Final report AO-2014-005: Eurocopter AS350-B2 (ZK-HYO), collision with terrain during heli-skiing flight, Mount Alta, near Mount Aspiring National Park, 16 August 2014

Final Report

Aviation inquiry AO-2014-005
Eurocopter AS350-B2 (ZK-HYO)
collision with terrain during heli-skiing flight
Mount Alta, near Mount Aspiring National Park
16 August 2014

Approved for publication: November 2017

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (the 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.

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Important notes

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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 1982 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

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Verbal probability expressions

The expressions listed in the following table are used in this report to describe the degree of probability (or likelihood) that an event happened or a condition existed in support of a hypothesis.

Terminology (adopted from the Intergovernmental Panel on Climate Change)	Likelihood of the occurrence/outcome	Equivalent terms
Virtually certain	> 99% probability of occurrence	Almost certain
Very likely	> 90% probability	Highly likely, very probable
Likely	> 66% probability	Probable
About as likely as not	33% to 66% probability	More or less likely
Unlikely	< 33% probability	Improbable
Very unlikely	< 10% probability	Highly unlikely
Exceptionally unlikely	< 1% probability	

Eurocopter AS350-B2 (ZK-HYO)

(Courtesy of The Helicopter Line)

Source: mapsof.net

Location of accident

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Abbreviations

BEA	Bureau d'Enquêtes et d'Analyses (France)
CAA	Civil Aviation Authority
cm	centimetres
Commission	Transport Accident Investigation Commission
kg	kilogram(s)
km	kilometre(s)
m	metre(s)

Glossary

aft of datum	effectively the nose of a helicopter
Category A pilot	a pilot authorised to act as pilot in command on any flight, unless a specific restriction is applied
collective lever	one of the flight controls, used by a pilot to manage the collective pitch (lift or thrust) of the main rotor
cyclic	one of the flight controls, used by a pilot to manage the attitude of the disc (main rotor blades) to control the direction and speed of a helicopter
datum	a reference point on an aircraft used to calculate centres of gravity. The point may vary between different aircraft types
density altitude	the pressure altitude corrected for any temperature difference from the temperature at that altitude in the International Standard Atmosphere
ground effect	a helicopter is 'in ground effect' when the downwash from the main rotor strikes the surface, stopping the downward wash and generating an increase in pressure, effectively a cushion of air that reduces the power required to maintain position. The effect reduces as the helicopter moves higher, meaning more power will be required. At a height equivalent to the distance of half to one rotor diameter, the effect is considered to be nil and the helicopter is said to be 'out of ground effect'
pressure altitude	the altitude in the International Standard Atmosphere with the same pressure as the part of the atmosphere in question
translation	the phase of flight when accelerating from a hover to forward flight or back to a hover
vortex ring state	a helicopter is said to be in vortex ring state when it is descending in its own downwash and any increase in power to counter the descent further accelerates the downwash and the helicopter descends faster

Data summary

Aircraft particulars

Aircraft registration:	ZK-HYO
Type and serial number:	Eurocopter[1] AS350-B2, 3885
Number and type of engines:	one Turbomeca Arriel 1D1
Year of manufacture:	2004
Operator:	The Helicopter Line
Type of flight:	commercial charter
Persons on board:	seven
Pilot's licence:	commercial pilot licence (helicopter)
Pilot's age:	48
Pilot's total flying experience:	4,176 flight hours (605 hours on type)

Date and time	16 August 2014, 1155[2]
Location	Mount Alta, Otago, east of Mount Aspiring National Park latitude: 44° 30.2´ south longitude: 168° 58.3´ east
Injuries	one fatal three serious three moderate or minor
Damage	helicopter destroyed

[1] On 2 January 2014 the Eurocopter Group, previously Aérospatiale, was renamed Airbus Helicopters.
[2] Times in this report are in New Zealand Standard Time (Co-ordinated Universal Time + 12 hours) and expressed in the 24-hour format.

1. Executive summary

1.1. On Saturday 16 August 2014, the weather was fine and clear with light variable winds in the Mount Aspiring National Park area. The Helicopter Line was using several AS350-B2 (Squirrel) helicopters to ferry heli-ski groups to the top of various ski runs in the area.

1.2. One of the helicopters was on its fourth heli-ski flight for the morning, ferrying a group of five skiers and their ski guide to a ridgeline close to the summit of Mount Alta. On the approach to the landing site the helicopter began to descend below the pilot's intended angle of approach. The pilot discontinued the approach by turning the helicopter away from the ridgeline and down the mountain. However, the pilot was unable to avoid the terrain and the helicopter struck the steep, snow-clad slope heavily and rolled 300 metres down the mountain.

1.3. The cabin structure broke apart and five of the seven occupants were ejected from the helicopter as it rolled down the mountain. Two passengers remained strapped to their seats. One of the passengers was trapped under the helicopter and died from his injuries. The remaining six occupants received moderate to serious injuries. The helicopter was destroyed.

1.4. The Transport Accident Investigation Commission (Commission) found that the total weight of the helicopter was about 30 kilograms over the maximum permissible weight, and the centre of gravity was about 3.0 centimetres ahead of the forward limit. The helicopter was operating at or close to the limit of its performance capability to maintain a hover outside of 'ground effect' at that weight and at the temperature and altitude of the landing site. This was a likely factor in the pilot not achieving a safe landing.

1.5. The Commission was unable to make a conclusive finding on whether the helicopter was affected by a phenomenon known as 'vortex ring state'.

1.6. The Commission found no mechanical reason for the accident. The engine was delivering high power and the helicopter was controllable. The pilot was experienced and had received training in mountain flying and heli-ski operations.

1.7. Two safety issues were identified during this inquiry. The first was that the operator's standard operating procedures did not require its pilots to routinely calculate the performance capabilities of their helicopters for the intended flights.

1.8. The second was that there was a risk of not knowing an aircraft's capability when using standard passenger weights, and therefore of pilots operating close to the limits of their aircraft's performance.

1.9. This accident and others are suggestive of a third safety issue, which is some New Zealand helicopter pilots may have a culture of operating their aircraft beyond the manufacturers' published and placarded limits, with the possibility that such a culture has become normalised.

1.10. The importance of pilots knowing the performance capabilities of their aircraft and of observing published limitations is well known. For example, the Civil Aviation Authority has commented:

> Take-off, landing and hovering are all potentially risky phases of helicopter flight. The more that we can do as pilots to minimise these risks – especially when operating at high gross weights, from challenging sites, with high density altitudes – the safer we will be.
>
> Most performance-related accidents can be prevented, provided that the pilot maintains a good awareness of the surrounding conditions, knows the performance limitations of the helicopter, always does a power check before committing to a marginal situation, and is disciplined enough to "give it away early" if the odds are stacking up against getting the job done safely. (CAA, 2012, p. 33)

1.11. A number of safety actions were taken in respect of these safety issues.

1.12. The Commission made three recommendations to the Director of Civil Aviation to address the safety issues.

1.13. The key lessons arising from this inquiry are:

- flying in mountainous terrain places additional demands on a pilot's skills and an aircraft's performance. Both could be at or near the limits of their capabilities. Operators need to ensure that their safety management systems address the additional risks associated with flying in such an environment
- the use of 'standard' or 'assessed' passenger weights is not a licence to exceed an aircraft's permissible weight and balance parameters. Any aircraft being operated outside the permissible range will have a higher risk of having an accident, particularly when being operated near the margins of aircraft performance capability
- it is important for operators to keep comprehensive, formal records of all pilot training. Historical training records provide the basis for ongoing performance monitoring and professional development, particularly given natural attrition as safety and training managers move through the industry
- seatbelts are only effective in preventing or minimising injury if they are fastened and properly adjusted. Aircraft operators must ensure that passengers and crew fasten their seatbelts and adjust them to fit tightly across their hips
- vortex ring state is a known hazard for helicopters. To avoid the hazard, pilots must:
  a. remain alert to the conditions conducive to the formation of vortex ring state
  b. closely monitor the airspeed and rate of descent during the final approach
  c. initiate recovery action at the first indication that they may be approaching vortex ring state.

2. Conduct of the inquiry

2.1. On the afternoon of Saturday 16 August 2014, the Civil Aviation Authority (CAA) notified the Transport Accident Investigation Commission (the Commission) of the accident. The Commission opened an inquiry under section 13(1)b of the Transport Accident Investigation Commission Act 1990, and appointed an investigator in charge.

2.2. On 16 August 2014 the Commission notified the Bureau d'Enquêtes et d'Analyses (BEA) of France, which was the State of Manufacture for the helicopter and the engine. In accordance with Annex 13 to the Convention on International Civil Aviation, France appointed a BEA investigator as its Accredited Representative to participate in the investigation.

2.3. Three of the Commission's investigators arrived in Queenstown on the afternoon of 17 August 2014 and conducted an initial survey of the accident site from a helicopter. The investigators conducted a full site examination on 18 August 2014. The wreckage was removed later that day and transported to the Commission's technical facility in Wellington for further detailed examination.

2.4. In the following three days, witnesses and first responders to the accident were interviewed. The maintenance records for the helicopter were obtained by the Commission and relevant engineering personnel were interviewed. The helicopter was not fitted with any equipment to record data, and no other source of recorded data was obtained from the accident flight.

2.5. On 25 and 26 August 2014 the investigator in charge interviewed the surviving passengers. The investigation reviewed the CAA files concerning The Helicopter Line (the operator) and the pilot. On 3 September 2014 the operator's general manager and chief pilot were interviewed.

2.6. On 14 November 2014, at the request of the Commission, the helicopter manufacturer, Airbus Helicopters, completed an analysis of relevant helicopter performance data.

2.7. On 28 January 2015, once the snow had melted, a team searched the accident site for any unrecovered items. The search team recovered some items from the helicopter.

2.8. Between December 2014 and February 2015, the Commission obtained additional information through BEA concerning the helicopter seats and seatbelts.

2.9. On 19 October 2015 the engine was examined by Turbomeca at its maintenance facility in Sydney, Australia. The Australian Transport Safety Bureau appointed an Accredited Representative to the Commission's inquiry to supervise the examination on behalf of the Commission. On 29 October 2015 the Australian Transport Safety Bureau provided the Commission with a report on the engine examination.

2.10. On 27 January 2016 three investigators from BEA and a senior investigator from Airbus Helicopters travelled to New Zealand and examined the wreckage of the helicopter at the Commission's technical facility.

2.11. On 24 August 2016 the Commission approved the circulation of the draft report to interested persons for comment and received submissions from four interested persons.

2.12. In response to the submissions received, the Commission undertook further independent enquiries, which included a review of all the primary evidence and information it had received from all sources. The Commission also sought the opinion of an expert who had a long association with heli-skiing operations in Canada as a helicopter pilot, a regulator and an independent accident investigator.

2.13. On 24 May 2017 the Commission approved the circulation of a revised draft report to interested persons affected by the changes. Substantive submissions were received from three interested persons, including the operator and the regulator (CAA). The Commission requested further information concerning those submissions.

2.14. On 23 August 2017 the Commission approved the circulation of a 2nd revised draft report to interested persons for their comment. Further submissions were received and these were considered in the preparation of the final report.

2.15. On 25 October 2017, the Commission deferred publication of its final report due to prosecution proceedings the CAA and the operator were parties to, and which was proceeding to trial in November. The Commission wanted to ensure its report did not affect the fair administration of justice.

2.16. On 16 November 2017, the Commission approved publication of its final report following notification the prosecution proceedings were not proceeding to trial.

3. Factual information

3.1. Narrative

3.1.1. On the evening of Friday 15 August 2014, the pilot and the heli-skiing co-ordinator for the operator discussed the plan for the next day. There were three skiing groups[3] with whom the pilot would be flying the next day.

3.1.2. The heli-skiing was initially organised through an associated company (the heli-ski provider), which had taken the bookings and organised guides for each group.[4] Five of the operator's helicopters were to be used to support heli-skiing groups during the day, mainly in the mountains between Mount Aspiring National Park and Lake Wanaka.

16 August 2014

3.1.3. At 0754 on Saturday 16 August 2014, the pilot took off from Queenstown in an AS350-B2 helicopter and took a group of passengers to the Cardrona snow park. He then continued to Wanaka where he delivered the helicopter to the maintenance provider. The pilot then picked up another AS350-B2 helicopter, the one involved in the accident (the helicopter). The operator had recently imported the helicopter from the United States, and this was to be its first commercial flight in New Zealand.

3.1.4. The pilot met with the engineer who had supervised the maintenance check and fitting of equipment to the helicopter. Together they transferred the ski basket and other equipment, checked the documentation and conducted a visual inspection of the helicopter. The pilot then flew the helicopter back to Queenstown to meet up with the ski groups.

3.1.5. At 1002 the pilot landed back at Queenstown and the three groups were given their helicopter safety briefing in preparation for the day's activities. A heli-ski guide loaded the first group of five, group A, and their gear onto the helicopter. Group A was to be flown to the Phoebe Creek staging area in the lower Matukituki Valley west of Wanaka (see Figure 1), while groups B and C travelled by road.

3.1.6. When the pilot boarded the helicopter he noted that the passengers in group A were all males of about medium build. The guide told the pilot that he did not know what the passenger weights were. The pilot spoke with one of the passengers, who confirmed that they had not been individually weighed but that they each weighed about 85 kilograms (kg). The pilot thought this was a reasonable estimate that he would use when calculating his fuel loads for the loaded flights to the high-altitude drop-off points for the rest of the day. At 1014 the helicopter departed for Phoebe Creek.

3.1.7. The pilot fuelled the helicopter at Phoebe Creek while the groups were briefed by their allocated guides on mountain safety and the day's activities. The guides were equipped with radios to communicate with their respective pilots on a common frequency.

3.1.8. The helicopter, like most of the operator's other helicopters, was configured with a dual front seat to the left of the pilot and four seats across the rear of the cabin. The pilot asked a smaller member of the group to occupy the front centre seat next to him. This was a company procedure to minimise the risk of exceeding the weight and balance limits of the helicopter, and to minimise the risk of a passenger's arm obstructing the pilot's use of the collective lever[5] located between them.

3.1.9. Group A and their guide then boarded the helicopter and were flown to the top of their first ski run – known as Tony's Run. The pilot returned to the staging area and repeated the exercise

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[3] The three groups are identified as groups A, B and C.
[4] See section 3.6 for more detailed comment on the commercial arrangements.
[5] One of the flight controls used by a pilot to manage the collective pitch (lift or thrust) of the main rotor.

with group B. On returning to uplift group C the pilot refuelled the helicopter to nearly 60% capacity.

