Air Nelson maintenance control centre of the defect before taking off. Before commencing the approach to Wellington, the captain noted that the crosswind was below 20 knots, and the first officer radioed the Air Nelson operations office at Wellington with a request for a terminal gate that would not require tight turns while taxiing.[6]

3.1.5. On the approach to Wellington, when the landing gear selector lever was moved to DOWN, the landing gear system did not respond. It was later determined that a faulty Landing Gear Down Select Inhibit Switch (inhibit switch), which blocked hydraulic pressure to the down (extend) side of the landing gear system, had caused this failure and the earlier steering defect at Hamilton.

3.1.6. The captain commenced a go-around and, not knowing the cause of the landing gear problem, instructed the first officer to leave the selector lever in the down position. The pilots advised air traffic control that they had a landing gear problem and flew clear of the aerodrome in order to carry out the QRH "Landing gear fails to extend" procedure (see Appendix).

3.1.7. The first steps in this procedure were to ensure that the flight deck controls were correctly configured for normal extension of the landing gear, including that the inhibit switch was in the guarded NORMAL position, which it was.

3.1.8. The alternate *release* door, referred to in the checklist, is a flap in the flight deck ceiling above the first officer's seat (see Figure 1) and the alternate *extension* door is a flap in the flight deck floor (see Figure 2).

[5] The Minimum Equipment List is a manual that lists those items that may be inoperative for flight and any operational or maintenance conditions to be met before commencing a flight with a specific item inoperative. The manual can be referred to and its provisions applied at any time before take-off.

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

Figure 1
Landing gear alternate release door (above first officer's seat), with inhibit switch circled
(Photograph courtesy Air Nelson Limited)

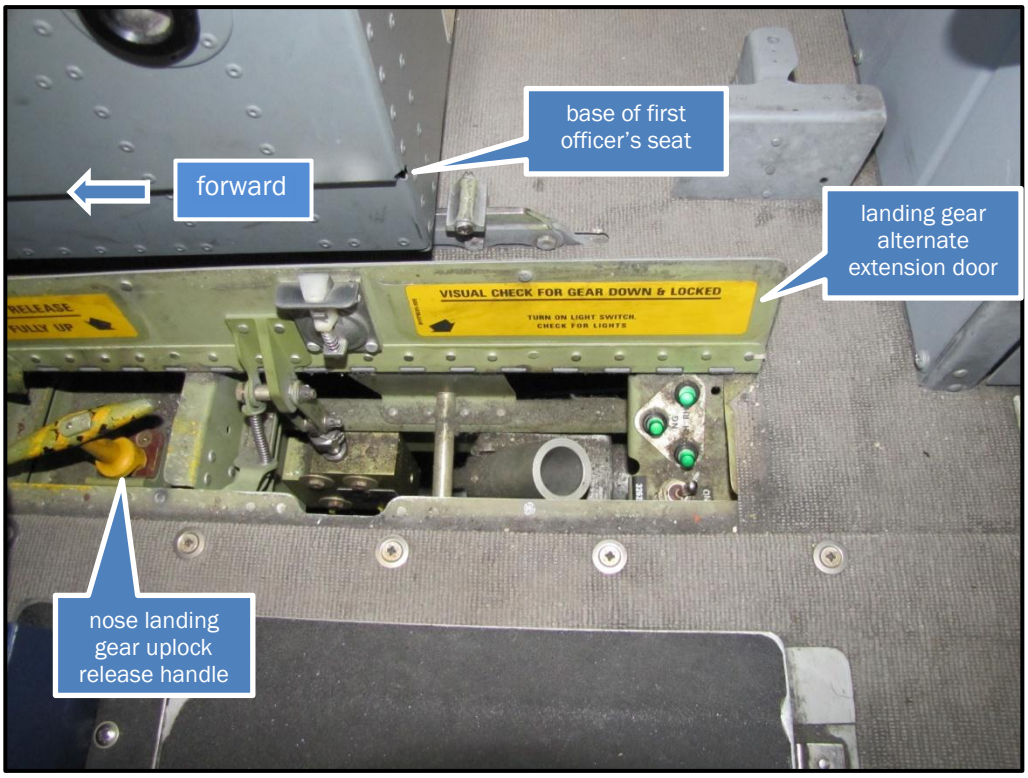

Figure 2
Landing gear alternate extension door and nose landing gear uplock release handle

3.1.9. The first officer misread part of the "Landing gear fails to extend" checklist, as shown in the comparison between the QRH and the cockpit voice recording below (item 3 in the excerpt; emphasis added):

Item [**not** numbered in QRH]	QRH item	First officer said
1	Landing gear inhibit switch – NORM [normal]	Landing gear inhibit switch to NORM, yes.
2	Landing gear alternate **release** door – closed	Landing gear alternate **release** door is closed.
3	Landing gear alternate **extension** door – closed	Ah, gear alternate **release** door is closed, yes.
4	Landing gear extends/indicates normally? YES/NO	Landing gear extends indicates normal, no.
5	Landing gear alternate extension door – open	Landing gear alternate extension door, open.
6	Landing gear down verification light switch – On/Check/Off [Text layout as in QRH – see Appendix]	Landing gear, ah, open. Landing gear down verification light switch, check. No lights.
7	Note that either green position advisory light or green downlock verification light means that that gear leg is down and locked	[Not read out.]
8	Is at least one green light illuminated for each Gear Leg position? – YES/NO	Is at least one green light illuminated? No.

3.1.10. With the landing gear still not extended, the checklist directed the pilots to carry out the Alternate Gear Extension procedure (see Appendix). Before doing this, the captain informed the passengers of the situation.

3.1.11. The Alternate Gear Extension procedure checklist was headed:

> WARNING
> Landing gear will not retract following this procedure

When the first officer pulled the main landing gear uplock release handle in the ceiling, the main landing gear extended and locked down. After he pulled the nose landing gear uplock release handle in the floor (see Figure 2), the nose landing gear doors opened almost immediately, but the pilots did not hear the sound of the gear leg locking down. The first officer checked the downlock verification lights, which showed that the left and right main landing gear legs only were down.

3.1.12. The first officer then quickly read through the QRH considerations for landing with the nose landing gear not extended (see Appendix). He misread the item "If the nose landing gear is not extended…" as "If the nose landing gear is not retracted…", and misidentified the line "Continued on next page" as a part of this checklist. Although these errors were inconsequential in this case, their relevance to QRH design and use is discussed in the Analysis section of this report.

3.1.13. The captain considered diverting to another aerodrome – either Palmerston North, the planned alternate, or Woodbourne – rather than obstruct the busy Wellington runway by landing without the nose landing gear extended. The Woodbourne weather was fine with a southeast crosswind of about 12 knots at the time, good visibility and the lowest cloud at 2000 feet.

3.1.14. The Wellington controller then advised that the nose landing gear doors appeared to be open, but the gear leg was not extended fully. At about this time, the first officer, apparently without direction from the captain, gave the nose landing gear uplock release handle another pull. He described it as "an easy pull to the stop", with the handle coming up to a height about level with the top of the centre instrument console. However, the uplock still did not release.

3.1.15. After 17 minutes' holding in the Wellington area, the pilots advised the controller that they would divert to Woodbourne for an emergency landing and they requested that emergency services attend.

3.1.16. En route, the captain briefed the flight attendant and instructed her to prepare the cabin for an emergency landing. He indicated that they would land in about 15 minutes. Six minutes later, he made a further announcement to inform the passengers. The pilots completed most of the QRH items for a landing with the nose landing gear not extended, apart from some items that they completed shortly before the final approach at Woodbourne.

3.1.17. The pilots decided that another visual check of the landing gear position by the Woodbourne controller was not required. Photographs taken from the ground at Woodbourne showed that the nose landing gear forward doors were open, but the gear leg was not extended.

