Inquiry 12-001: Hot-air balloon collision with power lines
and in-flight fire, near Carterton,
7 January 2012

Final Report

Aviation inquiry 12-001
Hot-air balloon collision with power lines and in-flight fire, near Carterton, 7 January 2012

Approved for publication: October 2013

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

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

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Deputy Chief Commissioner	Helen Cull, QC
Commissioner	Bryan Wyness (November 2004 – July 2012)
Commissioner	Howard Broad, CNZM (February 2013 – current)

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Important notes

Nature of the final report

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

Ownership of report

Citations and referencing

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

Photographs, diagrams, pictures

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

Cameron Balloons A210, ZK-XXF on an earlier flight

(Photograph courtesy of Geoff Walker)

Source: mapsof.net

Location of accident

Contents

Abbreviations ii
Balloon description iii
Data summary iv
1. Executive summary 1
General 1
Recommendations 1
Key lessons 2
2. Conduct of the inquiry 3
3. Factual information 5
3.1. Narrative 5
3.2. Site and impact information 8
3.3. Operator information 11
3.4. Personnel information 11
3.5. Toxicology 12
3.6. Performance-impairing substances 16
3.7. Aircraft information 17
3.8. Recorded data 21
3.9. Ballooning information 25
3.10. The regulator 26
4. Analysis 29
4.1. Introduction 29
4.2. What happened 29
Landing site 29
Did the pilot see the power line? 30
Post contact with the power lines 32
4.3. Performance of the pilot 33
General 33
Cannabis 33
ARCs relating to the pilot 36
Other accidents where performance-impairing substances were involved 37
4.4. Balloon maintenance and performance 39
4.5. Balloon safety 39
5. Findings 42
6. Safety actions 43
7. Recommendations 46
General 46
Recommendations 46
8. Key lessons 50
9. Citations 51
Appendix 1: ESR reports 53
Appendix 2: Dr Robertson's opinion dated 4 June 2012 56

Appendix 3: Police expert's report (undated) 58
Appendix 4: Review of toxicology report results 62
(The Police expert declined to make further comment in response to the invitation.) 64

Figures

Figure 1 Balloon description iii
Figure 2 Accident site 7
Figure 3 Basket reconstruction 10
Figure 4 Basket attached to ZK-XXF 19
Figure 5 Approximate flight path of ZK-XXF (Image courtesy of Google Earth) 23
Figure 6 Approximate final portion of flight (Image courtesy of Google Earth) 24
Figure 7 Power lines 31

Abbreviations

µg/l	microgram(s) per litre
AAIB	Air Accidents Investigation Branch (United Kingdom)
ARC	aviation-related concern
ATSB	Australian Transport Safety Bureau
BBAC	British Balloon and Airship Club
CAA	Civil Aviation Authority of New Zealand
Commission	Transport Accident Investigation Commission
ESR	Institute of Environmental Science and Research Limited
GPS	global positioning system
kg	kilogram(s)
km	kilometre(s)
kV	kilovolt(s)
LPG	liquefied petroleum gas
m	metre(s)
NPRM	notice of proposed rule-making
THC	tetrahydrocannabinol

Balloon description

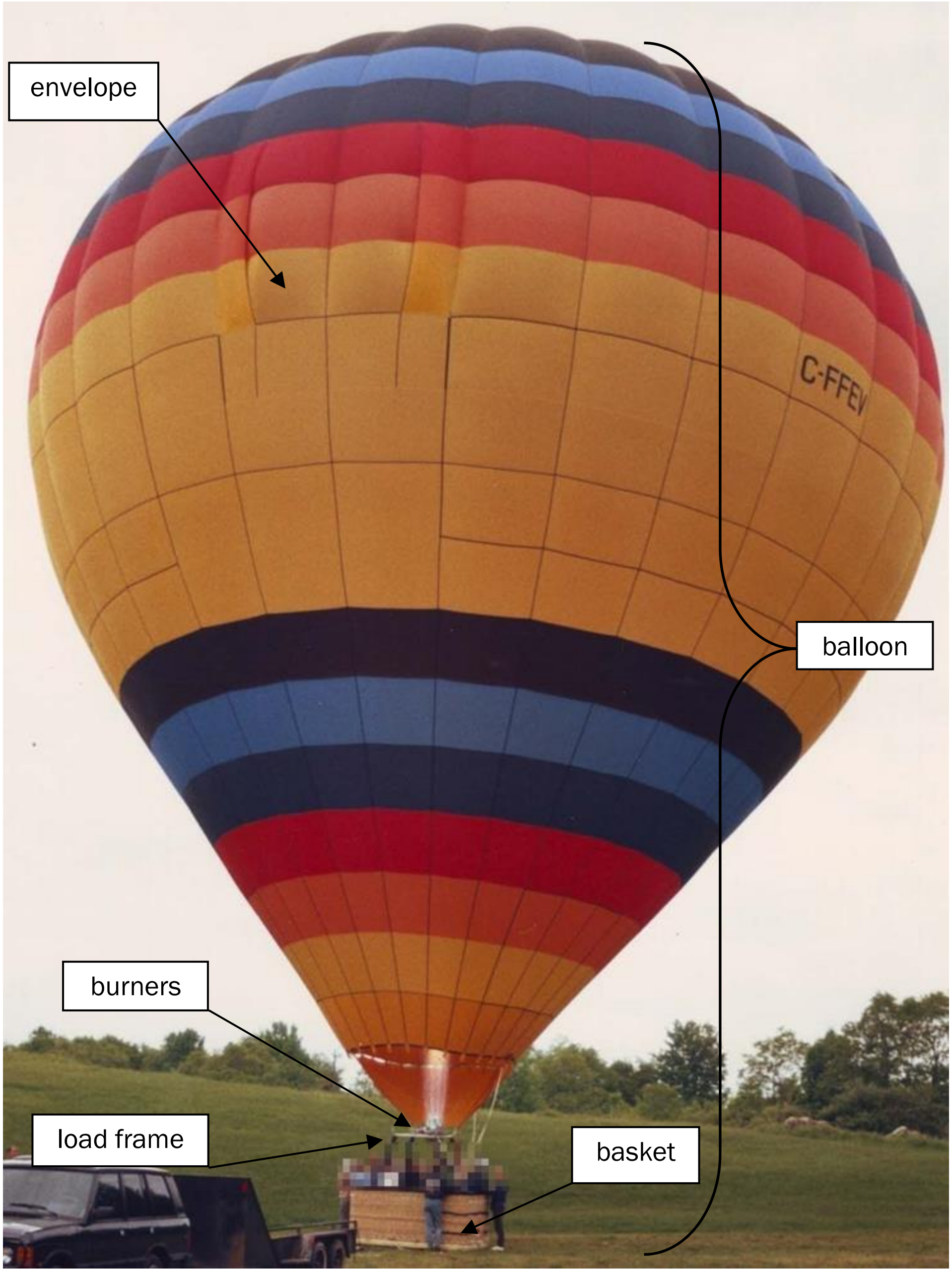

Figure 1
Balloon description

(Photograph courtesy of Jason Livingston)

Data summary

Aircraft particulars

Aircraft registration:	ZK-XXF
Type and serial number:	Cameron Balloons Limited A210, 4300
Number and type of engines:	2 Thunder and Colt C3 Magnum burners and one commercial liquid fire burner
Year of manufacture:	1997
Operator:	Ballooning New Zealand Limited (contracted to Early Morning Balloons Limited)
Type of flight:	commercial adventure
Persons on board:	11
Pilot's licences:	commercial pilot licence (balloon) commercial pilot licence (helicopter)
Pilot's age:	53
Pilot's total flying experience:	1286 hours (1060 balloon hours, including 222 hours on type)

Date and time	7 January 2012, 0722[1]
Location	1 kilometre east of Carterton, Wairarapa latitude: 41° 01.058´ south longitude: 175° 32.694´ east
Injuries	11 fatal
Damage	balloon destroyed 33-kilovolt electric power feeder line to Carterton broken, supply disrupted

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

1. Executive summary

General

1.1. At 0639 on Saturday 7 January 2012, a Cameron Balloons Limited A210 hot-air balloon lifted off from near Carterton in the Wairarapa area for a commercial flight. There were one pilot and 10 passengers on board. The weather conditions were fine with a light and variable wind, which was suitable for the flight. The balloon had been airborne for about 35 minutes when the pilot began to descend the balloon in preparation for landing in the Somerset Road area.

1.2. The balloon changed direction several times as it descended to lower levels. At about 0720 the balloon descended to between 5 and 7 metres (m) from the ground as it drifted over a silage paddock. The paddock was bounded on 2 sides by 33-kilovolt (kV) power lines with an average height of about 9 m. The balloon had earlier drifted near that paddock at a height of between 30 and 60 m, heading in the opposite direction.

1.3. The balloon was drifting towards the power lines on the far road-end boundary when the wind changed and took it towards power lines closer to the adjacent boundary. The pilot applied the burners to try to out-climb the power lines, but the basket of the balloon became entangled in them.

1.4. About 15-30 seconds later, at 0722, an intense electrical arcing occurred and fire erupted in the lower part of the basket. One of the balloon's liquefied petroleum gas (LPG) fuel cylinders was ruptured by the electrical arcing, and escaping fuel intensified the fire.

1.5. Two of the passengers jumped while the basket was still caught on the wires and continuing to climb. The height was about 20 m by this time and they died from their injuries. Heat from the fire further raised the air temperature in the balloon envelope to a point where it broke the wire that was restraining it. The balloon rapidly ascended to a height of between 110 and 150 m before the balloon envelope caught fire and collapsed, and the balloon fell to the ground. The pilot and 8 remaining passengers died from their injuries.

1.6. The Transport Accident Investigation Commission (Commission) concluded that the pilot had not intended to land in the paddock bounded by the power lines and that it had been an unsafe manoeuvre to allow the balloon to descend below the level of the power lines and remain at low level as it crossed the paddock. The Commission also concluded that when the balloon flew towards the power lines and collision was unavoidable, the pilot should have followed the balloon manufacturer's advice and rapidly descended his balloon instead of making it climb. Had he done so, the balloon occupants would have had a better chance of survival.

1.7. Post-mortem toxicology tests revealed the pilot had a tetrahydrocannabinol (THC) level of 2 micrograms per litre (µg/l) of blood. THC is an active ingredient of cannabis.[2] The Commission concluded that this THC level had been caused by both long-term and recent use of cannabis. While it is difficult to say how much each type of use contributed to the result, cannabis is known to affect a person's judgement and decision-making ability. Poor judgement and poor decision-making were factors contributing to this accident. The Commission found that the pilot's use of cannabis could not be excluded as a factor contributing to his errors of judgement, and therefore to the accident.