3.1.10. The pilot then flew group C to the top of Tony's Run and descended to the bottom of the run to uplift group A for their next run, which was to be from near the summit of Mount Alta. The smaller passenger returned to his allocated front-centre seat. The guide sat in the front-left seat and donned a headset to talk to the pilot and discuss the next run. The pilot then flew the helicopter in a climbing left-hand orbit around Mount Alta to enable the pilot and guide to assess the conditions. The pilot and guide agreed to land groups A and B at a designated landing site on a flat ridge near the summit and group C further down the mountain.[6]

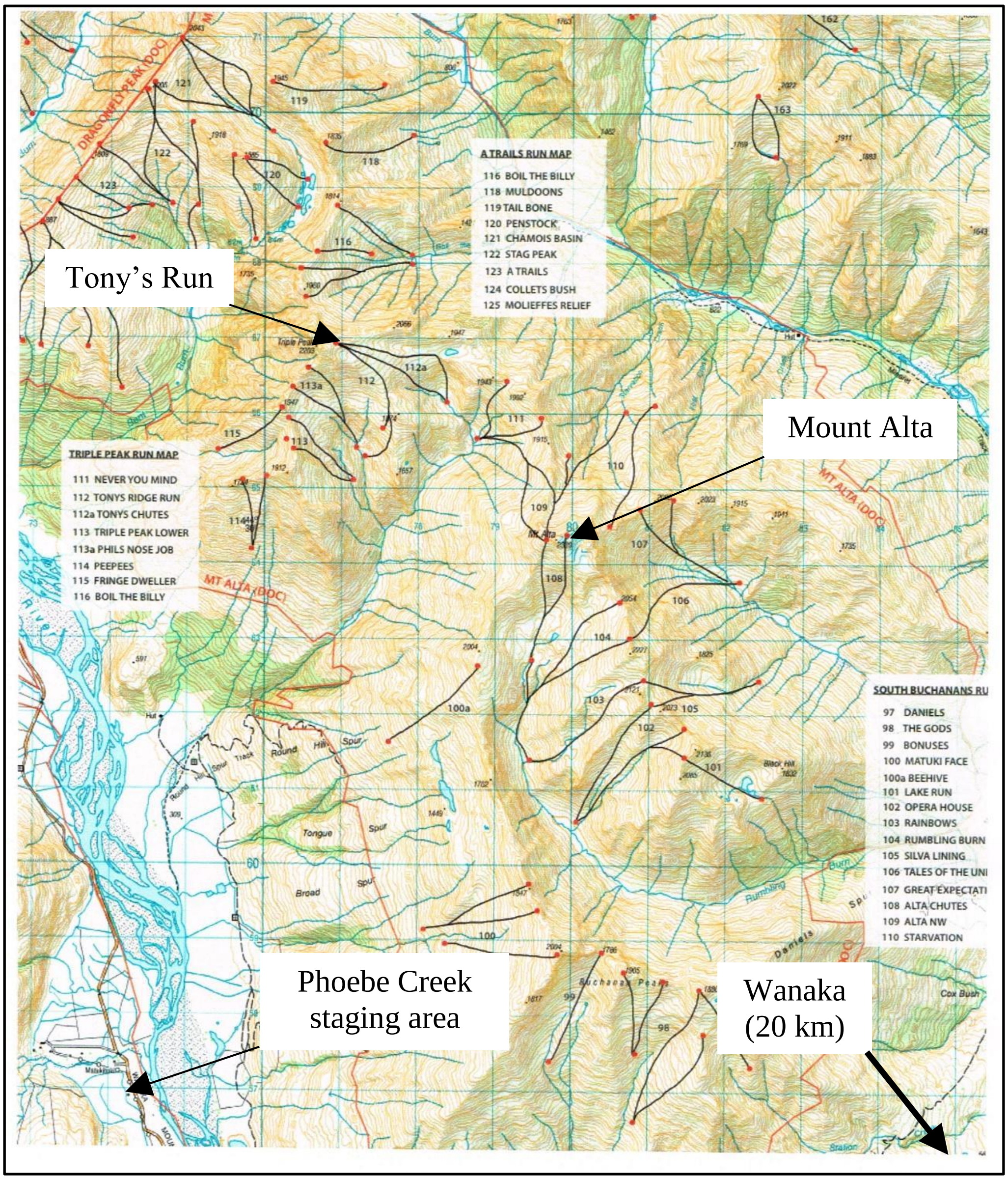

Figure 1
Ski run map
(Courtesy of The Helicopter Line)

[6] Group C was a family group considered to have a lesser skill level than the other groups.

3.1.11. The weather conditions were nearly calm with a very light southerly wind. The pilot elected to approach the landing site from the northwest, into the light southerly wind. A length of orange ribbon on a cane pole had previously been placed close to the landing site to act as a wind marker for pilots. As the helicopter neared the landing site the pilot was unable to see the wind marker, because it was below a small snowbank. He was not sure where the wind was from and considered the possibility that there was a tailwind, so he maintained his airspeed and overflew the ridge.

3.1.12. After passing over the ridge, the pilot and guide saw the wind marker below the ridgeline. The wind marker indicated a light southerly breeze, so the pilot overflew the landing site a second time and repositioned the helicopter on the north side of the ridge for an approach (see Figures 2 and 3).

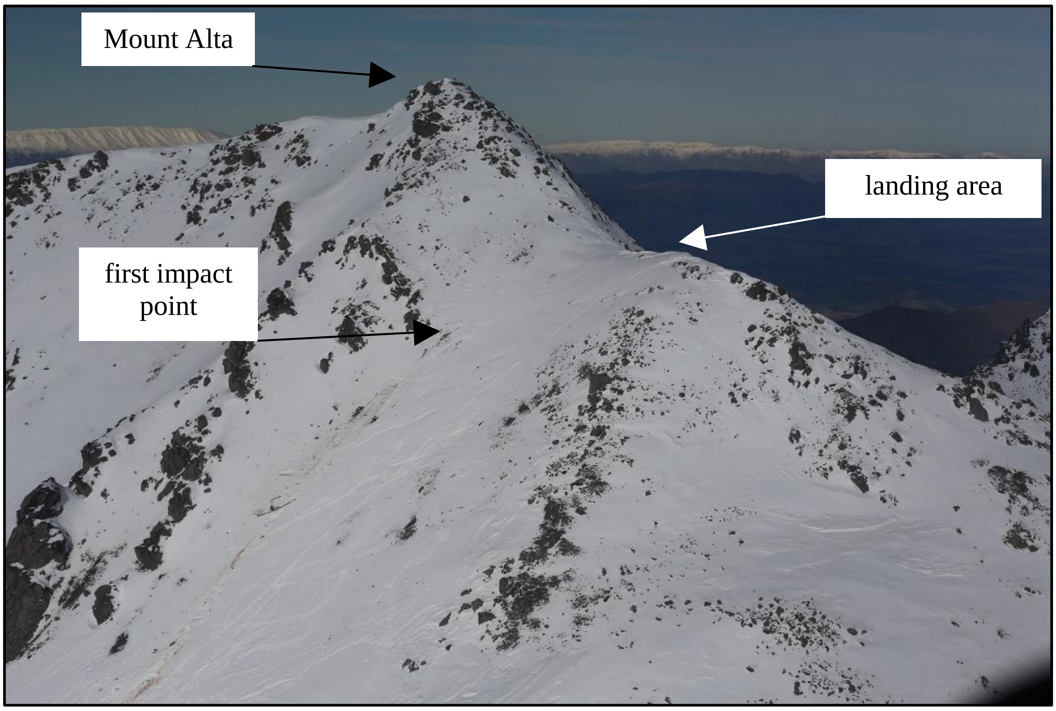

Figure 2
Mount Alta looking southeast in the direction of the landing approach

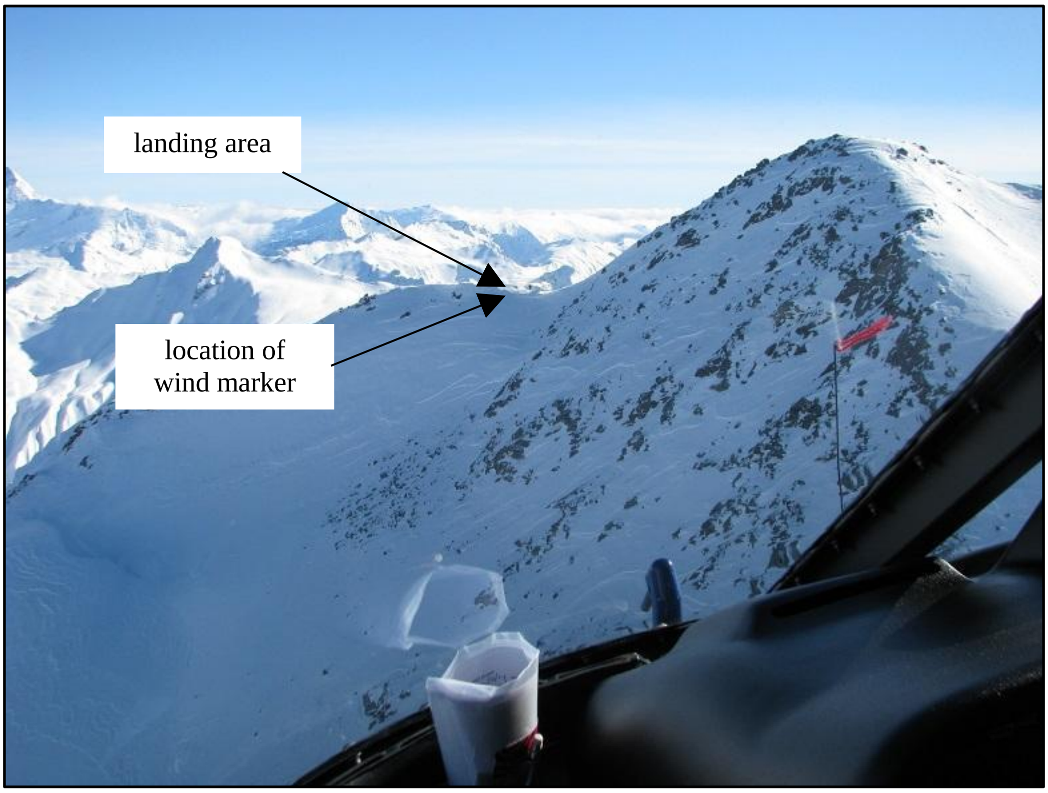

Figure 3
Mount Alta looking northwest

3.1.13. The pilot said he made a relatively shallow approach to the landing site. His last check of the engine torque gauge showed a power demand that he thought was appropriate for an approach at that altitude.[7] At a point the pilot later estimated to have been 10 to 20 metres (m) from the landing site, he noticed that the helicopter's rate of descent had increased; he described it as "a bit of a sink". The pilot raised the collective lever slightly in an attempt to maintain his preferred approach angle. The guide recalled that the helicopter appeared to be "almost stopped" when it was about 30 m from the site and 2 to 3 m above it. At that point the pilot turned the helicopter left in the direction of his planned escape route and descended away from the ridgeline. The pilot said that as the helicopter turned downhill, he felt it sink rapidly and unexpectedly. Before he could take any action to arrest the descent the helicopter struck the side of the slope heavily.

3.1.14. The helicopter tumbled forward then rolled down the steep slope, coming to rest 315 m below the ridgeline. Five of the occupants were thrown from the fuselage as it rolled down the side of the mountain. One of the five passengers was trapped underneath the helicopter where it came to rest in an upright position. He had died from his injuries. The remaining two passengers were still restrained in their seats.

3.1.15. The guide had been restrained in his seat until the seatbelt attachment broke and he was thrown from the helicopter. He used his radio to call the guides of groups B and C and alert them to the accident. The pilot of another company helicopter in the area heard of the accident and initiated the operator's emergency plan by informing the operator's Queenstown base staff and calling a halt to all other heli-skiing operations. Meanwhile, one of the passengers who had been thrown clear of the helicopter found the aircraft's first aid kit and moved down the mountain providing first aid to the other occupants. The pilot of the second helicopter uplifted two of his group's guides and flew them to the ridgeline landing site, from

[7] The torque gauge is marked with a green arc up to 94% and a yellow 'caution' range between 94% and 100%. The pilot estimated the torque was 95% of the green arc, or approximately 89% torque.

where they descended the mountain, assessed the condition of the injured and assisted where possible.

3.1.16. During the next hour emergency helicopters with medical personnel arrived on the scene. The more severely injured were winched off the mountain and flown to hospital in Dunedin. Others were taken to Wanaka for treatment.

3.2. Site examination

3.2.1. The accident site was on the northern slope of Mount Alta, 25 kilometres (km) northwest of Wanaka. The mountain summit was at 2,339 m (7,674 feet) and the intended landing site was on a ridgeline of a shoulder extending to the west of the peak at about 2,300 m (7,545 feet). The landing site was on a flat section of the ridgeline and was identified by a wind marker, a cane pole with an orange ribbon tied to it. The marker was located on the southern side of the ridgeline, still visible but below the crest of a small snowbank. The flat section of the ridgeline was long enough for up to three helicopters to land at the same time (see Figure 4).

3.2.2. The landing site and main slopes were covered in snow, but exposed rock was visible about the summit and on some of the steeper slopes. The ground sloped steeply away from the landing area on both sides. The northern face was the one down which the group intended to snowboard or ski and where the helicopter struck. It had an initial slope of about 35°, reducing to about 30° further down the mountain.

3.2.3. The first impact mark was a cut through the snow about 20 m below and 47 m from the intended landing site. The cut extended for several metres and was adjacent to a flattened or compressed area of snow and rock. Paint transfer was found on some of the exposed rocks in this area. The shape of the cut suggested that one of the helicopter's skids had struck first. The confused nature of the following marks in the snow and the paint transfer marks on the rocks were consistent with the fuselage having started to tumble immediately after the first impact.

3.2.4. The main rotor assembly, including the transmission and three main rotor blades, was found a further 45 m along the wreckage trail. The number and pattern of rotor blade strikes in the snow and on the exposed rock were consistent with the main rotor blades having been turning at high speed (see Figure 5).

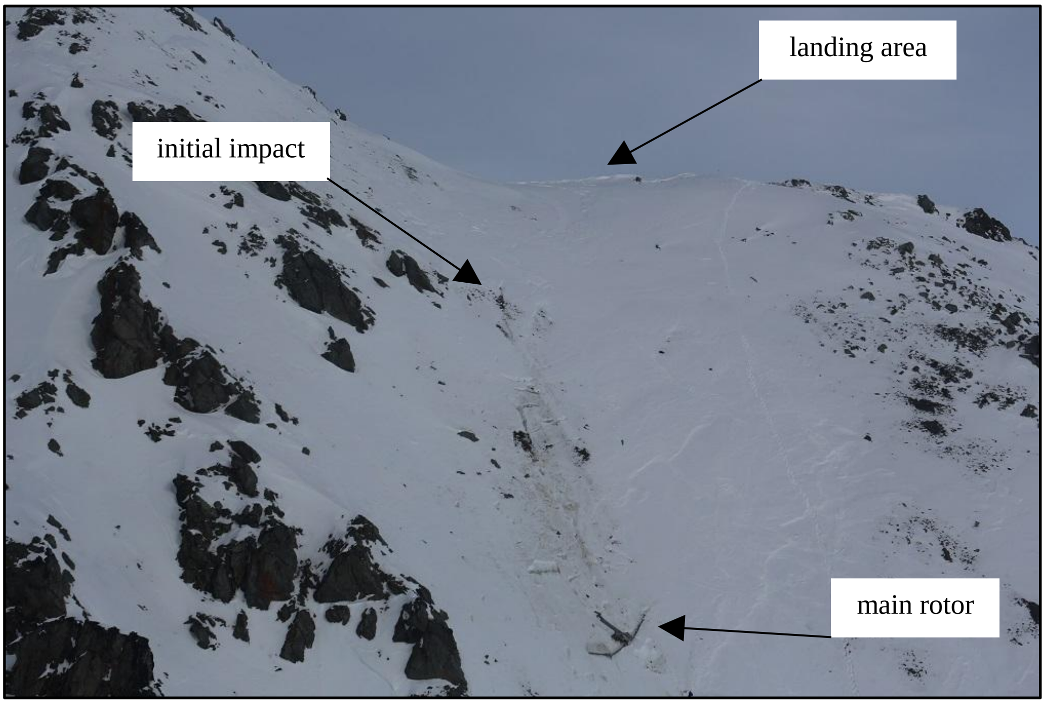

Figure 4
Initial impact site

3.2.5. The engine and part of the left skid were found about 35 m further down the slope. The tail boom had separated from the fuselage and was found approximately 35 m from the engine, but about 20 m to the right of the path taken by the fuselage. The tail rotor guard had been bent upwards but there was little damage to the tail rotor assembly.

3.2.6. Marks in the snow showed that the fuselage had rolled at least 25 times before coming to rest about 300 m below the first impact point. The direction of roll was to the left.[8] The ski basket, with its contents still secured inside, was found a further 300 m down the slope.

3.2.7. The fuselage had come to rest upright. The deceased passenger was found outside the fuselage, partially trapped underneath the right side of the helicopter belly. This was on the uphill side of the fuselage.

[8] As viewed from the normal seated position.