3.1.18. Air Nelson had been alerted to the problem by the Wellington controller. When the aeroplane arrived at Woodbourne, the pilots were asked to hold while Air Nelson technical and operational staff considered the defect and whether a normal landing could be achieved. Their questions were passed by telephone to the Woodbourne air traffic controller, who relayed them to the pilots. ZK-NEQ was the only aircraft in the Woodbourne control zone during the 20 minutes these exchanges took place.

3.1.19. While in the holding pattern, the pilots asked the controller to pass to the Air Nelson staff 2 sets of information concerning the nosewheel steering defect at Hamilton. The staff did not recall receiving that information. The controller passed to the pilots a report that the nose landing gear front left door appeared to be partially open, and a request from the engineers for the pilots to make a low pass so that a ground observer could attempt to confirm the nose landing gear position. Following the low pass, the pilots considered that they had enough fuel for another circuit before they should land.

3.1.20. The pilots asked what had been observed during the low pass, but no feedback was given. The controller passed on an Air Nelson suggestion that there could be dirt in the hydraulic lines that might shift if the pilots cycled the landing gear. However, the pilots opted not to do so because they had no procedure for reversing the Alternate Gear Extension procedure and there was doubt about the door positions. The pilots then informed the flight attendant and passengers that they were about to make the final approach to land, but 4 minutes later the controller relayed a further "strong recommendation" from the engineers to cycle the landing gear. Again, the pilots declined to do so.

3.1.21. The checklist for landing without the nose landing gear extended called for the cabin announcement "Attention! Attention! Brace for impact!" to be made when the aeroplane was 500 feet above the ground, which would normally be about 50 seconds before touchdown. In this case, the announcement was made much earlier in order to complete the checklist, apart from selecting the final landing flap. As a result, the flight attendant began yelling the command "Head down! Stay down!" to the passengers early, and continued doing so until the aeroplane touched down more than 2 minutes later.

3.1.22. At about 1440 the aeroplane landed and the captain lowered the nose until the nose landing gear doors contacted the runway. The doors collapsed before the aeroplane came to a stop on the centreline. The pilots shut down the engines, turned off the electrical power and ordered a precautionary evacuation of the aeroplane. No-one was injured and there was no fire.

3.1.23. Damage was confined to the nose landing gear doors and surrounding structure, and 3 antennae on the lower fuselage (see Figure 3).

Figure 3
Damage to ZK-NEQ

3.2. Aircraft information

3.2.1. The Q300 is a Bombardier Aerospace development of the de Havilland Canada "Dash 8" series of aeroplanes. It is a high-wing, pressurised aeroplane powered by 2 turbo-prop engines. The aeroplane, as configured by Air Nelson, had a crew of 2 pilots and one flight attendant and 50 passenger seats. The type certification authority for the Q300 is Transport Canada.

3.2.2. Air Nelson had a fleet of 23 Q300 aeroplanes that had entered service between July 2005 and June 2009. ZK-NEQ had been manufactured in March 2007 and entered service with Air Nelson that month. At the time of the accident, it had accrued 8791 flight hours and 10 508 cycles.[7]

3.2.3. According to Air Nelson's records, the aeroplane had been maintained in accordance with the approved maintenance programme. The previous scheduled maintenance had been a 7-day line check completed on 2 February 2011.

3.2.4. No nose steering defect had been reported on ZK-NEQ since the aeroplane entered service and no relevant landing gear defect had been logged on the aeroplane during the 14 months prior to the incident. On 9 February 2011 there were 3 deferred maintenance items in the aeroplane maintenance log, but none was relevant to this occurrence.

Hydraulic system

3.2.5. Hydraulic power to operate various items on the aeroplane is provided by 2 independent systems. The No.2 hydraulic system is pressurised by a pump driven by the right engine and powers the landing gear and nosewheel steering. Filters in the pressure and return lines remove foreign debris from the hydraulic oil. The oil is usually analysed at least once a year.

[7] A cycle is one take-off and landing.

Landing gear description and operation

3.2.6. The Q300 has a retractable, tricycle landing gear. The nose landing gear retracts forward into the fuselage nose. Figure 4 shows some of the nose landing gear components referred to in this report.

3.2.7. The landing gear operation is controlled by moving the cockpit landing gear selector lever to the UP or DOWN position. This sends an electrical signal to the appropriate solenoid in the landing gear selector valve to allow the corresponding landing gear hydraulic lines to be pressurised. The extend solenoid of the selector valve remains energised when the landing gear is down to allow hydraulic pressure to the nosewheel steering.[8] When the landing gear is selected UP, the extend solenoid de-energises, removing hydraulic pressure from the extend lines.

3.2.8. 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 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 uplock
- the nose landing gear extend/retract actuator.

3.2.9. Sequence valves ensure that the components move in the correct order and delay the nose landing gear actuator operation to allow time for the forward doors to open fully before the landing gear leg extends. Once the nose landing gear is locked down, the forward doors close. A "Landing Gear INOP" caution light illuminates if any of the landing gear legs and their hydraulically operated doors move out of sequence.

3.2.10. A 2-position (NORMAL and INHIBIT) inhibit switch is located beside the alternate release door in the flight deck ceiling (see Figure 1).[9] The switch is used in the "Landing Gear INOP" procedure to prevent landing gear extension when a door might be closed or closing, and it can also be used to simulate a landing gear failure condition.

3.2.11. If the switch is put to INHIBIT while the landing gear is retracted, the extend solenoid of the landing gear selector valve cannot energise. Therefore, no landing gear legs will extend when the landing gear selector lever is next moved to DOWN.

3.2.12. If the switch is put to INHIBIT while the landing gear is extended, the extend solenoid will de-energise and hydraulic pressure will be removed from the landing gear system, including the nosewheel steering. However, the landing gear remains in the extended position because of the mechanical over-centre downlocks. The position of the switch does not affect landing gear retraction.

Alternate landing gear extension

3.2.13. The alternate landing gear extension controls include:

- the main landing gear uplock release handle, behind the alternate *release* door in the flight deck ceiling above the right-hand pilot's seat (see Figure 1)
- the nose landing gear uplock release handle under the alternate *extension* door in the floor by the right-hand pilot's seat (see Figure 2).

[8] Under normal conditions of electrical power and with the right-hand engine operating.

[9] Honeywell single pole-single throw toggle switch, part number MS24523-33, catalogue listing 1TL1-31.