Recommendations

1.8. The Commission has already made recommendations to the Government about passing legislation to address the safety issue of the use of performance-impairing substances in all transport modes. The Commission makes a further recommendation on this matter.

[2] Cannabis is a general term for the many different preparations of the drug. Marijuana comes from the dried flowering tops and leaves of the plant. Hashish comes from the dried cannabis resin and compressed leaves.

1.9. The Commission also found that the practices of the maintenance provider for the balloon were not in accordance with Civil Aviation Rules. An urgent recommendation was made to the Director of Civil Aviation to address any maintenance issues with the balloon industry. The Director has already taken sufficient action to close that recommendation. However, the investigation found no maintenance issues or mechanical defects with the balloon that contributed to the accident.

1.10. Although not relevant to this accident, the Commission also expressed concern at the lack of regulation covering private ballooning. The Civil Aviation Authority of New Zealand (CAA) has already issued a notice of proposed rule-making (NPRM) to address this safety issue.

Key lessons

1.11. Both long-term and recent use of cannabis may significantly impair a person's performance of their duties, especially those involving complex tasks. Under no circumstances should operators of transport vehicles, or crew members and support crew with safety-critical roles, ever use it.

1.12. Power lines are a well recognised critical hazard to hot-air balloon operations. Balloon pilots should give them a wide margin and if they ever inadvertently encounter them, they should follow the balloon manufacturers' advice and best industry practice to mitigate the possible consequences.

2. Conduct of the inquiry

2.1. The balloon struck power lines at 0722 on Saturday 7 January 2012. The Rescue Coordination Centre and later the CAA notified the Commission of the accident at about 0800 that same day. The Commission immediately opened an inquiry into the accident under section 13(b) of the Transport Accident Investigation Commission Act 1990 and appointed an Investigator in Charge. The Commission assembled an investigation team in Carterton by midday that same day, with the remainder of the team arriving later that afternoon.

2.2. Because the balloon had been manufactured in the United Kingdom, the Commission asked the United Kingdom Air Accidents Investigation Branch (AAIB) to appoint an Accredited Representative under Annex 13 to the Convention on International Civil Aviation. The Air Accidents Investigation Branch appointed a non-travelling accredited representative to participate in the inquiry.

2.3. During the following 5 days the investigation team conducted the site investigation and interviewed witnesses, including the ground crew for the operator.

2.4. Once the site investigation was complete, the wreckage was removed and transported to the Commission's secure workshop in Wellington for further examination. The components of the basket structure were reconstructed at the workshop.

2.5. The Commission liaised with the power lines company (Powerco) and the grid operator (Transpower) to establish the sequence of events relating to the power outage caused by the balloon strike. The severed and damaged section of power line was also taken to the Commission's secure workshop in Wellington, where it was examined together with the reconstructed balloon basket. The New Zealand Fire Service also provided specialist advice on the characteristics of the fire.

2.6. A global positioning system (GPS) was being used by the pilot of the balloon during the flight. This damaged GPS was sent to the Australian Transportation Safety Bureau (ATSB) recorders laboratory, where data was successfully downloaded. This data was cross-referenced with witness statements and photographs taken by witnesses and passengers on board the balloon to recreate the flight of the balloon.

2.7. Records were obtained from the CAA, and from New Zealand Police, which was also conducting an investigation for the Coroner. Balloon maintenance records were reviewed and the maintenance provider and owner were interviewed.

2.8. The initial enquiries into the balloon maintenance revealed a safety issue that urgently needed addressing, so on 15 February 2012 the Commission made an urgent recommendation to the Director of Civil Aviation to address that safety issue.

2.9. The Commission published an interim report on the accident on 10 May 2012, which included the facts that had been established up to that time, but no analysis or findings.

2.10. Post-mortem and toxicology reports were obtained, and because the initial results showed that the pilot had tested positive for performance-impairing substances, the Commission engaged its own independent expert in the area of toxicology to review the report and conclusions of the expert for the testing laboratory.

2.11. The Commission also considered the evidence of a third expert in the area of toxicology who was engaged by New Zealand Police on behalf of the Coroner.

2.12. The Commission's consultant medical specialist also assisted the Commission during its inquiry, particularly in terms of reviewing medical information, including post-mortem and toxicology reports.[3]

2.13. Statements were taken from 2 witnesses following the release of the interim report. On 21 March 2013 the same 2 witnesses appeared before the Commission to give their evidence in person. As a result, the 3 experts who had provided comment on the toxicology reports were requested to make additional comment.

2.14. On 5 June 2013 the Commission approved the draft final report to be circulated to "interested persons" for comment. The Commission identified 11 "persons" who should receive a copy of the draft report. A closing date of 28 June 2013 was set for submissions on the draft report. This was extended to 5 July 2013 at the request of one of the recipients. During the next few days the recipients and the next-of-kin of the passengers were contacted and updated on the progress of the inquiry.

2.15. Submissions on the draft report were received from the following:

- the 2 ground crew
- the freelance photographer
- the Police expert
- the CAA
- the AAIB, including comment by a ballooning expert engaged by the AAIB
- the Ministry of Transport.

Those recipients who did not make submissions were contacted to ensure they had the opportunity to comment.

2.16. On 24 July 2013 the Commission reviewed all the submissions, and changes to the draft report were made where appropriate. The Commission also directed that a further investigation be undertaken on the relevance of the toxicology results from the pilot, and as a result a further 3 witnesses appeared before the Commission to give evidence in person. Additional changes were made to the draft report as a result of hearing the 3 witnesses.

2.17. The Commission approved the final report for publication on 9 October 2013.

2.18. The Commission acknowledges the assistance of the ATSB in the recovery of GPS data, and the AAIB in the co-ordinating of specialist advice from the balloon manufacturer, the British Balloon and Airship Club (BBAC) and a ballooning expert. The Commission also acknowledges the specialist advice provided by Powerco, Transpower and the New Zealand Fire Service.

3 Dr Rob Griffiths is the Director of the Occupational and Aviation Medicine Unit at the University of Otago, Wellington. His qualifications include MBChB (Hons) (Bristol) 1978, FAFPHM (RACP, Sydney) 1985, FFOM (RCP, London) 1986, FAFOEM (RACP, Sydney) 1987, FFOM(I) (RACPI, Dublin) 2009, MACOEM (ACOEM, USA) 2009, MPP (VUW) 1994, DipAvMed (Univ London) 1983, DIH (Soc. Apoth., London) 1984.

3. Factual information

3.1. Narrative

3.1.1. On Saturday 7 January 2012, a Cameron Balloons A210 hot-air balloon[4] (registration ZK-XXF) was booked to fly a local commercial adventure flight from Carterton. At 0457 the pilot sent a text message to his 2 ground crew and a freelance photographer, asking them to meet him at the shed where the balloon was stored by 0545. The 3 had worked with the pilot for several years. The pilot arrived at the shed on the northern outskirts of Carterton at about 0525, with the others arriving between about 0530 and 0550.

3.1.2. At about 0540 the pilot released a small helium-filled pilot balloon to check if the wind conditions were suitable for the flight. The flight path of the small balloon confirmed there was little or no wind present and the pilot decided to make the flight. The balloon was then taken by trailer to a gate nearby that led to the launch area – a small mown area in an adjacent paddock.

3.1.3. The passengers started arriving from about 0545 and were met by the 2 ground crew members, and shortly after by the pilot who had walked from the shed. The ground crew gave each arriving passenger a breakfast order and passenger loading form to complete. Meanwhile the pilot went and unlocked a nearby building that had toilet facilities for the passengers. Shortly afterwards 2 witnesses[5] saw the pilot standing on a balcony of the building between 20 m and 30 m from the assembly area. They observed that he was smoking but they thought nothing of it at the time. (See paragraphs 3.5.6 and 3.5.7 for further comment.)

3.1.4. At about 0610 the pilot re-joined the group, stood on the side of the trailer and welcomed the 10 passengers and introduced the crew. He then gave an initial briefing on the balloon and the planned sequence of events. The balloon was taken by trailer to the launch site, where it was offloaded and laid out on the grass in preparation for inflation. Initially a cold-air fan was used to inflate the envelope, a process that one of the ground crew reported took a little longer than normal. There was morning dew on the ground, which can hold the envelope down, making it more difficult to inflate. To complete the inflation and lift the envelope off the ground, hot air was added using the balloon's burners. Several of the passengers assisted the pilot and ground crew with the inflation, which was a typical way of involving passengers with the flight preparation.

3.1.5. The freelance photographer recorded the inflation of the balloon and was following his usual pattern of photographing the passengers and balloon during the preparation for the flight. He would then follow the flight of the balloon, taking photographs along the way.

3.1.6. At 0635 the passengers boarded the balloon and the pilot gave them a second briefing, primarily covering what the passengers should do when landing. At 0638 the launch restraint or tie-off line attaching the basket to one of the support vehicles was released, the burners were operated to heat the air in the envelope further, and the balloon lifted off.

3.1.7. The pilot and ground crew had a set of 3 pre-arranged radio calls, called Check One, Check Two and Check Three. As the balloon departed, the ground crew packed up the remaining equipment and the crew chief made the Check One call, confirming that the launch site was clear and that they were leaving. The pilot acknowledged the call, which meant that all was well with the balloon and passengers. The 2 ground crew then drove the operator's 2 vehicles to a local café where the orders for the post-flight breakfast were placed. The ground crew were followed by a group of relatives of 2 of the passengers on board the balloon.

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[4] For simplicity, hot-air balloons are hereafter referred to as balloons.

[5] The witnesses came forward with this information immediately after attending Police and Commission briefings in preparation for the release of the interim report, which included information that the pilot had tested positive for cannabis.

3.1.8. The ground crew remained at the café and kept a watch on the progress of the balloon. The flight was also witnessed by the photographer, who travelled independently. Local residents were familiar with the sight of the balloon flying around the area and some witnessed portions of the flight, as did several visitors to the area. Witnesses described the balloon climbing to about 450 m in near-calm conditions, then drifting slowly south-east before moving in a northerly then an easterly direction. Because of the near-calm conditions and the slow, irregular movement of the balloon, the ground crew remained near the café for about 20 minutes before leaving. The Check Two call was then made, advising the pilot that they were on the road following the balloon. The chase vehicles initially moved to just north-east of Carterton and waited in a car park by State Highway 2.

3.1.9. About 30 minutes after lift-off, the crew chief made the Check Three call, a reminder to the pilot of the time and to gain an indication from the pilot of where the balloon might land. The pilot acknowledged that call and advised that the landing looked like being in the Somerset Road area. The balloon was seen to descend about this time, crossing Somerset Road about 100 m from State Highway 2 and drifting south-east. The crew chief in the first chase vehicle started to move along Somerset Road to watch the balloon. The balloon then started to drift to the north-east, crossing Somerset Road again. At about this time the pilot radioed the ground crew and told them to "hold there" as the balloon drifted farther away from the road (see Figure 2).