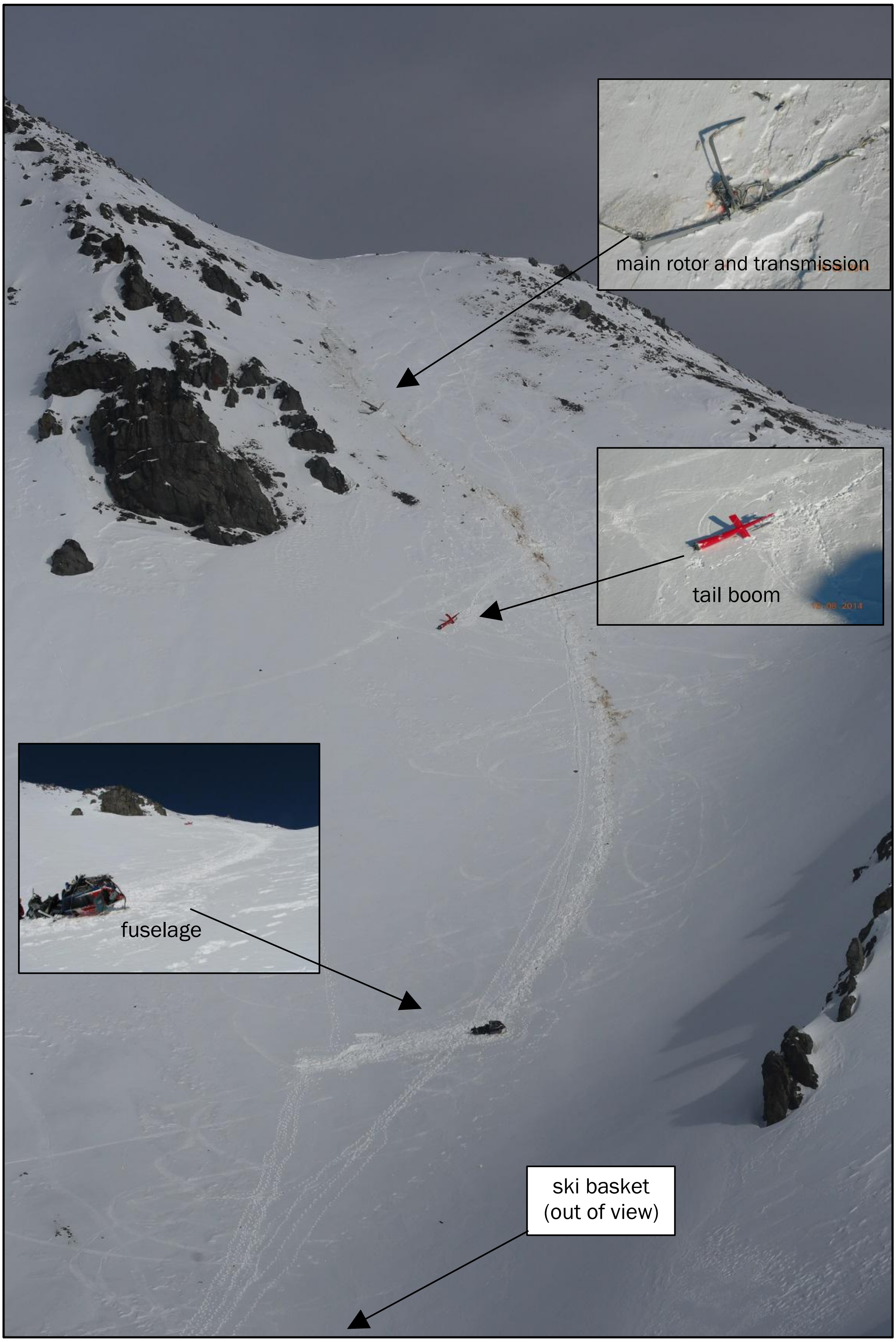

Figure 5
Accident site – general

Wreckage examination

3.2.8. The structure around the cabin, including all the doors, roof and nose cowling, had separated, exposing the seats (see Figure 5). The instrument panel had broken from its mounting but remained attached by wiring. Both skids had broken in several locations. The fuel tank was intact but a small amount of fuel was found leaking from the fuel line leading to the engine. The emergency locator transmitter had activated but the cable leading to the aerial had broken as a result of the tail boom separating. The emergency locator transmitter was reported to have been turned off soon after rescue personnel arrived on-site.

3.2.9. The aircraft seats remained attached to the aircraft with their cushions in place. The pilot's seat back had broken but was retained by both shoulder straps that ran through guides on the back of the seat. The back of the dual front seat was bent rearwards about 15° and the rear bench seat was deformed in several places.

3.2.10. With the exception of two passengers having released themselves from their seats, there was no other known disturbance of the seatbelts before the arrival of the Commission's investigators. Four seatbelts were found released, while the seatbelts for the pilot and a rear-seat passenger remained buckled. The metal tube framing that held the attachment for the front outboard passenger seat[9] was broken. The missing left lap belt was found a short distance up the slope along the wreckage trail.

3.2.11. The inertia reel units for the shoulder straps of all seven seatbelts functioned after the accident as intended. The lap belts for the passengers were found extended to varying degrees, with some at near-full extension. The pilot's lap belts were found in a position consistent with the belts being firm around the pilot's lap. (See paragraphs 3.3.6 and 4.6.4–4.6.11 for a fuller description of the seatbelts.)

3.2.12. After the initial site examination, the wreckage was removed to an assembly area, where the remaining fuel was removed and weighed. A sample of the fuel was clean and of the correct type for the engine. No fuel problems were reported by other users of the same fuel stock.

3.2.13. The ski basket and its contents of skis and snowboards were examined and weighed. The wreckage was then transported to the Commission's technical facility in Wellington for more detailed examination.

3.2.14. All major components of the helicopter were accounted for and matched with logbook part descriptions and serial numbers. No useful engine instrument readings could be obtained.

3.2.15. The continuity and correct operation of the main rotor cyclic[10] and collective controls were confirmed from the pilot's controls to the engine deck, where the connections to the main rotor had separated during the accident sequence. Correct tail rotor control functionality was confirmed from the tail rotor pedals to where the tail boom had separated from the fuselage, and from that point to the tail rotor.

3.2.16. The outer section of each main rotor blade displayed damage that indicated the main rotor had been operating at high speed when it struck the slope. The three arms of the Starflex main rotor head displayed rotational damage. The arms of the yellow and blue blades were fractured but the blades remained attached to the hub.[11] The attachment for the red blade had fractured but not separated. The direction of the fractures was consistent with the blades having been under power at the time of impact.

[9] The seat occupied by the guide.
[10] A flight control used by a pilot to manage the attitude of the disc (main rotor blades) to control the direction and speed of a helicopter.
[11] For ease of identification the manufacturer colour coded the three main rotor blades yellow, blue and red.

3.2.17. The drive shaft and coupling tube that connected the engine to the main transmission had separated at the two flexible couplings. Scoring on the inside of the coupling tube was consistent with the engine having continued to rotate the drive shaft as the engine and transmission separated from the fuselage. The damage to the flexible couplings was consistent with this sequence and showed that the engine had continued to drive the freewheeling assembly[12] as the helicopter started to disintegrate.

Engine investigation

3.2.18. The engine was shipped to the engine manufacturer's facility in Sydney, Australia for detailed examination under the supervision of the Accredited Representative for Australia, on behalf of the Commission.

3.2.19. A condensed version of the report prepared by the Australian Accredited Representative is in Appendix 1. The examination determined the following:

- it was concluded that the engine was operating and capable of normal operation
- the misalignment of the drive shaft was indicative of an engine delivering power at the time the helicopter struck the ridgeline. This movement of the drive shaft was associated with a torque spike attributed to power-train shock loads generated from a main rotor system strike.

3.3. Aircraft information

3.3.1. ZK-HYO was a Eurocopter AS350-B2 helicopter, serial number 3885, manufactured in November 2004. Also known as the Écureuil or Squirrel, the AS350 was first developed by Aérospatiale of France in 1974. The B2 was powered by one Arriel 1D1 engine and was a higher-gross-weight version of the original B1 model.

3.3.2. The helicopter had been imported to New Zealand from the United States in April 2014 and given the registration ZK-HYO. For the helicopter to be issued with a New Zealand airworthiness certificate, the CAA had directed the owner to complete the certification requirements prescribed by Civil Aviation Rules.[13] The requirements had included, among other things, the completion of a 100-hour inspection in accordance with the manufacturer's maintenance schedule, and an inspection of the helicopter and associated documents by a CAA airworthiness inspector. The helicopter's documentation recorded that the required maintenance actions had been completed.

3.3.3. Additional work requested by the operator had included the fitting of a dual front seat,[14] a guard for the collective lever and attachments for a ski basket on the left side of the helicopter. These had been fitted in accordance with the relevant supplemental type certificate requirements. The helicopter had been repainted and its empty weight and balance determined.

3.3.4. One of the operator's senior pilots had completed a maintenance check flight on 5 August 2014 and had considered that the helicopter performed satisfactorily. On 15 August 2014 the helicopter had been issued with an airworthiness certificate in the Standard Category and placed on the operator's Operations Specifications. At this time the helicopter had been recorded as having accrued a total of 3,214.7 flight hours.

3.3.5. The engine, serial number 9517, had entered service in May 1997 and been installed in the helicopter in April 2009. It had accrued a total of 6,788.1 hours.

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[12] An assembly within the drive train that allows the main and tail rotors to continue to rotate should there be a power interruption.
[13] Specifically, Civil Aviation Rules Part 21, Certification of Products and Parts, paragraph 21.191.
[14] The seat fitted was a Dart Aerospace seat, which did not have a weight limit. Other dual seat types used by the operator were restricted to 154 kg.

3.3.6. The front seats consisted of the pilot's seat on the right side and a dual seat on the left side, each position with a four-point harness (lap belt and two shoulder straps) and a single inertia reel for the shoulder straps. The four rear seats each had a three-point harness (lap belt and one shoulder strap) and an inertia reel. The six passenger seats were fitted with the standard 'airline' type buckle, which required a flap to be lifted to release it. To release the pilot's harness, a locking mechanism on the buckle had to be lifted before the buckle was rotated to release the straps.

Weight and balance

3.3.7. The helicopter had a maximum certified take-off weight of 2,500 kg, but was limited to 2,250 kg when the load was carried internally. At 2,250 kg the allowable centre of gravity range was between 3.210 m and 3.425 m aft of datum.[15]

3.3.8. The helicopter's basic (empty) weight, determined on 2 August 2014, was 1,326.95 kg,[16] with a centre of gravity 3.604 m aft of datum.

3.3.9. See paragraphs 4.3.6–4.3.23 for a detailed examination of the weight and balance for the accident flight.

3.4. The pilot

3.4.1. The pilot had completed his initial helicopter training in Australia and obtained his Australian commercial pilot licence (helicopter) in November 2002. He had obtained grade 2 and grade 1 instructor qualifications in 2003 and 2004 respectively.[17] In November 2005 the pilot had been issued with a New Zealand commercial pilot licence (helicopter). He had joined the operator in December 2007 as a full-time line pilot.

3.4.2. At the time of the accident the pilot had accrued 4,176 hours flying helicopters, including about 605 hours in the AS350. He had also flown 1,493 hours in the AS355 helicopter, a twin-engine version of the AS350. His previous annual competency check flight had been flown on 1 May 2014 and he had passed the associated theory examination the following day.

3.4.3. The pilot held a current Class 1 medical certificate valid until April 2015. A requirement of his medical certificate was that he wear distance-vision spectacles. At the time of the accident the pilot was wearing his prescription glasses. The glasses were tinted to help protect against bright light. The pilot said that he had slept well the night before the accident and was not suffering from any illness or fatigue. In accordance with the operator's procedures, blood and urine samples were taken from him after the accident. These were found to be negative for any performance-impairing substances.

3.4.4. A review of the pilot's activities in the seven days leading up to the accident identified nothing of note. He had had two rostered days off but had otherwise averaged eight-hour working days. He had flown a total of 4.3 hours in the preceding three days. The remainder of his time had been spent undertaking his additional duties as the operator's quality assurance officer, a position he had held since September 2010.

3.4.5. According to the pilot's logbook and the operator's records, the pilot had been first considered for heli-skiing flights in July 2011. The pilot had completed the operator's ground training and then undergone an assessment flight, after which it had been determined that he did not meet the operator's required standards for heli-skiing flying. During the assessment flight the instructor had not been comfortable with the pilot's approaches and considered that he

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[15] Effectively the nose of the helicopter. Datum is a reference point on an aircraft used to calculate centres of gravity. The point may vary between different aircraft types.
[16] Includes unusable fuel, fixed ballast, full operating fluids (oils) and 'equipment list' items, for example first aid kit, fire extinguisher, collective guard and the dual front seat.
[17] These Australian qualifications were equivalent to New Zealand Category B and Category A instructor qualifications respectively.

needed more training before he flew heli-skiing operations, and that he needed to be re-evaluated for heli-skiing in the future. The operator had deferred further heli-ski training for the pilot until the 2012 season, so he had continued with his normal flying duties, accruing a further 290 hours of flying time.

3.4.6. On 2 May 2012, before the start of the heli-skiing season, the pilot had completed a one-hour heli-skiing training flight and assessment with the same instructor who had assessed him in the previous season. The instructor recommended that the pilot work on aspects of his flight skills and be reassessed in one month's time. On 7 June 2012 the pilot completed a further 1.6-hour training and assessment flight with the same instructor. The instructor considered that the pilot was flying safely and conservatively and recommended that he commence heli-skiing operations under supervision and with restrictions. The pilot repeated the ground training syllabus and was approved for heli-skiing operations with restrictions. The restrictions included:

- being under supervision
- being limited to the Motatapu Ridge, Black Peak and Fog Peak A trails
- a marker stake was to be present at each of the landing sites
- he was to be briefed on avalanche terrain and where to park the helicopter safely.

3.4.7. The operator's records showed that the pilot had completed the avalanche safety training on 3 July 2012. He had then flown a total of 29 hours on heli-skiing operations during the 2012 heli-skiing season, under the supervision of the operator's senior heli-skiing pilots. On 30 June 2013, at the start of the 2013 heli-skiing season, the pilot had been approved as a Category A pilot.[18] The pilot had then flown a total of 25 hours on heli-skiing operations during the 2013 winter season. At the time of the accident he had accrued approximately 69 hours on heli-skiing operations in the Queenstown and Wanaka areas. His logbook recorded that he had most recently landed at the Mount Alta landing site on 26 July 2014, three weeks before the accident.[19]

3.4.8. The operator advised that, unless otherwise stated, the appointment to Category A pilot removed any previous restrictions, including any restrictions for heli-skiing. The document approving the pilot as a Category A pilot had been signed off by the instructor and the chief pilot. There were no records of the processes that management had followed prior to the appointment of the pilot as a Category A pilot.

3.4.9. Notwithstanding the absence of documentation on the decision to upgrade the pilot, the operator considered that the pilot met its standards of a Category A pilot and could therefore fly without landing site restrictions.

3.5. Meteorological information

3.5.1. On the day of the accident a large anticyclone covered the Tasman Sea with a ridge extending over the South Island.

3.5.2. The aviation forecast for the area that included Mount Alta was for wind from the southwest at 10 knots (19 km per hour), increasing to 25 knots (46 km per hour) at 10,000 feet (3,050 m). The freezing level was forecast to be 6,000 feet (1,830 m) and the temperature at 7,000 feet (2,135 m) to be -1° Celsius. The visibility was forecast to be 30 km, reducing to 2 km in early-morning fog. Any low-level cloud was forecast to clear by late morning.

3.5.3. Witnesses said that the weather on the morning of the accident had been frosty and fine. At a weather station near the Treble Cone ski field, 17 km south of Mount Alta, the temperature at an elevation of 2,300 feet (700 m) was 9° Celsius at midday. Other pilots who had been flying in the general area of the accident site reported generally calm conditions with the occasional

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[18] A pilot authorised to act as pilot in command on any flight, unless a specific restriction is applied.
[19] The nature of heli-skiing meant that it was likely the pilot had landed on Mount Alta several times that day.

light breeze from the southwest. A pilot of one of the helicopters involved in the rescue said that as he approached the landing site from the north he had felt "a puff of wind from behind".

