Inquiry AO-2013-009: RNZAF Boeing 757, NZ7571, landing below published minima
Pegasus Field, Antarctica, 7 October 2013

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.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

Final Report

Aviation inquiry 13-009
RNZAF Boeing 757, NZ7571
landing below published minima
Pegasus Field, Antarctica
7 October 2013

Approved for publication: December 2014

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing commission of inquiry and 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 the 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 and the public, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

Commissioners

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

Key Commission personnel

Chief Executive	Lois Hutchinson
Chief Investigator of Accidents	Captain Tim Burfoot
Investigator in Charge	Ian McClelland
General Counsel	Cathryn Bridge

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

Important notes

Nature of the final report

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

Ownership of report

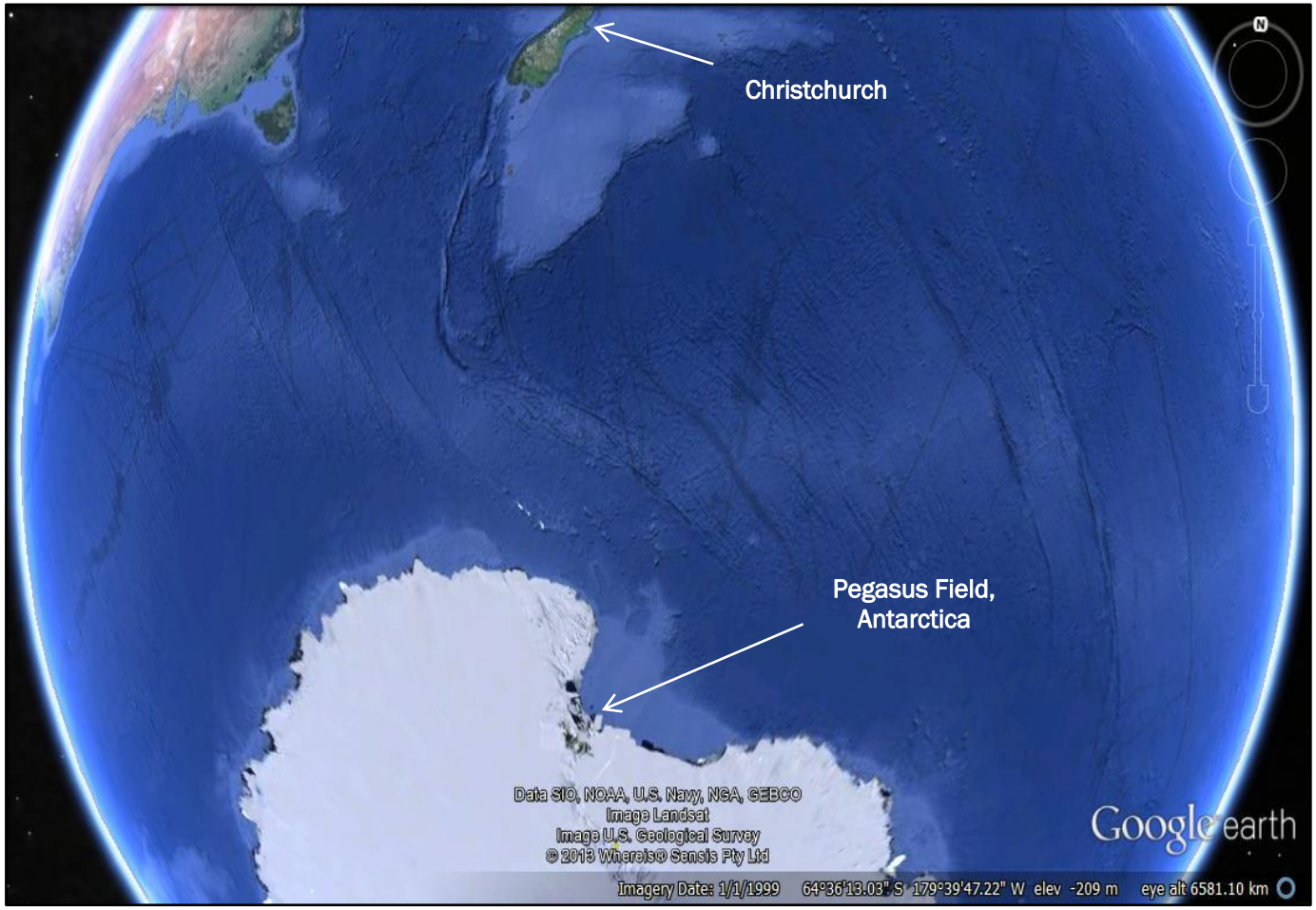
Citations and referencing

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

Photographs, diagrams, pictures

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

RNZAF Boeing 757-2K2, Antarctica
(Courtesy of the Royal New Zealand Air Force)



Location of incident
(Image courtesy of Google Earth)

Contents

Abbreviations ii
Glossary iii
Data summary iv
1. Executive summary 1
2. Conduct of the inquiry 3
3. Factual information 5
3.1. History of the flights 5
Previous flight on 3 October 2013 5
Incident flight on 7 October 2013 5
3.2. Personnel information 11
3.3. Meteorological information 12
3.4. Airspace and local area information 14
Airfield information 14
Local area information 15
3.5. Operator and aeroplane information 16
The Boeing 757-2K2 and Antarctic operations 17
4. Analysis 20
4.1. Introduction 20
4.2. Preparation for the flight 20
4.3. The decision to continue past the point of safe return (PSR) 21
4.4. Descent below minimum descent altitude (MDA) 23
4.5. The risk of using the Boeing 757 for Antarctic operations 24
4.6. Management of New Zealand ICAO allocated airspace 28
5. Findings 29
6. Key lessons 30
7. Safety actions 31
7.1. General 31
7.2. Safety actions addressing safety issues identified during an inquiry 31
RNZAF Antarctic operations 31
Weather information 32
Airspace management 32
8. Recommendations 33
8.1. General 33
8.2. Recommendations 33
9. Source 35
Appendix 1: RNZAF Boeing 757 NMB569 flight to Antarctica – timeline 36
Appendix 2: Weather observations (METARs and SPECIs) – see Appendix 4 for an explanation of terms 37
Appendix 3: Weather forecasts (TAFs) – see Appendix 4 for an explanation of terms 38
Appendix 4: Weather codes 39

Figures

Figure 1 Approach to Pegasus Field runway 33, 3 October 2013 (Courtesy of the RNZAF) 6
Figure 2 Runway markings, 3 October 2013 (Courtesy of the RNZAF) 9
Figure 3 Runway markings, 7 October 2013 (Courtesy of the RNZAF) 9
Figure 4 Visibility an hour after landing (Courtesy of the RNZAF) 10
Figure 5 Visibility one hour and 45 minutes after landing (Courtesy of the RNZAF)..... 10
Figure 6 Local area (Courtesy of Google Earth)..... 15
Figure 7 Antarctica – general (Courtesy of Google Earth) 16

Tables

Table 1: United States Antarctic Program Inter-agency Air Operations Manual, dated 1 August 2012 . 13
Table 2: Weather trend data provided by NIWA..... 25
Table 3: Percentage of time ceiling (metres) and/or visibility (nautical miles), less than or equal to specified values, McMurdo..... 26

Abbreviations

ACARS	aircraft communications addressing and reporting system
BKN	broken
C	Celsius
CAA	Civil Aviation Authority of New Zealand
FEW	few
GPS	global positioning system
ICAO	International Civil Aviation Organization
km	kilometre(s)
m	metre(s)
MDA	minimum descent altitude
METAR	aviation routine weather report
MFAT	Ministry of Foreign Affairs and Trade
NSF	National Science Foundation
NIWA	National Institute of Water and Atmospheric Research
nm	nautical miles
NOTAM	notice to airmen
PSD	point of safe diversion
PSR	point of safe return
RNAV	area navigation
RNZAF	Royal New Zealand Air Force
SCT	scattered
SOPP	Space and Naval Warfare Systems Command – Office of Polar Programs
SPECI	special weather report
TACAN	tactical air navigation system
TAF	aerodrome forecast
USA	United States of America

Glossary

broken	five- to seven-eighths of the sky obscured by cloud
few	one to two oktas or eighths of cloud
grid wind	because of the strong convergence of the meridians and the variable location of the Magnetic Poles, navigation by reference to True or Magnetic in Antarctica is difficult. Therefore an artificial reference is adopted in which the Greenwich (Prime) Meridian is taken to be grid north. An aircraft flying parallel to this meridian, for example from McMurdo towards South Pole, would be flying a track of grid north. A wind blowing from 90° right of this track would be coming from grid east or grid 090
METAR	a routine weather report of observed meteorological conditions for a specific location and time
minimum descent altitude (MDA)	a specified altitude above mean sea level, below which descent must not be made without the required visual references
observation	a METAR or a SPECI
PSR-2d	the point on a route at which an aircraft, having suffered a loss of pressurisation and been forced to descend to a lower level, can safely return to its departure airfield on two engines with the required fuel reserves
PSR-alt	the point on a route at which an aircraft can safely return to its departure airfield at normal cruise altitude(s) and land with the required fuel reserves
scattered	three to four oktas or eighths of cloud
SPECI	a special weather report issued when some weather element passes a specified value or changes significantly. Depending on the time of issue, a SPECI may take the place of a METAR. In this incident it was also used to identify the additional reports issued 30 minutes after the hourly METARs

Data summary

Aircraft particulars

Aircraft registration:	NZ7571
Type and serial number:	Boeing 757-2K2, 26633
Number and type of engines:	two Rolls-Royce RB211-535 E4 turbofans
Year of manufacture:	1993
Operator:	Royal New Zealand Air Force
Type of flight:	charter
Persons on board:	130 (including 13 crew)
Captain's qualifications:	military: A-category captain and instructor, test supervisor civil: New Zealand and Australian airline transport pilot licences (aeroplane)
Captain's age:	40 years
Captain's flying experience:	5,439 hours total (including 852 hours on type)

Date and time	7 October 2013, 1656[1]
Location of incident	Pegasus Field, Antarctica latitude: 77° 58' south longitude: 166° 31' east
Injuries	nil
Damage	nil

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

1. Executive summary

1.1. At 0957 on 7 October 2013, a Royal New Zealand Air Force Boeing 757 departed Christchurch for Pegasus Field aerodrome in Antarctica. There were 117 passengers and 13 crew on board. The passengers included a New Zealand Government Minister, staff from the Ministry of Foreign Affairs and Trade, and staff from Antarctica New Zealand and the United States Antarctic Program.

1.2. The flight departure had been delayed while the flight crew gathered additional information on the forecast weather conditions at Pegasus Field. The Boeing 757 aircraft did not have sufficient fuel capacity to complete the return trip without refuelling at Pegasus Field.

1.3. A point of safe return had been pre-calculated. The aeroplane would only continue past this point if the weather conditions at Pegasus Field met certain criteria that would allow the aeroplane to land safely; otherwise it would return to Christchurch.

1.4. The crew received regular and additional weather observations and forecasts from staff at the United States Navy's Space and Naval Warfare Systems Command's Office of Polar Programs facilities at McMurdo and in Charleston, USA. Weather observers at Pegasus Field were noting the existence of a fog bank about five kilometres from the runway. The crew received assurances from the forecasters that the weather was forecast to improve. Based on these assurances and using the crew members' collective experience, both recent and from previous seasons, the crew made the decision to continue past the point of safe return towards Pegasus Field. About 20 minutes thereafter, the crew received the first of several weather observations that conditions had deteriorated and that a fog bank had enveloped the runway and its approaches.

1.5. With insufficient fuel on board to return to Christchurch, the crew was committed to continuing to Pegasus Field. There was no other safe alternative aerodrome in Antarctica where the aeroplane could land. The crew made two attempts to land at Pegasus Field but the restricted visibility prevented them gaining the required visual reference with the runway markings and lights. After the first attempt the crew decided to hold to see if the weather would start to clear. After holding for nearly two hours with no improvement in the conditions, the crew decided to make a second approach using a lower "minimum descent altitude" than the published minima in an attempt to increase the chance of becoming visual with the runway. A member of the flight crew caught a glimpse of runway markings just as the approach was aborted and a missed approach procedure was initiated (a "go-around").

1.6. With dwindling fuel reserves and conditions deteriorating the crew elected to make a third attempt at landing. They again used the lower "minimum descent altitude". When the aeroplane reached about 110 feet above the runway , the crew saw the runway approach lights and markings and was able to make a successful landing in near-whiteout conditions. There was no damage to the aeroplane and no-one was injured.

1.7. The Commission found that the observed and forecast weather conditions as reported to the crew met the criteria for the crew to continue past the point of safe return. It also found that, given no safe alternative, the actions of the crew in proceeding below the allowable minima for the aerodrome were appropriate, and that the crew had taken all reasonable precautions to mitigate the risks involved in doing so.