3.1.10. The ground crew, photographer and following relatives kept a watch on the balloon's progress. Several residents of Somerset Road and others who worked there saw the balloon after it descended and drifted slowly around their area. One resident ("Witness A") was inside her house immediately adjacent to where the balloon later entangled with power lines. She heard the noise of the burners, so she went outside to the back of the house and watched as the balloon moved slowly past the house heading to the north-east. Witness A was able to see the people in the basket and estimated that the balloon was not much higher than the top of nearby tall trees as it drifted past. These trees were about 20 m high. Witness A then went back inside as she thought the balloon was going to land well to the north of her house, as it seemed to her to be holding about the same height.

3.1.11. Other witnesses' estimates of the height of the balloon as it drifted farther north of Somerset Road varied between 30 m and 60 m.[6]

3.1.12. About 400 m from Somerset Road, the flight path of the balloon changed again and it started drifting in a south-westerly direction back towards Somerset Road. The pilot radioed the ground crew again and told them that the landing place looked to be near Somerset Road. The second chase vehicle and the relatives stopped in Somerset Road and alighted from their vehicles to watch as the balloon started to drift towards the centre of a silage paddock[7] near the property of Witness A. The crew chief in the first chase vehicle did a U-turn and joined them. At about 0720 the witnesses saw the balloon descend to between 5 m and 7 m as it crossed the silage paddock where several rows of irrigation sprinklers were operating.

3.1.13. A member of the group of relatives following the balloon later reported that after getting out of their vehicle, they felt a breeze blowing from their left (north) as they watched the balloon approach across the silage paddock. The breeze was not considered strong and was described as being "an isolated gust of wind". The crew chief, thinking the pilot might cross the road and land in an adjacent paddock, walked along the road to check for access and obstacles for the pilot. He radioed to the pilot asking if he had seen the horse in a paddock over the road. The pilot radioed back that he had seen the horse.

3.1.14. As the balloon approached Somerset Road, Witness A and members of the chase team and following group heard both burners operating. The balloon was seen to drift left towards power lines that ran along the side of the silage paddock and near Witness A's house. The balloon then slowly started to climb. During this time the crew chief continued walking along

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[6] Height estimates are from the ground to the base of the basket.
[7] The term "silage paddock" is used to help identify this specific paddock, which is central in the sequence of events.

Somerset Road and found an access gate on the western side of the road. As the crew chief returned to his vehicle he heard the pilot yell out, "Duck down". The crew chief turned around in time to see the balloon basket contact the top power line.

3.1.15. Witness A was near the kitchen window facing the silage paddock. She saw the balloon approaching the power lines at low level and ran outside and into the backyard in time to see the basket being caught under one of the wires. She recalled that the burners had stopped operating by this time.

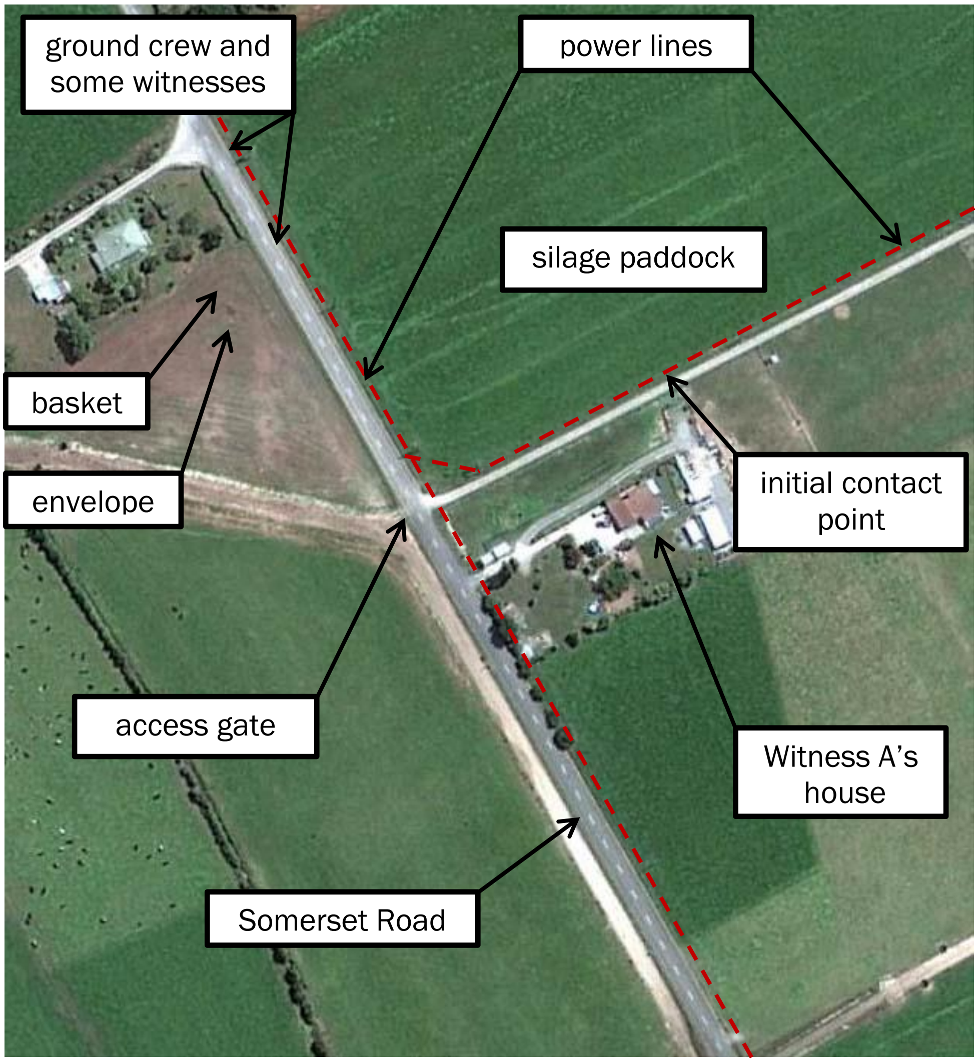

Figure 2
Accident site

3.1.16. The photographer, realising that the balloon was likely to land before he could get to the landing site, stopped his vehicle farther south along Somerset Road so that he could continue to take photographs using a telephoto lens. These showed the balloon as it collided with the power line. The photographs showed one of the wires caught over the pilot's end of the basket. The balloon was lifting the wire upwards, indicating that the balloon was trying to rise. Photographs also showed a second wire caught farther down the side of the basket at the same end. Witness A described some of the occupants trying to push the top wire off the lip of the basket.

3.1.17. As the balloon continued to rise it also began to slide along the power line towards Somerset Road. Based on photographic time stamp data, at between 15 and 30 seconds after contacting the wires an electrical arc and substantial flash occurred in the vicinity of the basket. A fire immediately erupted low down in the basket and quickly took hold. The wire that had been caught lower down on the basket disentangled and fell free. Two of the passengers jumped from the burning basket while it was still about 20 m above the ground.

3.1.18. The fire increased in intensity, engulfing the basket and eventually setting fire to the envelope. The balloon continued to climb but was still restrained by the remaining wire. This wire eventually parted and fell to the ground. The balloon continued to ascend rapidly to a height of between 110 and 150 m, at which point the envelope collapsed and the balloon fell to the ground.[8] The time from the arc flash to when the wire finally separated from the basket was between 75 and 80 seconds. The balloon continued to climb for about another 40 seconds before falling. The balloon hit the ground a total of 2 minutes and 5 seconds after the start of the arcing.

3.1.19. Emergency services were alerted to the accident at 0723 and the first response vehicle from Carterton arrived on the scene at 0729. This was shortly followed by other vehicles from Carterton, Greytown and Masterton. Emergency staff took over the first aid efforts, as well as extinguishing the still-burning wreckage. The balloon occupants, including the 2 who had jumped, were found to have died at the scene.

3.2. Site and impact information

3.2.1. The accident site was on Somerset Road, one kilometre (km) east of Carterton. The surrounding area was farmland, predominantly grassed for dairying. Several power lines crossed the local area, including a line running alongside Somerset Road.

3.2.2. The power line that the balloon struck ran perpendicular to Somerset Road and was part of a dual-voltage span with three 33 000-volt (33 kV) wires strung at the top and three 11 000-volt (11 kV) wires below. The 33 kV wires were each 17 millimetres in diameter and part of the feeder line to Carterton. The 33 kV wires were suspended 10 m above the ground at the poles, dropping to 8 m at the centre of the 100 m span. The 6.3-millimetre-diameter 11 kV wires were about 1 m below that. The power line ran alongside the northern side of a farm track that bordered the silage paddock with the sprinklers. A small paddock lay between the track and the house occupied by Witness A. The power line consisted mainly of single concrete poles, but there were 2 double poles at the Somerset Road end of the line where the span finished and the line changed direction to follow Somerset Road.

3.2.3. A preliminary examination of the 33 kV power line was completed before any repair work was started. The wire closest to the silage paddock (the blue phase wire) was found broken and lying across the remaining 2 wires. This was the wire that had been caught across the top of the basket. It displayed significant damage. The centre wire (the yellow phase wire) was still suspended from the poles and displayed some damage. This was the wire seen caught near the bottom of the balloon basket. The wire closest to the small paddock (the red phase wire) was still suspended from the poles and showed little damage.

3.2.4. The balloon wreckage was found concentrated in a paddock situated on the other side of Somerset Road, 150 m west of where the balloon first contacted the power line. The envelope had separated from the basket where the flying cables from the basket attached to the base tape at the mouth of the envelope, or at the opposite end where they attached to the basket. The basket had struck the ground almost level. The metal framing of the basket, the burner frame and burners had collapsed downwards with the impact and slightly away from the pilot's end. Two fuel cylinders had been thrown clear of the wreckage and lay near the envelope several metres away. The wreckage had continued to burn on the ground until extinguished by emergency services, with most of the wooden wicker and cane construction material destroyed. Debris was scattered between the point of contact with the power line and the wreckage.

3.2.5. The 2 passengers who jumped from the basket fell to the small paddock adjacent to Witness A's house. The other 8 passengers and the pilot were found in or next to the wreckage of the basket.

[8] Estimated height of the basket above ground based on witness accounts, photographs and balloon dimensions provided by the manufacturer.

3.2.6. Emergency personnel noted that 3 of the LPG fuel cylinders were empty when they arrived and that the fourth cylinder was still venting gas. This cylinder was moved away from the main wreckage and cooled as a precaution to protect personnel. The New Zealand Fire Service advised that a combination of water and fire-retardant additive was used to extinguish the last of the fires, with some of the retardant being sprayed onto the envelope.