3.6. Organisational and management information

3.6.1. The operator had been established in 1986 with the amalgamation of three helicopter companies, each with extensive alpine flying experience in the South Island. The operator's principal base of operations was Queenstown, with additional bases at Glentanner in Mount Cook National Park, Franz Josef Glacier and Fox Glacier. The operator held a Civil Aviation Rules Part 119 Air Operator's Certificate for Part 135 domestic helicopter operations involving the carriage of passengers and goods, including to remote areas.

3.6.2. At the time of the accident the operator had a fleet of 19 AS350 helicopters, which it considered was the most suitable type for the range of operations flown in the mountains.

3.6.3. The operator appointed 'lead pilots' for each of the bases, but pilot training and competency, and quality assurance requirements were managed from the Queenstown base. Both the operations manager[20] and the chief pilot (training and competency manager) would visit all bases as required. The operator's full-time pilots were paid salaries and part-time pilots paid a daily rate.

3.6.4. The operator and heli-ski provider were owned by the same parent company but operated as separate commercial identities. The heli-ski provider promoted the heli-skiing element of the business, managed the bookings and provided experienced guides for each group. It had an arrangement with the operator to provide helicopter support in the field. Before the start of each season the operator and heli-ski provider ran combined training sessions that lasted up to two days.

3.6.5. The operator advised that in preparation for the 2014 heli-skiing season, available staff from both companies had attended this training on 28 and 29 June 2014. The training had included a review of the lessons learnt in the previous season, but its main purpose had been to recertify some guides in first aid and helicopter loading, and to provide refresher training in transceiver use, avalanche awareness, and search and rescue. Those involved in heli-skiing who had not been able to attend had been briefed and recertified at a later date. It had not been a requirement for the pilot to attend this training and he had already received training in avalanche awareness and transceiver use.

CAA auditing

3.6.6. As a routine part of the investigation the Commission reviewed the CAA's documents relating to the pilot, aircraft and operator.

3.6.7. In July 2013 the CAA had undertaken a five-yearly recertification audit of the operator prior to the renewal of the operator's Part 119 Air Operator's Certificate. The audit team had made no adverse findings. The audit report stated that senior staff and operational procedures were maintaining "high levels of operational safety". The audit report also stated that a review of the CAA database "shows no significant safety issues or trends indicating systemic problems". The certificate had been renewed on 16 October 2013.

3.6.8. Between the renewal of its Air Operator's Certificate and August 2014, the operator had had two accidents involving its helicopters. On 28 October 2013, while approaching to land on a snowfield near Mount Tyndall, a helicopter had collided with another helicopter that had

[20] At the time of the accident the operations manager also performed the functions of the general manager.

already landed. The airborne helicopter had then become uncontrollable and crashed. The pilot had been seriously injured, and the passengers had received minor injuries.[21]

3.6.9. On 9 January 2014 a pilot from the operator's Glentanner base had been on a local scenic flight when he had reportedly experienced a loss of surface definition while landing on Richardson Glacier. The helicopter had been moving sideways as it touched down, and rolled onto its side. There had been no injuries.[22] During the recovery of the helicopter, a second helicopter's tail rotor guard had touched the snow while landing.[23] There had been no damage.

3.6.10. On 30 May 2014, following the 9 January 2014 accident, two CAA staff had conducted a 'risk assessment' of the operator. The risk assessment had been a desk-based exercise that assessed the operator against predefined risk areas, and provided a grading of low, medium or high risk for each area. Its purpose had been to guide auditors on areas on which to focus during scheduled on-site audits.

3.6.11. The risk assessment was amended following the Mount Alta accident. The risk assessment identified that the operator potentially fitted a 'medium' risk profile in the following areas:

- organisational profile
- people profile
- incident and safety profile
- specific group or unit safety initiatives
- types of operation and other risks.

3.6.12. The risk profile generated as part of the assessment placed the operator in "the lowest of the CAA risk assessment bands for this document type", based on the overall assessment of the risk indicators.

3.6.13. On-site audits of the operator's Queenstown, Pūkaki and Glentanner bases were undertaken in October 2014. The auditors made the following comments:

- management structure had been reviewed and reporting lines clarified
- the company had lost focus due to the diversity of the operation
- although induction training was to a high standard, recurrent training was not following procedures
- the company's written procedures for mountain recurrent training were weak
- a new training manager had recently been appointed and information and procedures were to be incorporated in the next exposition review, and follow the guidelines in AC 119-3 (Mountain Training)[24]
- the company lead pilot was questioned on his responsibilities with reference to maintenance activities, and was not as knowledgeable as expected. Actions raised included that pilots be retrained on a regular basis.

3.6.14. While the auditors made some adverse comments, the routine audit programme for the operator was not altered as a result of the risk assessment or the audit. The auditors also concluded that planned routine audits of the West Coast bases would be an opportunity to

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[21] Final Report AO-2013-010, Aérospatiale AS350B2 ZK-IMJ, collision with second helicopter, Tyndall Glacier, 28 October 2013.
[22] CAA incident report 14/52, AS350BA ZK-HKR, Richardson Glacier on 9 January 2014.
[23] Extract from CAA Surveillance Risk Assessment Form.
[24] Advisory Circular for operations involving helicopters and small aeroplanes (Part 135).

further review the effectiveness of the proposed management changes, exposition changes and pilot maintenance knowledge.

3.6.15. A subsequent Safety Audit Report generated for the operator in April 2015 found no instances of non-compliance with Civil Aviation Rules.

4. Analysis

4.1. Introduction

4.1.1. The accident occurred on the pilot's seventh flight for the day, the fourth heli-skiing flight. The previous three heli-skiing flights had been without incident. The pilot was in good health and there was no indication of any personal or medical issues that might have contributed to the accident.

4.1.2. The weather conditions were suitable for the flight.

4.1.3. The intended landing site was one of many in the area used by the operator and could be approached from several directions. The site was large enough to land up to three helicopters simultaneously if required. The pilot had landed there before. It was considered suitable for the conditions on the day.

4.1.4. The pilot said that he had been unable to maintain his intended angle of approach to the landing site, so he had elected to follow his escape path down the mountain slope. However, he had been unable to prevent the helicopter descending rapidly and it struck the slope heavily.

4.1.5. The following analysis considers whether any of the following factors affected the intended flight path or contributed to the escape manoeuvre being unsuccessful:

- the helicopter encountered 'sinking air'
- engine performance
- the helicopter performance at the altitude of the landing site
- a phenomenon known as vortex ring state[25]
- pre-flight planning
- any combination of these factors.

4.1.6. The analysis also discusses two safety issues and a potential third safety issue:

- the operator's standard operating procedures did not require its pilots to routinely calculate the performance capabilities of their helicopters for the intended flights
- there was a risk of not knowing an aircraft's capability when using standard passenger weights, and therefore of pilots operating close to the limits of their aircraft's performance
- some New Zealand helicopter pilots may have a culture of operating their aircraft beyond the manufacturers' published and placarded limits, with the possibility that such a culture has become normalised.

4.2. What happened

4.2.1. When planning an approach and landing, a pilot needs to consider numerous factors to ensure that the manoeuvre is as safe as possible, especially when landing at a new or restrictive landing site. For helicopter pilots many of these considerations are encapsulated in what is termed 'the Seven S's': size, shape, slope, surface, surrounds, sun and select (the landing spot) (Civil Aviation Safety Authority [Australia], 2012). The specifics of each are described in Appendix 2. A pilot also needs to consider the wind conditions as part of the process.

4.2.2. Having taken all the factors into account, a pilot will determine the best approach path and where the termination point – hover or landing – will be. The approach direction will

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[25] See paragraphs 4.3.36–4.3.47 for an explanation of and discussion on vortex ring state.

preferably be into the prevailing wind. This minimises the power required during the approach, helps a pilot to avoid flying in the helicopter's own downwash and gives them time to manage the approach and terminate in a hover or landing. The approach angle is also crucial. If it is too shallow or steep there may be insufficient power available to transition to the hover. When landing in a mountainous area, the approach angle should also be above the 'demarcation' line where the wind changes from an updraught to a downdraught and where turbulence can be present.

4.2.3. A pilot should always have an escape route available in the event that something goes wrong, for example having insufficient power to complete an approach safely. For a pinnacle or ridgeline landing, the escape path may simply be to turn away from the high ground. For a helicopter such as the AS350, with a main rotor that turns clockwise,[26] a turn to the left may be preferable.[27] A turn using left pedal requires less power than a right turn using right pedal, and therefore more power would be available to the main rotor to generate rotor thrust or lift.

4.2.4. The power required to perform a manoeuvre, for example a hover, increases as density altitude[28] or weight increases. There is a point where the power required exceeds the power available. This will determine how an approach is flown and a landing made. For example, there may be insufficient power available to terminate in a high or 'out of ground effect'[29] hover. The pilot may therefore have to terminate in a low or 'in ground effect' hover, or land without hovering at all. This is discussed in more detail in section 4.3.

4.2.5. The pilot needed to know the total weight of the helicopter and to confirm that it had the performance capability to land at the site. He also needed to assess the wind and temperature as accurately as possible. The variable light wind and obscured marker flag made it difficult initially for the pilot to choose the best approach direction.

4.2.6. The pilot said that as the helicopter was approaching to land, he had detected a slight sink that put the helicopter below his intended approach path. He had raised the collective lever slightly to increase the rotor thrust in an attempt to regain the desired approach profile. The pilot had then decided that he could not achieve the landing site so he had turned the helicopter to the left, his planned escape path, to fly away from the high ground and down the northern face of the mountain. However, the pilot said the rate of descent had then increased rapidly and unexpectedly.

4.2.7. The helicopter struck the steep slope heavily in a nose-down attitude. The right skid collapsed under the force of the impact and the belly of the helicopter struck the slope. The markings made in the snow indicated that this was likely followed by the tail rotor guard hitting the ground and the helicopter pitching forward. When the main rotor struck the slope this caused the helicopter to roll down the slope. Five of the occupants were thrown from the helicopter as it rolled 300 m down the mountain.

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[26] Direction viewed from above.
[27] Because the main rotor rotates clockwise, the fuselage reacts by wanting to rotate anticlockwise. Right pedal input is therefore required to counter this torque effect and keep the helicopter straight, which requires additional engine power.
[28] The pressure altitude corrected for any temperature difference from the temperature at that altitude in the International Standard Atmosphere.
[29] A helicopter is 'in ground effect' when the downwash from the main rotor strikes the surface, stopping the downward wash and generating an increase in pressure, effectively a cushion of air that reduces the power required to maintain position. The effect reduces as the helicopter moves higher, meaning more power will be required. At a height equivalent to the distance of half to one rotor diameter, the effect is considered to be nil and the helicopter is said to be 'out of ground effect'.

4.3. Factors affecting the flight path

Sinking air

4.3.1. It is unlikely that the helicopter encountered sinking air on the approach to land. There was little or no wind reported and therefore neither turbulence nor downdraughts were considered to have been a contributing factor. However, variable wind conditions can be encountered in the mountains. Therefore, the possibility of the helicopter encountering downdraughts or sinking air could not be totally excluded.

4.3.2. In calm, sunny conditions, differential heating causes updraughts. A steep slope exposed to the sun will heat up more than one that is not similarly exposed. The heated air adjacent to the slope rises and generates an upslope wind called an anabatic wind. Local paragliding pilots interviewed for the investigation advised that even in winter they had experienced anabatic wind off snow-covered slopes. The wind would normally be light in strength and would quickly dissipate as the afternoon progressed.

4.3.3. At the time of the accident the northern slopes of Mount Alta would have been facing directly towards the sun. The approach was being made from the side of the northern slope of Mount Alta, making it more likely that the air mass would be rising up the slope over which the pilot had chosen his escape path. On the approach to land the helicopter was unlikely to have encountered sinking air.

Engine performance

4.3.4. The possibility of a sudden power loss was examined in detail and discounted as a cause of the accident for a number of reasons. First, the pilot said there had been no power loss or engine problem and neither the pilot nor the guide, who was also on headset and familiar with helicopters, reported seeing or hearing any low engine or rotor RPM (revolutions per minute) warning indications.[30] This was supported by other witnesses who indicated that the helicopter had been performing normally as it approached the intended landing area.

4.3.5. Secondly, rotor strike marks on the slope and the damage to the main rotor blades and Starflex main rotor head were consistent with the blades rotating at high speed when they struck the slope. They were also consistent with the main rotor being driven by the engine when it struck the slope. Thirdly, the witness marks on the engine's fifth-stage module confirmed that the engine had been delivering power and, given the degree of misalignment, probably high power, at the time the helicopter struck the slope. Fourthly, the scoring marks on the inside of the coupling tube showed that the engine had still been driving the main rotor transmission as the helicopter tumbled down the hillside. Finally, there was no pre-existing fault found and the damage sustained by the engine was consistent with the impact sequence.

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[30] A constant aural warning horn and associated warning light will activate when main rotor RPM reduces below the normal operating range. A sudden engine failure will also result in a sudden yawing of the helicopter and a range of other instrument warning indications.

Weight and balance

Safety issue – the operator's standard operating procedures did not require its pilots to routinely calculate the performance capabilities of their helicopters for the intended flights.

Safety issue – there was a risk of not knowing an aircraft's capability when using standard passenger weights, and therefore of pilots operating close to the limits of their aircraft's performance.

4.3.6. The Commission determined that at the time of the accident the helicopter was over its maximum permitted weight by approximately 30 kg, and the longitudinal centre of gravity for the helicopter was about 3.0 centimetres (cm) forward of the limit.

4.3.7. To ensure that an aircraft is flown within its design limits, Civil Aviation Rule 135.303 requires an operator to establish the weight of the crew, passengers and baggage or goods for each flight (CAA, 2007). A weight and balance check is to be completed to determine an aircraft's weight and centre of gravity for the flight, and to provide a basis for performance calculations. The weight of the passengers can be determined using one of three options:

1. The operator conducts a survey to establish a standard passenger weight.
2. The operator uses a passenger's declared weight with 4 kg added to allow for the tendency of people to underestimate their weight.
3. The operator weighs each passenger.

4.3.8. The CAA issued an Advisory Circular (CAA, 2005) detailing the procedure an operator had to undertake in order to establish a standard passenger weight. The operator had undertaken a passenger weight survey in 2010, which resulted in an average passenger weight of 76.57 kg. This was rounded up to 80 kg to provide a more conservative and easier-to-use figure. The standard passenger weight of 80 kg was used for calculating helicopter weight and balance for most (tourist) trips.

4.3.9. The Advisory Circular made the point that "there is no relief provided in the Civil Aviation Rules for an aircraft to operate overweight when using standard passenger weights". Civil Aviation Rules also require air operators to adhere to the limitations set by the aircraft manufacturers.

4.3.10. For weight and balance calculations, the operator's pilots could use the weight and balance calculator,[31] which included the details for each helicopter, or use the operator's standard loading plan. However, the helicopter was new to the fleet and this was the first day the operator had used it for commercial operations. The operator had not yet entered the helicopter's weight and balance details into the calculator database. This would have been unlikely to make any difference on the day of this accident because the operator's pilots normally used the standard loading configuration based on standard passenger weights instead. Nevertheless, the weight and balance details should have been loaded into the calculator to allow the pilot the option of using it, particularly as the helicopter was new to the fleet.

4.3.11. The operator's procedures contained within its exposition[32] stated that: "A Weight & Balance Calculation is NOT required for any flight that is loaded in compliance with a standard loading plan authorised by Ops Procedures 9.1". The standard loading plan form described a range of passenger combinations and guidance information. For example, when there were two people in the dual front seat the form stated, "the smallest person of all the passengers

[31] A computer program usable for all of the operator's helicopters. A pilot or designated person would enter the weight of each seat occupant, the fuel load and any cargo to determine the helicopter's all-up weight and centre-of-gravity position. Alerts would be generated if the program calculated that the helicopter was outside any flight manual weight and balance limit.
[32] The Helicopter Line Operations Manual 9.1, dated June 2014.

present should be located in the inboard position". This would help to ensure that: any weight limit for the dual front seat was not exceeded; the helicopter's centre of gravity was within allowable limits; and the passenger's right arm was less likely to interfere with the pilot's use of the collective lever located between the two seats.[33] The surveyed exposition weight of 80 kg was to be used for each adult, with lesser weights used for children and infants.