1.8. However, the Commission found that the risk assessment undertaken when considering the suitability of the Boeing 757 aircraft type for Antarctic operations had not adequately taken into consideration five key points:

- the potential consequences of the weather deteriorating were elevated for the Boeing 757 aircraft because of the lack of alternative approach procedures and aerodromes suitable for the aircraft type

- the weather criteria for an aeroplane passing the point of safe return should consider the presence of low cloud and fog below the main cloud base as a limiting factor
- there is an increased likelihood of weather conditions deteriorating below minima early in the summer season
- the accuracy of instrument approaches should be treated with caution prior to re-calibration flights being conducted early in the summer season
- the Royal New Zealand Air Force Boeing aircraft is capable of completing only one type of instrument approach in Antarctica.[2]

1.9. The Commission recommended that the Chief of Air Force review the risk assessment for using the Boeing 757 aircraft for Antarctic flight operations, taking into account these matters and any other matters not considered during the initial risk assessment.

1.10. The key lessons learnt from the inquiry into this occurrence were:

- Effective crew resource management enables a crew to perform as a cohesive unit and provides the best opportunity for a safe outcome. This incident demonstrates how a properly trained crew was able to function effectively in demanding circumstances and make a safe landing.

- An essential element of risk management is the continuous review of the relevance of the original assessment and its context, hazards and mitigations. This is especially important when there are changes in the circumstances or conditions of the assessment to ensure that it remains valid and provides the appropriate level of safety.

[2] GPS area navigation approach.

2. Conduct of the inquiry

2.1. The Royal New Zealand Air Force (RNZAF) notified the Transport Accident Investigation Commission (Commission) of the incident on the evening of Monday 7 October 2013 in accordance with the terms of a memorandum of understanding between the Commission and the New Zealand Defence Force. The aeroplane was a military aeroplane carrying both military and civilian people and the service was being provided for a joint logistics pool involving Antarctica New Zealand and the National Science Foundation (NSF) of the United States. Consequently, the Commission determined that the incident involved a combination of military and non-military transport-related service and persons.

2.2. On 11 October 2013 the Commission opened an inquiry under section 13(1)b of the Transport Accident Investigation Commission Act 1990, because it believed that the circumstances of the incident had or were likely to have significant implications for transport safety. The Commission's inquiry was conducted in parallel to the RNZAF inquiry under the terms of the memorandum of understanding.

2.3. On 14 October 2013 the investigator in charge and a second Commission investigator, both with experience operating to and within Antarctica, travelled to Auckland to interview members of the crew. The crew members interviewed included the four pilots present on the flight deck during the flight south, and the chief loadmaster who managed the cabin. Other personnel interviewed included the Commanding Officer 40 Squadron, which operated the Boeing 757 and C130 Hercules aircraft, and RNZAF safety staff.

2.4. Flight planning documents and copies of operating procedures and other related data were collected, including weather information provided before and during the flight and all messages sent and received via the aircraft communications addressing and reporting system (ACARS). During the next few weeks investigators had discussions with Antarctica New Zealand and Ministry of Foreign Affairs and Trade (MFAT) personnel, including a representative of the MFAT group that had travelled on the flight. The Commission also obtained information from an overseas commercial operator that regularly flew to Antarctica.

2.5. On 21 October 2013 the Commission, through Antarctica New Zealand, passed written questions to the National Science Foundation, mainly concerning the provision of meteorological information. On 5 November 2013 the Commission received an initial response to the questions.

2.6. On 24 October 2013 the Commission obtained a copy of the documents supporting the supplemental type certificate issued by the air force that gave approval for the Boeing 757 to conduct flights to Antarctica. Other organisations that also provided information to the inquiry included the Civil Aviation Authority of New Zealand (CAA) and Airways Corporation of New Zealand (Airways).

2.7. On 16 December 2013 a list of supplementary questions was sent to the headquarters of the National Science Foundation in Washington. A response to the questions was received on 28 January 2014. The National Science Foundation also supplied audio recordings of Pegasus Field tower radio and of a telephone conversation between the crew of the Boeing 757 and National Science Foundation staff in the control tower.

2.8. During July 2014 the New Zealand National Institute of Water and Atmospheric Research (NIWA) conducted a review of Antarctic meteorology. The focus of the review was to obtain a better understanding of seasonal variations in the Ross Sea area, in particular during the summer period. Advice was obtained from the CAA's chief meteorological officer; the Meteorological Service of New Zealand; and RNZAF meteorological support staff. On 21 August 2014 NIWA provided a summary of seasonal weather conditions around Ross Island.

2.9. On 24 September 2014 the Commission approved the draft report for distribution to interested persons for comment. The interested persons included the flight crew of the aeroplane, the Chief of Air Force for the RNZAF, the Divisional Manager for MFAT (Environment

Division), the Head of the Antarctic Infrastructure & Logistics Section of the National Science Foundation, the Chief Executive of Antarctica New Zealand and the Director of Civil Aviation.

2.10. Responses were received from all persons, with substantive submissions made by the National Science Foundation, RNZAF and CAA. Their submissions were considered in preparing the final report.

2.11. On 10 December 2014 the Commission approved the publication of the report.

3. Factual information

3.1. History of the flights

Previous flight on 3 October 2013

3.1.1. On Thursday 3 October 2013, NZ7571, an RNZAF Boeing 757-2K2 aeroplane (the aeroplane) flew the first of three flights planned for the early summer season from Christchurch to Pegasus Field in Antarctica. The flights were part of a joint logistics pool involving Antarctica New Zealand and the National Science Foundation of the United States. A further three flights were planned for February and March 2014.[3] The flight to Pegasus Field normally took about four hours and 45 minutes, depending on the winds encountered. A refuel was required before the aeroplane returned to Christchurch.

3.1.2. The flight crew (the crew) for the first flight consisted of a captain, who was also an instructor on the Boeing 757, a captain under training and a co-pilot. The flight was uneventful and the opportunity was taken during the flight south to talk with a senior United States Antarctic Program[4] weather forecaster who was travelling to McMurdo for the summer season. The approach to and landing on runway 33[5] at Pegasus Field were flown in visual meteorological conditions.

3.1.3. The captain under training, who was sitting behind the two pilot seats, took photographs of the area and the runway during the approach (see Figure 1). The crew was also able to validate the accuracy of the area navigation (RNAV) global positioning system (GPS) instrument approach for runway 33. The crew noted after landing that the runway centreline was offset to the right of the published inbound track information by about 15 metres (m).[6]

Incident flight on 7 October 2013

3.1.4. Adverse weather conditions in the McMurdo Sound area meant that the second flight scheduled for Saturday 5 October 2013 was delayed twice until Monday 7 October 2013. A second captain joined the crew on the Sunday afternoon. The planned load for the flight consisted of 117 passengers, including a New Zealand Government Minister, MFAT staff and Antarctica New Zealand and United States Antarctic Program personnel. The 13-person aeroplane crew consisted of the four pilots, three loadmasters, four flight stewards and two engineers.

3.1.5. At about 0600 on 7 October 2013, the crew and authorising officer assembled at Christchurch International Airport and received a briefing package for the flight. The package included several satellite weather images, upper-level wind charts and the current aerodrome forecast (referred to by the industry as a TAF) for Pegasus Field. The TAF predicted scattered and broken layers of cloud between 4,000 feet and 12,000 feet, with conditions improving during the day. (See Appendix 1 for a timeline of events.)

3.1.6. At 0611 the crew held a video conference with the briefing officer who had prepared much of the weather information. The briefing officer worked in the United States Navy's Space and Naval Warfare Systems Command – Office of Polar Programs (SOPP) in Charleston, South Carolina. The briefing officer predicted that the conditions at Pegasus Field would continue to improve during the morning, confirming the aerodrome forecast.

---

[3] The flight schedule for the summer season was developed from initial negotiations between the National Science Foundation and Antarctica New Zealand, and was not determined solely by the RNZAF.
[4] The United States Antarctic Program is funded and managed by the National Science Foundation.
[5] Unless otherwise stated, all directions in this report, including runway alignment and surface winds, are referenced to grid north. See the glossary for an explanation of the "grid" system.
[6] A likely consequence of the ice shelf moving since the runway and instrument approaches had last been validated at the beginning of the previous summer season.

3.1.7. At about 0700 the crew received the first Pegasus Field weather observation for the day. The observation reported the presence of mist with some cloud on the ground and "few"[7] cloud at 3,000 feet. The surface and horizon definitions were both reported as fair. (See paragraph 3.3.5 for explanations of terms.) The crew telephoned the SOPP facility in Charleston and was advised that this was not unusual for the time of year and the mist and fog were expected to clear during the morning. This was confirmed in a new aerodrome forecast that was issued shortly afterwards. The crew decided to delay their departure by one hour to collect more information and to evaluate any trends.

Figure 1
Approach to Pegasus Field runway 33, 3 October 2013
(Courtesy of the RNZAF)

3.1.8. During the next two hours the crew received another aerodrome forecast and four observations, consisting of two routine weather reports (METARs) and two special weather reports (SPECIs).[8] The crew also contacted the crew of an RNZAF C130 Hercules that had remained overnight at McMurdo and was preparing to return to Christchurch. The combined information showed that the weather conditions were improving as forecast. At 0957 the aeroplane departed Christchurch with the flight number NMB 569.

3.1.9. The flight was planned to take four hours and 40 minutes, with an estimated time of arrival at Pegasus Field of 1437. Because the Boeing 757 aeroplane could not carry sufficient fuel to reach Pegasus Field and return without refuelling, the operating procedures used a point of safe return (PSR) methodology, meaning the calculation of the point that the aeroplane could reach and have sufficient fuel reserves to return to Christchurch. Once the aeroplane flew beyond that point, it was committed to a landing in Antarctica, where it could be refuelled for the return journey.

3.1.10. Two PSR scenarios were calculated. The first and most conservative was PSR 2-engine depressurised (PSR-2d), which was based on the assumption that the aeroplane became unpressurised for some reason, meaning it would have to return at a low level with a consequent greater fuel consumption. The second scenario was PSR-altitude (PSR-alt), which

[7] Cloud is reported in oktas or eighths and few is one to two eighths.
[8] The weather observers will submit a special observation if there is a significant change in one or more specified weather criteria.

meant a normal high-altitude return. PSR-2d was the primary (more conservative) scenario used. For the outward journey to Antarctica the aeroplane was estimated to reach PSR-2d at 1244.

3.1.11. As the aeroplane flew south the crew received regular weather reports. The crew contacted the SOPP facilities in Charleston and McMurdo by satellite telephone and discussed the inclusion of fog in the later reports. The crew was assured that the fog was in the distance and would not affect the airfield. The surface and horizon definitions improved from *fair to good.*

3.1.12. Before reaching PSR-2d the crew requested an updated forecast for Pegasus Field, which they received at 1216. The forecast conditions met the criteria to continue past PSR-2d. Nevertheless, the crew was concerned about the continued presence of fog in the reports and again called the SOPP facilities in Charleston and McMurdo. The crew was reassured that the weather forecasts predicted the fog to be "shallow" and moving to the west away from the field. The crew was told that they could expect visual meteorological conditions for the descent and landing.

3.1.13. At 1225 a SPECI report was issued by the SOPP for Pegasus Field, but this was never received by the crew and no record could be found of this being sent to the aeroplane or the crew requesting it. At 1244, after completing a crew briefing and confirming the decision to continue, the aeroplane passed PSR-2d.

3.1.14. At 1257 the crew received the Pegasus Field weather report issued at 1255. The report was similar to the SPECI report issued 30 minutes earlier, which had reported an increase in the cloud. The crew called the SOPP McMurdo facility, which advised that the fog had remained over five kilometres (km) away and the sky was clear over the airfield. The aeroplane passed PSR-alt about 20 minutes later at 1325.

3.1.15. At 1345 the crew received a SPECI that had been issued at 1332. The SPECI noted cloud on the ground with a broken base at 300 feet. The crew immediately called the SOPP McMurdo facility, which advised that fog had now formed over the airfield. The following two reports contained similar information, with the horizon definition lowering to *poor* in the direction of the fog.

3.1.16. The crew discussed their options and decided to fly the RNAV instrument approach to runway 33. That approach had a minimum descent altitude (MDA) of 360 feet.[9] However, because the first 1,000 feet of runway were not available for landing, the crew agreed to raise the MDA to 410 feet to try to provide a constant glidepath angle to touchdown. To ensure that the most experienced combination of pilots was used, the captain moved into the left seat to be the pilot flying, the co-pilot into the right seat and the second captain into the observer's seat behind the co-pilot. The fourth pilot, the captain under training, remained on the flight deck as long as possible before taking a seat by one of the cabin emergency exits.

3.1.17. The crew requested the approach lights to be turned up to their maximum setting for their approach. The aeroplane was initially in visual conditions before entering a low cloud bank at about 700 feet. At 410 feet the crew was unable to see any visual references so commenced the missed approach procedure, climbing to 5,000 feet and entering a holding pattern.

3.1.18. Approximately 10 minutes later a Canadian Twin Otter aeroplane also flew the runway 33 RNAV approach. The Twin Otter used the published MDA of 360 feet, but was unable to gain visual reference with the airfield. The Twin Otter was ski-equipped, so it was diverted to Williams Field 17 km away where it made a visual approach and landing.