Damage assessment

3.2.7. The balloon wreckage was first examined on site before being removed to Commission facilities, where a reconstruction of what was left of the basket was made (see Figure 2). Two of the 3 power line wires from the span that the balloon contacted were removed and examined by investigators with the assistance of staff from Powerco, the local lines company, and the New Zealand Fire Service.

3.2.8. An examination of the broken and damaged power line wires confirmed that the balloon had first contacted the wires about 85 m in from Somerset Road, before sliding along the line towards the road. The damage to the power line wires included stress marks, mechanical damage, burn patterns and evidence of arcing.

3.2.9. Powerco reported that based on its experience and knowledge, "high voltage electrical arcs comprise a cloud of ionised air plasma, with a temperature at the boundaries of approximately 5000 degrees Celsius, and internal arc temperatures reaching 20 000 degrees Celsius". Further, the rapid increase in temperature causes "an expansion of air and vaporisation or melting of solid material adjacent to, or surrounded by the arc. The associated expansion in volume can spread molten metal over quite wide distances".

3.2.10. The New Zealand Fire Service specialist fire investigator considered that "the burn patterns were those that would normally be associated with a high temperature fire such as LPG which burns at around 1950 degrees Celsius".

3.2.11. The basket's stainless steel framing was severely distorted. Evidence of electrical arcing was found around the top of the basket piping frame and on the wire around the bottom of the basket frame around the pilot's compartment that also housed the LPG cylinders. All but one of the support suspension cables running around the basket were intact. That one cable had indications of electrical arcing.

3.2.12. The fire specialist noted that the 4 fuel cylinders all "showed signs of extreme heat which had melted the aluminium fittings. None of the cylinders showed signs of expansion due to internal pressure. This would indicate that the gas most probably vented through their pressure relief valves". One of the cylinders had a small hole near the base that looked as if it had been caused by electrical arcing. This was determined to be the origin of the fire.

3.2.13. The lines company's electrical protection trip records confirmed that the short circuiting and arcing occurred at 0722:17. The type of circuit trip also confirmed that the balloon basket had been part of the conduction path between 2 of the 33 kV wires.

3.2.14. All the fuel hoses and fittings to connect the cylinders to the burners were accounted for. The lever-style tap fittings for each of the cylinders were dismantled to confirm the positions of the taps. The taps of the 2 inboard LPG cylinders closest to the centre of the basket were determined to be in the OFF or CLOSED position. The cylinder that had the small puncture hole in it was also CLOSED. The tap of the fourth cylinder was determined to be OPEN. There were 2 cross-feed valves, one between the 2 burners and the second between the 2 outboard cylinders. Both were found to be CLOSED.

3.2.15. The on-board fire extinguisher was found severely damaged with the handle/nozzle assembly broken off and the bottle depleted of its contents. The release pin was found still inserted into the activation handle. Also found was the partially burnt aircraft flight manual, Issue 10 dated 10 April 2006, pre any amendments.

3.2.16. The envelope was severely damaged by fire and heat, and possibly also by the retardant used to extinguish the fires. A balloon envelope is constructed of several types of material, and possibly different colours of the same material, all of which deteriorate at varying rates with time, heat and exposure to the elements. To obtain an indication of the condition of the envelope prior to the fire, several samples of the lesser damaged material were removed from points around the envelope and examined. The examination included checking the porosity[9] of the material using approved equipment. The samples generally performed well in strength and either exceeded or were close to the minimum porosity specifications considered viable for flight.[10]

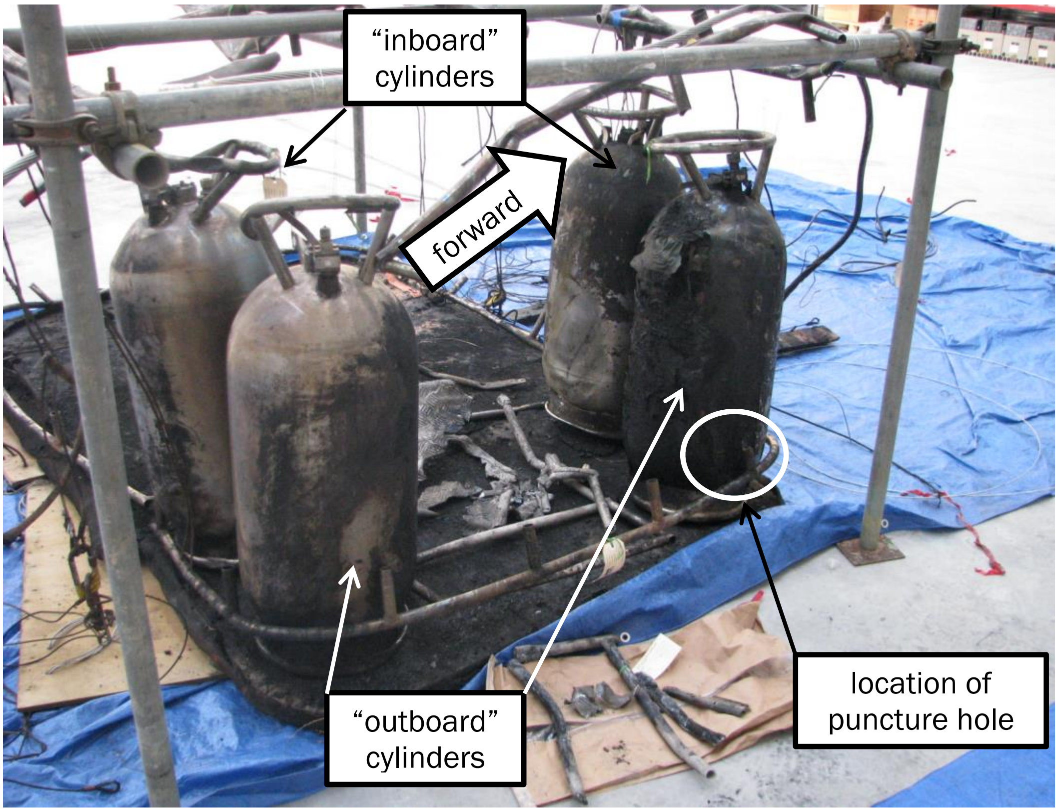

Figure 3
Basket reconstruction

Weather

3.2.17. The weather conditions were described by witnesses as fine with little or no wind. The ground crew members and other local balloonists spoken to thought the conditions that morning were suitable for ballooning.

3.2.18. The weather data recorded at 6 weather stations positioned in vineyards located around Carterton was obtained. At 10-minute intervals the weather stations recorded the temperature, rainfall, humidity, average wind direction and speed and maximum wind strength during that 10-minute period. At 0600 the temperature recorded at the 6 stations varied between 9 and 13.1 degrees Celsius and the humidity ranged from 81% to 100%. At 0720 the temperatures had increased to between 12.6 and 14.1 degrees Celsius. The humidity also increased generally to between 86% and 100%.

3.2.19. Three of the stations recorded calm conditions for the duration of the flight. Two of the stations recorded occasional "gusts" of between 0.9 and 5 km per hour. The sixth station recorded average winds of between 1.2 and 7.3 km per hour and gusts of 5.2-11.4 km per

[9] How porous material is.
[10] Were the envelope to become more porous it could still be flown safely but increasingly more heat would need to be added to sustain flight. The cost of flying would therefore continue to increase.

hour. The wind direction was mostly from the north-east but did swing around to the south and west occasionally.

3.3. Operator information

3.3.1. Ballooning New Zealand Limited was owned by the pilot, who had a contract with Early Morning Balloons Limited to fly ZK-XXF. Ballooning New Zealand was therefore the operator of ZK-XXF. The pilot was a director of Ballooning New Zealand and he employed the ground crew. The pilot was responsible for the safe management of the operation, staff and passengers. The pilot was also responsible for facilitating any routine and non-routine maintenance on the balloon. The pilot would normally inform the owner before any maintenance action was undertaken.

3.3.2. The pilot had produced a range of company documentation for Ballooning New Zealand. These included a health and safety policy, a code of safe conduct, an employment job description and procedures for employees. The pilot also had several local area maps showing areas to avoid and hazards, including power lines. The maps were typically used by the pilot to brief other pilots attending the annual local balloon fiesta, for which the pilot had previously been the safety officer.

3.3.3. Crew members reported that the pilot normally used the 2 inboard cylinders first and switched over to the 2 outboard cylinders when descending or about to descend in preparation for landing. The cylinders were normally refilled after each flight. Refuelling records showed that between 140 and 175 litres of fuel (LPG) had been consumed on each of the previous 10 flights, the actual usage being dependent on the duration of the flight, passenger load and ambient temperature. The highest fuel usage was noted for flights where between 8 and 10 passengers were carried.

3.3.4. The owner of ZK-XXF had in the few weeks preceding the accident discussed with the pilot the possibility of expanding the owner's business interests On the Friday before the accident the owner had contacted the pilot again by email and advised that they were planning to take back possession of the balloon. Refer to paragraph 3.5.2 for further comment.

3.4. Personnel information

3.4.1. The pilot was 53 years old. He held commercial helicopter and commercial balloon pilot licences. He ran 2 logbooks, one for his helicopter flying and a second for his balloon flying. His first balloon logbook could not be located, but a witness thought he had started his balloon flying in the mid-1980s. CAA records showed he had obtained his commercial pilot licence (balloon) on 23 June 1995. The pilot's current balloon logbook had commenced on 17 May 2006, by which time it recorded that he had accumulated 677 hours flying balloons.

3.4.2. The pilot had started flying commercial balloon flights for the owner in about 1997, initially flying ZK-EMB, a Thunder and Colt 160A balloon.[11] In 2001 he had started flying ZK-XXF and by 7 January 2012 had accumulated about 215 hours on this balloon. He also flew 7 hours on another Cameron Balloons A210 balloon while ZK-XXF was undergoing maintenance work. At the time of the accident the pilot had accumulated a total of 1286 flying hours, comprising 226 hours flying helicopters and 1060 hours flying balloons.

3.4.3. The pilot typically flew about 70 hours per year, concentrated around the January to April period. He had flown 7 balloon flights in December 2011, including 3 flights in ZK-XXF on 24, 27 and 28 December with 7 or 8 passengers. The pilot had last flown ZK-XXF on 3 January 2012 on a local flight with 7 passengers. The following day he had flown 3 passengers in a smaller balloon, landing near a road 2 km to the north-east of Somerset Road. The most recent flight with 11 persons on board had been on 28 August 2011.

3.4.4. The pilot's logbook recorded that on 5 occasions since August 2006 the landing location had been Somerset Road; the most recent had been on 23 September 2011.

[11] See section 3.7 for more information about balloons and the different types.