4.3.12. The standard loading plan applied to the majority of the operator's scenic operations. For specialised activities, such as heli-rafting, heli-biking and heli-skiing, pilots were directed to the weight and balance calculator's 'Frequent Unique Activities' page.[34] The page contained standard loading configurations, which used a range of assumptions for each of these activities. However, in June 2014, before the commencement of the heli-ski season, the operator had issued an Operations Notice that took precedence. This notice described the standard empty weight configuration for heli-ski flights and included standard pilot and passenger weights (95 and 80 kg respectively), 20% fuel load, 4 kg in the boot locker, no survival bags,[35] 10 kg for empty lunch containers in the boot and the heaviest ski basket containing 42 kg of ski equipment, an 8 kg guide pack and 2 kg for other client gear.

4.3.13. The Commission calculated the helicopter's take-off weight and balance for the accident trip using each of the three options referred to in paragraph 4.3.7. A fuel load of 50% (270 litres weighing 216 kg) was used for each of the calculations. This was based on the pilot having refuelled the helicopter to nearly 60% before loading group C and flying them to the top of Tony's Run, then descending and loading group A.

4.3.14. Using standard passenger weights. In the operator's Operations Notice 261 for heli-skiing the following figures are used: 480 kg for the six passengers, 95 kg for the pilot and 4 kg for the pilot's bag. For the lunch containers, 20 kg was used as the clients had yet to eat lunch. The heaviest ski basket at 43 kg contained a total of 52 kg of ski equipment and bags. This gave a total weight of 2,237 kg on the accident flight, 13 kg less than the maximum allowed 2,250 kg. The centre of gravity was calculated to be at the forward limit of 3.210 m.

4.3.15. The pilot's use of declared passenger weights. For the accident flight the pilot assumed that the five passengers weighed an average of 85 kg, which was based on his observation of the group and a discussion with one of the passengers. The pilot did not add the 4 kg allowance that was required, because he thought 85 kg was a good approximation.[36] The pilot recalled that the weight of the guide had been 78 kg and allowed 95 kg for the ski basket and equipment and 20 kg for the lunches in the baggage compartment. The pilot had known his own weight to be 80 kg with another 5 kg for his bag. The take-off weight for these conditions had been calculated as 2,246 kg, 4 kg under the maximum permissible weight, and the centre of gravity at the forward limit. Had the pilot added the mandatory 4 kg to each declared passenger weight, he would also have had to reduce the fuel load for each flight in order to prevent the helicopter's weight exceeding the maximum permissible.

4.3.16. Estimated weight. The weights of the pilot, guide and passengers were obtained through interviews and medical records. The ski basket and contents were weighed soon after the accident. The pilot's weight was stated to be 80 kg. The combined weight of the guide, passengers and their gear was estimated to be 603 kg. The pilot's bag weighed 5 kg, there was 2 kg of gear in the left locker, and the ski basket weighed 36.5 kg. The lunches were

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[33] A collective guard also helped to reduce the possibility of interference.

[34] The operator's 'standard operating procedures' for heli-skiing also directed pilots to follow these loading procedures.

[35] Survival bags were not carried because all occupants wore warm clothing and there were other helicopters in the vicinity that would be able to render immediate assistance.

[36] CAA Advisory Circular AC 119-4 directed operators to determine a more indicative weight when a passenger's weight was "clearly greater than the exposition or standard weight". "The term 'clearly greater' refers to a passenger whose weight can be readily assessed as being over the applicable exposition or standard weight." To help describe this, the Advisory Circular used the example of a person being 34 kg over the standard weight, while for a person who weighed "less than 110 kg, the term 'clearly greater than' is not applicable and a more indicative weight is not necessary".

estimated to weigh 20 kg. With an estimated fuel load of 216 kg, the total weight of the helicopter at the start of the accident flight was estimated to have been 2,289.5 kg (about 39 kg more than the maximum permitted). At this weight, and using the known seating positions, the centre of gravity was determined to be up to 0.030 m (3.0 cm) ahead of the forward limit (see Appendix 3). The lateral centre of gravity was determined to be within the maximum permissible limits for each of the three calculations, at about 7.1 cm left of centre. The maximum distance allowed was 18 cm.

4.3.17. During the accident some passengers' ski apparel was contaminated with fuel and subsequently discarded by the passengers. Therefore the Commission weighed a range of commonly used skiing and snowboarding apparel and used these weights in its calculations. An allowance was added for personal items such as cameras, cell phones, snacks and water.

4.3.18. Allowing for about 9 kg of fuel used in the climb up Mount Alta, the weight of the helicopter as it approached the landing site was estimated to have been 2,280 kg, which would have been 30 kg over the maximum permitted weight.

4.3.19. Civil Aviation Rules allow the use of standard passenger weights, in recognition that it is not always practical for all helicopter operations to physically weigh every passenger carried. However, the rules are explicit that no aircraft should be flown outside permissible weight and balance limits, regardless of the method used to calculate weight and balance.

4.3.20. Heli-skiing is considered one of the riskiest types of helicopter passenger operation. It is conducted at high altitude in mountainous terrain, with the additional challenges that pilots face when landing in snow. Also, the helicopters are often being operated with loads that place them at the margins of their performance capabilities.

4.3.21. It is not difficult to weigh every passenger who is undertaking heli-skiing. Every passenger passes through some point where this could occur. It is also not difficult to provide pilots with devices that enable them to calculate accurately the weight and balance of their helicopters at any time in the field should that be required.

4.3.22. There was considerable risk in an operator using a standard loading configuration that assumed standard passenger weights for heli-skiing operations, particularly when two passengers were to occupy the dual front seat in the Squirrel helicopter. In this case the use of a standard loading configuration and weights was not appropriate because the passengers could be loaded in such a way that the helicopter was outside its weight and balance limits. This had been the situation for some time and was not recorded in CAA audits or the operator's own quality assurance processes. The same would have applied to any Squirrel helicopter similarly configured and loaded using standard weights.

4.3.23. The pilot attempted to manage the loading of his helicopter after he left the base. However, he had no means of weighing the passengers. Having changed his weight calculation from using a standard loading plan to using assessed weights, he was required to include the additional 4 kg for each passenger. Had he done so, he could have reduced his fuel load to keep the helicopter below the maximum all-up weight. However, it was never going to be possible for him to calculate the helicopter's longitudinal centre of gravity accurately without the aid of a weight and balance calculator. The risk of inadvertently exceeding the limits was therefore high.

Helicopter performance

4.3.24. The need for pilots to understand the performance capabilities of their aircraft is well known. The CAA comments in its Helicopter Performance publication:

> Take-off, landing and hovering are all potentially risky phases of helicopter flight. The more that we can do as pilots to minimise these risks – especially when operating at high gross weights, from challenging sites, with high density altitudes – the safer we will be.
>
> Most performance-related accidents can be prevented, provided that the pilot maintains a good awareness of the surrounding conditions, knows the performance limitations of the helicopter, always does a power check before committing to a marginal situation, and is disciplined enough to "give it away early" if the odds are stacking up against getting the job done safely (CAA, 2012, p. 33).

4.3.25. To determine accurately an aircraft's performance capability, it is necessary to know the total aircraft weight, the pressure altitude[37] and the air temperature before the intended take-off and landing. The pilot recognised that the helicopter would be heavy, but he did not estimate the total weight accurately. Therefore he would not have known accurately the combined effect of the total weight, the air temperature and the pressure altitude. The pilot noted that at some point the outside air temperature gauge in the helicopter was reading about 0ºC.[38]

4.3.26. A landing onto a site like that on Mount Alta is usually made after a steady descent, the steepness of which depends on the excess power available and the wind strength. The excess power, or power margin, decreases with increasing altitude or weight. It is good practice to check the power required before landing by flying at minimum power speed when in the vicinity of the landing site. However, the pilot did not check the power until he was on the final approach to the landing site. He considered that the power being demanded at that point was not "excessively high" for the conditions.

4.3.27. A pinnacle landing site such as Mount Alta would not offer the benefit of a true ground effect,[39] because the ground would slope away too steeply in all directions. Therefore operations at such a site should be planned on the basis of landing from an out-of-ground-effect hover, which requires more power.

4.3.28. The helicopter flight manual performance charts showed that at the maximum permissible weight of 2,250 kg and an air temperature of 0ºC the helicopter had an out-of-ground-effect hover capability of up to 7,750 feet and an in-ground-effect hover capability of up to 9,500 feet. The charts also showed that the maximum altitude for an out-of-ground effect hover at the estimated weight of 2,280 kg was about 7,300 feet. The altitude of the landing site was 7,545 feet.

4.3.29. The performance charts were conservative, in that they assumed an engine that met the minimum guaranteed performance. The operator reported that the engine had been performing satisfactorily before the accident flight. Airbus Helicopters advised that the operator's most recent engine performance data had indicated that the engine was "able to supply more than the minimum guaranteed engine power". However, the best way for a pilot to assess the likely capability was to check the power margin before landing.

4.3.30. The topography of the landing site was such that there would have been some ground effect available only if the helicopter had reached the chosen landing site. Helicopter performance

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[37] The altitude in the International Standard Atmosphere with the same pressure as the part of the atmosphere in question.
[38] 0ºC was used in the following performance calculations.
[39] When hovering close to the ground, the ground acts as a cushion and reduces the power required to maintain position. Moving higher reduces the effect of the cushioning, and the power required increases until about the equivalent of half of the rotor diameter, when the effect is considered to be nil.

charts indicated that there was a sufficient power margin available for an in-ground-effect hover at weights up to about 2,450 kg.

4.3.31. BEA (and Airbus Helicopters) advised that at the calculated centre of gravity, "the pilot would not have been able to observe that he was outside the flight envelope defined by the flight manual". In other words, the position of the centre of gravity was not so extreme that a pilot would have noticed, and they would have had no difficulty controlling the helicopter. A forward centre of gravity would assist a pilot to move forward or accelerate the helicopter, provided there was sufficient terrain clearance to do so.

4.3.32. Before departing on the flight to the top of Mount Alta, the helicopter was over its maximum allowable weight by 39 kg. It was also forward of its centre of gravity limit by about 3.0 cm. The pilot said that the performance of the helicopter on lifting from the staging area, landing at the top of Tony's Run and uplifting group A from the bottom of Tony's Run, had been as expected and he had had no problem controlling the helicopter.[40] The landing site at the top of Tony's Run was about 140 m lower than the Mount Alta landing site.

4.3.33. The first sign that the helicopter was not performing as the pilot expected was the unexpected slight sink when approaching the landing site. The pilot said that as he got close to the landing site he had been focused outside the helicopter, managing the approach path, and had not paid close attention to the airspeed or power demand. He had noticed that he was demanding about 90% of the normal operating range before the sink occurred, after which he had immediately initiated his escape manoeuvre. The guide recalled that the helicopter had "almost stopped" before it turned away to the left. It was very likely that the helicopter's speed had reduced below that for translational[41] lift and the power requirement was increasing with further speed reduction.

4.3.34. It is very unlikely that the helicopter entered into ground effect, because when the pilot turned the helicopter left it had not reached the landing site and was moving over ground that sloped steeply away. Therefore it was very likely that the helicopter had been approaching an out-of-ground-effect hover, and it may not have had sufficient performance to achieve that, even if the pilot had demanded all available power.

4.3.35. The last recollection the pilot had of the power he was demanding was about 90% of normal torque, which he observed before he abandoned the approach. It was unclear from the evidence whether the pilot increased the power demand after that, but the performance graphs indicated that there may not have been sufficient power anyway. The distance from the intended landing site to the first point of impact was 20 m vertically and 47 m horizontally. If the helicopter was already operating beyond its performance capabilities and descending, any banked turn would have increased the rate of descent. The greater the angle of bank, the greater the effect. It is unclear whether the helicopter gained sufficient forward speed to achieve translational lift before striking the slope.

Vortex ring state

4.3.36. The previous sections have described how the approach was flown when the helicopter was operating above the limit of its performance capability, which resulted in a sink rate developing before it reached the landing site. The initial sink rate was very unlikely to have been high, but occurred close enough and low enough to the terrain for the pilot to make a deliberate turn in the direction of his planned escape path.

[40] Controllability and the estimated performance are checked against the amount of power being used (weight) and cyclic control (centre of gravity).
[41] Translation is the phase of flight when accelerating from a hover to forward flight or back to a hover

4.3.37. The pilot reported that an unexpected increase in the rate of descent had developed as he initiated his escape manoeuvre. Vortex ring state[42] is a phenomenon that can cause an increased and rapid rate of descent, so consideration was given to whether it could have been a factor at some point in the accident sequence. Vortex ring state occurs when a helicopter is descending in its own downwash at a very low airspeed and a moderately high rate of descent. Any increase in power increases the downwash and results in the helicopter descending faster. Further information on vortex ring state is given in Appendix 4.

4.3.38. The pilot could not recall any of the symptoms of incipient or established vortex ring state as having occurred at any time during the accident sequence. Possible reasons are that the AS350 main rotor design has an anti-vibration feature that could have masked the onset of buffet. If they were present, any symptoms might have been assumed to be associated with the helicopter accelerating through translation as the helicopter dived away.

4.3.39. The pilot initially assessed the wind at Mount Alta as almost calm or possibly from the south, so he approached towards the south into the anticipated wind. However, during that approach he could not be sure of the wind direction, so he turned and made an approach from the south, heading north. When he and the guide saw the wind indicator, he was satisfied that any wind was light and from the south, which was consistent with the aviation forecast for the area. It was unlikely that there was a northerly wind blowing over the landing area.

4.3.40. As mentioned above, a moderate rate of descent through the air is one of the factors that can induce vortex ring state. If a helicopter is descending through updraughting air it will need a lesser rate of descent relative to the ground before it encounters vortex ring state. The sun was shining on the northern-facing slope area over which the helicopter was approaching to land. Therefore it was possible that a light anabatic wind was blowing up the side of the mountain.

4.3.41. Airbus Helicopters stated that the helicopter under the accident conditions would not generally enter vortex ring state unless the rate of descent was in the order of 900 feet per minute.[43] The pilot said he had commenced the escape manoeuvre immediately after the aircraft had begun a slight sink and not responded to the small increase in power he had applied. Therefore it was very unlikely that the helicopter would have encountered vortex ring state on the approach.

4.3.42. During the escape manoeuvre the pilot turned the helicopter left through about 90°. The heading change would have altered the relative direction of any wind that was present, but as the strength of the prevailing wind and any anabatic flow were both likely to have been light, their effect on the outcome of the manoeuvre was likely minimal.

4.3.43. When the pilot turned the helicopter and flew it down the slope, it was likely that the airspeed increased as a result, which would generally have caused the helicopter to exit from the 'envelope' in which vortex ring state could be encountered.[44]

4.3.44. When the helicopter was banked during the latter part of the escape manoeuvre, the vertical component of the rotor thrust would have decreased. The vertical component balances the weight of the helicopter, so any reduction in that component will cause any rate of descent to increase. Also, the pilot was actively trying to fly the helicopter down his intended escape path.

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[42] Sometimes called 'settling with power', the term 'vortex ring state' is used in this report to avoid any confusion with 'over-pitching' and 'power settling', where a helicopter may have insufficient power to maintain a hover and subsequently settles onto the surface.
[43] A rate of descent of 300 feet per minute is often quoted as the upper limit in order to avoid approaching vortex ring state (FAA, 2012). The actual rate of descent depends on the specific helicopter type.
[44] Airbus confirmed that at the weight estimated for the flight, the vortex ring state envelope was bounded by an airspeed less than 20 knots and an existing rate of descent of more than 900 feet per minute.

4.3.45. The pilot said he was aware of the conditions required to enter vortex ring state, the characteristics of vortex ring state, and how to exit it. He had therefore been surprised by the helicopter's behaviour.