3.1.19. The weather was forecast to improve, so the crew entered a holding pattern to conserve fuel and review options. After nearly two hours' holding, and with the weather continuing to

[9] MDA is referenced to mean sea level. The runway 33 threshold was 19 feet above mean sea level.

deteriorate, the crew of the aeroplane reviewed their options and agreed that a second approach to runway 33 provided the best chance of becoming visual. The crew also agreed that the MDA could be lowered to 100 feet. This would still provide a safety margin above the known obstacles around the runway. The flight crew briefed the remainder of the crew and passengers and positioned crew and others beside the various emergency exits. The aeroplane then commenced its second approach at 1620.

3.1.20. At 100 feet the crew was still unable to gain visual reference and commenced the missed approach procedure. As the aeroplane started to climb away, the second captain observed several markers and some lights about 15 m out to the right of the aeroplane. After the missed approach procedure was completed, the second captain reported his observation to the captain. The crew compared this information with photographs taken by the captain under training during the approach and landing four days earlier. The markers and lights were identified as being the runway centreline approach indicators, which confirmed to the crew that the approach track was about 15 m to the left of the runway centreline.

3.1.21. At 1645 the aeroplane was positioned about 15 km from the runway for a long straight-in approach commencing from 2,500 feet. At 1,000 feet, while still above the low cloud bank, the aeroplane was turned to the right to move the approach track to the right by about 15 m before returning to the original heading. At about 110 feet the co-pilot called “visual, continue”, meaning he had sufficient visual references with the runway for the landing to be made.

3.1.22. At this time the captain looked up from the instruments and said he was able to make out some ground markings and then the markers on both sides of the runway, confirming he was lined up with the centre of the runway (see Figures 2 and 3). He disconnected the autopilot and shortly after flared the aeroplane for a normal landing.

3.1.23. The aeroplane was brought to a halt with about 4,000 feet remaining. A “Follow Me” vehicle met the aeroplane as it was taxied back to the apron, guiding it to a parking spot. The fuel remaining on board after shutting down the engines was calculated to be about 3,000 kilograms, sufficient for one further approach if required. The fog started to clear about one and a half hours after the aeroplane had landed (see Figures 4 and 5).

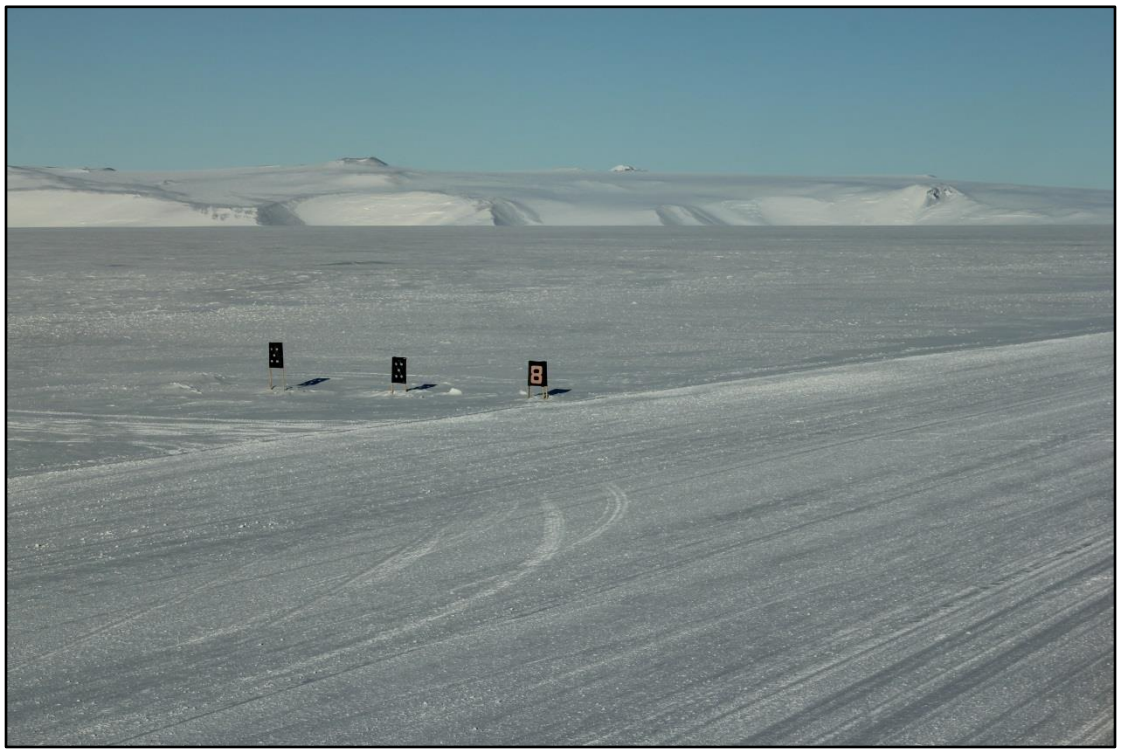


Figure 2
Runway markings, 3 October 2013
(Courtesy of the RNZAF)

Figure 3
Runway markings, 7 October 2013
(Courtesy of the RNZAF)

Figure 4
Visibility an hour after landing
(Courtesy of the RNZAF)

Figure 5
Visibility one hour and 45 minutes after landing
(Courtesy of the RNZAF)

3.2. Personnel information

3.2.1. The captain was 40 years old. He had flown the Boeing 757 for several years before he left the RNZAF in August 2007 to fly another version of the Boeing 757 for a civil airline. He had rejoined the air force in October 2010 as a captain on the Boeing. At the time of the incident he had accrued a total of 5,430 flying hours, including 852 hours on the Boeing 757-2K2 aeroplane.

3.2.2. On 7 October 2013 he held the position of 40 Squadron Boeing Flight Commander and had previously been the Boeing Training Officer. As the Flight Commander he was responsible for co-ordinating Boeing operations and overseeing the training of crew.

3.2.3. The captain had attained his air force A-category instructor rating in May 2013 and at the same time completed his annual proficiency checks on the Boeing 757. His last annual medical examination had been on 12 August 2013. He held both New Zealand and Australian airline transport pilot licences and had flown from Christchurch to Antarctica on six previous occasions.

3.2.4. The co-pilot was 27 years old. He had joined the RNZAF in January 2007. At the time of the incident he had accrued a total 1,740 flying hours, including 1,165 hours on the Boeing 757-2K2 aeroplane. The co-pilot's last annual medical examination had been on 1 February 2013. His last annual proficiency checks had been completed on 15 May 2013.

3.2.5. The co-pilot had previously flown on nine flights to Pegasus Field in the Boeing 757. He recalled two occasions where the aeroplane had returned to Christchurch before passing the PSR because of deteriorating weather conditions at Pegasus Field.

3.2.6. The captain under training was 34 years old. He had joined the RNZAF in April 1999. He had accrued a total of 2,175 flying hours, including 580 hours on the Boeing 757-2K2 aeroplane. He was qualified as a captain on the Boeing 757 and held an air force B-category flying instructor rating, but was not yet qualified to instruct on the Boeing 757. His last annual medical examination had been on 29 January 2013. His last simulator check had been on 7 June 2013 and line and instrument checks on 1 August 2013.

3.2.7. The captain under training had observed one flight to Pegasus Field only – the flight flown four days previously.

3.2.8. The second captain was 33 years old. He had joined the RNZAF in January 1999. He had qualified as a line captain on the Boeing 757 in February 2013. He had accrued a total of 2,690 flying hours, including 1,370 hours on the Boeing 757-2K2 aeroplane. His last simulator and annual checks had been completed on 13 and 26 February 2013 as part of his upgrade training. His last annual medical examination had been on 21 August 2013.

3.2.9. The second captain had flown to Antarctica on 10 occasions before the incident flight, on Hercules and Boeing 757 aeroplanes. He recalled one turn-back to Christchurch on 11 February 2011 because of deteriorating weather conditions at Pegasus Field.

3.2.10. The majority of the crew had deployed to Christchurch on Tuesday 1 October 2013. The Wednesday had been spent preparing for the first three flights to Pegasus Field, including attending briefings and liaising with other operators either flying or preparing to commence flying to Antarctica. On Thursday 3 October 2013, the crew had flown the first of the flights to Pegasus Field and return. Friday 4 October had been a crew rest day.

3.2.11. The next two days had consisted of attending the first "Go/No go" meetings held at 0450 each morning, where it was agreed that the weather conditions were unsuitable to depart. The crew had spent the remainder of the days on administration work, studying or unassigned. At about 2000 each evening the crew had prepared for the possibility of a flight the next day by organising weather information and flight plans, before retiring at about 2100.

3.2.12. The second captain had joined the crew on the afternoon of Sunday 6 October 2013, the day before the incident flight. He had had a rest day on the Saturday after five days' work, including three days flying between New Zealand and Australia.

3.2.13. The pilots each reported that they were well rested and prepared for the flight on 7 October 2013.

3.3. Meteorological information

3.3.1. In accordance with the requirements of the International Civil Aviation Organization (ICAO), the CAA was responsible for the provision of meteorological information within the New Zealand and Auckland Oceanic flight information regions, including the airspace between New Zealand and Antarctica (AIP, 2011). The Meteorological Service of New Zealand, as a certificated organisation, was approved by the CAA to provide this service. However, because of logistical restrictions, routine aerodrome weather information, including forecasts, observations and special weather reports, was provided by the SOPP.

3.3.2. Antarctic weather data was collected from a range of sources, including weather satellites and automatic weather stations and observers in Antarctica. Weather observers were stationed at the American-operated airfields on the continent. The observers were required to have a minimum of two years' experience as qualified weather observers and pass local certification standards before being able to issue observations in Antarctica. Two weather forecasters were assigned to the SOPP McMurdo facility. A forecaster needed to have a minimum of 10 years' forecasting experience, including at least three years at an aviation weather facility, and to have completed local certification standards before qualifying to issue forecasts for Antarctic locations.

3.3.3. Most observers and forecasters arrived in Antarctica at the start of the summer season, before the main flying activity commenced and before a 24-hour service was required. In the interim, staffing was based around scheduled flights to ensure that appropriate services and information were available to pilots. The services consisted of pre-flight briefing packages, flight briefings, hourly METARs, SPECIs as required and six-hourly TAFs, with amendments issued as required. Weather information was fed into the collective international weather database that provided weather information globally.

3.3.4. The crew of the aeroplane was issued with the weather information described above. At the request of the crew, the frequency of the observations was increased from one every hour to one every 30 minutes. Three air traffic control staff and one certified weather observer were in the Pegasus Field tower to support the aeroplane for the duration of its flight.

3.3.5. Because of the unique characteristics associated with Antarctic weather, horizon and surface definitions are used to help describe the conditions. The definitions are as follows:

Table 1: United States Antarctic Program Inter-agency Air Operations Manual, dated 1 August 2012

Qualitative term	Surface definition	Horizon definition
Good	Snow surface features such as sastrugi[10], drifts and gullies are easily identified by shadow. The sun is usually unobscured. Surface features are clearly defined for as far as the eye can see.	The horizon is sharply defined by shadow or contrast. The horizon is distinct with an obvious difference between land (snow) and sky.
Fair	Snow features can be identified by contrast. No definite shadows exist. The sun is usually totally obscured. Surface features become indistinct at distances of more than a few kilometres.	The horizon may be identified, although the contrast between sky and snow is not sharply defined.
Poor	Snow surface features (e.g. skidoo[11] tracks) cannot readily be identified except from close up (within 50 m). The sun is usually totally obscured.	The horizon is barely discernible; in other words, the sky can be discriminated from land but no distinct horizon is visible.
Nil	Snow features cannot be identified. No shadows or contrast exist. Dark-coloured objects appear to float in the sky. The sun is totally obscured, although the overcast sky may exhibit considerable glare. The glare appears equally bright from surface reflection and from all directions.	Total loss of horizon: the snow surface merges with the whiteness of the sky.

3.3.6. Satellite imagery and weather maps show that on the morning of the incident there was a weak upper-level low or depression over the Terra Nova Bay area, with a trough extending on to the Ross Ice Shelf. The National Science Foundation was asked to provide comment on the weather situation during the day. Its response included comment from an observer based at Pegasus Field and a forecaster.

3.3.7. The forecaster said that they expected an upper-level ridge to move in during the day, pushing a low-pressure system away. A small high-pressure system near Ross Island and associated with the ridge was expected to have a drying effect over the area. The National Science Foundation commented that the presence of morning fog or low stratus cloud and the fluctuations with a slight improvement as the aeroplane approached the PSR, going from (cloud) *few* to *scattered* and back to *few*, supported the belief that the situation was improving overall. The forecaster commented that they had "seen this sort of scenario numerous times" and that "the stratus [cloud] coming down through McMurdo Sound hugging the true west coast of Ross Island would be a short-lived occurrence, of three or four hours' timeframe".

3.3.8. The observer said that the low cloud in the distance "made its way to the airfield and at [1225] it became SCT003 [scattered at 300 feet]". The cloud cover continued to increase and as recorded in the 1332 SPECI it became a cloud layer broken at 300 feet. The weather then deteriorated quickly and by the time the 1515 SPECI was issued the visibility from the tower had reduced to 400 m in fog.