3.4.5. The Commission received information that the pilot had been on board a balloon that contacted power lines in about 1999. The CAA advised that it had no record or knowledge of the alleged incident. Powerco records confirmed that a balloon had struck 11 kV wires near Masterton on 26 March 1999, and the pilot of ZK-XXF was one of the occupants of the balloon. Further enquiries confirmed that the incident had taken place during a balloon fiesta in Wairarapa and that the pilot had been a passenger. During take-off a wind gust had pushed the small 2-person balloon onto a nearby power line. As the balloon lifted free of the wires there had been an arcing that caused a "small burn mark on the side of the basket".

3.4.6. The pilot's most recent biennial flight review had been on 14 January 2010 and his last Class 1 medical certificate had been issued on 25 November 2010. A Class 1 medical certificate would normally have a validity period of 6 months for pilots aged 40 years and over (CAA, 2007). However, certain commercial activities, including sightseeing flights in hot-air balloons by day, were exempted from being classified as commercial transport operations (CAA, 2008). The pilot's medical certificate for ballooning had therefore been valid for one year, until 25 November 2011. This meant that his medical certificate had expired 6 weeks before the accident.

3.4.7. The medical examiner who had completed the certificate said that as part of his call-up system he had contacted the pilot before his medical certificate was due to expire. The medical examiner recalled making an appointment that he thought the pilot later cancelled. He had not followed this up because he thought the pilot may have completed his examination elsewhere, which had occasionally happened.

3.4.8. The medical questionnaire completed by the pilot on 18 November 2010 as part of his examination contained a section titled "Medical History: Have you ever experienced any of the following?". For the question on "Use of legal or illegal recreational drugs or substances", the pilot had circled N for No. For the section on smoking the pilot had recorded that he had smoked for 3 years but not within the previous 12 months.

3.4.9. Medical evidence was provided that the pilot suffered from gout. Gout is a joint inflammation (arthritis) and often affects parts of the foot. Gout can cause sudden bouts of pain and swelling. The medical examiner was aware that the pilot suffered from gout, but otherwise considered he was a very fit person. This assessment was supported by the pilot's general practitioner and others who knew him. On the morning of the accident the pilot was seen by the ground crew and several witnesses to be hobbling slightly. Those who knew him thought this was caused by the gout. The pilot was not known to have any medical condition that should have affected his ability to pilot a balloon.

3.5. Toxicology

3.5.1. On 11 January 2012 the pathologist sent blood[12] and urine samples taken from the pilot's body to the Institute of Environmental Science and Research Limited (ESR) for analysis as part of the post-mortem. On 16 March 2012 a report was received from ESR showing a positive result for THC with a reading of 2 µg/l of blood. THC is a constituent of cannabis. As a consequence of the findings in the ESR report, the pilot's 24-hour history before the flight was reviewed.

24-hour history

3.5.2. The pilot, in addition to his flying duties, was also a local truancy officer. Because of the school holidays he was not working in this capacity in the days before the accident. On the morning before the accident the owner of ZK-XXF sent a follow-up email to the pilot, again advising that they were planning to expand their own business interests. As part of that expansion they intended to take possession of the balloon, possibly towards the end of May. The pilot met with his partner later that day and discussed the possibility of purchasing a replacement balloon. The freelance photographer was also present for part of the discussion. The pilot and his partner again discussed the subject after returning home at about 1715.

[12] See Appendix 4 regarding comment on the quality of the blood sample examined by ESR.

3.5.3. At about 1830 on 6 January 2012, the pilot visited a friend to discuss matters around the purchase of a replacement balloon. He returned home at about 2000, had dinner, and at about 2100 went to bed in preparation for the early morning flight. The pilot's partner and the friend he visited both commented that the pilot had been positive about continuing the ballooning business and, while he may have had a couple of drinks, he had not been intoxicated. Both were also adamant that he had not smoked any substance in their presence or displayed any signs of having recently consumed cannabis.

3.5.4. At about 0520 on 7 January 2012, the pilot left his home for the shed where the balloon was located, arriving there about 5 minutes later. The 2 ground crew arrived thereafter and, with the pilot, went about their duties preparing for the flight. The pilot discussed the probable return of the balloon to its owner with the ground crew and photographer. Two of those persons said that the pilot was not happy about returning the balloon but appeared positive about continuing with ballooning. The 3 stated that the pilot showed no signs of having consumed cannabis that morning. The times recorded above are approximate but there was nothing reported to be untoward or unusual in the pilot's behaviour on the morning of the accident.

3.5.5. At about 0605 the pilot was observed standing on a balcony of a building by 2 witnesses who had gathered with the passengers between 20 m and 30 m away. Behind the balcony was a staff room with toilets at the back. The pilot was the only person present that morning who had a key to the building and the code to disable the security system. Company records showed that the security system was disabled at 0602 and reset at 0608. Two passengers were seen exiting the building, and it was the noise of the door closing behind them that attracted the attention of the 2 witnesses.

3.5.6. The 2 witnesses who saw the pilot on the balcony were interviewed separately, initially by the Police, then by a Commission investigator and on 21 March 2013 by the Commission. The 2 witnesses had both known the pilot by sight and were able to identify him clearly from their position about 25 m away. They independently confirmed that he had had something in his right hand that he put to his mouth. Smoke was then seen rising from his mouth or head area. The witnesses were confident that it was smoke and not water vapour as no-one had seen vapour being emitted from the people present that morning. The pilot had what appeared to be a cup in his left hand, but did not take it to his mouth. A clipboard or something similar was seen under his left arm. The 2 witnesses both thought the pilot was having a regular cigarette, so thought nothing more of it and did not continue to observe him.

3.5.7. As a result of receiving the draft report a further 3 witnesses took issue with the testimony of the first 2 witnesses. The further 3 witnesses did not believe the pilot had been smoking on the balcony. The Commissioners conducted interviews with these other 3 witnesses as well.

Toxicology reports

3.5.8. Following receipt of the initial ESR report, further testing of the pilot's urine sample showed a THC-acid level of 120-130 micrograms per litre. The updated report, dated 23 May 2012, was then provided to the Commission. The ESR reports by the forensic toxicologist (ESR toxicologist) had been peer reviewed. The full ESR report can be found in Appendix 1.

3.5.9. The ESR report stated that:

> Under normal conditions a blood THC level of 2 micrograms per litre would be consistent with [the pilot] smoking the equivalent of a single cannabis cigarette within 5 hours prior to death. Blood THC levels may remain elevated for a longer period if cannabis is used frequently.

3.5.10. The ESR report further stated that no medicinal drugs that affect the mind, alter mood or cause sleep were detected in the blood, and no common analgesic medication was detected. Also there was no evidence of the use of amphetamine-type stimulants, opiate-type drugs or cocaine. An alcohol reading of 5 milligrams per 100 millilitres of urine was found, but no alcohol was detected in the blood. The report stated that: "Low levels of alcohol may be due to means other than deliberate ingestion" [principally decomposition].

3.5.11. In commenting on the results, the ESR report stated:

> Cannabis cannot be easily classified as a sedative or stimulant since it can have different effects in different people and its effects generally vary over time. Its main psychological and behavioural effects are euphoria and relaxation, an impairment of perception and cognition, and loss of motor coordination.
>
> Subjective symptoms of cannabis intoxication usually peak 10 to 15 minutes after smoking cannabis and last 1.5 to 4 hours.
>
> Blood THC levels produced by smoking a cannabis cigarette and the rate at which the levels decrease vary widely between individuals and are dependent on a number of factors. These factors include frequency of use, smoking technique and experience, and size and potency of the cannabis cigarette.
>
> Blood THC levels are generally a poor indicator of cannabis intoxication. It is not usually possible to determine whether a subject was intoxicated based on blood levels alone. Because of the degree of trauma sustained I cannot be confident that the level of THC detected in the blood sample accurately reflects the level present immediately prior to death. However, a level of 2 micrograms per litre indicates recent use and it is possible that [the pilot] was affected by the drug at the time of the crash.
>
> Peak levels of THC-acid occur in the urine within 6 hours after smoking cannabis. Because THC is absorbed into the fatty tissues and slowly excreted as THC-acid, high levels of THC-acid may be detected in the urine of frequent users for several days.

3.5.12. The Commission sent the ESR toxicology report and autopsy report to Dr Shelley Robertson, an expert in forensic medicine and pathology in Melbourne, Australia, for an independent review. After reviewing the ESR and autopsy reports and other information, Dr Robertson expressed the following written opinion:

> In general I agree with the comments regarding interpretation of the results of toxicological analysis made by [name deleted] of ESR Laboratories. She states "Because of the degree of trauma sustained I cannot be confident that the level of THC detected in the blood sample accurately reflects the level present immediately prior to death." Interpretation of THC levels in post-mortem blood specimens is problematic, particularly (as in the present case) if the specimen is suboptimal (ie cavity blood from an extensively traumatised body). Other factors include the possible post-mortem redistribution of THC in blood (from tissue stores of the compound). The finding of a level, however of 2 μg/l [2 micrograms per litre] in blood, strongly suggests recent use of cannabis by the deceased in the hours prior to the accident. This is supported by the presence of THC-acid in the urine.
>
> The effects of cannabis use in an individual are extremely variable and include such factors as history of usage (that is, chronic as opposed to 'one-off'). Some research suggests that a blood level of 5 μg/l and above causes cognitive impairment however blood levels of THC tend to decline quite rapidly after use (several hours) whilst studies have shown (specifically flight simulator studies in pilots) that cognitive deficits can persist at least up to 24 hours following cannabis use (the 'carry-over effect'). This leads to the conclusion that direct correlation of cognitive impairment with blood levels of THC is also problematic.
>
> The testing of the blood and urine specimens obtained from the deceased, [name deleted] by ESR Laboratories was directed at the active metabolite of cannabis, that is Δ9-THC. Levels of this compound give the best indication of recent usage, unlike the inactive metabolite, 11-nor-Δ-tetra hydrocannabinol-9-carboxylic acid (THC acid) which can persist in blood and urine for days following cannabis use and has not been demonstrated to correlate with cognitive impairment at all.

3.5.13. In conclusion Dr Robertson wrote:

> In conclusion, the pilot of this hot-air balloon, which crashed resulting in the death of all persons on board, was shown to have the active metabolite of cannabis in blood at a level of 2 μg/l. Whilst this level may not accurately reflect the actual blood level

> at the time of death, it strongly suggests recent cannabis use (4-6 hours prior to death). This in turn suggests that at the time of use (within the 4-6 hour time-frame) the blood levels of THC would have been much higher and the likelihood of cognitive impairment also high. Cognitive impairment at or around the time of the accident cannot be excluded, given the 'carry-over' effect of cannabis.
>
> The testing of the specimens by ESR Laboratories and the report issued including the comments by [name deleted] appear to be entirely appropriate.