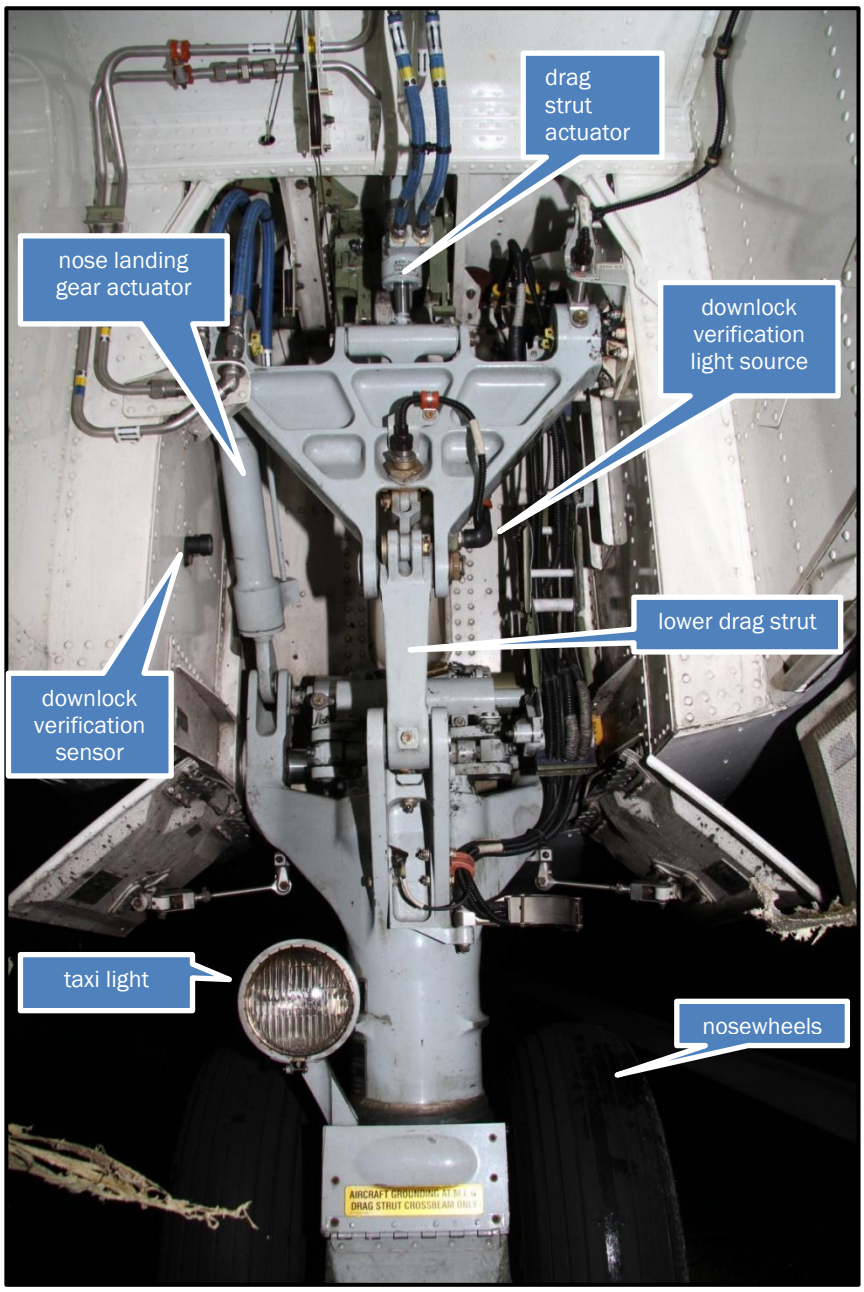

Figure 4
Q300 nose landing gear

3.2.14. The action of opening the overhead alternate release door connects the pressure and return lines of the landing gear hydraulic system, thereby bypassing the actuators.

3.2.15. When the nose landing gear uplock release handle in the floor is pulled, the attached cable releases the forward door lock followed by release of the uplock. The nose landing gear leg should then lower freely under gravity, with the airflow assisting it to lock down.

3.2.16. A very light force is required to release the door locks, because their opening is facilitated by a spring. There are no mechanical restrictions, such as a detent, in the sequence for an alternate landing gear release, but the much higher force required to release the uplock, compared with that to open the doors, is perceived, and was described, as a detent. The Air Nelson Q300 Systems Training Manual stated:[10]

[10] Air Nelson Bombardier DHC-8 Q300 Systems Training Manual, p.13-17, 4 August 2007.

> [The] uplock release handles are detented. Pulling to the first detent releases the door uplocks and pulling the rest of the way releases the gear uplocks. The first detent is to facilitate opening the gear doors for ground servicing. During an alternate extension, the handles should be pulled as far as they will go in one motion.

3.2.17. The Bombardier Q300 Maintenance Manual also referred to a detent when pulling the handle to open the doors in order to perform maintenance on part of the nose landing gear.[11]

3.2.18. The nose landing gear retraction actuator will not extend freely until the forward doors have opened completely and the locking mechanism has been fully released. If the pull on the release handle is relaxed while the doors are in the process of opening and before the locking mechanism has released, spring tension in the locking mechanism can re-engage the lock. This possibility was not widely known among pilots at the time of the accident.

3.2.19. The nose landing gear uplock release handle is operated prior to an aeroplane's first flight each day. A pull of approximately 6 to 8 kilograms (kg) is required on the handle to open the nose landing gear forward doors so that pilots can inspect the inside of the wheel well.

Training in alternate landing gear extension procedure

3.2.20. Procedures such as the Alternate Gear Extension were once permitted to be practised during air transport flights, which ensured that pilots were aware of the actual forces needed to release the uplocks, but training for such non-normal procedures now has to be performed in a flight simulator.[12] In this case the 2 pilots had not performed an alternate landing gear extension in the aeroplane.

3.2.21. The pilot in the right seat usually performs the procedure, including pulling the uplock release handle, but all of the Air Nelson pilots had practised the procedure in flight simulators during their aeroplane type rating courses. Thereafter, it was practised when the recurrent training programme for pilots included a scenario with that requirement, which was nominally every 18 months.

3.2.22. The captain and the first officer had completed their Q300 ground training courses with Air Nelson staff, and their simulator training had been conducted by a certificated training organisation. The organisation advised that it had stressed to trainees that when pulling the release handle the door lock would be felt to have released but the pull had to be continued as hard as possible until the green position advisory light illuminated. The green light indicated that the nose landing gear had locked down. If the procedure was not successful, it could be repeated, using both hands on the handle. Air Nelson said that its ground course at the time did not address the Bombardier advice to pull the handle to the stops and to repeat the action if necessary until the landing gear was down and locked.

3.2.23. In 1997 Bombardier published a Safety of Flight Supplement that noted that the pull forces required during an alternate landing gear extension "may exceed those experienced during practice extensions, particularly those experienced in flight simulators".[13] That statement was included in the Bombardier flight manual. While Air Nelson said that its practice was to assess Safety of Flight Supplements and to incorporate relevant material into manuals and training courses, it acknowledged that the information in the Safety of Flight Supplement concerning the alternate landing gear extension procedure had not been included in the ground training course notes provided to the 2 pilots involved in this accident, nor had it been incorporated into company manuals at the time.

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[11] Bombardier Q300 Maintenance Manual, section 32-20-31, p.201. Bombardier later indicated that it would remove that reference,

[12] Civil Aviation Rule 121.579, *Manoeuvres requiring a flight simulator.* The Rule was changed before Air Nelson acquired Q300 aeroplanes.

[13] de Havilland Dash 8, Operating Data Manual, Safety of Flight Supplement No.7, 10 January 1997.

3.2.24. In late 1997 the Commission published a report on a Dash 8 accident that had occurred in 1995 ("the 1995 accident") while the pilots were performing an alternate extension of the main landing gear.[14] The report noted that the involved airline (Ansett New Zealand, which ceased operations in 2001 and had no connection with Air Nelson) had not included any reference to the required pull force in its QRH (Transport Accident Investigation Commission, 1997, p.86).

3.2.25. At the time of the ZK-NEQ accident in February 2011, the Air Nelson QRH Alternate Gear Extension procedure stated that the uplock release handle should be "pull[ed] fully up", but did not give a force required, nor state that the handle had to be pulled as hard and held for as long as it took to release the uplock. The QRHs of both Air Nelson and Bombardier were subsequently amended to draw attention to the forces required.

Nosewheel steering

3.2.26. The nosewheel steering system is electrically controlled and hydraulically operated, using a hand control next to the left-hand pilot's seat or by moving the rudder pedals. The hydraulic pressure comes from the DOWN, or extend, side of the landing gear selector valve.

3.2.27. A fault in the electronic control unit is indicated by the NOSE STEERING caution light. In that case or if the system is switched off, the steering actuator is depressurised and the nosewheel castors freely. The aeroplane can then be steered using differential brakes and power.