[10] Sharp, irregular ridges or grooves formed on a snow surface, generally by wind erosion.
[11] Snowmobile.

3.3.9. The TAFs, METARs and SPECIs relating to the flight of the aeroplane are contained in Appendices 2 and 3.

3.4. Airspace and local area information

3.4.1. Airways was the CAA-certificated organisation responsible for the provision of air traffic services in the Auckland Oceanic flight information region[12], including the area of airspace between New Zealand and Antarctica. Airways entered into an arrangement with the United States Navy[13] on how to manage that portion of airspace below 60° south, known as the McMurdo Sector. The sector was to be activated in anticipation of a flight using a mechanism called a NOTAM (notice to airmen). The sector then became the responsibility of the United States Navy.

3.4.2. At the start of each summer season the McMurdo Sector was activated on a flight-by-flight basis. Once the aircraft had either landed in McMurdo or vacated the sector enroute to Christchurch, the sector was deactivated. During the peak of the season the sector remained continuously active. On 7 October 2014 the sector was activated by NOTAM at 0600 in anticipation of the flights by the aeroplane and the Hercules aeroplane that was scheduled to depart Pegasus Field that morning.

3.4.3. A review of the management of the McMurdo Sector showed that the Letter of Agreement current at the time of the incident, and effective from 20 December 2012, was between Airways and the Joint Task Force[14] only. This replaced an agreement dated 20 December 2005. No copy of the 2005 agreement could be found. However, a letter of agreement dated 31 October 2002 showed that the CAA was party to the agreement made between Airways and the then Commander of Support Forces Antarctica for the creation and management of the McMurdo Sector.

Airfield information

3.4.4. Pegasus Field was located on the Ross Ice Shelf about seven nautical miles grid north of McMurdo Station (see Figure 6). The airfield consisted of one major runway orientated 33/15, with a nearby second skiway for ski-equipped aeroplanes.[15] The runway was constructed on permanent ice for use by wheeled aeroplanes and was normally 10,000 feet long and 150 feet wide (approximately 3,050 m x 45 m).[16] On 7 October 2013 a NOTAM advised that an inset threshold for runway 33 reduced the available length to 9,000 feet (2,745 m).

[12] Roughly the area of airspace between 163° east and 131° west, from 5° south to 90° south.
[13] A letter of agreement between Airways and the United States Navy (Joint Force Task Force – Support Forces Antarctica), dated 20 December 2012.
[14] Joint Task Force – Support Forces Antarctica, the United States Navy led element supporting the National Science Foundation's Antarctic Research Program.
[15] Because Williams Field was operational, this skiway was closed.
[16] A 25-foot (8 m) stressed shoulder on both sides was available for aircraft operations if needed.

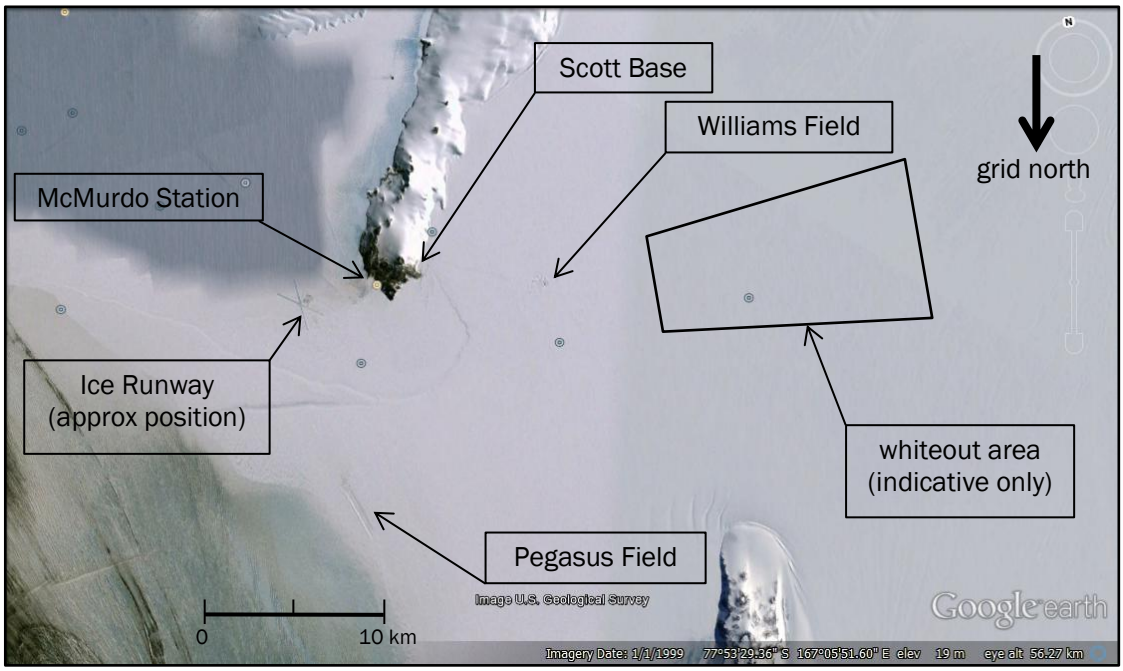


Figure 6
Local area
(Courtesy of Google Earth)

3.4.5. Instrument approaches, including a tactical air navigation system (TACAN) and RNAV (GPS), were published for both runways. The Boeing 757 was equipped for the RNAV (GPS) approaches only. The instrument approaches were subject to annual calibration checks, with the next check due by 29 October 2013.

3.4.6. Runway 33 was equipped with approach lights (including sequenced centreline strobe lights), runway-end identification lights and a precision approach path indicator. All of the lighting systems were operating at the time of the occurrence and were set to the highest intensity available as the aeroplane made each approach. There was no approach lighting system for runway 15. Marker boards were located every 500 feet on each side of the runway, with "distance-to-go" indicators every 1,000 feet.

3.4.7. The Pegasus Field rescue fire service was equipped to ICAO category 8 to cater for C17 Globemaster aeroplane operations.[17] The Boeing 757 required category 7 support only. At the time the aeroplane was making its final approach, the emergency services at Pegasus Field had been placed on alert and the aerodrome emergency plan had been activated. The plan included placing support services at McMurdo Station and Scott Base on standby.

Local area information

3.4.8. Three other aerodromes or landing areas were located about McMurdo Sound. They included Williams Field, the Ice Runway and the emergency whiteout landing area. Williams Field was located nine nautical miles west of Pegasus Field, but was only suitable for ski-equipped aeroplanes. The Ice Runway was located near McMurdo. It was a temporary runway made on the annual sea ice and was normally capable of handling wheeled aeroplanes. However, on 7 October 2013 the Ice Runway had yet to be opened for operations and lacked any emergency services or approach aids. The whiteout area was a designated area west of Williams Field suitable for ski-equipped aeroplanes only.

[17] ICAO Annex 14 Aerodromes, Volume 1 Aerodrome Design and Operations, 9.2 Rescue and Firefighting.

3.4.9. A fourth runway at the Italian station at Terra Nova Bay, 190 nautical miles grid south of McMurdo, was designed to handle aircraft no larger than the Hercules. [18] On 7 October 2013 it had yet to be opened for the summer season and the level of emergency services was unknown.

3.4.10. Other than the airfields listed above, the nearest airfields that could possibly be used by the Boeing 757 are the blue ice runways[19] about 2,100 km away at Wilkins, near the Australian Casey Station, and Union Glacier operated by Chile in the Ellsworth Mountains.[20]

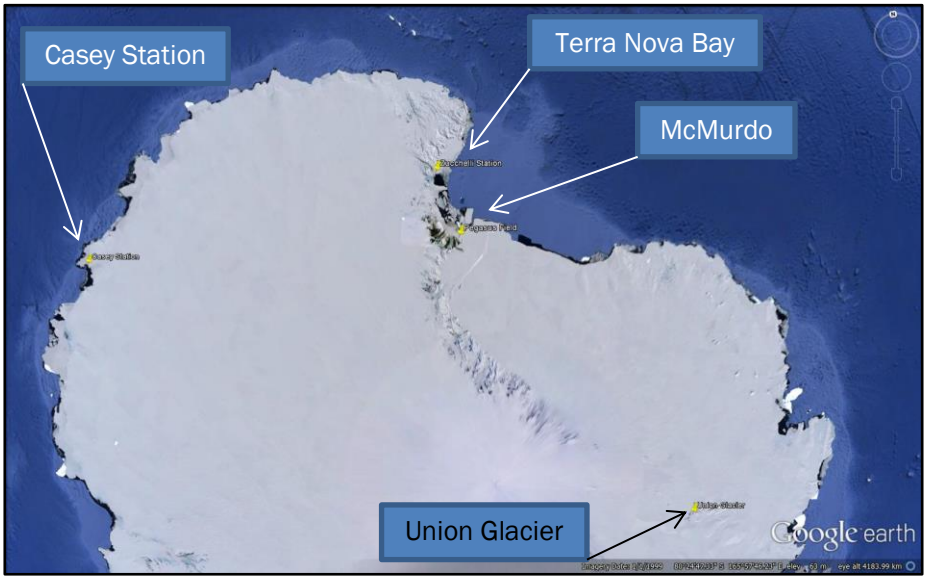


Figure 7
Antarctica – general
(Courtesy of Google Earth)

3.5. Operator and aeroplane information

3.5.1. The Boeing 757 and Hercules aeroplanes were both operated by 40 Squadron, out of the RNZAF base in Auckland. The RNZAF had commenced regular flights from Christchurch to McMurdo as part of the joint logistics pool in 1965, using Hercules aeroplanes. The Boeing had become part of the joint pool in 2010. Between 1965 and 7 October 2013, the RNZAF had completed 650 return flights to Antarctica, including 14 flights using the Boeing 757. Following this incident the Boeing 757 completed a further three uneventful flights before the close of the 2013/2014 summer season.

3.5.2. The RNZAF advised that before the commencement of each season's flights, crews completed pre-deployment training.[21] This included survival training, aeroplane simulator training and the practice of self-contained approaches.[22] A lecture programme included discussions on Antarctic procedures, weather, navigation and flight planning. There was also a review of the previous season's operations, including any lessons learnt. New crew members were put through a training and familiarisation programme before being approved to operate to the Antarctic unrestricted. Before the commencement of each flight, an authorisation process was followed to ensure that risks associated with the flight were identified and addressed before approval was given. This complimented an annual risk management plan covering New Zealand Defence Force operations in Antarctica for each season.

[18] Now called Mario Zucchelli Station and operated by the Italian National Antarctic Programme.
[19] A blue ice runway is constructed in an area where there is no net annual snow accumulation, so the resultant ice surface is capable of supporting aeroplanes using wheels instead of skis.
[20] See paragraph 4.4.1 for a discussion on the potential use of these runways.
[21] This formed part of a crew member's "approved 'Add To Category' qualification", required before being allowed to operate to Antarctica.
[22] No ground-based navigation resources were used.

The Boeing 757-2K2 and Antarctic operations

3.5.3. The RNZAF operated two Boeing 757 aeroplanes, and both entered service in 2003. In October 2004 a three-person team was directed to investigate the feasibility of conducting flights to Antarctica using the Boeing 757 aircraft. The team recommended against the use of the aeroplanes, primarily because of the incompatibility of the navigation equipment then fitted to the aeroplanes.

3.5.4. In July 2006 a Cabinet Business Committee accepted the advice that Antarctic operations with the Boeing 757 were neither safe nor practicable. However, in December 2006 the Cabinet Policy Committee agreed on the importance of New Zealand retaining a strategic air supply capability for continued Antarctic operations. The committee identified this as a core defence output and concluded that the Boeing 757 as a passenger aeroplane could complement the United States' C17 Globemaster transport aeroplane, with the Hercules continuing to support both passenger and cargo requirements as required.

3.5.5. The navigation equipment fitted to the aeroplanes was upgraded and in 2008 a second feasibility study was initiated. The study identified that a major risk continued to be weather deteriorating after the aeroplane had passed the PSR. The PSR for the Boeing 757 was notionally three hours into the four-and-a-half-hour flight from Christchurch to McMurdo. This compared with a PSR of five hours for the seven-and-a-half-hour flight for the Hercules. After a consideration of the flight time, the quality of available weather information and the PSR weather criteria, the PSR criteria were amended by raising the minimum cloud base from 2,000 feet to 5,000 feet. The minimum visibility requirement remained at 8,000 m. The residual risk of weather deteriorating from the amended PSR criteria to below the instrument approach minima in the final 90 minutes of the flight was assessed as "unlikely" and a flight trial was approved.

3.5.6. Trial Boeing 757 flights were flown on 16 December 2009 and 11 February 2010. Pilots who had experience flying the Hercules to Antarctic were used, and a United States Air Force reservist pilot with Boeing 757 and C17 Globemaster Antarctic experience provided specialist advice. An Air New Zealand standards pilot also provided input.

3.5.7. After reviewing the trial the RNZAF considered that the 5,000-foot PSR cloud base minima was restrictive, especially when compared with that used for other aircraft and operators. The RNZAF Hercules continued to use a 2,000-foot cloud base and 8,000 m visibility, while the United States C17 Globemaster had a cloud base limit of 1,500 feet and 4,800 m visibility. The 5,000-foot cloud base was amended to 2,000 feet. On 29 November 2010 the Chief of Air Force approved the Boeing 757 for routine passenger flights to Antarctica with the issue of a supplemental type certificate.