3.5.14. Dr Robertson's full opinion can be found in Appendix 2.

3.5.15. The pilot was reported to be a "social drinker" only and, with the exception of a cigar at Christmas, did not smoke tobacco. He was known by 2 people close to him to smoke the "occasional" cannabis cigarette. Those 2 people also acknowledged that they could only comment on what they knew about. As neither of the 2 spoken to were with the pilot all of the time, they were unwilling to say how often he smoked cannabis in any one day, or how many days in a typical week or weeks. They both thought that he would not smoke cannabis so soon before flying as to cause concern. They considered he was a responsible pilot who would not fly while under the influence of the drug. Both spoken to had known the pilot for a long time.

3.5.16. New Zealand Police, on behalf of the Coroner, sought independent advice from another forensic pathologist with expertise in forensic toxicology (hereafter referred to as the "Police expert"). The Police also requested ESR to conduct additional testing. The second ESR report can be found in Appendix 1. The Commission obtained a copy of the Police expert's report, which can be found in Appendix 3. The Police expert was working on the information given to him by the Police that the pilot was a regular user of cannabis and had been for a long period of time. The Police expert took that to mean that the pilot was a "chronic" cannabis user and based his opinion on that assertion. The following are relevant excerpts from his report:

> Opinion
>
> 1. The information as provided supports the fact that [the pilot] was a chronic user of cannabis
> 2. The information provided can not prove or exclude that [the pilot] had ingested cannabis in the hours prior to the balloon crash.
> 3. The information can not prove the notion that [the pilot] was under the influence of cannabis at the time of the crash.
>
> When interpreting post-mortem toxicology you must consider whether the person is a naïve user, intermittent [user] or chronic user of the drug. When looking at a value of 2 micrograms per litre (that is 2 parts per million) of THC in such a sample under these conditions, you cannot draw a firm conclusion of acute exposure in a person known to be a chronic user of cannabis, as was [the pilot]. The 2 micrograms may well be stored THC from previous exposures that redistributed and/or leached from fat stores during decomposition. It is entirely possible that if a blood sample was drawn from [the pilot] minutes before he lifted off that morning, it may have shown levels of THC less than 2 micrograms per litre in his blood.
>
> You could infer that it represents recent use in a person known not to take cannabis, or take it on an infrequent basis. You simply cannot infer that it represents recent use in a chronic user. The THCCOOH in urine is known to be detectable for many days after the last exposure in a chronic user, up to 10-13 days after the last use.
>
> Their suggestions [ESR's and the Commission's independent forensic toxicologists] cannot be disproven beyond scientific and medical certainty due to the problematic delay between the [accident] and the recovery of the post-mortem samples. In the four days between the incident and retrieval of the blood sample upon which the toxicity is based, the vital information that may have answered this pivotal question was irretrievably lost.
>
> In order to address the allegation that [the pilot] was smoking either a cigarette or something else just before the balloon took off, I requested that cotinine (found in

urine of tobacco smokers) be looked for in his urine and this proved negative, supporting the assertion that [the pilot] did not smoke tobacco.

Conclusions:

The toxicology results from the decomposing samples taken from [the pilot] three days after the balloon crash support the established fact that he was a chronic smoker of cannabis (THCCOOH in urine) and he did not smoke tobacco. The results do not prove that he smoked cannabis on the morning of the flight. It is entirely probable that he did not smoke cannabis for several days prior to the incident. There is no definitive evidence to suggest he was under the influence of THC at the time of the incident and the THC found may well have resulted from post-mortem redistribution. The THC does not prove recent use in a chronic user (i.e. within a 4-6 hour timeframe).

If there is still a question as to whether [the pilot] smoked cannabis in full view of ground crew and customers that morning then these results cannot disprove it beyond doubt.

Toxicology review

3.5.17. On 2 April 2013 the Commission invited the 3 experts to review the toxicology results and their reports, given that their reports had been prepared without knowing that the pilot was seen smoking some 20-25 minutes before commencing the flight and that it "was highly likely" to have been cannabis that he was smoking. The conclusions by ESR and Dr Robertson are summarised in the following paragraphs. Their full responses can be found in Appendix 4. The Police expert declined to provide any further comment on the results.

3.5.18. ESR's opinion was that the level found would normally indicate recent use of the drug, anywhere from 0.5 to 5 hours, and could be consistent with the pilot smoking cannabis 90 minutes prior to his death. However, the use of cannabis at an earlier time could not be ruled out.

3.5.19. Dr Robertson said that although "the actual blood level of the sample used for analysis cannot be clearly determined by this result, the facts remain that the pilot was a cannabis user and cognitive impairment at or around the time of the accident and its contribution to the cause of the accident, cannot be excluded, given the 'carry-over' effect of cannabis".

3.6. Performance-impairing substances

3.6.1. Civil Aviation Rule 19.7 stated that:

> No crew member while acting in his or her official capacity shall be in a state of intoxication or in a state of health in which his or her capacity so to act would be impaired by reason of his or her having consumed or used any intoxicant, sedative, narcotic, or stimulant drug or preparation. (CAA, 2010)

3.6.2. In 2004 the ATSB completed a study of cannabis and its effects on pilot performance (ATSB, 2004). The executive summary to the study stated that:

> Cannabis is a commonly used recreational drug, which has widespread effects within the body. Smoking is the most common form of administration. The adverse effects of cannabis on behaviour, cognitive function and psychomotor performance are dose-dependent and related to task difficulty. Complex tasks such as driving or flying are particularly sensitive to the performance impairing effects of cannabis.
>
> Chronic cannabis use is associated with a number of adverse health effects, and there is evidence suggesting the development of tolerance to chronic use as well as a well-defined withdrawal syndrome. There is also evidence that the residual effects of cannabis can last up to 24 hours. Significantly, the modern dose of cannabis is

> much more potent than in the past, when the majority of the research was conducted. As such, the reported adverse health effects may be conservative.[13]
>
> Although only a limited number of studies have examined the effects of cannabis on pilot performance, the results overall have been consistent. Flying skills deteriorate, and the number of minor and major errors committed by the pilot increase, while at the same time the pilot is often unaware of any performance problems. Cannabis use in a pilot is therefore a significant flight safety hazard.

3.6.3. The ATSB study made reference to numerous other studies and reference material. Some of the key findings contained in the study are identified below.

> Cannabis contains over 400 chemical compounds, including over 60 pharmacological active constituents known as cannabinoids. The most potent and psychoactive of these is Δ9-tetrahydrocannabinol (Δ9-THC). Cannabinoids act on those parts of the brain related to cognitive processes, memory, pain perception and psychomotor coordination.
>
> Cannabis produces a wide range of effects and shares some of the properties of alcohol and other drugs such as tranquillisers and opiates. Some of the effects include perceptual alterations like colour, tastes, smell and time distortion, impaired attention and learning, increased reaction time and difficulty in concentration. The ability to perform complex tasks requiring attention and mental coordination were "particularly sensitive to the effects of marijuana".
>
> The smoking of cannabis, in addition to being the most common form of administering the drug, promotes the rapid onset of symptoms, with the effects of THC becoming perceptible after a few seconds and fully apparent in minutes. The impairment of performance and skills was at a maximum in the first 4 hours after taking cannabis. The residual adverse effects of cannabis were shown to last between 12 and 24 hours, even after as little as a single dose. The more complex the tasks, the more pronounced were the effects, especially on cognitive function. A study in the United States using aircraft simulators supported this finding (Leirer, 1989).

3.6.4. The Commission has investigated 6 occurrences in the past 10 years, including in the rail and marine modes, where crew members and others in safety-critical roles were found to have taken performance-impairing substances in the hours or days leading up to the accidents (TAIC, 2002, 2009, 2011 and 2012). The aviation occurrences included another Part 119 adventure activity (TAIC, 2010) and a commercial air transport flight (TAIC, 2005). While substance impairment could not be identified as a primary cause in any of these occurrences, the Commission sees the use of these substances by personnel responsible for performing safety-critical tasks as a transport-wide safety issue.

3.6.5. The Commission has made several recommendations relating to drug and alcohol detection and deterrence regimes for persons employed in safety-critical transport roles. More information on these recommendations is given in the analysis section of this report.

3.7. Aircraft information

3.7.1. A complete balloon comprises the envelope, the basket and the fuel and burner assembly. A single company can manufacture all the components and offer them as a complete set or, if within the performance or type certificate limits for the balloon, the manufacturer may permit alternative components to be used. In New Zealand, the CAA registration is held against the envelope.

3.7.2. ZK-XXF was a Cameron Balloons A210 balloon envelope, serial number 4300, manufactured in the United Kingdom in 1997 and first registered there in 1998 as G-BXXF. The designation A210 referred to the conventional shape of the envelope and its capacity of 210 000 cubic feet (about 6000 cubic metres). The manufacturer advised that the envelope was similar to

[13] The potency of cannabis has increased by as much as 15 times in the past 30 years (Aldington, ND).

the Z-210, which measured 25 m in height and had a diameter of 23.5 m. The envelope was purchased by its New Zealand owner in 2001 to replace the Thunder and Colt[14] 160A.

3.7.3. The Thunder and Colt 160A envelope had been manufactured in the United Kingdom in 1989 as a complete balloon – envelope, basket, 2 primary burners, one commercial liquid fire burner and 4 approximately 46-kilogram (kg) capacity LPG fuel cylinders. That balloon was given serial number 1377 and sold to a Canadian operator in 1989 and registered as C-FFEV. A photograph of it is shown in Figure 1. In 1996 the complete balloon was imported into New Zealand and registered as ZK-EMB. When the envelope reached the end of its economic life in 2001, it was replaced with the Cameron Balloons A210 envelope and registered as ZK-XXF.[15]

3.7.4. The basket measured 2.6 m long, 1.52 m wide and 1.125 m high (see Figure 4). The pilot's compartment was at one end and contained the fuel cylinders, fuel hoses, fittings, instruments, a 1 kg powder fire extinguisher and other equipment. The equipment carried in ZK-XXF met the requirements specified in the balloon flight manual. Other equipment included an emergency lighter should the pilot lights for the burners extinguish, and a drop-line that could be dropped to persons on the ground to pull the balloon to a safe area should it become becalmed near obstacles. The pilot had also installed a small aluminium platform to provide easy access to the burner controls.

3.7.5. The pilot's compartment was at the head of a "T" shaped divider that ran along the centre of the basket, dividing the passenger area into 2 sections. The basket was of conventional cane and wicker construction with a metal frame and a heavy-duty plywood floor supported by runners and steel wire. The steel wire looped under the basket and was attached through 4 support rods to the burner or "load" frame above the occupants. The envelope was attached to the burner frame through "flying cables" that ran from the envelope down to karabiners on the frame. Rope handles were located inside the basket for passengers to hold on to during landing. Some pilots wore harnesses to ensure they remained on board should the basket tip over on landing. Harnesses were not mandatory and no harness was carried on ZK-XXF.