Flight recorders

3.2.28. The aeroplane was fitted with a Honeywell flight data recorder, but parameters relating specifically to the nosewheel steering or to the alternate extension of the landing gear were not recorded.

3.2.29. The aeroplane was also fitted with a Honeywell cockpit voice recorder with a 2-hour recording duration. Radio transmissions, intercom and cabin announcements, and cockpit area ambient sounds were recorded on the cockpit voice recorder. The recorder was taken to the Australian Transport Safety Bureau laboratory in Canberra where the audio recording was downloaded and examined. The separate audio tracks that recorded the last 30 minutes of the captain's and the first officer's intercom and radio transmissions were of good quality and included the landing at Woodbourne. The combined 2-hour track was also of good sound quality, but after commencing with a short segment (about 90 seconds) on the ground at Hamilton it skipped to the climb after departing Hamilton. The remainder of the flight was recorded continuously on the combined track.[15] The 2 pilots later assisted the Commission to prepare a transcript of the recording.

3.2.30. The sound of the nose landing gear uplock releasing on the recording might have been present on the recording and obscured by a radio call made to the Wellington controller at the same time as the release handle was pulled. The recording was compared with another made on a different Q300 in an attempt to isolate the "signature" of the uplock releasing. This confirmed that the sound of the nose landing gear uplock releasing was not recorded during the alternate extension procedure carried out at Wellington.

[14] Report 95-011, de Havilland DHC-8, ZK-NEY, controlled flight into terrain, near Palmerston North, 9 June 1995.
[15] The reason for the recording gap in the combined track was not determined.

3.3. Tests and research

Initial tests

3.3.1. After the accident, the doors in the flight deck that covered the uplock release handles for the main and nose landing gear were found open. The aeroplane nose was lifted off the runway with a crane. The nose landing gear was found in the uplock, but it extended under its own weight when the uplock release handle was pulled.

3.3.2. On 10 February 2011, after taking the required engineering action and obtaining regulatory approval, the aeroplane was flown to the Air Nelson base at Nelson Aerodrome with the landing gear locked down and the forward nose landing gear doors removed.

3.3.3. Initial tests found no anomalies in the electrical circuits from the landing gear selector handle to the landing gear selector valve solenoids.

Failure of all landing gear to extend by the normal system

3.3.4. The landing gear selector valve and hydraulic sequencing valve were examined at the premises of the manufacturer, Eaton Aerospace, under the supervision of an investigator of the United States National Transportation Safety Board on behalf of the Commission. Both components passed all functional tests.

3.3.5. During functional testing of the landing gear after the aeroplane had been repaired, an intermittent fault was found with the inhibit switch. The landing gear did not extend when it was selected DOWN with the switch in the NORMAL position, but correct operation could be obtained by bumping the switch.

3.3.6. The connection between the nosewheel steering defect at Hamilton and the landing gear not extending by the normal system at Wellington was then apparent. After the inhibit switch was replaced, all functional checks, including those of the nosewheel steering, were satisfactory. A check of Air Nelson's Q300 fleet did not find any more defective inhibit switches.

3.3.7. Switches with the same part number were used on the Q300 flight deck for 2 bleed air control switches and for the propeller synchrophaser switch. Those 3 switches were used daily and Air Nelson had no history of defects with them. In contrast, the inhibit switch was rarely used. Bombardier advised that the calculated mean time between unscheduled removals of this type of switch was more than 220 million flight hours.

3.3.8. On 12 February 2011 Air Nelson suspended the use of the Minimum Equipment List provision to operate with an inoperative nosewheel steering system, because, unless the cause of the defect could be positively determined, normal extension of the landing gear could also be affected. Bombardier later amended the Minimum Equipment List Procedures Manual to require verification that hydraulic pressure was available for the normal extension of the nose landing gear before commencing a flight with an inoperative nosewheel steering system.

Failure of nose landing gear to extend by the alternate system

3.3.9. The following potential causes of this failure were examined:

- the method used by the first officer to pull the uplock release handle
- a failure of the release cable to open the uplock
- a restriction or failure of an hydraulic actuator
- a failure of the bypass valve (when opening the alternate release door)
- incorrectly rigged mechanical components
- a mechanical obstruction of the nose landing gear doors, wheels or strut.

3.3.10. The first 2 possibilities are discussed fully in the next section.

3.3.11. The rigging of the bypass valve and the nose landing gear assembly, including the doors, were checked and no fault was found. There was no indication of mechanical binding or obstruction.

3.3.12. The nose landing gear actuator and the drag strut actuator were removed and examined by their manufacturer, Messier-Dowty INC, under the supervision of an investigator from the Transportation Safety Board of Canada on behalf of the Commission. No faults were found.

3.3.13. The nose landing gear door actuator, mechanical sequence valve and steering manifold assembly and steering actuator were examined. No fault was found.

Nose landing gear alternate extension rigging and operation

3.3.14. The nose landing gear uplock did not release at Wellington in spite of the first officer pulling the release handle with what he believed was a lot of force. He took part in subsequent testing and observed that there was a more marked change in the force required between the doors opening and the uplock releasing than there had been on the accident aeroplane, but that the handle pulled out about as far. Some of the Air Nelson training captains who took part in these tests expressed surprise at the force required to release the uplock.

3.3.15. The rigging of the nose landing gear alternate extension system on ZK-NEQ was checked and no discrepancy was found.

3.3.16. The Q300 Maintenance Manual procedure for rigging the alternate extension system did not specify a value or range for the uplock release force or for the cable extension. Bombardier advised that no values had been specified because aeroplanes had individual mechanical characteristics. It said that pilots should pull the handle with whatever force and for as long as it takes to release an uplock, and that the release handle should be pulled in one movement. Air Nelson's training had generally emphasised that it was a single movement, noting that after the doors had opened the required force would seem to increase until the uplock was released.

3.3.17. Air Nelson undertook a fleet-wide inspection of the nose landing gear alternate extension system and measured the forces required to open the doors and release the uplocks. There was some variability according to whether the handle was pulled swiftly in one movement, or the tension held while the doors opened and then increased until the uplock released.

3.3.18. The results of the fleet inspection are summarised below:

- if the uplock release handle was pulled in one movement, the highest force was 65 kg. The force increased proportionally with the rate at which the handle was pulled
- if an arbitrary 5-second delay was observed between the door locks releasing and making a further pull to release the uplock, the peak force reduced to as little as 25 kg
- if the handle was pulled beyond the point at which the doors opened until an increase in pull force was felt and then held, the additional force required to release the uplock was significantly reduced
- the time for the doors to open fully was consistently about 2 seconds[16]
- the release handle could be pulled fully up in less than 2 seconds.

3.3.19. Air Nelson later advised its pilots when carrying out an alternate extension of the nose landing gear to use a 2-stage pull: the first was that usually applied to open the doors for the pre-flight check, followed by a pause for up to 5 seconds to allow the doors to open, and then a strong, continuous pull until the advisory position light showed that the nose landing gear had locked

[16] Bombardier later submitted that the time for the nose landing gear doors to open is reduced for an aircraft in flight.

down. Air Nelson said that with this technique an average force of 30 kg was enough to release the nose landing gear uplock.

3.3.20. ZK-NEQ was returned to service on 24 March 2011.

Other occurrences

3.3.21. Air Nelson pilots had resorted to the Alternate Gear Extension procedure successfully 5 times on air transport flights, with 4 of those occasions having been caused by a loss of system hydraulic pressure. The procedure had not been required previously to deal with the landing gear not extending when selected DOWN. Even with the 2 recent occurrences, Air Nelson's rate of landing gear failure-to-extend incidents was marginally better than the global rate advised by Bombardier (0.029 per 1000 flight hours).