3.5.8. Discussions with Antarctica New Zealand, the National Science Foundation and pilots confirmed that it was not unusual for flights departing from Christchurch to be delayed because of current or forecast adverse conditions at McMurdo. The delays could be up to a week or more. Less common, but still not unusual, were aeroplanes turning back to Christchurch at or before reaching the PSR. Precise numbers were not available, but it was considered to be fewer than five flights out of about 110 each summer season involving aeroplanes from New Zealand, the United States and other operators contracted to provide logistics support.[23]

3.5.9. A review of the history of RNZAF flights to Antarctica initially identified only one previous occasion when the weather had deteriorated below the instrument approach minima after the aeroplane had passed the PSR. On 10 November 1993, an RNZAF Hercules was following about one hour behind an Italian Air Force Hercules enroute to the Ice Runway at McMurdo. After both aeroplanes had gone past the PSR, the weather at McMurdo deteriorated to near-whiteout conditions. Unbeknown to the New Zealand crew, the Italians had recently constructed an airstrip at the Italian station at Terra Nova Bay that could handle the

[23] In the 2013/2014 summer there were six recorded turn-backs out of 109 programmed flights.

Hercules.[24] The station was approximately 190 nautical miles from McMurdo and close to the direct Christchurch-to-McMurdo track. The poor weather conditions were expected to last for several hours, so the RNZAF crew followed the Italian aeroplane and diverted to Terra Nova Bay, where a safe landing was made.

3.5.10. An investigation by the RNZAF into that incident identified the standard of weather forecasting as a contributing factor to the Hercules having to divert to Terra Nova Bay. A United States Navy ski-equipped Hercules, scheduled to land at Williams Field at about the same time as the RNZAF Hercules was to land on the Ice Runway, was unable to do so. After five failed attempts the aeroplane diverted to the whiteout area and made a safe landing. A United States Air Force C141 Starlifter that was scheduled to depart Christchurch an hour after the RNZAF Hercules was stopped from departing because of concerns about the deteriorating weather conditions. The Starlifter would have landed about an hour before the RNZAF Hercules.

3.5.11. On 17 November 2014 the RNZAF informed the Commission of a second incident in which the weather conditions had deteriorated significantly after an aircraft passed the PSR. That incident was on 24 January 2002, when the crew of a Hercules made the decision to continue past the PSR based on "a favourable forecast and conditions, despite distant (10 kilometres) fog". Forecasters were also involved in the discussion on the weather conditions. "In the space of one hour the weather deteriorated from an 8,000-foot cloud base to an indeterminate ceiling, visibility reduced from 10 kilometres to 400 metres, while surface and horizon definitions reduced from Fair/Fair to Nil/Nil." Two United States ski-equipped Hercules were diverted from Williams Field to Pegasus Field, and the three aeroplanes were eventually able to land. One aeroplane landed off its first instrument approach. The New Zealand Hercules landed off its second approach and the third aeroplane made three attempts before landing.

3.5.12. Number 40 Squadron's standard operating procedures and Ice Flip booklet contained planning and operating information for flights to Antarctica, including departure and PSR criteria for the Boeing 757. The procedures noted that "while individual factors meet the requirements, in combination they may present an undesirable situation. Crew input and experience are necessary for the Captain to make an informed decision".

3.5.13. The departure criteria included a combination of airfield and communication requirements, as well as minimum forecast weather conditions. These are summarised as follows:

1. full runway length and width to be available[25]
2. a runway condition reading[26] of nine or greater and maximum groomed snow depth of one inch (25 millimetres)
3. the forecast weather for the period one hour before the estimated time of arrival to three hours afterwards was to be a cloud base of 2,000 feet or higher and visibility greater than 8,000 m, and the minimum horizon and surface definitions to be a combination of fair and poor
4. the forecast weather for the time of departure and the period three hours afterwards was to be a cloud base at least 1,000 feet above the MDA, a visibility of at least 8,000 m and the combination of definitions to be a minimum of fair and poor
5. the crosswind to be within limits
6. runway approach and glidepath lighting to be available
7. suitable communications to be available throughout the flight.[27]

[24] At the time runway data had not been finalised and passed to other Antarctic Treaty nations.
[25] 9,000 feet was considered sufficient provided all other criteria were met.
[26] A measure of the tyre-to-runway friction coefficient. Dry (good) – 23, wet (medium) – 12, icy (poor) – 5.
[27] Including a possible combination of high-frequency radio and satellite communications.

3.5.14. The PSR criteria required the crew to consider an updated arrival forecast for the period one hour before to three hours after the estimated time of arrival at Pegasus Field. In assessing the weather conditions consideration was also to be given to the three most recent observations. The three observations should show a trend towards the PSR forecast and current aerodrome forecast.

3.5.15. The following criteria were to be met before the aeroplane could pass the PSR:

1. cloud base. Minimum of broken cloud at 2,000 feet above ground level or 1,500 feet above MDA, whichever is the higher[28]
2. visibility. A minimum of 8,000 m (five statute miles) was required and runway approach and glidepath lighting was to be available
3. wind. Maximum crosswind (including gusts) was not to exceed 20 knots[29]
4. surface and horizon definitions. No worse than one element fair, one element poor.

   Note: Restricted visibility in the PSR forecast implied definitions less than fair/fair.

3.5.16. Meteorologists regarded wind direction as a good indicator of weather trends. The 40 Squadron operating procedures provided interpretations of the likely trends with various wind directions. These included:

grid south:	Depending on the sea-ice state, in the summer wind from this direction means moist air off the sea, which can cause cloud to wrap around Ross Island, occasionally spreading over the airfields in the form of fog or low cloud
grid north:	Lows moving in with strengthening wind, blowing snow and deteriorating ceiling
grid west:	Katabatic wind coming off [Ross Island] glaciers helping to clear any low cloud
grid east:	Rare, with a similar effect as for the grid west wind.

[28] The MDA for the runway 33 GPS approach was 360 feet. Therefore a cloud base of broken at 2,000 feet was the requirement for the flight.
[29] Subject to the runway condition reading current at the time.

4. Analysis

4.1. Introduction

4.1.1. The RNZAF has provided regular transport flights to Antarctica since 1965, as part of the aviation element in the joint United States – New Zealand logistics pool. The Boeing 757 was included in the pool in 2010 after the successful completion of two trial flights. For the first three years the Boeing 757 was used primarily to return personnel from Antarctica at the end of each season. The incident flight was the second of six pre-planned flights from Christchurch to Pegasus Field for the season and the first time that the Boeing 757 had been used at the start of the season.

4.1.2. The weather in Antarctica is known for its severity and potential to change rapidly. Weather systems move around the continent at pace and, partly because of its isolation and lack of weather data, forecasting can be challenging. Storms can form and dissipate with little or no warning. The use of remotely located automatic weather stations, satellite imagery and computer modelling based on historical information has resulted in a steady improvement in the availability and accuracy of weather information. Nevertheless, properly trained and experienced staff are still required to validate the data and provide real-time information to pilots.

4.1.3. On 7 October 2013 the forecast sent to the crew of the aeroplane before they reached the PSR was derived from a range of data sources and followed careful analysis by experienced forecasters. However, the expected clearance of the low cloud did not occur. Instead, soon after passing the PSR the low-level cloud and fog that had been some distance from the airfield began to spread, quickly engulfing the airfield.

4.1.4. The following analysis discusses the circumstances around the crew's decision to continue past the PSR, and what occurred for the crew to be left with no option other than to land at Pegasus Field in near-whiteout conditions. In particular the analysis covers the following areas:

1. preparation for the flight
2. the decision to continue past the PSR
3. the decision to descend below the MDA and land at Pegasus Field.

4.1.5. The analysis also discusses the risk of using the Boeing 757 for Antarctic operations, and in particular how changes in circumstances could affect the validity of the risk assessment made in support of the original decision to use the Boeing 757 for Antarctic operations.

4.1.6. A further issue that did not contribute to the incident, but is discussed, concerns the management of airspace within the McMurdo Sector, below 60° south.

4.2. Preparation for the flight

4.2.1. The crew of the aeroplane undertook the normal pre-deployment training, which included learning about Antarctic weather and flight planning considerations. A weather forecaster with more than five years of Antarctic forecasting experience also participated in the training. The RNZAF had reviewed past Antarctic operations and applied the lessons learned to its operations plan. The captain had practised the whiteout landing technique in a simulator. The crew had therefore been prepared as far as possible for the forthcoming flights and were well aware of the risks associated with the operation. Collectively, the flight crew was well trained and experienced for Antarctic flights.

4.2.2. The three flights planned for the early part of the season were primarily to carry personnel. The first flight on 3 October 2013 went as planned. The good weather conditions at Pegasus Field allowed the crew to re-familiarise themselves with the airfield layout. The observing pilot took the opportunity to take photographs during the approach, which proved useful when planning for the final approach in near-whiteout conditions.

4.2.3. The crew also took the opportunity to assess the accuracy of the aeroplane's navigation equipment and instrument approach data. This suggested to the crew that the final approach track was some 15 m to the left of the centreline of the runway. This information also proved useful when faced with landing in near-whiteout conditions.

4.2.4. With a normal runway width of 200 feet, the 15 m or 45-foot offset was an issue that increased the risk of operations into the aerodrome. The instrument approaches, while still current, were scheduled for revalidation within the following three weeks. This issue is discussed later in the analysis when considering the changes in operational plans potentially affecting the initial risk assessment.

4.2.5. The flight was delayed for two days because of adverse weather conditions at McMurdo. The decisions on those occasions not to launch and continue as far as the PSR were joint decisions by the authorising officer and the captain. Weather delays were not uncommon and were accepted as part of normal Antarctic operations.

4.2.6. The passenger list for the flight south included a group of very important persons (VIPs). There was no evidence to suggest that the decision-making by the crew was influenced by the presence of this group or the two-day delay because of the weather conditions at McMurdo. The crew was experienced in dealing with VIPs and were trained to prioritise the safety of the aeroplane.

4.2.7. The conditions on 7 October 2013 met the launch criteria and were considered by the crew and authorising officer to be very similar to those for the first flight four days previously. The weather systems had moved through and the forecast and briefing by the SOPP forecaster were for improving conditions. Nevertheless, the crew delayed the departure to obtain further information. Only after receiving an updated forecast and additional observations, having a second briefing with the SOPP staff and getting confirmation from the crew of the Hercules departing Pegasus Field that the weather was improving, did the crew and authorising officer agree that it was suitable to depart Christchurch.

4.2.8. The decision to depart Christchurch was well considered and appropriate based on the information that the RNZAF had received prior to the flight being authorised.

Findings

1. The crew was well prepared and sufficiently experienced for the flight.
2. The decision for the aeroplane to depart Christchurch was well considered and appropriate based on the information that the RNZAF had received prior to the flight being authorised.

4.3. The decision to continue past the point of safe return (PSR)

4.3.1. The crew obtained regular weather updates, including observations and forecasts, as the flight progressed south. The crew also requested 30-minute observations rather than the normal hourly reports. The early reports of fog in the distance caused the crew some initial concern, so they contacted the SOPP staff at McMurdo and in Charleston to question this. The crew was told that the conditions were not unusual and the fog would remain clear of the airfield. After receiving the forecast prior to reaching the PSR, the crew again contacted both the SOPP facilities and was again told that the conditions would improve.

4.3.2. The forecast prior to PSR was for conditions better than the squadron's criteria for continuing to Pegasus Field. The forecast predicted scattered cloud at 300 feet, 3,000 feet and 8,000 feet. The minimum allowable was broken cloud at 2,000 feet. The forecast was for unrestricted visibility with the wind well below the 20-knot limit. The forecast wind direction was from the grid west, off the Ross Island glaciers. According to the meteorologists' guiding

information, the likely trend with the wind blowing from that direction should have been for any low cloud to dissipate.

4.3.3. The two observations leading up to the PSR forecast reported the surface wind swinging from the north-west around to the south. However, the wind continued to change direction, moving to the east before becoming calm. With the wind strength being so light, it may not have had the anticipated clearing effect, and the fog was able to form quickly over the airfield.

4.3.4. The observations prior to the issuing of the PSR forecast varied but were all above the minimum criteria to continue and, with the exception of the reported fog in the distance, trended towards an improvement in the conditions. The crew called both the SOPP facilities and asked about the fog. Again they were reassured that it was not a factor and they could expect good conditions on arrival. The airfield surface and horizon definitions continued to be better than the PSR criteria at good and good respectively.

4.3.5. The criteria to continue past PSR-2d included a minimum cloud base only; that is, broken or overcast cloud. There was no allowance in the criteria for few or scattered cloud or fog below this level. This issue is discussed later in the analysis when considering the changes in operational plans potentially affecting the initial risk assessment

4.3.6. No reason could be found for the special weather report issued at 1225, part of the normal 30-minute cycle of reports, not being forwarded to the crew of the aeroplane. The crew had requested a special forecast (PSR forecast) because they were about to make a decision on whether to continue past the PSR. This PSR forecast was received some nine minutes before the 1225 special report was issued. A quick review of the crew's weather log should have detected the missing report. The crew may therefore not have realised that the 1225 report had not arrived, or been unconcerned about not receiving it. If they were concerned they could have specifically requested the report.