4.3.46. The distance from the intended landing site to the first point of impact was only 20 m vertically and 47 m horizontally. The pilot estimated that the helicopter had been close to and about 3 m higher than the landing site when he initiated his escape manoeuvre. The helicopter was already sinking at that point. It is feasible that his perception of a rapid rate of descent was explained by any increase in the rate brought about by his manoeuvring the helicopter, and because he was closing with the ridgeline to the right of his intended escape path, which was where the helicopter first struck.

4.3.47. Based on the above analysis, it is unlikely that vortex ring state was a significant contributing factor to the accident. However, the description of the helicopter's flight path in the seconds before the collision was deduced from the recollection of the people involved, and could not be wholly substantiated by physical evidence. It could therefore not be ruled out that the helicopter was affected to some degree by vortex ring state at some stage as the pilot carried out his escape manoeuvre.

Summary

4.3.48. The accident highlighted the importance of pilots' pre-flight planning to ensure that helicopters will have sufficient performance to conduct intended flights safely. It also highlighted the importance of pilots checking the performance capabilities of helicopters while in flight.

4.3.49. The flight manual performance charts showed that at a weight of 2,280 kg the helicopter could not have achieved an out-of-ground-effect hover at the altitude of the landing site and in an air temperature of 0ºC.

4.3.50. The evidence showed that it was very likely the helicopter began an uncommanded descent during the final phase of the landing, because it was approaching an out-of-ground hover with minimal performance capability to hover at that weight, altitude and temperature. The descent continued as the pilot executed his escape manoeuvre, likely exacerbated by the helicopter banking as the pilot turned it away from the landing site. Although vortex ring state could not be ruled out as having contributed to the helicopter's rate of descent in the moments before impact, this was considered unlikely.

4.3.51. Heli-ski operations are a high-risk activity. The risk is too high to be relying on standard loading plans with assumed standard passenger weights, when relatively small variations from the standards can put a helicopter outside its published maximum performance capability. In addition, pilots should not rely on ground effect to make successful landings in confined or high-risk areas.

4.3.52. The operator has since amended its procedures to require a calculation of the actual weight and balance for every flight. Flexibility is provided for remote operations, where mobile devices and declared weights plus 6 kg can be used.

Findings

1. The helicopter struck the face of the mountain heavily in a nose-down attitude with a high rate of descent.
2. The engine was almost certainly operating normally and delivering a high level of power when the accident occurred.
3. The helicopter was loaded by an estimated 30 kilograms over the maximum permitted weight of 2,250 kilograms, with its longitudinal centre of gravity an estimated up to 3.0 centimetres forward of the maximum permissible limit when the accident occurred.

4. The helicopter's weight and the altitude at which it was being flown meant that it was operating at or close to the performance limit for an out-ground-effect hover. It is likely that the initial sink on the landing approach was a result of the helicopter moving into an out-of-ground-effect hover as the airspeed reduced.
5. It is unlikely that vortex ring state was a significant factor contributing to the accident. However, it could not be ruled out that the helicopter was affected to some degree by vortex ring state at some stage as the pilot carried out his escape manoeuvre.
6. The use of standard loading plans for Squirrel helicopters fitted with dual front seats was inappropriate, in that it was possible for pilots and ground staff to follow the plans and operate the helicopters outside their permissible limits.
7. The use of standard loading configurations that use standard passenger weights should not be permitted when aircraft are fully loaded and operating close to permissible limits.

4.4. The operator's training policies and procedures

4.4.1. The operator was one of the largest helicopter operators in New Zealand, with extensive experience of flying in the mountains around Queenstown and Wanaka and further afield. The operator's pilots were experienced in this environment, with nearly all having more than 3,000 hours of flying helicopters. The pilot of the helicopter involved in this accident had more than 4,000 hours.

4.4.2. The CAA, as part of its audit programme, had routinely audited the operator with no major concerns identified. A more thorough five-yearly recertification audit had been undertaken in July 2013, 13 months before the accident. That audit report had made no serious adverse findings and had been overall complimentary about the operator and management. In addition, while some adverse findings were made in audits of some of the operator's bases in 2014, the CAA did not consider it necessary to alter the operator's audit programme, and the operator remained in the CAA's lowest risk assessment band.

4.4.3. The operator's induction, training and competency programmes were tailored to alpine operations. For example, new pilots were not allowed to make their first landings at remote mountain sites. These had to be undertaken by more qualified, senior pilots, who would assess the landing sites and ensure that wind markers were available. The syllabus for this qualification included subjects such as in-ground-effect and out-of-ground-effect approaches, escape routes, performance considerations and vortex ring state "assessment and recovery technique". Following the Mount Alta accident, the operator reviewed its management, supervision and training structure, resulting in a new management position and change of responsibilities and personnel.

4.4.4. The operator considered heli-skiing to be a specialised task to be undertaken by a restricted number of pilots only. The operator had written a standard operating procedure titled Heli-ski & Heli-hike Operations, which detailed the requirements, planning and procedures to be followed.

4.4.5. Pilots nominated for heli-skiing were required to undergo specific training and obtain approval before commencing any heli-skiing flights. The training and assessment syllabus for heli-skiing included a range of oral briefings and air exercises. Once a pilot was approved for heli-skiing operations, the operator continued to provide supervision through more senior pilots and through feedback from experienced guides. Guides were not allocated to one pilot and could therefore compare their performance as the heli-skiing season progressed.

4.4.6. The operator's general manager aviation commented that the risk of vortex ring state was greater when flying in the mountains because of the variable conditions likely to be encountered, and because the terrain often necessitated a steep or downwind approach. The operator's training programme addressed this risk by requiring its pilots to undertake flight instruction on vortex ring state. The manager commented that they demonstrated vortex ring state in mountainous terrain, which made the rapid vertical acceleration and the height loss during recovery very apparent.

The pilot's training

4.4.7. The pilot had been with the operator for nearly four years before he was considered for heli-skiing. He had been assessed in 2011, but the operator had considered that he required more dedicated heli-ski training and experience, so he had been held over until the following year. He had begun his dedicated heli-ski training in June 2012. Some areas for improvement had been identified, but these had later been signed off as being addressed before the pilot was allowed to begin heli-skiing operations under supervision. He had then completed two seasons without incident and was considered competent in this role. Neither the operator nor the guides spoken to had any safety concerns about his performance as a heli-ski pilot.

4.4.8. The pilot said he considered his training to have equipped him well for the role of a heli-ski pilot. Although the operator had been satisfied that the pilot was ready to become a Category A pilot (unrestricted), it would have been good practice for him to undergo a specific heli-ski assessment flight for what is acknowledged as a high-risk operation. The results of such a flight should have been included in his training record.

4.4.9. The Commission investigated an accident involving another of the operator's helicopters near Mount Tyndall in October 2013 (10 months prior to this accident). Although the circumstances of that accident were different, the Commission noted a lack of formal recording of issues relating to that pilot's performance.

4.4.10. It is important for operators to keep comprehensive, formal records of all pilot training. Historical training records provide the basis for ongoing performance monitoring, particularly given natural attrition as safety and training managers move through the industry.

4.4.11. The operator's training policies and procedures received a thorough review in the course of this inquiry and that into the Mount Tyndall accident.[45] Notwithstanding the shortcomings in training record-keeping found in both inquiries, the training each pilot had received was broadly comparable with that of other New Zealand operators. The Commission heard from a Canadian expert[46] that the training was also broadly comparable with that given by Canadian heli-ski operators. Nevertheless, this operator experienced three serious landing accidents within three years.

4.4.12. The CAA had raised no recent adverse findings against the operator's policies and procedures for training its pilots prior to these three accidents.

Findings

8. The operator's policies and procedures for training its pilots were broadly comparable to those of other New Zealand operators and to those of heli-ski operators in Canada.
9. The pilot was trained in accordance with the operator's training standards and was experienced in heli-ski operations.

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[45] See footnote 21.

[46] The expert had a long association with heli-skiing operations in Canada as a helicopter pilot, a regulator and an independent accident investigator.

4.5. A potential sector-wide safety issue

4.5.1. New Zealand's helicopter accident rate is higher than that of other aviation sectors.[47] There has been public criticism of how helicopters are operated in New Zealand, including a culture of operating outside the manufacturers' published and placarded 'never exceed' limitations. Should this situation exist, there is a possibility that such a culture has become normalised. The core safety issue would therefore lie within the wider helicopter sector, with flow-on effects to individual operators' safety systems.

4.5.2. The Commission's inquiries have not fully explored this potential wider issue. However, the Commission is aware that the CAA is undertaking a review of the helicopter sector risk profile, and has recommended that the Director of Civil Aviation include the issue of operational culture in that review.

Finding

10. There are indications that a culture exists among some helicopter pilots in New Zealand of operating their aircraft beyond the published and placarded limits. Such a culture adversely affects the safety performance of the helicopter sector.

[47] CAA. 2017-2019, Safety and Security Focus Area, work programme.

4.6. Survival

Injuries

4.6.1. The injuries sustained by the deceased passenger were consistent with his having been struck by the broken right skid (see Figure 6), and being ejected from the helicopter and caught between it and the snow-covered slope as the helicopter came to rest. His injuries were unsurvivable. Three of the surviving occupants sustained serious injuries, including fractures, internal injuries and extensive bruising. The remaining three occupants sustained minor to moderate injuries, predominantly extensive bruising and sprains.

Safety briefing

4.6.2. As discussed in section 3.1, the briefing of passengers involved in heli-skiing was normally conducted in two separate briefings. The first briefing was a general helicopter safety briefing given to passengers before commencing flying. The second briefing concerned activities while skiing, for example avalanches and snow survival, and was normally given just prior to commencing heli-skiing.

4.6.3. The content of the first briefing, which was detailed in the heli-skiing standard operating procedure, included (among other things) how to approach and depart the helicopter, no-go areas and emergency equipment carried on board. The operation of seatbelts was to be discussed, with a requirement to ensure that the belts were fastened throughout the flight. There was, however, no mention of how tight the seatbelts were to be and this aspect was not raised during the briefing of any of the groups on the day of the accident.

Seatbelts

4.6.4. The seats and seatbelts fitted to the helicopter were of the usual type fitted to AS350 helicopters and conformed with internationally agreed technical standards.[48] However, the force experienced in the impact exceeded the design capability of the helicopter, its seats and likely also the seatbelts.[49] Of the seven persons on board, two were retained in their seats and five were ejected from the helicopter, either during the initial impact or as the helicopter rolled down the mountain. The following section reviews the accident sequence in terms of survivability and explains why two people were retained in their seats and five were not. Figure 6 and Table 1 describe the occupants' seat positions, seatbelt status and injuries.

[48] SAE International Aerospace Standard SAE AS8043 and European Technical Standard Order ETSO-C22g (and the Federal Aviation Administration equivalent TSO-C22g) and specifically Federal Administration Regulation FAR 27, amendment 10.

[49] The designed maximum loading for the seats was 6 g (longitudinal), 2 g (lateral) and 6 g (vertical). The seatbelts were approved to 10 g (longitudinal).

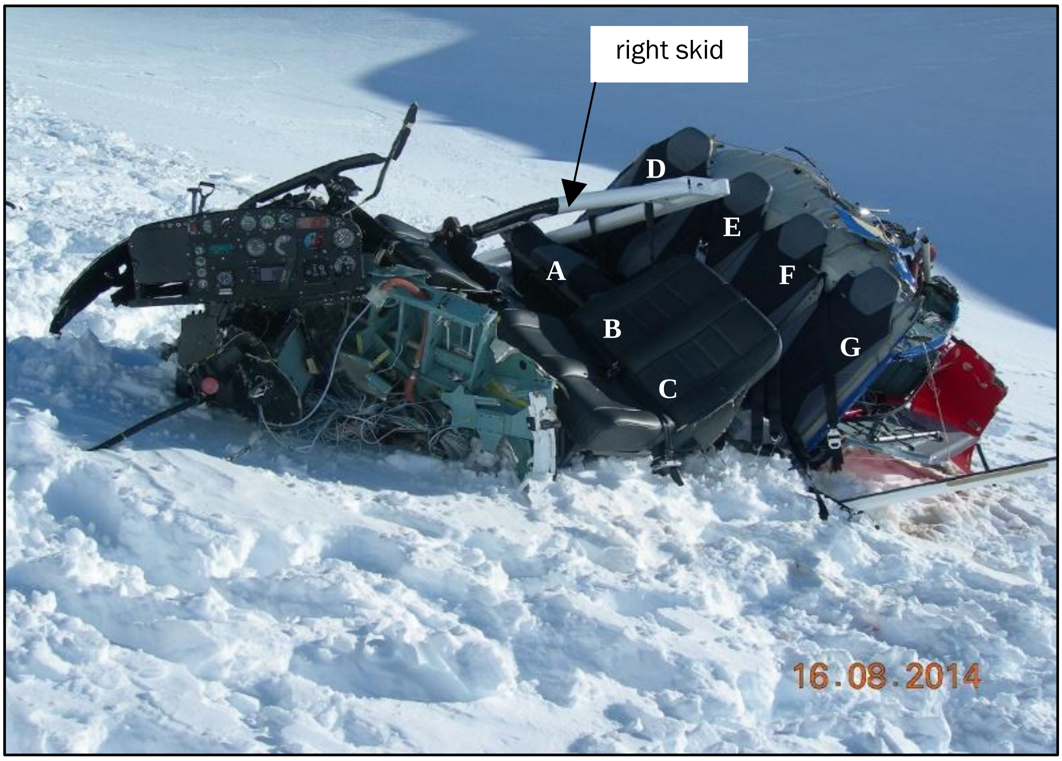

Figure 6
Seating positions

Occupant	Injuries	Seatbelt (type, status found, fitting)	Retained/Thrown out
A (pilot)	Moderate	Four-point harness, buckled, pulled tight	Thrown out (probably up and forward)
B	Minor	Four-point harness, buckled, pulled firm	Retained
C (guide)	Serious	Four-point harness, buckled, but broken, pulled firm	Thrown out
D	Fatal	Lap-diagonal, lap unbuckled, loose	Thrown out
E	Serious	Lap-diagonal, buckled, loose	Thrown out
F	Moderate	Lap-diagonal, buckled, firm	Retained
G	Serious	Lap-diagonal, lap unbuckled, loose	Thrown out

Table 1
Occupant status

4.6.5. The two passengers who remained in their seats (positions B and F) were positioned about the centreline of the helicopter. Therefore as the helicopter rolled they would not have been subjected to the same centrifugal forces as those seated further outboard. Other factors that might explain why they were not ejected from the helicopter are discussed below.

4.6.6. The three front seats (positions A, B and C) were all equipped with four-point harnesses – a lap belt and two shoulder straps. The outboard lap belt attachment fitting for seat C broke. Despite the seatbelt remaining buckled, the broken attachment effectively released the seatbelt and allowed the guide to be thrown out.

4.6.7. The pilot recalled tightening his seatbelt firmly before the flight and the latch remained buckled during the accident sequence. The forward section of the cabin floor was bent upwards when the nose of the helicopter struck the slope, probably after being pitched forward from the initial impact. It was therefore almost impossible for him to have 'submarined'[50] down and forwards out of his lap belt. It is more likely that he was pulled upward between the two shoulder straps and the broken seat back. The occupant in seat B was retained in his seat.

4.6.8. The four rear seats (positions D, E, F and G) were each fitted with a three-point harness comprising a lap belt and single shoulder harness. The person in seat F, directly behind seat B, was retained in his seat. The person to his right, in seat E, was thrown clear of the rolling helicopter despite his seatbelt remaining buckled. Both lap belt connections for this passenger were found to be nearly fully extended. This would have given a very loose fit around the waist and, like the pilot, he most likely slipped up through his lap belt.

4.6.9. The seatbelts for seats D and G were found to be released and both persons had been ejected from the helicopter as it rolled down the mountain. Although it was possible that the buckles were deliberately released, it was more likely that something caught the buckles while the helicopter was rolling down the slope and released the seatbelts. The lap belts for seats D and G were found at or near full extension, which would have given a very loose fit around the waist.