3.4. Personnel information

3.4.1. On 9 February the crew reported for duty at 0655 after an overnight and 10 hours free of duty at Invercargill. They flew 3 sectors in ZK-NEQ before arriving at Hamilton.

3.4.2. The captain had joined Air Nelson in January 2006 and obtained a Q300 type rating, as a first officer, in September 2007. He had been promoted to captain in March 2009. He held an airline transport pilot licence (aeroplane), issued in December 2008, and a valid Class 1 medical certificate with no conditions, restrictions or endorsements. His total flight time experience to 8 February 2011 was about 5550 hours, of which about 2310 hours were on the Q300. The captain's previous flight crew competency check had been conducted on 29 October 2010 and his previous line check on 26 August 2010.

3.4.3. The captain said that during the Invercargill overnight he had had 7 hours of good sleep. His last rostered day off had been on 5 February 2011. He had flown about 56 hours in the 30 days prior to 9 February 2011, and about 23 hours in the 7 days prior.

3.4.4. The first officer had joined Air Nelson in August 2008 and completed the Q300 type rating course that month. He held an air transport pilot licence (aeroplane), issued in August 2010, and a valid Class 1 medical certificate with no conditions, restrictions or endorsements. His total flight time experience to 9 February 2011 was about 2443 hours, of which about 1315 hours were on the Q300. The first officer had completed a flight crew competency check on 7 December 2010 and his previous line check had been conducted on 1 November 2010.

3.4.5. The first officer said that during the Invercargill overnight he had had 7 hours of broken, but sufficient sleep. His last rostered day off had been on 5 February 2011. He had flown about 39 hours in the 30 days prior to 9 February 2011, and 26 hours in the 7 days prior.

3.4.6. The flight attendant had joined the company in August 2006 and qualified as a flight attendant on both Saab 340 and Q300 aeroplanes. Her previous line check had been completed on 24 January 2011.

3.5. Aerodrome information

3.5.1. Woodbourne Aerodrome is 6 kilometres west of Blenheim in a broad valley. The circuit for the single, sealed runway is, for a Q300-size aeroplane, comfortably clear of terrain. ZK-NEQ landed on runway 06. The aerodrome rescue service is provided by the former operator of the aerodrome, the Royal New Zealand Air Force, which still has active facilities there.

3.6. Other information

Flight simulator requirements

3.6.1. An aircraft flight simulator that is used for type rating training is certificated by the National Aviation Authorities of the simulator operator and of the airline and pilots who wish to obtain credit for its use. The certification level depends on the simulator fidelity, that is, how faithfully the simulator reproduces the flight and system characteristics, or the "look and feel", of the aircraft. The evaluation of simulators entails objective and subjective tests.[17] Objective testing is performed on primary flight controls only, and requires a computer-based comparison of the simulator performance with that of the actual aircraft, using validated reference data. Each test must meet mandated tolerances. Generally, the primary flight control forces exerted by pilots must be within 2.25 kg of the reference forces. The secondary controls, such as the alternate landing gear mechanism, are subjectively assessed for their function and performance by approved pilots.

3.6.2. The Civil Aviation Authority approved simulators in accordance with Civil Aviation Rule 121.11, which stated in part:

> **121.11 Flight simulator and other training device approval**
>
> (a) A holder of an air operator certificate must ensure that each flight simulator, or training device, that is used in the certificate holder's training programme is specifically approved for—
>
> (1) use by the certificate holder; and
>
> (2) the aeroplane type and, if applicable, the particular variant within that type, for which the training or check is being conducted; and
>
> (3) the particular manoeuvre, procedure, or crew member function involved.
>
> (b) The certificate holder must ensure that any flight simulator or any training device that is used to accrue flight credits—
>
> (1) maintains the performance, functional, and other characteristics that are required for approval; and
>
> (2) is modified to conform with any modification to the aeroplane being simulated that results in changes to performance, functional, or other characteristics required for approval; and …

3.6.3. The Civil Aviation Authority said that the simulator procedure for an alternate landing gear extension did not require specific approval. Prior to Air Nelson installing a Q300 simulator in Auckland, its pilots had been trained in simulators in Canada and Australia. The National Aviation Authorities of these 3 countries confirmed that the simulated Q300 uplock release force was assessed subjectively. Transport Canada explained that the wear caused by unusually frequent use of the simulator alternate landing gear extension mechanism and the variability of wear across operators' fleets made the isolation of a representative force very difficult. The Civil Aviation Safety Authority of Australia noted that a recent check of the Australian Q300 simulator "found subjectively that there was sufficient resistant and release forces to indicate to the pilot that the gear up-locks had been released and the gear had extended".

3.6.4. The forces required for the alternate nose landing gear extension procedure in Air Nelson's simulator were measured with the same strain gauge that was used for the fleet check. The average forces were 6.5 kg to open the doors and 8.1 kg to release the uplock. Depending on the technique used, the actual force required to release the uplock averaged 30 kg on the fleet check, and the maximum measured was 65 kg.

[17] The standard reference is the International Civil Aviation Organization Doc 9625, Manual of criteria for the qualification of flight training simulator devices.

QRH procedures

3.6.5. The requirement for an operator to provide pilots with a flight check system is given in Civil Aviation Rule 121.77, which states in part:

> The certificate holder shall ensure that the system enables safe real-time decision making and aeroplane management by conforming with the principles—
>
> (1) contained in the aeroplane flight manual; and
>
> (2) contained in the manufacturer's technical and safety instructions.

3.6.6. A QRH provides pilots with the necessary procedures and guidance to deal with most non-normal and emergency situations that might occur. It is derived from, but subordinate to, the approved aircraft flight manual and is not evaluated as a part of the aircraft type certification process. Operators may adapt aircraft manufacturers' QRHs to suit their flight operations philosophy and practice. Amendments to a QRH must be notified to the Civil Aviation Authority, but do not require its approval.

3.6.7. The preface to the Bombardier Q300 QRH was similar to those in the QRHs of other aircraft manufacturers 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.

3.6.8. The Air Nelson Q300 training course and its QRH had not, prior to this accident, included the notes in the Bombardier aircraft flight manual concerning the forces required when pulling the landing gear alternate release handles. The absence of that important information, particularly from the QRH, had not been noticed when the Civil Aviation Authority determined the acceptability of Air Nelson's training and operational manual suite.

3.6.9. Air Nelson was one of a number of Q300 operators that had asked Bombardier to provide a specific procedure for a landing gear leg not extending when selected DOWN, and for landings with non-normal gear configurations, for example with the nose landing gear retracted. In response, in March 2008 Bombardier issued a Service Letter containing considerations for pilots if the Alternate Gear Extension procedure did not result in all of the gear locking down.[18]

3.6.10. Air Nelson had customised a procedure, "Landing gear fails to extend", that was not in the Bombardier QRH, but which was based on information in Bombardier Service Letters. The Air Nelson procedure firstly checked that a normal extension had not been prevented by the flight deck switches being incorrectly configured, and also involved checking the verification lights. If those checks did not correct the condition, the procedure led to the Alternate Gear Extension procedure.

3.6.11. After this accident, Air Nelson amended its QRH "Landing gear fails to extend" procedure by adding an initial step to cycle the landing gear selector lever. However, that change was reversed after Bombardier issued Service Letter DH8-SL-32-030A in July 2011, stating that cycling the landing gear should be considered only as a last resort.

3.6.12. During this accident, the first officer misread the adjacent items "alternate release door" and "alternate extension door' in the QRH checklist for "Landing gear fails to extend" (see

[18] Bombardier Flight Operations Service Letter DH8-SL-32-026, 10 March 2008.

paragraph 3.1.9). A similar error had occurred prior to the 1995 accident, referred to earlier, even though in that case the 2 items were separated by another action.[19] The steps are also separated in the "Alternate gear extension or 'LDG GEAR INOP' (Caution Light)" procedure in the Bombardier flight manual.