4.3.7. The absence of the 1225 report would have been unlikely to alter the actions of the crew because it contained information similar to that in the following weather report issued at 1255. The 1255 report was received by the crew some 13 minutes after passing the first PSR (PSR-2d). When the crew received it, they were reassured by the SOPP McMurdo facility that the fog remained in the distance and made the decision to continue. At that time the aeroplane still had about 25 minutes to run to the second PSR (PSR-alt). The crew therefore still had the option of returning to Christchurch or diverting to Dunedin – albeit that a safe return would have to have been at normal cruise altitude.

4.3.8. The special report issued at 1332 was not received by the crew until 1345. This was the first report that indicated to the crew that conditions had deteriorated. Again, no explanation was given for the unusually long time taken in forwarding the report to the aeroplane. Having already passed PSR-alt at about 1325, the crew was now committed to landing in Antarctica. Nevertheless, it is unusual that special weather observations and forecasts were either not sent or, as in this case, took a significantly longer period of time than usual to be delivered. The various agencies directly involved were aware that the aeroplane was near to the critical decision point, and that the weather conditions were essential to the crew making that decision. See safety actions at section 7.

Findings

3. Based on the available weather information and the reassurances by the United States Navy's Office of Polar Programs' forecasters in Charleston and McMurdo, the crew was justified in continuing past the point of safe return.

4. The absence of the 1225 special weather report and the delay in sending the 1332 special weather report, while unlikely to have altered the outcome, need to be examined further to ensure that safety-critical information is passed to crews in a timely manner.

4.4. Descent below minimum descent altitude (MDA)

4.4.1. The crew, having passed the PSR, was left with no option other than to land in Antarctica, regardless of the weather. A diversion to either Wilkins or Union Glacier might have theoretically been possible, but it was not viable, safe or practicable for the following reasons:

1. the crew did not have any weather information for either of the airfields
2. they did not have information on the winds for the routes to either destination
3. they were not familiar with either location
4. they did not have any information on the runways or whether instrument approaches were available. Because of the long distances involved, any decision to divert would have needed to be made early and would have precluded the option of holding in the McMurdo Sound area, possibly for two or three hours, waiting for the weather to improve.

4.4.2. The crew raised the MDA for the first approach by 50 feet to 410 feet to allow for the displaced threshold and in an attempt to provide a constant descent path through to touchdown. Leaving the MDA at the standard 360 feet would have increased the possibility of sighting the runway on the first landing attempt. The final portion of the approach path could then have been adapted to ensure the landing was at least 1,000 feet along the runway. However, at 360 feet it was unlikely that the crew would have sighted the runway anyway. The Twin Otter that attempted to land after the Boeing 757 aeroplane was using the 360-foot MDA and still had to overshoot. And when the aeroplane descended to 100 feet on its second attempt to land, the crew still could not see anything until after the missed approach procedure was commenced.

4.4.3. The crew considered each of the other landing sites around McMurdo Sound, and agreed that Pegasus Field was the most suitable. The MDA for the runway 15 RNAV instrument approach was lower than that for runway 33 and the outer runway approach area was clear of obstructions. However, the entire runway, including the intermediate approach area, was also obscured by the fog and there were no approach or runway-end identification lights to lead the crew on to the runway. Further, the crew was not familiar with this runway and the approach would have been towards the airfield buildings and fuel storage area. Runway 33 was therefore considered the safest and best option.

4.4.4. An MDA for an instrument approach is set to provide a safety margin above known obstacles during an instrument approach. Normally a pilot can descend below a MDA only when they have the required visual references to help ensure a safe landing. In this case the crew had no option other than to descend below the minima. They were not expecting the weather to clear until after the aeroplane had exhausted its fuel and there was no other safe alternative aerodrome where they could land.

4.4.5. All that the crew could do was to mitigate the risks. In some respects the RNZAF had begun that process before the flight departed Christchurch. The captain being able to practise landing in near-whiteout conditions in a simulator would have been one such measure. The

crew used their experience and familiarity with the approach and airfield to good effect. They knew the locations and heights of the obstacles and were confident in the accuracy of the aeroplane's navigation equipment. The second approach confirmed the accuracy of the instrument approach compared with the approach of four days earlier and gave them confidence that they could continue the descent and have a good chance of making a near-whiteout landing on the runway.

4.4.6. They also took measures to reduce the consequences of an unsuccessful landing by briefing the emergency services and preparing the aeroplane cabin for such an eventuality. The decision was the best one that any captain could have made faced with similar circumstances.

4.4.7. The captain used the resources available to him to help ensure he had as much information as possible on which to make his decisions. This incident provides a good example of a crew performing in a cohesive manner. The successful landing was the result of an experienced crew performing well as a team and is a good example of crew resource management.

Findings

5. The RNAV approach to runway 33 at Pegasus Field was the best option for a successful landing.

6. The decision to fly to a lower minimum descent altitude was the only reasonable option available to the crew in order to make a successful landing.

7. The incident was a good demonstration of effective crew resource management that enabled a safe landing to be made in demanding circumstances.

4.5. The risk of using the Boeing 757 for Antarctic operations

4.5.1. The fundamental safety issue arising from this incident was not the decisions by the crew to pass the PSR and descend the aeroplane below the MDA in order to make a successful landing. The issue and question is why the aeroplane ended up in that position when the crew had followed standard operating procedures.

4.5.2. The use of the Boeing 757-2K2 for Antarctic flights was subject to an extensive evaluation process before a supplementary type certificate was issued giving approval for Antarctic operations. As part of that process a risk assessment was conducted. The deterioration of the weather after the aeroplane had gone past the PSR was listed as a "possible" risk. In applying the risk treatment process the chances of this occurring were reduced to "unlikely". The risk mitigation was achieved by applying the same PSR weather criteria used by the Hercules, and applying the notion that when the Boeing 757 reached its PSR it was one hour closer to its destination when compared with the Hercules aeroplane. On the grounds that there was one hour less for the weather to deteriorate before arrival, the risk was considered to be "significantly less". The same principle used in the original type certificate risk assessment also filtered down to the risk assessment for each individual flight. This was a reasonable assumption, although it needed to be tempered with the knowledge that when localised weather conditions in Antarctica deteriorate, they can do so quickly, as happened in this case.

4.5.3. History showed that the weather had deteriorated to or below approach minima after an aeroplane passed the PSR on only two occasions out of 650 Antarctica flights in 48 years. The likelihood of this occurring was therefore reasonably low. What was missing from the risk assessment were the potential end consequences of an event such as this occurring when using the Boeing 757, compared with those when using the Hercules aircraft. The consequence of not being able to complete a visual or instrument approach successfully was the same for both aircraft – a whiteout landing. However, in the event of this occurring the likelihood of injury was significantly greater for the Boeing 757, with its long landing gear

supporting low-slung engines on a low wing, than it was for the Hercules with its rough-field landing capabilities.

4.5.4. Compared with the Hercules, the Boeing 757 had limited alternative approach options or aerodromes available in the event of the weather suddenly deteriorating below instrument approach minima. The Hercules was fitted with a tactical air navigation system, commonly called TACAN, enabling it to fly a range of additional instrument approaches to the various airfields and runways. The Hercules could divert to Terra Nova Bay, subject to weather conditions. As a final resort it could also land either at Williams Field or in the whiteout area, albeit sustaining damage. The only option noted in the risk profile for the Boeing was a "blind" landing off an instrument approach. From a risk perspective then, the likelihood of the weather closing in was low, but the potential consequences for Boeing 757 operations were significantly more serious than were those for the Hercules aircraft.

4.5.5. The two trial flights had been flown in December and February and, until 2013, all subsequent Boeing flights had been flown towards the end of the season, in either February or March. The risk evaluation process made no reference to the time of year in which the flights were to be flown. Meteorological advice on the subject varied. With the sea ice extending well to the (true) north at the beginning of the summer season, meteorologists thought that there was unlikely to be the same level of relative humidity to help generate fog as there would be late in the season.

4.5.6. By contrast, NIWA found that "there is a marked deterioration in average weather conditions outside of the period November-February".[30] The table below shows weather trend data provided by NIWA.[31]

Table 2: Weather trend data provided by NIWA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	**Oct**	Nov	Dec
Days of blowing snow	2	3	11	14	12	14	13	11	16	**10**	4	3
Frequency of snow (%)	9	14	12	18	17	17	16	18	15	**12**	11	13
Frequency of fog (%)	2	1	4	3	3	1	2	3	2	**3**	1	2
Frequency visibility <2 nm[32] (3.7 km) (%)	3	4	12	14	13	16	13	12	17	**11**	4	5

Climatological means, McMurdo

[30] Based on Scott Base weather summaries 1957-1992 and McMurdo Station data 1957-1972 from six-hourly observations. The data was considered unlikely to have changed significantly since.
[31] It should be noted that weather conditions can vary between McMurdo Station and Scott Base, where the data was collected, and the various airfields between 5 and 30 kilometres away.
[32] Nautical miles.

Table 3: Percentage of time ceiling (metres) and/or visibility (nautical miles), less than or equal to specified values, McMurdo

	Sep	**Oct**	Nov	Dec	Jan	Feb	Mar
600 m, 5 nm (9.3 km)	24	**15**	7	11	11	3.5	13.5
300 m, 3 nm (5.6 km)	17	**8.5**	4.5	4.5	3.5	1	8
100 m, 1 nm (1.9 km)	12	**5.5**	2.5	2	2	0	5.5

4.5.7. The formation of fog around Ross Island was often associated with a depression or low centred near Cape Adare that pulled moist air down into McMurdo Sound. The meteorological experts consulted agreed that given the prevailing conditions present on 7 October 2013, it would have been reasonable to assume that any early-morning fog and low cloud would dissipate with the advancing high pressure.

4.5.8. A second consideration with undertaking flights early in the season was the adequacy of the provision of weather information for flight crews. Other than those personnel wintering over, weather forecasters and observers deployed south with the first few flights. This meant that until all posts were filled, services had to be tailored around the requirements of each flight. This was an unavoidable situation and one recognised by the crew of the aeroplane, who delayed their departure from Christchurch to obtain additional observations and to communicate with the crew of the returning Hercules. The crew was also able to talk directly to both the SOPP Charleston and McMurdo weather offices and discuss the various observations and forecasts.

4.5.9. A third consideration was the validity and accuracy of the instrument approaches. Some inaccuracies resulting from equipment limitations and satellite signal strength in the Antarctic can be expected. However, with the use of augmented systems[33], errors of less than three metres are not unrealistic. The approximately 15-metre offset between the approach track and runway centreline identified by the crew of the aeroplane was a further risk to the safety of aircraft using the runway. The likely reason for the offset was that the ice sheet upon which the aerodrome was located had moved during the winter season. This was predictable.

4.5.10. The instrument approaches were re-calibrated annually in mid to late October, before the level of aviation activity increased significantly in support of summer programmes, camps and other stations. The re-calibration checks were valid for one year and could only commence once the first suitable airfield had opened. Thus the re-calibration flights could only follow the initial deployment flights. On 7 October 2013 the RNAV instrument approach to runway 33 was still within its validation period.

4.5.11. During better meteorological conditions, the 360-foot minimum descent altitude would normally be reached at a point about two kilometres from the runway.[34] This should give sufficient time for a pilot to manoeuvre and position an aircraft towards the centre of the runway for a safe landing. In the near-whiteout conditions experienced by the crew of the aeroplane on this occasion, however, the first indication that a pilot would have that the runway centreline was offset would be as he was flaring the aeroplane to land. The offset runway was another factor that increased the risk of Antarctic flight operations early in the season, before re-calibration flights could take place.

4.5.12. The PSR forecast criteria that the crew used to help them make the decision to continue past the PSR has provided good guidance in the past. One exception involved an RNZAF Hercules

[33] For example differential GPS and wide area augmentation system.
[34] Based on a standard 3° glidepath to touchdown.

in 1993, which was the result of inaccurate forecasting.[35] In a second incident involving rapidly deteriorating conditions in 2002, a Hercules was still able to land off the normal instrument approach, although it required two attempts. The standard of forecasting has since improved but, as shown in this incident, even with the best of resources available, localised weather in Antarctica can still prove difficult to predict accurately.

4.5.13. The Boeing 757 and Hercules[36] are two large aircraft operating between New Zealand and Antarctica that require PSRs. The New York Air National Guard Hercules aeroplanes are ski equipped and have the option of diverting to unprepared areas if required. The Australian-modified civil Airbus A319[37] does not normally operate with a PSR unless it is heavily loaded. The United States C17 Globemaster usually has a PSR some 20-30 minutes out from landing at McMurdo. This equates to about the start of the descent for landing. For the C17 Globemaster to continue past the PSR, it requires a minimum 1,500-foot cloud base and visibility of 4,800 m.