3.7.6. Padding was fitted to the top of the basket, allowing occupants to lean on it for a better view and to help entry to and exit from the basket using steps located at each end. Padding also covered the 4 support rods attaching the basket to the burner frame. The burners were mounted within the frame and were connected to the fuel cylinders by flexible hoses that ran down 2 of the support rods to the 4 fuel cylinders located on 2 sides of the pilot's compartment. Connectors and 2 cross-feed valves allowed the burners to be supplied from any one or a combination of cylinders. Fuel flow from the cylinders could be shut off using a single-action tap located on the top of each cylinder. Any fuel remaining in the lines after the tap had been turned off was vented through the burners. (See Figure 4.)

3.7.7. The envelope was fitted with vents around the sides to turn the balloon in either direction. The vents were controlled by green and black coloured ropes or lines running down to the pilot's compartment. The vents enabled the pilot to rotate the balloon and orientate the basket correctly for landing. The basket was fitted with 2 runners or support beams along one side to strengthen that side should the basket tip over on landing, which was a not uncommon occurrence for balloons, even in light winds. In preparation for landing the pilot would rotate the balloon to face the side with the runners in the direction of flight. The operation of the turning vents released hot air from the envelope and therefore reduced lift and caused the balloon to descend. According to the owner, between 20 and 30 seconds were needed to rotate the balloon through 360 degrees.

3.7.8. A "parachute valve" in the top of the envelope was able to be opened to release hot air and descend the balloon. The valve was controlled by a red-and-white-coloured line connected to the pilot's end of the basket. The balloon was also fitted with a rapid deflation system, which, as the name suggests, enabled the rapid deflation of the envelope in an emergency descent

[14] Thunder and Colt was purchased by Cameron Balloons in 1995.
[15] The type certificate and registration applied to the envelope only. Different equipment, including baskets, burners and gas bottles, could be fitted if approved by the type certificate for the envelope.

or after landing in strong winds. The rapid deflation system was operated by pulling on a red-coloured rope commonly called a rip line. The flight manual stated that "use of the rip line is not permitted at heights greater than 2 m (6 ft) above ground level, except in an emergency".

3.7.9. ZK-XXF had a certificated maximum take-off mass of 1905 kg. As part of the most recent annual maintenance check, the weight of the balloon, including full gas cylinders, had been calculated at 708 kg. The passenger load sheet for the accident flight recorded the passenger weights. When combined with the estimated weight of the pilot, they gave a total load figure of 791 kg and therefore a take-off weight of 1499 kg.

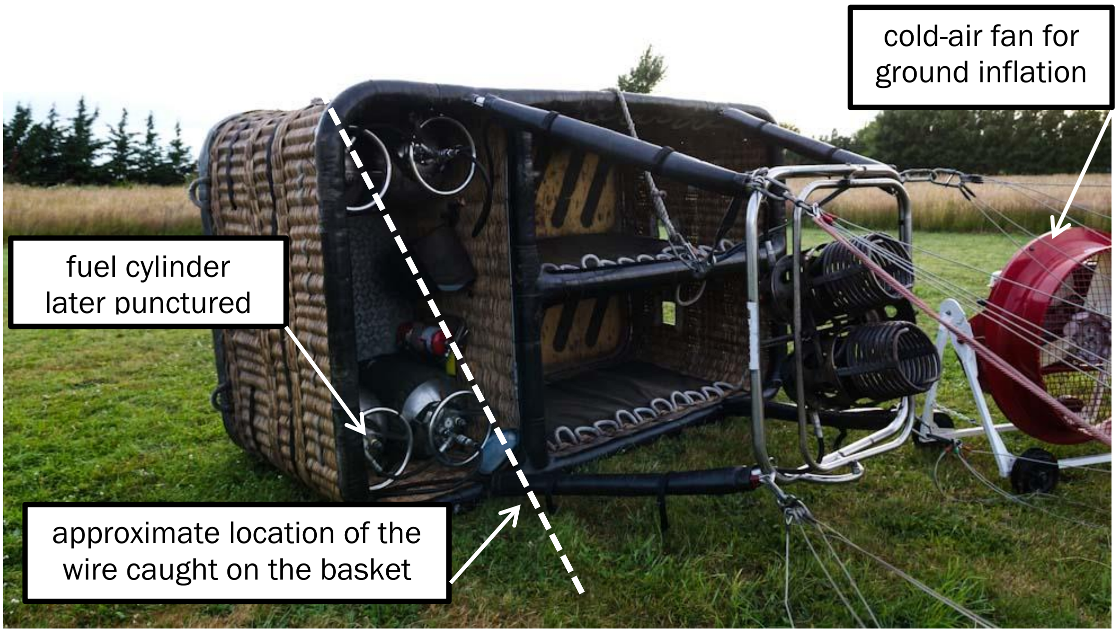

Figure 4
Basket attached to ZK-XXF

3.7.10. On 7 January 2012, for the average air temperature of 11 degrees Celsius recorded by local vineyards and a launch site elevation of 85 m above sea level, the maximum permitted lift for the balloon was determined, using the manufacturer's performance and load calculator, to be 1727 kg. This gave a spare lift capacity of 228 kg for the assumed conditions on the day.

3.7.11. Section 3 of the flight manual contained emergency procedures for the balloon (Cameron Balloons, 2010). Paragraph 3.3 of this section was titled "Contact with Electric Power Lines" and included the following:

> Contact with electric power wires is extremely dangerous and can result in serious or fatal injuries. It should be avoided at all costs.
>
> If contact with power wires cannot be avoided, initiate a rapid descent so the contact with wires will be made by the envelope instead of the basket assembly.
>
> Shut off all fuel supplies at the cylinder valves and vent the fuel hoses before contact.
>
> If the balloon is caught in the power wires, do not touch any metallic parts.
>
> If the basket is not in contact with the ground remain in it, if possible, until the electrical power is shut off.
>
> If it is necessary to leave the basket, do not place the body in contact with the ground and any part of the balloon at the same time.
>
> Do not attempt to recover the balloon until the electricity authority has been contacted, and had indicated that it is safe to do so.

3.7.12. Aircraft records showed that at the time of the accident the ZK-XXF envelope had accrued a total of 520 flight hours. The balloon was required to undergo a maintenance check every 100 flight hours or an "Annual Review of Airworthiness" – whichever occurred first. Records showed the balloon had flown about 30-40 hours each year. The most recent combined annual and 100-hour check had been recorded as undertaken on 14 September 2011 when the envelope had accrued 512 flight hours.

3.7.13. The combined check included the standard Cameron Balloons inspection schedule and the CAA's Review of Airworthiness "Check List Report – Hot Air Balloon". The Check List Report correctly recorded the manufacturer of the envelope and the model type and serial number. The type certificate was erroneously recorded as being B2GL, which was only applicable to Cameron Balloons balloons manufactured in the United States with serial numbers 5000 and higher. The Cameron Balloons A210 balloon, serial number 4300, had been manufactured against United Kingdom type certificate BB12. With the inception of the European Aviation Safety Agency (EASA), the United Kingdom type certificate BB12 was changed to EASA.BA.013, and this should have been recorded as the type certificate for ZK-XXF. The type certificate determined how the aircraft was to be maintained. This error had continued since the envelope was first registered in New Zealand. Both the basket and burners were recorded as being Cameron Balloons products, but they had been produced by Thunder and Colt.

Maintenance

3.7.14. When first asked about the maintenance schedule for the balloon, the maintenance engineer produced Issue 7 of the manufacturer's "Flight and Maintenance Manual", dated 1992. After Issue 7 the manual had been split into 2 separate documents titled "Flight Manual" and "Maintenance Manual". The maintenance manual that was current when the most recent maintenance had been done on 14 September 2011 was Issue 10. The maintainer later submitted that he did not hold copies of the maintenance manual and that in preparation for any scheduled maintenance he would download the latest issue directly from the manufacturer's website. However, the aircraft logbook recorded that the inspection on 14 September 2011 had been done in accordance with the manufacturer's "Flight and Maintenance Manual", a title not used since Issue 7.

3.7.15. Anomalies found in the maintenance logbook included incorrectly identified components such as the basket and burner, and no reference to 4 airworthiness directives. In 2008 the 4 fuel cylinders had been tested by a local certified gas company, but there was no associated entry in the aircraft logbook by a licensed aircraft engineer that approved the use of the tested cylinders on the balloon.

3.7.16. At an initial interview, the maintenance engineer demonstrated that he had not used the prescribed method, referred to by the manufacturer as a "grab test", for testing the strength of the envelope fabric. The prescribed method involved clamping 2 sections of fabric and pulling them apart using a calibrated spring gauge to measure the force applied. A minimum pull of 30 pounds (13.6 kg) was required to confirm the serviceability of the fabric. The engineer showed how he used his hands to determine the strength of the fabric. He later advised that if there was any doubt about the strength of the fabric he would use the correct equipment. The maintenance engineer later submitted that "at all times, when required, the grab test is carried out using the correct tool and calibrated scales in accordance with the approved instructions".

3.7.17. The maintenance engineer was the same person who had completed the initial certificate of airworthiness inspections of ZK-EMB and ZK-XXF in 1996 and 2001 respectively. These inspections had been done under a CAA delegation. A maintenance engineer, when performing an airworthiness inspection, must refer to the aircraft type certificate to ensure that the inspection is correctly carried out. The inspection documentation for both ZK-EMB and ZK-XXF did not include the type certificate in the allocated space on the form. The documentation contained other anomalies, including the incorrect model and serial numbers for the burners. The incorrect and incomplete documentation had not been identified by the CAA when the forms were submitted for the issue of airworthiness certificates.

3.7.18. The aircraft flight manual found in the wreckage, Issue 10 dated 10 April 2006, was the incorrect version. The version current at the time of the accident was Issue 10, Amendment 9, dated 2 March 2011. As part of an Annual Review of Airworthiness, the inspecting authority, in this case the maintenance engineer, was required to confirm that the correct flight manual was carried on board the balloon. On the 14 September 2011 inspection form the maintenance engineer had written "Y" [yes] in the box titled "Current?" for the aircraft flight manual.

3.7.19. In December 2011 several of the envelope panels on ZK-XXF had been damaged and subsequently repaired. The repair had been completed by the owner of the balloon, who had previously undertaken a Cameron Balloons repair course and was therefore permitted to undertake the repair. Civil Aviation Rule 43.69 "Maintenance records" directed that an entry be made in the aircraft logbook describing any damage, what had been done to rectify the damage, what approved technical data had been followed, and who had performed the repair. The logbook entry was to be made by a licensed maintenance engineer with the appropriate rating. The aircraft logbook for ZK-XXF contained no reference to the damage or the subsequent repair.