3.6.13. The report on the 1995 accident cited the similarly named items in close proximity within an un-numbered checklist as a contributory factor in that accident. At that time, the Commission recommended to Ansett New Zealand that similar equipment names be eliminated, but the airline replied that the naming of items was a matter for the manufacturer. The Commission did not then repeat the recommendation to Bombardier. After the February 2011 occurrence, Bombardier said that it considered that a pilot mistaking the 2 items in the Alternate Gear Extension procedure was a training issue.

3.6.14. In its report on the 1995 accident, the Commission quoted from a Flight Safety Foundation report that had recommended numbering the steps of a non-normal or emergency procedure checklist as a method for reducing checklist reading errors (Flight Safety Foundation, 1995, p.5). However, the Commission at the time did not explicitly make that recommendation. Bombardier noted after the February 2011 occurrence that checklist procedural steps were numbered in its Q300 aeroplane flight manual. The Commission observed that the practice of numbering the procedural steps in QRH checklists was increasingly followed for newer aircraft types.

[19] Transport Accident Investigation Commission, 1997, p.66.

4. Analysis

4.1. The landing gear did not extend on arrival at Wellington because of a fault with the inhibit switch. The aeroplane was required to have an alternative system to extend the landing gear when the normal system failed. The alternative extension system was capable of getting all of the landing gear down and locked on this occasion. There was no technical reason for the nose landing gear not extending.

4.2. The main point of discussion in the following analysis is centred on why the crew actions did not succeed in getting the nosewheel down and locked using the alternate extension procedure.

4.3. The loss of nosewheel steering prior to departure from Hamilton was also linked to the faulty inhibit switch. The first event was therefore a precursor to the second and this is also discussed.

4.4. Although not contributory to the accident, some safety issues around the design and use of QRH checklists and how they are followed were identified. These are discussed also.

Inhibit switch defect

4.5. The pilots had no information to suggest what had caused the nosewheel steering failure at Hamilton. Their reference to the QRH and Minimum Equipment List and their decision to continue the flight were appropriate responses. However, without nosewheel steering the aeroplane was restricted to taking off and landing in crosswinds of less than 20 knots and would have had difficulty using some airport gates with tight turning circles. For these reasons it would have been prudent for the pilots to advise the operator sooner of the defect.

4.6. The nosewheel steering failure was caused by an intermittent defect in the inhibit switch. Although the switch was in the NORMAL position, the defect caused the landing gear extend solenoid to de-energise. Consequently the landing gear system hydraulic extend lines did not pressurise. The nosewheel steering system is pressurised by the extend line, which is why it stopped working.

4.7. The inhibit switch position does not affect landing gear retraction. When the landing gear was selected UP after take-off from Hamilton, the extend solenoid would have gone to the de-energised state in any case. However, when the landing gear was selected DOWN at Wellington, the defective inhibit switch prevented the extend solenoid energising. Therefore hydraulic pressure was not directed to extend the landing gear.

4.8. The decision to permit operations without the nosewheel steering appears to have been based on operational considerations only and to have not considered the potential for a related system failure.

4.9. Air Nelson considered the inhibit switch to have excellent reliability, and global data from Bombardier confirmed that. However, in order to reduce the chance of a similar defect causing multiple system failures, Bombardier promptly amended the Q300 Minimum Equipment List to require confirmation that hydraulic pressure was available for normal landing gear extension before an aeroplane may be dispatched with the nosewheel steering system inoperative.

4.10. If the revised requirements had been in place at the time, the pilots would have returned to the gate. Maintenance staff would have found that no hydraulic pressure was available and the problem would have been rectified before the aeroplane was released to service. The landing gear would then have lowered normally when next selected DOWN.

Findings:

A faulty inhibit switch caused the loss of nosewheel steering when the aircraft was departing from Hamilton.

The same faulty inhibit switch was the cause of the landing gear not extending normally when the aircraft was approaching Wellington.

The Minimum Equipment List provision that had previously allowed a flight to commence without an operative nosewheel steering system appeared to be based on operational considerations only, and to have not considered the possibility of a related system failure.

Failure of nose landing gear to extend by alternate system

4.11. The nose landing gear was found to be retracted when the aeroplane nose was raised from the runway. The uplock released readily when the release handle was pulled. Photographs confirmed that the nose landing gear had not extended before the landing, but they could not prove whether the uplock had released during the Alternate Gear Extension procedure. However, that possibility was discounted for 2 reasons. The cockpit voice recorder had not recorded the sound of the uplock releasing; and the aeroplane had settled onto the open nose landing gear doors after touchdown, and not onto partially extended nosewheels that would have been pushed back into the wheel well.

4.12. If the uplock did not release either time that the first officer pulled the release handle, even though he was sure that he had pulled the handle hard enough, he must have been mistaken as to the force required. No other explanation was found for the nose landing gear not extending.

4.13. Bombardier subsequently published a Service Letter that advised that up to 40 kg of force was required to release the landing gear uplocks manually. Air Nelson found that the average force required was 30 kg. The first officer did manage to release the main landing gear uplock, but there were at least 3 factors that might have contributed to his not releasing the nose landing gear uplock:

- the technique described in the Air Nelson publications for pulling the nose landing gear uplock release handle was not consistent, and the information in the Bombardier flight manual and in Safety of Flight Supplement No.7 had not been provided to pilots
- pilots were very used to pulling the nose landing gear uplock release handle a short distance, enough to open the forward doors, for which an average force of 8 kg was sufficient. They were not used to the greater force required to release the uplock
- the flight simulator did not accurately reproduce or differentiate the actual forces required to open the nose landing gear doors and uplock on the aeroplane.

4.14. The Air Nelson Q300 Systems Training Manual described the change in the required force when the nose landing gear alternate release handle was pulled as a detent. Although there was not an actual mechanical detent, pilots were used to feeling a change in the force requirement from their experience of opening the doors only for daily pre-flight external inspections. As springs assisted the doors to open, a light pull force was enough for that.

4.15. However, the Training Manual also instructed pilots to pull the handle “in one continuous motion” when performing an actual alternate extension. Air Nelson trials showed that if the handle was pulled quickly, the uplock would release immediately, but the mechanical sequence valve could prevent the landing gear leg moving until the forward doors were open. In that case, an apparently strong pull on the handle might have been ineffective if it was relaxed too early and the uplock then re-engaged before the nose landing gear had begun to move down.

4.16. Following this accident Air Nelson amended its Q300 pilot training to recommend a 2-stage pull on the uplock release handle during an alternate extension procedure, a technique that the airline considered reduced the maximum force required. If pilots pause after releasing the door locks, then pull the handle hard and maintain the tension until the uplock releases, the alternate extension procedure should be successful.

4.17. The nose landing gear forward doors were open when the first officer tried again to release the uplock. It is likely that he used a similar force as on his first attempt, as he described it as "an easy pull". Even if he had pulled harder and with considerably more force than he was used to when opening just the doors, that force might still have been less than was needed to release the uplock. Therefore, his training and experience, and the QRH procedure at the time, had not given him adequate guidance as to the force required.

4.18. During the alternate landing gear extensions conducted in the hangar after the accident, some senior Air Nelson pilots expressed surprise at the force required to release the uplock. Their reactions confirmed that not all of the operator's pilots had been adequately trained for the alternate extension procedure.

4.19. Alternate extensions of the landing gear are performed during periodic maintenance and occasional troubleshooting. Airlines could use these maintenance opportunities to give their pilots experience of the actual forces required to release the uplocks.