4.5.14. The crew used the PSR weather criteria in deciding whether to proceed past PSR-2d, which made no allowance for the presence of cloud (few or scattered) or fog below a 2,000-foot cloud base (broken or overcast). When assessing the risk, the presence of low cloud and fog near the aerodrome, regardless if forecast to dissipate, still needs to be considered. This is even more essential when operating early in the summer season when the NIWA data shows an increased risk of fog forming.

4.5.15. Finally, developments in Antarctica might mean that there are other destinations that a Boeing 757 could use in the event of the weather conditions deteriorating below minima after an aeroplane has passed the PSR. These possibilities should be investigated and considered when reviewing the risk assessment for Antarctica flights.

Findings

8. There was a low likelihood of the weather conditions at Pegasus Field aerodrome deteriorating below minima after an aeroplane passed the point of safe return. However, the potential consequences of that happening were elevated for the Boeing 757 aircraft, because of the lack of alternative approach procedures and aerodromes suitable for this aircraft type.

9. There are four factors that were not, but should have been, considered when assessing the risk of using the Boeing 757 aircraft for Antarctic operations:
   - the weather criteria for an aeroplane passing the point of safe return should consider the presence of low cloud and fog below the main cloud base as a limiting factor
   - there is an increased likelihood of weather conditions deteriorating below minima early in the summer season
   - the accuracy of instrument approaches should be treated with caution prior to calibration flights being conducted early in the summer season
   - the Royal New Zealand Air Force Boeing aircraft is capable of completing only one type of instrument approach in Antarctica.

[35] See paragraph 3.5.9.
[36] Includes the civil version of the Hercules, the Lockheed L100.
[37] The Airbus 319 used has an additional fuel capacity compared with A319s in regular airline use.

4.6. Management of New Zealand ICAO allocated airspace

4.6.1. When considering wider aspects of its inquiry into this incident, the Commission noted an apparent anomaly in the management of the airspace known as the McMurdo Sector. The anomaly did not contribute in any way to the incident.

4.6.2. The so-called "McMurdo Sector" was part of the Auckland Oceanic flight information region, which is airspace allocated to New Zealand by ICAO. In accordance with ICAO requirements and the New Zealand Civil Aviation Act 1990[38], New Zealand's civil aviation rules require that air traffic services and certain meteorological information can only be provided within the flight information region by organisations certificated under New Zealand civil aviation rules.

4.6.3. Under a letter of agreement, responsibility for the provision of air traffic services for aircraft (military and civilian) operating within the McMurdo Sector was passed from Airways to the Joint Task Force whenever the sector was activated by NOTAM. Absent from the agreement was any involvement by the Director of Civil Aviation, who was the only person who had the authority to permit a sub-delegation of responsibility for the provision of services for this airspace. The Meteorological Service of New Zealand was still to provide upper-level weather information, for example upper-level winds or forecasts of severe turbulence. The Joint Task Force, through the SOPP, would provide routine aerodrome weather reports and forecasts.

4.6.4. In a 2006 ICAO audit of the New Zealand civil aviation system, a finding was made relating to the provision of air navigation services for the McMurdo Sector (ICAO 2006). The finding stated:

> In order to facilitate Antarctic operations, a substantive portion of the southern part of Auckland Oceanic FIR [flight information region] is release[d] to an alternative ATS [air traffic service] (McMurdo) under the terms of a letter of agreement between ACNZ [Airways Corporation of New Zealand] and McMurdo ATS. However, the CAA does not have a mechanism in place to ensure compliance by McMurdo ATS with Annex 11[39] and the CAA does not conduct effective regulatory oversight over McMurdo ATS.[40]

4.6.5. In response to that finding the CAA stated:

> The finding is accepted. New Zealand will enter into high level agreement with the Agency providing air traffic services in the McMurdo Sector to ensure that such services are provided in accordance with Annex 11 and to an equivalent standard as that provided by New Zealand Civil Aviation Rules.

The estimated completion date for the proposed corrective actions was July 2007. See safety actions, paragraph 7.2.7.

[38] New Zealand Civil Aviation Act 1990, section 28(1)(a).
[39] ICAO Annex 11 to the Convention on International Civil Aviation – Air Traffic Services.
[40] ICAO Audit Report, Appendix 1-7-05, Audit Finding ANS/05.

5. Findings

5.1. The crew was well prepared and sufficiently experienced for the flight.

5.2. The decision for the aeroplane to depart Christchurch was well considered and appropriate based on the information that the RNZAF had received prior to the flight being authorised.

5.3. Based on the available weather information and the reassurances by the United States Navy's Office of Polar Programs' forecasters in Charleston and McMurdo, the crew was justified in continuing past the point of safe return.

5.4. The absence of the 1225 special weather report and the delay in sending the 1332 special weather report, while unlikely to have altered the outcome, need to be examined further to ensure that safety-critical information is passed to crews in a timely manner.

5.5. The RNAV approach to runway 33 at Pegasus Field was the best option for a successful landing.

5.6. The decision to fly to a lower minimum descent altitude was the only reasonable option available to the crew in order to make a successful landing.

5.7. The incident was a good demonstration of effective crew resource management that enabled a safe landing to be made in demanding circumstances.

5.8. There was a low likelihood of the weather conditions at the Pegasus Field aerodrome deteriorating below minima after an aeroplane passed the point of safe return. However, the potential consequences of that happening were elevated for the Boeing 757 aircraft, because of the lack of alternative approach procedures and aerodromes suitable for this aircraft type.

5.9. There are four factors that were not, but should have been, considered when assessing the risk of using the Boeing 757 aircraft for Antarctic operations:

- the weather criteria for an aeroplane passing the point of safe return should consider the presence of low cloud and fog below the main cloud base as a limiting factor
- there is an increased likelihood of weather conditions deteriorating below minima early in the summer season
- the accuracy of instrument approaches should be treated with caution prior to calibration flights being conducted early in the summer season
- the Royal New Zealand Air Force Boeing aircraft is capable of completing only one type of instrument approach in Antarctica.

6. Key lessons

6.1. Effective crew resource management enables a crew to perform as a cohesive unit and provides the best opportunity for a safe outcome. This incident demonstrates how a properly trained crew was able to function effectively in demanding circumstances and make a safe landing.

6.2. An essential element of risk management is the continuous review of the relevance of the original assessment and its context, hazards and mitigations. This is especially important when there are changes in the circumstances or conditions of the assessment to ensure that it remains valid and provides the appropriate level of safety.

7. Safety actions

7.1. General

7.1.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result 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 result in the Commission issuing a recommendation.

7.2. Safety actions addressing safety issues identified during an inquiry

RNZAF Antarctic operations

7.2.1. Antarctic flights utilising the Boeing 757-2K2 were initially suspended after the incident on 7 October 2013. Three end-of-season flights were approved subject to the aeroplane only being allowed to carry non-essential personnel from Antarctica to New Zealand. This was not considered a safety action, rather an operating limitation until other safety measures could be put in place.

7.2.2. On 26 February 2014 the standard operating procedures for the Boeing 757 were amended to cater for flights occurring before the annual revalidation of the instrument approaches. The new procedures state:

> At the beginning of each Antarctic summer season the RNAV (GPS) approaches need to be validated to confirm they are accurate. Validation of these approaches must be conducted by RNP [required navigation performance] certified aircraft on the first missions of the season. This validation can be conducted by either foreign RNP certified aircraft or RNZAF RNP certified aircraft. If the approach has not been validated then the weather minima must be increased to allow the approach to be flown in VMC [visual meteorological conditions]. Once a validation approach has been flown and proven to be accurate then subsequent RNP approaches may be flown in IMC [instrument meteorological conditions] down to normal published minimas.

7.2.3. On 11 November 2014 the RNZAF issued a temporary order concerning revised meteorological requirements for passing the PSR. The new requirements are to become permanent with the next routine amendment cycle. The new cloud-base minima are as follows:

> Minimum BKN [broken] 2000 feet above ground level or BKN 1500 feet above MDA for approach in use, whichever is higher. Reported or forecast visible moisture below minima must be considered with crews ultimately being satisfied that the drivers that may cause these conditions to worsen will not be present for arrival, e.g. FEW003 [few at 300 feet] will not degenerate to FOG at airfield.

7.2.4. The RNZAF advised that in addition to amending the weather criteria it had reviewed its flight profiles. As a result for the 2014/2015 season a revised flight profile supporting increased fuel carriage against an increased operational weight for the Hercules has been implemented. This means that the Hercules PSR is moved to approximately 60-90 minutes from Pegasus, instead of the original 150-180 minutes from Pegasus. Further, the implementation of risk management plans has been supplemented with an operational capability statement, which ensures that commanders are aware of operational limitations or constraints and appropriate risk management practices can be implemented.

7.2.5. The RNZAF had briefed all other flying squadrons that support Antarctica operations on the 7 October 2013 occurrence. The circumstances of the occurrence and the lessons learnt had also been included in the training packages for future Antarctica operations.

Weather information

7.2.6. The National Science Foundation advised that the SOPP was reviewing its processes/procedures for ensuring that reports are sent. This would help to provide a second tier to ensure that a report was not missed by another party.

Airspace management

7.2.7. On 20 November 2014 the CAA advised that the letter of agreement between Airways and the Joint Task Force – Support Forces Antarctica was a provider-to-provider agreement and did not transfer any of the State-based responsibilities for the provision of services; rather it worked as a technical co-ordination document between the parties. Further, that since the 2006 audit the CAA had worked to clarify arrangements in the Auckland Oceanic flight information region, initially on contracts with Pacific States in the region. The focus had now moved to the Antarctica arrangements and the CAA was working with the Ministry of Transport and the Ministry of Foreign Affairs and Trade to open communications with United States agencies to seek a resolution to the McMurdo Sector oversight situation.

8. Recommendation

8.1. General

8.1.1. 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.

8.1.2. In this case, the Commission makes one recommendation to the Chief of Air Force.

8.1.3. In the interests of transport safety it is important that this recommendation is implemented without delay to help prevent similar accidents or incidents occurring in the future.

8.2. Recommendation

8.2.1. There was a low likelihood of the weather conditions at Pegasus Field aerodrome deteriorating below minima after an aeroplane passed the point of safe return. However, the potential consequences of that happening were elevated for the Boeing 757 aircraft because of the lack of alternative approach paths and aerodromes suitable for this aircraft type.

There are five factors that were not considered, or only partly considered, but should have been when assessing the risk of using the Boeing 757 aircraft for Antarctica operations:

- the weather criteria for an aeroplane passing the point of safe return should consider the presence of low cloud and fog below the main cloud base as a limiting factor
- there is an increased likelihood of weather conditions deteriorating below minima early in the summer season
- the accuracy of instrument approaches should be treated with caution prior to calibration flights being conducted early in the summer season
- the RNZAF aircraft is capable of completing one type of instrument approach only in Antarctica – a GPS approach
- the lack of suitable diversion airfields and the consequences of a whiteout landing.

The Commission recommends that the Chief of Air Force review the risk assessment for using the Boeing 757 aircraft for Antarctic flight operations, taking into account these matters and any other matters not considered during the initial risk assessment. (024/14)

8.2.2. On 19 January 2015, the Chief of Air Force replied in part:

> The RNZAF accepts and will implement the Commission's final recommendations from Inquiry AO-2013-009 as follows.
>
> - Effective 11 November 2014 the weather criteria for Antarctic operations for all RNZF aircraft were amended by temporary order to take in to account visible moisture below weather minima. This temporary order will be enshrined in General Orders for New Zealand Defence Force Military Aviation Operations on the next amendment cycle (02 March 2015).
>
> - The Risk Management Plan (RMP)[41] for Antarctic operations will be updated to include detailed recognition of the other four factors no later than 09

[41] An RMP articulates and assess risks associated with specific activites (e.g. deployments for major operations), it supports the flight authorisation process. An RMP is developed for Antarctic operations annually for each aircraft type.

February 2015, which is before the next scheduled flight to Antarctica. I will write to you again with a copy of the updated RMP in due course.