4.6.10. The seatbelt catch mechanism was a common design found in most passenger aircraft around the world. To release the belt, the lever had to be pulled up nearly 70°. The lap belts being extended would have made it easier for the passengers to locate and fasten them after boarding. However, if a belt remains loose around the waist the chances of something inadvertently catching the semi-guarded release lever increase. Therefore, after buckling up the straps the two lap belts should be pulled as tight as possible to minimise movement in the event of an accident. It also reduces the possibility of the buckle being inadvertently released. Only after landing, and when about to depart the aircraft, should the buckle be released.

4.6.11. On 20 November 2015 the operator issued a notice to all staff reminding them that seatbelts were to be fitted "snug across the hips".

Other means of protection

4.6.12. Five of the seven occupants were wearing ski helmets during the flight. However, this appears to have had little influence on survivability in this case. The two occupants who were not wearing helmets survived. Among the five who were wearing helmets, most had their chin straps either loose or undone. While ski-type helmets are not designed for surviving a helicopter crash, in the event of an accident they could provide an additional level of safety, if worn properly.

4.6.13. The sudden and violent nature of the accident meant that none of the occupants had time to adopt a 'brace position' prior to the helicopter striking the slope. The two occupants who

[50] 'Submarined' is a term used to describe a person being pulled downward by the impact forces, and potentially through their still-secure seatbelt.

remained in the helicopter said that they had curled up as much as possible as it rolled down the mountain. The remaining occupants were either immediately thrown clear or did not think to adopt the brace position. The deceased passenger was wearing upper-torso protection, similar to that worn by motocross riders. It was considered very unlikely that this would have prevented his adopting the brace position if he had wished or was able to do so. Wearing additional body armour might have reduced the severity of injury during the crash. However, it would not have provided any protection against the fatal injuries he received on this occasion.

Emergency response

4.6.14. The helicopter was fitted with a 406-megahertz emergency locator transmitter. This activated as a result of the impact and at 1251 the Rescue Coordination Centre New Zealand received an initial alert. The injured guide was able to alert the pilot of another of the operator's helicopters within minutes of the accident. If this had not been done, the guides of the other groups would have raised the alarm when the helicopter did not return when expected. A further back-up was provided by the operator's normal flight-following through its base in Queenstown.

4.6.15. There were no issues with the speed at which the relevant authorities learned of the accident and responded.

Finding

11. It is very likely that several of the passengers' seatbelts were not securely adjusted. If seatbelts are loosely fitting, occupants are more likely to be ejected from an aircraft and the seatbelts are more prone to inadvertent release during an accident.

5. Findings

5.1. The helicopter struck the face of the mountain heavily in a nose-down attitude with a high rate of descent.

5.2. The engine was almost certainly operating normally and delivering a high level of power when the accident occurred.

5.3. The helicopter was loaded by an estimated 30 kilograms above the maximum permitted weight of 2,250 kilograms, with its longitudinal centre of gravity an estimated up to 3.0 centimetres forward of the maximum permissible limit when the accident occurred.

5.4. The helicopter's weight and the altitude at which it was being flown meant that it was operating at or close to the performance limit for an out-ground-effect hover. It is likely that the initial sink on the landing approach was a result of the helicopter moving into an out-of-ground-effect hover as the airspeed reduced.

5.5. It is unlikely that vortex ring state was a significant factor contributing to the accident. However, it could not be ruled out that the helicopter was affected to some degree by vortex ring state at some stage as the pilot carried out his escape manoeuvre.

5.6. The use of standard loading plans for Squirrel helicopters fitted with dual front seats was inappropriate, in that it was possible for pilots and ground staff to follow the plans and operate the helicopters outside their permissible limits.

5.7. The use of standard loading configurations that use standard passenger weights should not be permitted when aircraft are fully loaded and operating close to permissible limits.

5.8. The operator's policies and procedures for training its pilots were broadly comparable to those of other New Zealand operators and to those of heli-ski operators in Canada.

5.9. The pilot was trained in accordance with the operator's training standards and was experienced in heli-ski operations.

5.10. There are indications that a culture exists among some helicopter pilots in New Zealand of operating their aircraft beyond the published and placarded limits. Such a culture adversely affects the safety performance of the helicopter sector.

5.11. It is very likely that several of the passengers' seatbelts were not securely adjusted. If seatbelts are loosely fitting, occupants are more likely to be ejected from an aircraft and the seatbelts are more prone to inadvertently release during an accident.

6. Safety actions

General

6.1. 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.

Safety actions addressing safety issues identified during an inquiry

6.2. On 20 November 2015 the operator issued a notice to all staff reminding them that "the seatbelt must fit snug across the hips of passengers during the loading process. Further, harnesses, where fitted, must be worn".

Safety actions addressing other safety issues

6.3. In late 2014 the operator changed its standard pilot weight to 88 kg and amended procedures to require pilots to weigh passengers on scenic flights, including heli-skiing operations, when departing from bases equipped with weighing equipment.

6.4. On 27 November 2015 the CAA issued Emergency Airworthiness Directive DCA/AS350/128[51] concerning operating limitations for AS350 helicopters fitted with two-place front passenger seats (see Appendix 5). A similar directive was issued for operators of AS355 helicopters, the twin-engine version of the AS350. The directive required operators to ensure that the helicopters were within their weight and balance limits by calculating their longitudinal and lateral centre-of-gravity positions, and completing weight and balance data forms.

[51] The directive was updated to DCA/AS350/128A, effective 14 December 2015.

7. Recommendations

General

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

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

Recommendations

7.3. Five of the seven occupants were ejected from the helicopter as it tumbled and rolled down the mountain. One was fatally injured and three received serious injuries. The injuries might have been reduced had the passengers' seatbelts been fitted tightly around their waists.

Seatbelts can only be effective in preventing or minimising injury if they are fastened and properly adjusted. Aircraft operators must ensure that passengers and crew fasten their seatbelts and adjust them to fit tightly across their hips.

On 25 October 2017 the Commission recommended to the Director of Civil Aviation that he use the key lessons arising from this report to remind aircraft operators and pilots of the importance of ensuring that aircraft occupants fasten and properly adjust their seatbelts at all times. (005/17)

On 13 November 20717, Civil Aviation Authority replied:

> The CAA will implement the recommendation by way of a Vector article. We will advise when the article will be published in due course.

7.4. It is inconclusive to what extent vortex ring state contributed to this accident. Nevertheless, it is a known hazard for helicopters. To avoid the hazard, pilots must:

- remain alert to the conditions conducive to the formation of vortex ring state
- closely monitor the airspeed and rate of descent during the final approach
- initiate recovery action at the first indication that they may be approaching vortex ring state.

On 25 October 2017 the Commission recommended to the Director of Civil Aviation that he use the key lessons arising from this report to remind aircraft operators and pilots of helicopter performance and environmental conditions that can lead to vortex ring state, and of the need to be alert to the potential for it to occur, even in apparently benign conditions. (006/17)

On 13 November 2017, Civil Aviation Authority replied:

> In a similar manner, the CAA will produce a Vector to remind operators and pilots of helicopter performance and environmental conditions that can lead to vortex ring state and the potential for it to occur.

7.5. New Zealand's helicopter accident rate is higher than that of other aviation sectors. There has been public criticism of how helicopters are operated in New Zealand, including a culture of operating outside the manufacturers' published and placarded 'never exceed' limitations. Should this situation exist, there is a possibility that such a culture has become normalised. The core safety issue would therefore lie within the wider helicopter sector, with flow-on effects to individual operators' safety systems.

7.6. The Commission is aware that the CAA is currently reviewing the 'sector risk profile' of commercial helicopter and small aeroplane operations, and that that work will take a structured approach to risk identification and mitigation.

On 25 October 2017 the Commission recommended that the Director of Civil Aviation include the safety issue of helicopter operational culture in its current 'sector risk profile' review. (032/17)

On 13 November 2017, Civil Aviation Authority replied:

> The Part 135 sector risk profile (SRP) published in 2015 identified culture as a risk. Over the next two weeks workshops will confirm the 2015 risks and allocate treatment owners. The CAA will monitor the implementation of the treatments, however it must be stressed that it will take some years to convert in the aviation sector.

8. Key lessons

8.1. Flying in mountainous terrain places additional demands on a pilot's skills and an aircraft's performance. Both could be at or near the limits of their capabilities. Operators need to ensure that their safety management systems address the additional risks associated with flying in such an environment.

8.2. The use of 'standard' or 'assessed' passenger weights is not a licence to exceed an aircraft's permissible weight and balance parameters. Any aircraft being operated outside the permissible range will have a higher risk of having an accident, particularly when being operated near the margins of aircraft performance capability.

8.3. It is important for operators to keep comprehensive, formal records of all pilot training. Historical training records provide the basis for ongoing performance monitoring and professional development, particularly given natural attrition as safety and training managers move through the industry.

8.4. Seatbelts are only effective in preventing or minimising injury if they are fastened and properly adjusted. Aircraft operators must ensure that passengers and crew fasten their seatbelts and adjust them to fit tightly across their hips.

8.5. Vortex ring state is a known hazard for helicopters. To avoid the hazard, pilots must:

- remain alert to the conditions conducive to the formation of vortex ring state
- closely monitor the airspeed and rate of descent during the final approach
- initiate recovery action at the first indication that they may be approaching vortex ring state.

9. Citations

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Vortex ring state

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Appendix 1: Engine examination

1. Factual information

1.1 Initial observations

- The engine was intact with evidence of random impact damage to surfaces associated with its departure from the airframe.
- The axial compressor blades bore signs of high and low energy strike marks and peel back of one blade. Not all blades were damaged.
- Compressor and N1 drive train rotated freely without signs of binding or unusual noises.
- Power turbine and N2/NFT drive train rotated freely without signs of binding or unusual noises.
- The exhaust pipe was crushed and distorted, and damage to the engine front support was evident.
- The tail rotor output drive flexible coupling (flector) failed at the attachment flanges.
- No engine logbook or engine history information was made available.

1.2 Components fitted at time of assessment

The following engine components / items were found installed:

- Fuel control unit (FCU), fuel pressurising and drain valves
- Tacho generators (2)
- T4 harness
- Start fuel solenoid, drain valve and starting injectors
- Ignitors and high energy generators
- Oil pump, oil filter, magnetic and electrical chip plugs and oil system check valve
- External fuel and oil system plumbing
- Bleed air valve
- Torque transmitter.

1.3 Oil system and oil contents

Summary: The oil system was found to be free of significant defects.

<u>Main oil filter</u>

Examined – no evidence of engine-related material associated with oil contact. Debris free.

<u>Oil strainers</u>

Examined and found free of debris.

<u>Oil pump – pressure and scavenge</u>

Not disassembled for detailed inspection. Oil inlet port found severed from pump body.

<u>Chip plugs and chip detectors</u>

Examined and found free of debris.

<u>Oil system indicating / monitoring</u>

Electric chip plugs, oil pressure transmitter and oil filter clogging indicator visually inspected and found serviceable with no apparent defects or debris. No specialist tests conducted.

1.4 Fuel system and fuel control unit(s)

Summary: The engine fuel system was found to be free of significant defects.

The fuel control unit was intact – minor strike mark on forward, inboard section of FCU body.

<u>Fuel filter and strainers</u>

FCU filter removed and inspected. No evidence of debris – clean and unobstructed.

<u>Fuel delivery plumbing / nozzles</u>

Fuel injection wheel permeability check carried out and found to be within published limits. Average flow time recorded as 7.0 seconds (average of three tests).

Start fuel nozzles present – not inspected as not in operation in flight.

<u>Fuel system indicating / monitoring</u>

N/A to this engine.

<u>Power turbine governor / N2 control</u>

Part of FCU – no external defects noted.

<u>Engine controls</u>

FCU throttle (N1 control) and anticipator (N2/NFT) controls were found connected and attached hardware present and secure. Both control cable assemblies found severed in area of mount brackets. Unable to establish cause of failure of control cables. Nature of failure suggestive of overload associated with engine detaching from airframe at time of accident.

Control cables disconnected from FCU, and both throttle and anticipator levers and shafts found to operate freely without binding or restrictions.

1.5 Ignition / Ignitor system

Summary: The engine ignition system was found to be free of significant defects.
Engine ignition system found to be present and complete – no detailed inspection or tests conducted as items were not in operation in flight.
Ignitors
Both ignitors found installed in combustor housing – no defects were visually evident.
Ignitor box(s)
High energy ignition units found to be mounted securely and free from external defects. One ignitor cable found deformed and detached from associated ignitor plug.

1.6 Electrical / Power generation

The starter generator was not installed. The mount adapter flange showed signs of damage associated with clamp deflection / release.
Wiring loom and harnesses
Some damage to electrical loom present in the form of abraded or severed wiring. The loom was otherwise complete and fitted to the engine.

1.7 Compressor / Gas generator turbine

Summary: Some damage associated with rotational damage.
The air path was littered with fine particles considered to originate from the airframe manufacturer supplied air intake trunk. The size and shape of the particles appeared to have been ground by the axial compressor and distributed within the engine. Particles were found in the secondary cooling air path (inner combustion chamber liner) and noted to have entered the primary combustion air path. These particles appeared to have melted in the engine hot section and deposited on downstream rotating and static turbine components.
No specific tests were conducted to definitively identify the particles, however they bore the characteristics of soft aluminium.
The axial compressor blades bore signs of high and low energy strike marks and peel back of one blade. Not all blades were damaged. Compressor rotated freely and the nose cone showed signs of rotational scrape marks.
No visible damage to compressor turbine.
Air intake and bleed valve
The air intake (airframe supplied bellmouth) was not available for inspection.
The bleed valve was found intact and securely mounted. Butterfly valve in open (normal) position and free to move.
The bleed valve was further disassembled and a visual inspection did not reveal any apparent defects. No further testing of the bleed valve took place.
Bleed valve filters and jets
Evidence of white powder deposits on bleed valve finger filter leading to partial blockage. Bleed valve operation considered to be unaffected by deposits.
Compressor blades / stators / scrolls
Eleven of the 13 blades suffered impact damage with variable loss of material and significant peel back of one blade. Damage attributed to rotational forces and contact with unknown foreign objects.
Gas generator turbine[52] / NGV / stators
The gas generator turbine was intact with no apparent damage other than being coated in a rough layer of what appeared to be molten metal particles resulting in a rough surface finish.
Molten remnants were found to have coated the first stage gas generator turbine blade trailing edges, the second stage NGV and second stage wheel. The first stage NGVs were free from molten particles and this was attributed to the local temperature resulting in deposits on downstream, cooler operating, turbine stages. The coating was not considered to have a detrimental effect on engine operation.

[52] Also known as the 'high pressure turbine' in this engine configuration.

1.8 Power turbine

The power turbine[53] and associated guide vanes were also coated in a molten metal spray / spatter on the gas path surfaces. The coating was not considered to have a detrimental effect on engine operation.

Power turbine blades and stators

The power turbine was found to rotate freely and was free from obvious defects other than the presence of a molten metal coating spattered on the blade surface. Stators were undamaged and free from major defects. Slight rub marks were present on several blades and reflected on the compressor turbine shroud housing.

1.9 Exhaust system

The exhaust pipe was found crushed, with strike and deformation damage to the right side. The damage was attributed to the engine becoming detached from the airframe in the course of its movement down the slope.

1.10 Engine monitoring

Summary: No significant effects noted.

All components associated with the engine monitoring system were fitted with the exception of the T4 junction box that was not supplied with the engine. There was evidence that the junction box became detached in the accident sequence. The T4 loom connecting to the box showed signs of tearing and wires had been pulled from connectors.

Overspeed protection

N2/NFT drives to FCU found intact and free to rotate. Gear shaft present.

N1 drive to FCU intact and consistent with engine operating. Rotated freely.

Engine speed monitoring

Both tacho generators found fitted and drive trains free to rotate. Tacho drive shafts intact and tachos free to rotate.

Engine temperature monitoring / indicating / thermocouples

All thermocouples present and fitted to Module 3. Leads associated with the T4 junction box damaged and damage found consistent with forced removal.