4.20. If a simulated characteristic differs significantly from that on the actual aircraft, pilots should be made aware of that during their training and reminded of this in any relevant QRH procedure. Bombardier and Air Nelson later amended their QRH procedures for alternate landing gear extensions to include the note (from the Bombardier flight manual) that the release handle forces could be greater than those experienced in training.

4.21. On the aeroplane, the force to open the doors only ranged between 6 and 8 kg, and the simulator also needed only a pull of 6 kg. Pilots frequently opened the doors only, so their arm muscles were likely to have a "memory" of the force required. However, whereas a pull of 25 to 50 kg or more was required to release the uplock in the aeroplane, the simulator force was only 8 kg. Therefore the simulator did not accurately simulate or differentiate the forces required in the aeroplane.

4.22. The Civil Aviation Authority and 2 other National Aviation Authorities said that subjective testing of the simulated alternate landing gear extension mechanism was sufficient. The difficulty of determining a reference uplock release force, which would be necessary for objective testing, is acknowledged. However, the simulated force should do more than simply "indicate to the pilot that the gear up-locks had been released and the gear had extended". As this accident showed, a major goal of the exercise should be to make pilots familiar with the magnitude of the force required to release the uplock compared with that for releasing the door locks. Therefore, the simulated forces should be very similar to the actual forces required.

4.23. The previously light forces in the Air Nelson simulator had resulted in pilots being mis-trained. Had the simulator more closely represented the actual forces required, it is likely that the first officer would have succeeded with the procedure and that the occurrence would have been avoided.

4.24. Air Nelson later modified its Q300 flight simulator so that the forces were at the high end of the range of forces encountered on the aeroplane.

4.25. Although the sole Dash 8/Q300 simulator in New Zealand has been modified, the Commission recommends that the Director of Civil Aviation liaise with Transport Canada to make other National Aviation Authorities aware of this incident and of the desirability of Dash 8 flight simulators closely representing the actual forces required for a landing gear alternate extension.

4.26. The captain's decision not to cycle the landing gear and attempt another alternate extension, as the technical staff recommended, was reasonable. More than 20 minutes had been spent circling while technical staff sought a solution, so the aeroplane fuel state was low. He was

responsible for the safety of the aeroplane and the QRH procedure began with a warning that the landing gear could not be retracted after an alternate extension. At the time, there was no published procedure for reversing the steps of the Alternate Gear Extension procedure. A method for retracting the landing gear could have been deduced, and might have been successful, but it would have put the pilots in the unusual position of having to assess the acceptability of an unfamiliar procedure.

Findings:

There was no defect with the alternate extension system that would have prevented any of the landing gear extending and locking down.

The nose landing gear uplock did not release during the alternate extension procedure because the release handle had not been pulled hard enough or had not been held for as long as it took for the uplock to release.

The training that Air Nelson gave its pilots on the alternate landing gear extension procedure did not include key information provided by Bombardier concerning the release handle forces, and there was no guidance in the QRH procedure.

The simulator that Air Nelson used for training its pilots in the alternate landing gear extension procedure was not representative of the actual forces required to release the uplock.

QRH format and use

4.27. When reading the QRH checklists, the first officer made 2 inconsequential errors that could have been caused, in part, by his reading them too quickly. The considerations listed with a QRH non-normal or emergency procedure must be evaluated carefully if the procedure is to be effective, so time must be allowed for both pilots to assimilate each step.

4.28. The misreading of the QRH also highlighted the importance of checklists being formatted so that readers do not lose their place and omit potentially critical steps, as appeared to happen when the first officer was reading the "Landing gear fails to extend" procedure (see paragraph 3.1.9). The tone of his voice suggested that he might have thought he was repeating the step for the alternate *release* door, then omitted the step for the alternate *extension* door. However, the captain later said that he had seen from the first officer's hand movements that both steps were completed, and both doors were found open after the landing.

4.29. Similarly, the first officer appeared to lose his place before reading the sixth step in that excerpt, perhaps because successive lines in the checklist began with the words "Landing gear". These minor errors, neither of which contributed to the accident, show how the checklist format can lead to a step being mistaken or omitted.

4.30. The potential for confusing similar items, like "alternate release door" and "alternate extension door", when they are adjacent items in a checklist was referred to in the report into the 1995 accident.

4.31. Air Nelson had reduced this risk in its "Alternate gear extension" checklist by adding the location of the item (see Appendix, page 3). The airline later advised the Commission that the "Landing gear fails to extend" checklist would be similarly improved as part of a project then underway to align its manuals with "airline industry best practice".

4.32. An additional safeguard against losing one's place when reading a checklist is to number each step in the procedure, as the Commission recommended to Ansett New Zealand in its report on the 1995 accident. In February 2011 the emergency and non-normal procedures in the Bombardier Q300 flight manual had numbered steps. However, neither the Bombardier nor

the Air Nelson QRH did. Air Nelson later advised that its manual review project would include improvements to QRH readability, including the numbering of procedural steps.

4.33. The Commission noted with concern that although these QRH formatting issues were identified many years ago, some airlines had been slow to adopt the associated recommendations.

4.34. As the content and format of a QRH are not regulated, unlike the associated aircraft flight manual, and may be varied by operators, the Commission recommends that the Director of Civil Aviation urge operators to adopt QRH checklist formats that reduce the possibility of misreading or omitting a procedural step.

Finding

The similarity of text in adjacent steps of the QRH and the lack of numbered steps contributed to the first officer making minor errors in reading the landing gear non-normal procedures. However, these errors did not contribute to the accident.

Communications

4.35. The pilots kept the flight attendant well informed, and the passengers were well informed by both the pilots and the flight attendant. The following observations consider opportunities for more effective communication between the pilots, and between them and other airline staff.

4.36. Under normal flight conditions, procedures that are routine and standardised are performed by pilots with a minimal amount of direction and co-ordination, and often using non-verbal communication such as gestures. However, when a non-normal or emergency procedure is required, the actions will be less familiar and the outcomes less certain. It is important that each pilot knows what the other is doing when dealing with a non-normal situation. In that respect, the first officer ought to have clearly checked with the captain before trying to release the nose landing gear uplock the second time.

4.37. The captain was not required to inform Air Nelson of the nosewheel steering defect before the flight departed Hamilton. However, although the pilots later asked for details of the defect to be passed to the operator, the operator's staff could not recall having received that information. If the technical staff had known of the steering defect sooner, they might have recognised the connection with the failure of the normal landing gear extension. Whether that knowledge would have prevented the accident cannot be said, but having pertinent information generally assists with better decision-making.

4.38. The QRH procedure for landing with a non-normal landing gear configuration specified making the cabin announcement "Brace for impact" when the aeroplane was passing 500 feet, or about 45 seconds before touchdown. On the accident flight the captain made the announcement 2 minutes before landing, in order to complete the checks and let the pilots concentrate on the landing. While the intention was understandable, it resulted in the "Brace!" call being made much too soon, and obliged the flight attendant to repeat her commands over and over until the aeroplane landed. The long wait for the landing would have been likely to cause unnecessary stress in the cabin and could have led to some passengers looking up from the brace position. The pilots ought to have adhered to the QRH guidance.

4.39. The relaying of questions and suggestions between Air Nelson technical staff and the pilots, via the air traffic control tower, was necessary in this case, but cumbersome. Fortunately the controller had diverted other traffic from the control zone, an option that was not usually possible. Communication through a third party takes longer, hinders full discussion and can lead to misunderstandings and "lost" information, all of which are undesirable when trying to resolve an airborne emergency. The different reports about whether or how many of the nose doors were open also did not help the pilots to understand the situation correctly. Having the capability for direct air-ground-air communication assists airlines in the operational control of their aircraft.

5. Findings

5.1. A faulty inhibit switch caused the loss of nosewheel steering when the aircraft was departing from Hamilton.

5.2. The same faulty inhibit switch was the cause of the landing gear not extending normally when the aircraft was approaching Wellington.