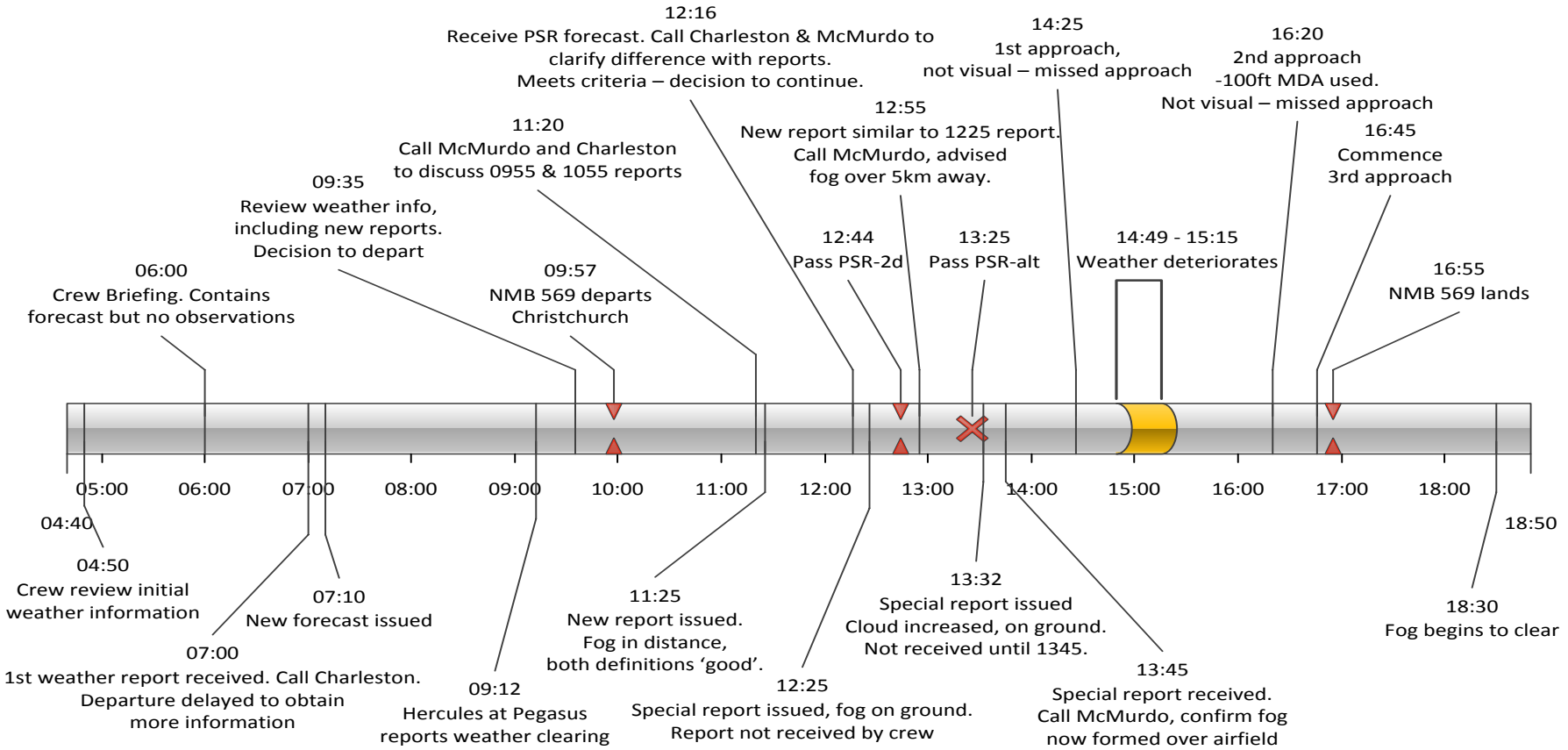
- The RNZAF aviation operational risk management system is currently befing refined. In due course standard mission risk profiles capturing risks inherent to that mission will be published. These profiles will support the development of activity based RMPs. Once the risk management system is finalised, the risk factors you recommend will be captured in the Antarctic operations mission risk profile for each aircraft type. I do not have a completion date for this activity, but I will inform you when it is resolved.

9. Source

AIP, 2011 Aeronautical Information Publication New Zealand, GEN 3.5 – 1, Civil Aviation Authority, 28 July 2011.

ICAO, 2006 International Civil Aviation Organization, Final Report on the Safety Oversight Audit of the Civil Aviation System of New Zealand, 14 to 24 March 2006. A copy of the report is available on the CAA's website at http://www.caa.govt.nz/ICAO/ICAO-USOAP_Final_Audit_Report.

Appendix 1: RNZAF Boeing 757 NMB569 flight to Antarctica – timeline



Appendix 2: Weather observations (METARs and SPECIs) – see Appendix 4 for an explanation of terms

OBSERVATIONS TABLE

Time (NZDT)	Report type	Wind (grid)	Visibility (m)	Cloud	Temp (-°C)*	Pressure (inches)	Remarks
0655	METAR	260/06	8000	BR FEW000 FEW030 SCT080	25/27	29.35	VIS GRID W-N 3200 FG FEW000 SDF/HDF HDG GRID E-S-SW (called Charleston)
0740	SPECI	280/06	9999**	VCFG FEW000 FEW025 SCT080	26/29	29.36	VIS GRID W-NW 3200 VCFG GRID W-NW SDG/HDG HDF GRID W-NW
0755	METAR	290/07	9999	VCFG FEW000 FEW030 SCT080	26/29	29.36	VIS GRID W-NW 3200 FG FEW000 VCFG GRID W-NW SDG/HDG HDF GRID W-NW
0855	METAR	310/03	9999	VCFG FEW000 FEW002 SCT030	25/27	29.36	VCFG GRID NW SDG/HDG
0935	SPECI	300/03	9999	FEW002 FEW030 SCT070	25/28	29.36	SDG/HDG
0955	METAR	280/03	9999	FEW005 FEW030 SCT070	25/28	29.36	SDG/HDG (take-off at 0957)
1055	METAR	310/02	9999	SCT003 SCT030	25/28	29.37	FG DSNT GRID N-NW SDG/HDG (called McMurdo and Charleston)
1125	SPECI	190/03	9999	FEW003 SCT030	25/28	29.37	FG DSNT GRID W-N SDG/HDG
1155	METAR	170/05	9999	FEW003 SCT025	23/26	29.37	FG DSNT GRID W-N SDG/HDG HDF GRID W-N (called McMurdo and Charleston)
1225	SPECI	120/04	9999	FEW000 SCT003 SCT025	24/26	29.37	FG FEW000 FG DSNT GRID W-N SDG/HDG HDF GRID W-N (not received)
1255	METAR	100/04	9999	FEW000 SCT003 SCT025	24/27	29.37	FG FEW000 FG DSNT GRID W-N SDG/HDG HDF GRID W-N (called McMurdo)
1332	SPECI	110/02	9999	FEW000 BKN003 BKN025	24/27	29.34	FG FEW000 FG DSNT GRID W-N SDG/HDG HDF(P) GRID W-N (received at 1345, called McMurdo)
1355	METAR	000/00	9999	FEW000 BKN003 BKN025	23/26	29.34	FG FEW000 FG DSNT GRID SE-SW FATA MORGANA GRID NW-SE SDG/HDG HDP GRID SE-SW
1410	SPECI	000/00	9999	FEW000 BKN003 BKN025	22/25	29.34	FG FEW000 FG DSNT GRID SE-SW FATA MORGANA GRID NW-SE SDG/HDG HDP GRID SE-SW
1425	SPECI	000/00	9999	FEW000 OVC003	22/25	29.34	FG FEW000 FG DSNT GRID S-NW FATA MORGANA GRID N-SE SDG/HDF HDP GRID S-NW
1431	SPECI	000/00	9999	VCFG FEW000 BKN003	22/24	29.34	VIS GRID NW-NE 1200 GRID NW-NE SDF/HDF HDP GRID NW-NE VCFG
1436	SPECI	000/00	1200	BR OVC003	21/24	29.34	SDF/HDP
1455	METAR	000/00	0600	FZFG VV003	21/23	29.35	SDF/HDN
1515	SPECI	000/00	0400	FZFG VV003	20/22	29.35	SDF/HDN
1555	METAR	000/00	0400	FZFG VV003	19/21	29.37	SDF/HDP
1618	SPECI	060/03	0200	FZFG VV003	18/20	29.34	SDF/HDN
1642	SPECI	070/04	0300	FZFG VV003	18/20	29.35	SDF/HDN
1655	METAR	060/04	0300	FZFG VV003	18/20	29.38	SDF/HDN
1716	SPECI	080/03	0200	FZFG VV003	18/20	29.37	SDP/HDN

*temperature/dew point *9999 means unlimited visibility

Appendix 3: Weather forecasts (TAFs) – see Appendix 4 for an explanation of terms

TAFs TABLE 7 October 2013

Time (NZDT)	Forecast period	Wind (grid)	Visibility (m)	Conditions	Pressure (inches)	Additional conditions	Comments
0352	TAF 0704/0804*	230/10	9999	SCT040 BKN080 BKN120	29.30		
	BECMG 0710/0712	230/08	9999	BKN080 BKN140	29.34		
0710	TAF AMD 0707/0804	230/10	8000	BR FEW000 FEW040 SCT080	29.30	BR FEW000	
	TEMP 0707/0710		1600	BR BKN002			
	BECMG 0709/0711	230/08	9999	NSW FEW040 SCT080 BKN140	29.34		
0902	TAF AMD 0709/0804	270/08	9999	SCT030 SCT080	29.30		
	BECMG 0801/0803	230/08	9999	VCFG BKN040 BKN080 BKN140	29.34		
1000	TAF 0710/0810	270/08	9999	SCT030 SCT080	29.30		
	BECMG 0723/0801	250/08	9999	VCFG SCT040	29.34		
	BECMG 0808/0810	240/10	9999	NSW SCT040 BKN080	29.35		
1216	**PSR FORECAST**	**270/08**	**9999**	**SCT003 SCT030 SCT080**	**29.37**		
1404	TAF AMD 0713/0810	270/08	9999	VCFG FEW000 BKN003 BKN025	29.30		W/V T250/08 & G270/08
	BECMG 0718/0720	040/08	9999	VCFG SCT003 SCT025	29.30		
	BECMG 0808/0810	240/10	9999	NSW SCT040 BKN080	29.35		
1510	TAF AMD 0715/0810	000/00	0600	FG VV003	29.30		
	BECMG 0718/0720	040/08	4800	BR BKN003 SCT025	29.30		
	BECMG 0808/0810	240/10	9999	NSW SCT040 BKN080	29.35		
1610	TAF 0716/0816	000/00	0600	FZFG VV003	29.30		
	BECMG 0718/0720	040/08	4800	BR BKN003 SCT025	29.30		
	BECMG 0808/0810	240/10	9999	NSW SCT040 BKN080	29.35		
	BECMG 0812/0814	040/08	4800	BR SCT005 SCT025 BKN080	29.30		
1613	TAF COR 0716/0816	000/00	0600	FZFG VV003	29.30		
	BECMG 0718/0720	040/08	4800	BR BKN003 SCT025	29.30		
	BECMG 0808/0810	240/10	9999	NSW SCT040 BKN080	29.35		
	BECMG 0812/0814	040/08	4800	BR SCT005 SCT025 BKN080	29.30		

* Forecast period is day and hour. 0704/0804 is the period from 0400 on 7 October to 0400 on 8 October.

Appendix 4: Weather codes

Weather Code

Identifier	Description
AMD	amendment
BECMG	becoming
BKN	broken
BR	mist
DSNT	in the distance
E	east
FEW	few
FG	fog
FZFG	freezing fog
HDN, HDP, HDF, HDG	horizon definition nil, poor, fair, good
METAR	routine aerodrome weather report
N	north
OVC	overcast
S	south
SCT	scattered
SDN, SDP, SDF, SDG	surface definition nil, poor, fair, good
SPECI	special aerodrome report (in the METAR code)
TAF	aerodrome forecast
TAF COR	TAF correction
VCFG	fog in the vicinity
VIS	visibility
VV	vertical visibility
W	west
260/06	indicates surface wind direction and velocity (260° at six knots)
9999	visibility greater than 10 km
25/27	temperature/dew point (-° Celsius)
29.35	pressure measured in inches of mercury

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

AO-2013-002	Robinson R44, ZK-HAD, engine power loss and ditching, Lake Rotorua, 24 February 2013
11-007	Descent below instrument approach minima, Christchurch International Airport, 29 October 2011
11-006	Britten-Norman BN.2A Mk.III-2, ZK-LGF, runway excursion, Pauanui Beach Aerodrome, 22 October 2011
11-003	In-flight break-up ZK-HMU, Robinson R22, near Mount Aspiring, 27 April 2011
12-001	Hot-air balloon collision with power lines, and in-flight fire, near Carterton, 7 January 2012
11-004	Piper PA31-350 Navajo Chieftain, ZK-MYS, landing without nose landing gear extended, Nelson Aerodrome, 11 May 2011
11-005	Engine compressor surges, 18 September 2011
11-001	Bell Helicopter Textron 206L-3, ZK-ISF, Ditching after engine power decrease, Bream Bay, Northland, 20 January 2011
11-002	Bombardier DHC-8-311, ZK-NEQ, Landing without nose landing gear extended Woodbourne (Blenheim) Aerodrome, 9 February 2011
10-010	Bombardier DHC-8-311, ZK-NEB, landing without nose landing gear extended, Woodbourne (Blenheim) Aerodrome, 30 September 2010
12-001	Interim Factual: Cameron Balloons A210 registration ZK-XXF, collision with power line and in-flight fire, 7 January 2012
10-009	Walter Fletcher FU24, ZK-EUF, loss of control on take-off and impact with terrain, Fox Glacier aerodrome, South Westland, 4 September 2010
10-007	Boeing 737-800, ZK-PBF and Boeing 737-800, VH-VXU airspace incident, near Queenstown Aerodrome, 20 June 2010
10-005	Cessna A152, ZK-NPL and Robinson R22 Beta, ZK-HIE near-collision. New Plymouth Aerodrome, 10 May 2010
10-003	Cessna C208 Caravan ZK-TZR engine fuel leak and forced landing, Nelson, 10 February 2010

Price $19.00

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