1.11 Gearboxes, drive train, bearings and cages

All rotating shafts found to move freely with no evidence of binding, abnormal noises or unusual play. Coking deposits on the compressor turbine rear bearing were considered normal.

The M05 drive pinion retaining nut witness marks found to be misaligned, indicating that a significant torque spike had occurred. The misalignment is consistent with an engine delivering power and the drive train suffering from shock loading typically associated with a rotor strike.

Output drives

Freewheel unit: The freewheel unit came into contact with the engine forward support evidenced by strike and scrape marks on the inside surface of the housing bellows. Five of the six free wheel unit front flange attach bolts were damaged – the heads of the fasteners were sheared off on contact with the front support housing.

A run-out check of the free wheel shaft was performed after removal and the 'out of round' amount was measured at 1.84 mm. The allowable limit per the Turbomeca Arriel overhaul manual is 0.05 mm. The free wheel clutch keys inner race surface of the shaft was found impacted, with corresponding crush marks on the clutch keys.

The tail rotor output shaft flector had failed at the attach flange.

1.12 Engine externals

As reported, the engine assembly became detached from the airframe at some point following the accident and suffered impact damage to casings, peripheral components, external plumbing and electrical loom.

Plumbing

The external plumbing was bent and deformed in various places and was attributed to the engine release. Casings and shrouds

The M01 linking tube was deformed in the area of the rear engine mount – the rear mount was not available for assessment.

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[53] Also known as the 'free turbine' in this engine configuration.

The engine front support was missing the forward mount flange and bore signs of material tearing associated with scrape marks provided by contact with the free wheel unit. Signs of power tool use (grind marks with local overheating) to free the front support remnants from the forward flange were present.
Slight impact marks were visible on the combustion chamber housing (M03) in the area of the right ignitor plug boss.
The M03 turbine shroud was deformed in several places and required to be cut from the module to facilitate removal.
No penetrating defects were evident on the casings and castings of the various modules.

1.13 Other

Module assemblies: All engine modules were separated from the engine in the course of the engine assessment. Other than the damage to the exhaust pipe and M03 turbine shroud that was required to be cut away, all the modules separated without difficulty using the standard or dedicated workshop tooling.
The modules were further disassembled to access areas of interest.
The power turbine nut was found to be over-torqued providing further indication of an engine torque spike associated with a main rotor system strike.

2. Summary and conclusions

2.1 Summary:

- The engine assembly was found to be intact, without significant external damage.
- Impact marks were found on the axial compressor blades and the exhaust pipe was crushed.
- The engine gear train rotated freely with no signs of binding or unusual noise.
- No significant defects were noted on the available external engine components.

2.2 Conclusions:

- It was concluded that the engine was operating and capable of normal operation.
- The misalignment of the witness marks on the M05 drive pinion nut was indicative of an engine delivering power at the time the helicopter impacted the ridgeline. The movement of the pinion nut was associated with a torque spike attributed to power train shock loads generated from a main rotor system strike.
- The internal air path was littered with metallic particles that were also deposited on hot section rotating and static components – indicative of an operating engine ingesting abraded material.

Appendix 2: Confined area – The Seven S's

Taken from the Royal New Zealand Air Force's *Helicopter Training Syllabus* and the Australian Civil Aviation Safety Authority's *Helicopter Flight Instructor Manual*, Issue 3: March 2012, produced in conjunction with the CAA:

Size. The size of the area is large enough to safely land, or if need be, winch or enable a low hover to load or offload. There should be sufficient distance from the main and tail rotors to allow for sudden or minor movement of the helicopter or surrounding vegetation.

Shape. The shape of a landing area may determine the final approach direction. This may also include objects on the landing area, for example people or freight. Consideration should also be given to vegetation at the side of the landing area, for example trees that may bend in the rotor downwash and alter the shape.

Surrounds. Consider the surrounding obstacles, for example wires, aerials and houses. This may alter the approach and departure directions, and escape route(s). The surrounds, along with the size, may also dictate the approach profile, for example coming to a high hover before descending vertically to land.

Slope. The ground is sufficiently level to permit a landing, or will a low hover be required.

Surface. What is the surface made of? Dust or snow that may blow up and suddenly restrict visibility. Or small stones and loose items that may be hazardous if blown about.

Sun. The position of the sun may restrict visibility by being in the face of the pilot. It may also generate shadows that hide hazards.

Select the landing point. Having considered all the above, along with wind strength and direction, identify the landing spot. The combination of these factors will determine the approach direction, type of approach, termination, departure direction and escape route(s). The pilot will then confirm they have a sufficient power margin to be able to safely achieve the intended landing. There may also be decision points along the approach that the pilot will use to decide whether to continue or initiate an escape.

Appendix 3: Estimated weight at start of accident flight

The table below outlines the Commission's estimate of the weight at the start of the accident flight, being 2,289.5 kg. The fuel used in flying to the landing site would have reduced the total weight by about 9 kg.

The pilot's and passengers' unclothed weights were obtained through interviews.[54] Following the accident some passengers' apparel was contaminated with fuel, discarded and not recovered. The Commission therefore had to estimate these weights based on a range of commonly used skiing and snowboarding apparel and boots, which were weighed by Commission investigators.

Item	Weight	Notes
Pilot	80	Clothed
Pilot's bag	5	Right locker
Guide	82	Clothed
Passengers	427	Bare weight
Passengers' clothing	44	Includes an allowance for personal items such as cameras, cell phones, snacks and water
Ski basket and gear	86.5	Includes guide's pack
Lunches	20	
Left locker	2	
Fuel	216	50%
Helicopter empty	1327	
TOTAL WEIGHT	**2,289.5**	

[54] Medical records in the case of the deceased passenger.

Appendix 4: Vortex ring state

When a helicopter is generating rotor thrust or lift, there will be some recirculation of air around the end of the blades or rotor disc.[55] The recirculation is most pronounced at high power and low airspeed, as in a hover, and reduces as the helicopter moves forward. Vortex ring state occurs when the tip vortex becomes more energised and a secondary inner vortex is established towards the centre of the rotor disc because the rate of descent exceeds the induced downward flow (see Figures 7 and 8).[56]

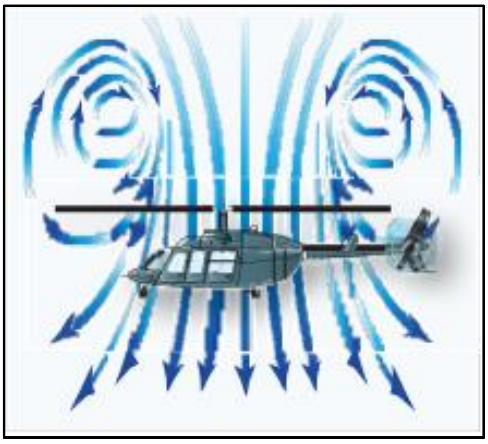

Figure 7
Typical rotor downwash flow
(Courtesy of Federal Aviation Administration)

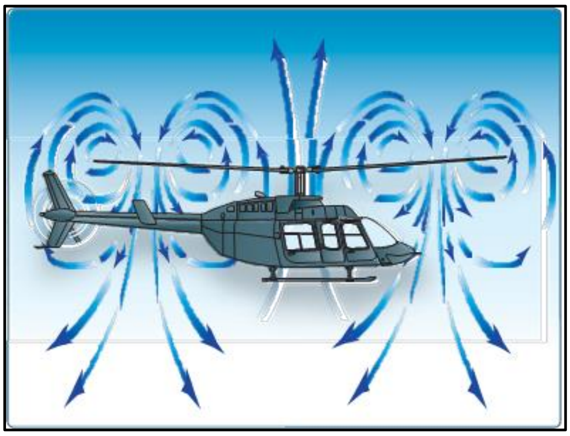

Figure 8
Vortex ring state
(Courtesy of Federal Aviation Administration)

The onset of vortex ring state can be sudden, resulting in the helicopter descending at a very high rate. Any increase in rotor thrust in an attempt to reduce the high rate of descent energises the vortices further and increases the rate of descent. Rates of descent of more than 3,000 feet per minute are not unusual. A United States National Transportation Safety Board report into an AS350-B2 accident cited rates of descent between 4,000 feet and 6,000 feet per minute (National Transportation Safety Board, 2001). This is significantly faster than the 1,500 to 2,000 feet per minute rate of descent experienced in an autorotation following a total power loss.

The conditions required for the formation of vortex ring state are very limited. The helicopter needs to be under power to generate the downwash that initiates the tip vortices, and be descending in its own downwash to energise the vortices and help establish vortex ring state over the full disc. The helicopter therefore needs to be slow and descending. Flying in updraughting air may reduce the rate of descent required to induce vortex ring state.

Airspeeds of 10 knots (19 km/hr) or less and a rate of descent of more than 300 feet (90 m) per minute[57] or more may be required to initiate vortex ring state. A steep downwind approach is often cited as a situation where power, low airspeed and a moderately high rate of descent can combine to create vortex ring state. The entry to vortex ring state is typically characterised by a vibration, buffet and 'twitching' of the fuselage from the turbulent air moving around the fuselage and through the main rotors. Similar but milder characteristics may be observed when moving through translation, which is the phase of flight when accelerating from a hover to forward flight or back to a hover.

To exit vortex ring state, the direction of the airflow through and around the rotor disc needs to be changed. A pilot can increase forward airspeed to move clear of the downwash, or enter autorotation,

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[55] The 'rotor disc' is the area enclosed within the circle described by the rotor blade tips.
[56] For further information on vortex ring state, see the references in section 9.
[57] It is noted that, for the accident helicopter, Airbus confirmed the rate of descent required to enter vortex ring state as being in excess of 900 feet per minute.

which stops the air being accelerated down through the disc.[58] Both actions will result in a significant height loss, more so when entering autorotation. The most common exit strategy is therefore to accelerate forward and away from the downwash. All licensed helicopter pilots are taught about vortex ring state and how to recover from it.

[58] A third technique, called the 'Vuichard Recovery', advocates for helicopters like the AS350 applying immediate left lateral cyclic while simultaneously increasing collective and applying right pedal.

Appendix 5: Airworthiness Directive – All Airbus Helicopters AS350 Series

DCA/AS350/128A Forward Two-place Seat - Operating Limitations

Applicability: All AS350 series helicopters fitted with any forward two-place seat.

Requirement: To prevent a reduction of flight safety from that provided by the manufacturer, accomplish the following:

1. Determine the longitudinal moment arm of the forward two-place seat using the center of the seat pan cushion as a measurement reference point.

   Complete and issue a new form CAA 2173 Weight and Balance Data.

   The weight of the seat components must be included in the CG calculations. If a seat adaptor plate is fitted the moment (position and weight) of the plate must also be considered for the CG calculation.

   The lateral CG arm of the helicopter must not be assumed to be zero. The lateral CG must be recorded and be within the limits specified in the AFM.

   Annotate the CAA2173 to include the value of the longitudinal moment arm of the forward two-place seat used.
2. Insert the following into section 2 of the AS350 Flight Manual:

   CAA Limitation Section, (1 page), dated 14 December 2015.

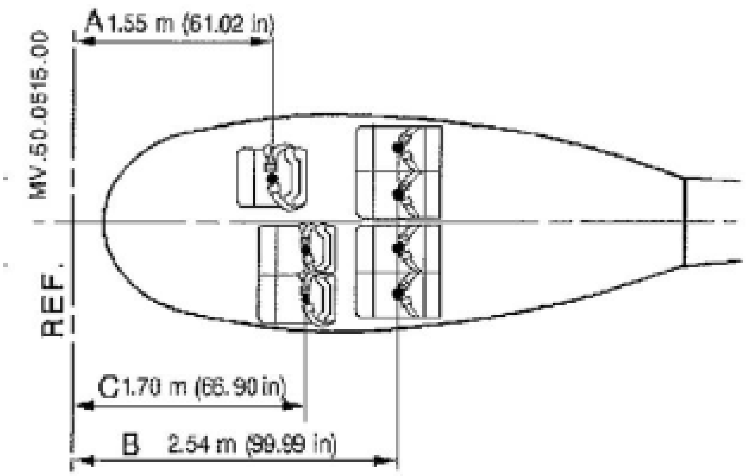

Figure: Airbus Helicopters recommended CG position of forward two-place seat

Compliance:
1. Before further use of the forward two-place seat.
2. Before further use of the forward two-place seat.

Effective Date: DCA/AS350/128 - 27 November 2015
DCA/AS350/128A - 14 December 2015

CAA Approved
AS350 Limitations
14 December 2015

LIMITATION SECTION*

Purpose:

To prevent a reduction of flight safety from that provided by the manufacturer this supplement details the weight and balance limitations for AS350 series helicopters fitted with a forward two-place seat.

Applicability:

All AS350 series helicopters fitted with any forward two-place seat.

Requirements:

Before every flight with occupant(s) or cargo on the forward two-place seat perform a longitudinal and lateral weight and balance calculation in accordance with the AFM and the associated Airbus Helicopters weight and balance procedure. The helicopter center of gravity (CG) must remain within longitudinal and lateral limitations specified in the AFM throughout all phases of flight.

a. For AS350B and AS350D helicopters the combined weight of the two occupants on the forward two-place seat must not exceed 120kg regardless of longitudinal seat position.

b. For all other AS350 series helicopters the combined weight of the two occupants on the forward two-place seat must not exceed 154kg regardless of longitudinal seat position.

c. For all AS350 helicopters the weight of any single occupant seated on the forward two-place seat must not exceed 120kg.

When performing the longitudinal and lateral weight and balance calculation use the center of the seat pan cushion as a measurement reference point for the longitudinal moment arm of the forward two-place seat.

Estimated or standard occupant weights are not acceptable to determine the helicopter CG. Actual occupant weights must be used and recorded for the CG calculation. Where weighing occupants is not practical (i.e. when uplifting passengers in remote locations), the declared passenger weight plus 6kg must be used for weight and balance calculations.

The lateral CG arm of the helicopter must not be assumed to be zero. Lateral CG must be calculated and must remain within the limits prescribed within the AFM.

*This page is inserted by NZ AD DCA/AS350/128A.

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AO-2015-005	Unplanned interruption to national air traffic control services, 23 June 2015
AO-2016-004	Guimbal Cabri G2, ZK-IIH, In-flight fire, near Rotorua Aerodrome, 15 April 2016
AO-2015-001	Pacific Aerospace Limited 750XL, ZK-SDT, Engine failure, Lake Taupō, 7 January 2015
AO-2013-010	Aérospatiale AS350B2 'Squirrel', ZK-IMJ, collision with parked helicopter, near Mount Tyndall, Otago, 28 October 2013
Addendum to final report AO-2015-002	Mast bump and in-flight break-up, Robinson R44, ZK-IPY, Lochy River, near Queenstown, 19 February 2015
Interim Report AO-2017-001	Collision with terrain, Eurocopter AS350-BA, ZK-HKW, Port Hills, Christchurch, 14 February 2017
AO-2013-011	Runway excursion, British Aerospace Jetstream 32, ZK-VAH, Auckland Airport, 2 November 2013
AO-2014-006	Robinson R44 II, ZK-HBQ, mast-bump and in-flight break-up, Kahurangi National Park, 7 October 2014
Interim Report AO-2016-007	Collision with terrain, Robinson R44, ZK-HTH, Glenbervie Forest, Northland, 31 October 2016
AO-2014-004	Piper PA32-300, ZK-DOJ, Collision with terrain, Near Poolburn Reservoir, Central Otago, 5 August 2014
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AO-2013-008	Boeing 737-300, ZK-NGI, Loss of cabin pressure, near Raglan, Waikato, 30 August 2013
AO-2013-003	Robinson R66, ZK-IHU, Mast bump and in-flight break-up, Kaweka Range, 9 March 2013
AO-2014-002	Kawasaki BK117 B-2, ZK-HJC, Double engine power loss, Near Springston, Canterbury, 5 May 2014
AO-2013-006	Misaligned take-off at night, Airbus A340, CC-CQF, Auckland Airport, 18 May 2013

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