5.3. The Minimum Equipment List provision that had previously allowed a flight to commence without an operative nosewheel steering system appeared to be based on operational considerations only, and to have not considered the possibility of a related system failure.

5.4. There was no defect with the alternate extension system that would have prevented any of the landing gear extending and locking down.

5.5. The nose landing gear uplock did not release during the alternate extension procedure because the release handle had not been pulled hard enough or had not been held for as long as it took for the uplock to release.

5.6. The training that Air Nelson gave its pilots on the alternate landing gear extension procedure did not include key information provided by Bombardier concerning the release handle forces, and there was no guidance in the QRH procedure.

5.7. The simulator that Air Nelson used for training its pilots in the alternate landing gear extension procedure was not representative of the actual forces required to release the uplock.

5.8. The similarity of text in adjacent steps of the QRH and the lack of numbered steps contributed to the first officer making minor errors in reading the landing gear non-normal procedures. However, these errors did not contribute to the accident.

6. Key lessons

6.1. In their simulator training pilots should be taught how to perform emergency and non-normal procedures as robustly and rigorously as if the procedures were being performed on the actual aircraft.

6.2. Pilots should be informed of flight simulator characteristics that differ from those in the aircraft to ensure that pilots are not misled during actual flight operations.

6.3. QRHs should be designed to minimise the potential for error as they are used by pilots during times of high workload and, potentially, high stress when dealing with emergencies.

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

(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 17 February 2011, 8 days after the accident, Bombardier amended the Minimum Equipment List Procedures Manual item 32-3 to require verification that hydraulic pressure was available for the normal extension of nose landing gear before operating with an inoperative nosewheel steering system.

7.3 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 landing gear utilizing the normal or alternate extension systems". The Service Letter also provided "considerations for Flight Crew if confronted with a non-normal landing gear configuration, which cannot be rectified with the existing Aircraft Flight Manual (AFM) procedures established within the scope of certification requirements".

7.4 As well as repeating procedures and considerations already included in the aircraft flight manual and Bombardier QRH, the Service Letter noted the following:

- flight crew should check the serviceability of indication lights when an expected gear configuration is not observed
- cycling the gear as an intermediate step to achieve an all gear down-and-locked indication is not approved or recommended
- the main and nose landing gear release handles are pulled with sufficient force (may exceed 90 pounds [40 kilograms]) to release the doors and uplocks. Pull forces in the air will likely be greater than those experienced on the ground or in a simulator. Continue pulling with whatever force is necessary to achieve release of all gear uplocks
- ensure the alternate gear indication lights are checked with the taxi light OFF.

7.5 The Service Letter noted that a defect that prevented normal and alternate extensions of the landing gear was outside the aircraft certification standards and would usually result in an emergency landing with an unusual landing gear configuration. For such a case, Bombardier introduced with this Service Letter a procedure for resetting the alternate extension system and retracting the landing gear. If successful, that would give the captain the option of cycling the landing gear in an attempt to get all of the landing gear down and locked.

7.6 On 28 May 2011 Bombardier advised Air Nelson that it would add the following note, which was already in the aircraft flight manual, to the Bombardier QRH Alternate Gear Extension procedure:

> [Landing] gear release handle loads may exceed those experienced during practice extensions.

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

7.8 During 2011 Air Nelson modified its Q300 simulator so that the landing gear uplock release handle loads were more representative of those required on the aeroplane.

7.9 On 8 May 2012 Bombardier advised operators of the Dash 8 series of aeroplanes, which included the Q300, that the following notes would be added to the aircraft flight manuals at the next revision:

> NOTE
>
> The main landing gear release handle pull force will be significantly higher than experienced during practice alternate landing gear extensions. The required pull force to release the main landing gear uplocks can be as high as ninety pounds [40 kilograms]. It may require a repeated pull effort to achieve a main landing gear down and locked indication.
>
> NOTE
>
> The nose landing gear release handle pull force will be significantly higher than experienced during practice alternate landing gear extensions. The required pull force to release the nose landing gear uplock can be as high as ninety pounds [40 kilograms]. It may require a repeated pull effort to achieve a nose landing gear down and locked indication.

7.10 On 31 July 2012 Air Nelson advised the Commission that it was well underway with a project to review all of its policies and procedures to ensure that they were aligned with recognised airline industry best practice. Improvements to the QRH format were included in that process.

7.11 On 2 December 2012 the Civil Aviation Authority advised that it had "strengthened its certification process for air operator expositions to include an evaluation of operator flight procedures for large aircraft against the criteria specified in [Civil Aviation Rule] 121.77, and in cases where an operator has developed its own procedures, confirmation that these procedures included all pertinent information provided by the manufacturer".

Safety actions addressing other safety issues

7.12 Nil.

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.

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 14 December 2012 the Commission recommended to the Director of Civil Aviation that he liaise with Transport Canada to make other National Aviation Authorities aware of this incident and of the desirability of Dash 8 flight simulators closely representing the actual forces required for a landing gear alternate extension. (036/12)

8.4 On 14 December 2012 the Commission recommended to the Director of Civil Aviation that he urge operators to adopt QRH checklist formats that reduce the possibility of misreading or omitting a procedural step. (037/12)

8.5 On 16 Januray 2013 the Director of Civil Aviation confirmed that the recommendations would be implemented by the Aircraft Cetification Group and the Air Transport and Airworthiness Group (036/12 and 037/12, respectively. Implementation dates had yet to be finalised.

9. Citations

Air Nelson. (2005). Q300 Minimum Equipment List and discrepancy procedures guide, rev. 0.

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Flight Safety Foundation. (1995). Flight Safety Digest, vol.14, no.5. *Studies suggest methods for optimizing checklist design and crew performance.* Flight Safety Foundation; Washington, DC.

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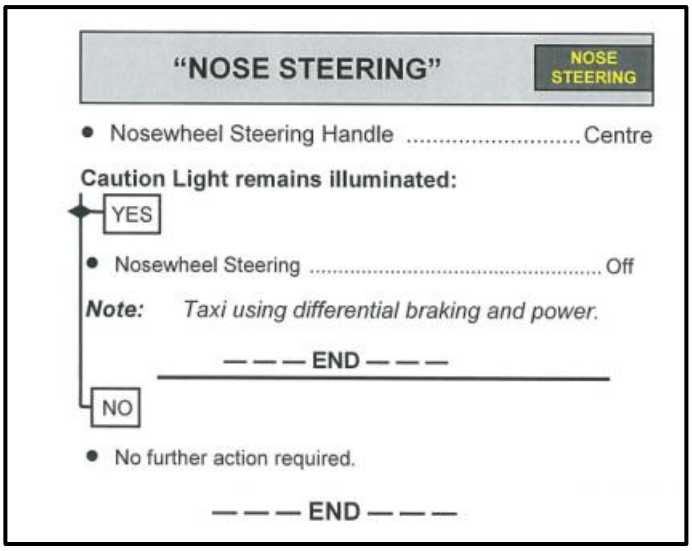
Appendix: Procedures for non-normal landing gear conditions

Relevant excerpts from the Air Nelson Q300 QRH that was current on 9 February 2011.



"NOSE STEERING" NOSE STEERING

- Nosewheel Steering Handle ..... Centre

Caution Light remains illuminated:

YES

- Nosewheel Steering ..... Off

Note: *Taxi using differential braking and power.*

— — — END — — —

NO

- No further action required.

— — — END — — —

Source: Air Nelson Q300 QRH, page 14.11, April 2010

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

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

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 — — —

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10-007	Boeing 737-800, ZK-PBF and Boeing 737-800, VH-VXU, airspace incident, near Queenstown Aerodrome, 20 June 2010
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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

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