3.7.20. As a result of its initial enquiries into the maintenance system for the balloon, the Commission made an urgent safety recommendation to the Director of Civil Aviation to address these maintenance issues. See section 7 of this report for the full text and the Director's response. See also section 6 on subsequent safety actions completed by the CAA.

3.7.21. The maintenance records held by the CAA for 8 other Cameron balloons were reviewed. Of the 8 balloons, 7 had no type certificate numbers entered on the initial certificate of airworthiness inspection documentation. A number of the balloons were missing type certificate numbers on their early Annual Review of Airworthiness forms and one was incorrectly entered on the aircraft register as being manufactured by Cameron Balloons United States when it was a United Kingdom product. The review showed that in the previous 3 years the level of attention to detail on the inspection forms had increased significantly, with no anomalies noted after 2009.

3.8. Recorded data

3.8.1. The pilot had attached a GPS unit to the basket to record the track and timing of each balloon flight. The unit was severely damaged during the accident. It was sent to the ATSB in Canberra for examination. The ATSB was able to locate the memory chip and extract data for some 31 track plots from the last flight, commencing from take-off. However, because of the way the GPS unit processed and stored data, about the last 10 minutes of the flight were not recoverable.

3.8.2. The GPS track followed the flight path shown in Figure 5. After lift-off the balloon averaged a groundspeed of about 10 km per hour as it climbed steadily to an altitude of about 470 m. At 0709, as the balloon approached State Highway 2, the balloon descended to about 244 m. During the next 2 minutes, as the balloon passed near the intersection of State Highway 2 and Somerset Road, it climbed to about 594 m. The last recorded data was at 0711:07 near the intersection of State Highway 2 and Somerset Road. Shortly after that the balloon was seen to start descending in a south-easterly direction close to Somerset Road and towards the accident area (see Figures 5 and 6). The remainder of the flight path was calculated from witness accounts and photographic evidence.

3.8.3. In addition to the photographs taken by the freelance photographer, photographs from a passenger's camera were recovered. These latter photographs recorded the preparation and inflation of the balloon prior to take-off and portions of the flight until less than a minute before the basket struck the power line.

3.8.4. The photographs revealed nothing untoward occurring in the basket during the flight. Both sets of photographs showed that the balloon was rotated or turned as it crossed Somerset Road and flew north-east before turning back south-west towards Somerset Road. As the balloon entered the silage paddock, the runners[16] on the landing side of the basket faced east towards the power line it later struck. This placed the pilot at the front end of the basket closest to the power line running along Somerset Road.

[16] As described in paragraph 3.7.7.

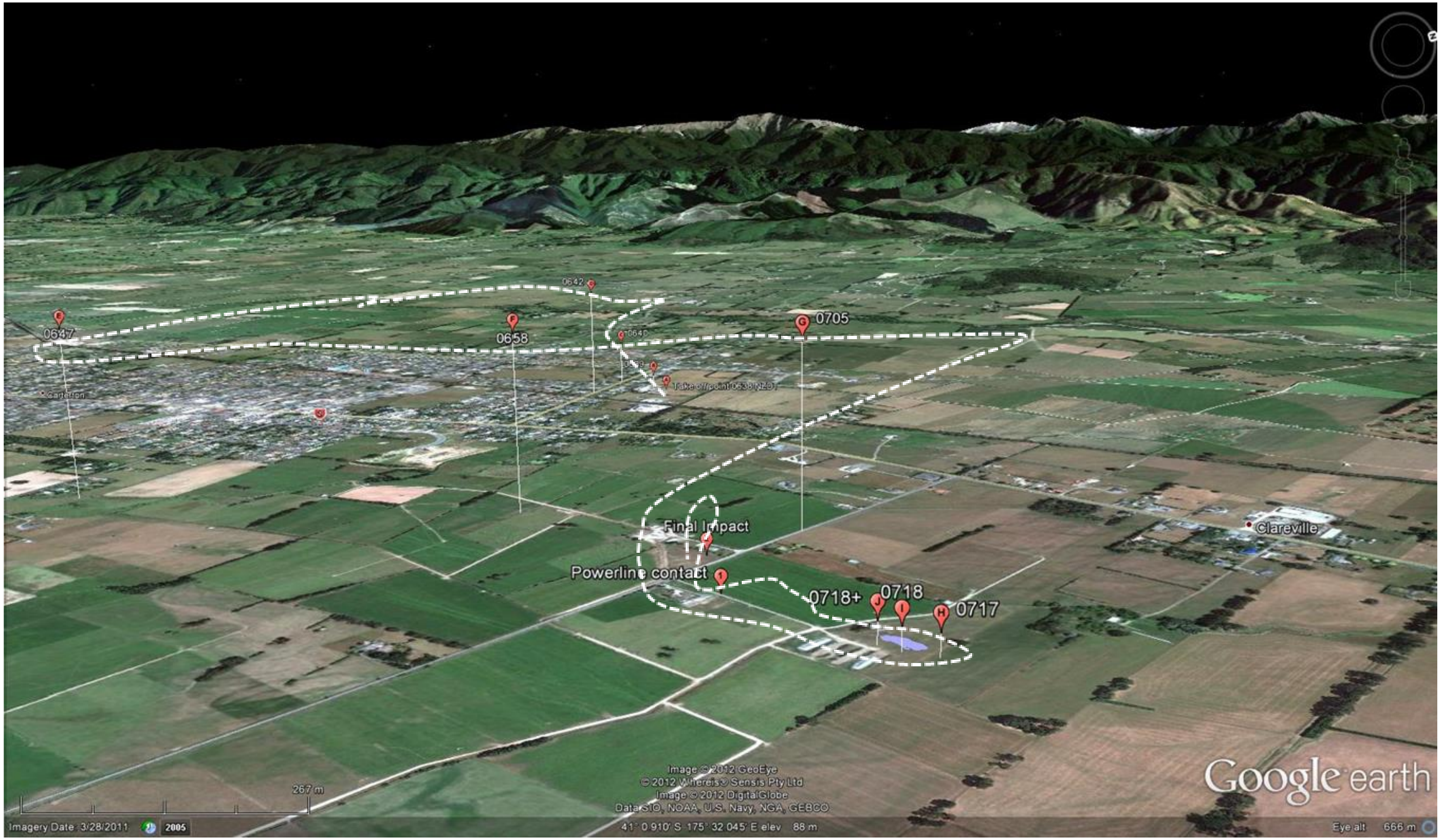

Figure 5
Approximate flight path of ZK-XXF
(Image courtesy of Google Earth)

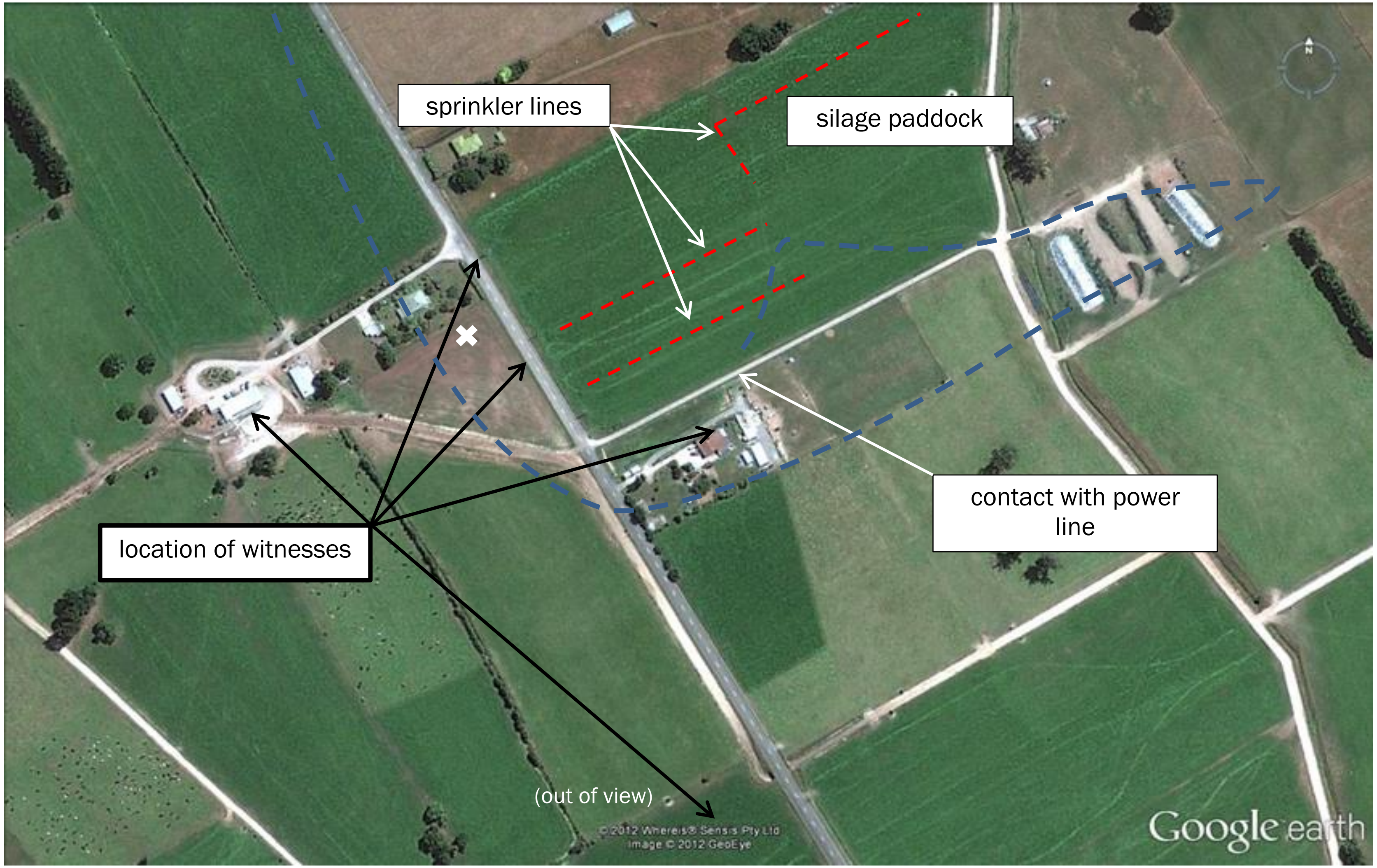

Figure 6
Approximate final portion of flight
(Image courtesy of Google Earth)

3.9. Ballooning information

3.9.1. There are 2 main types of balloon: gas balloons, which use gases like hydrogen and helium, and hot-air balloons. ZK-XXF was a hot-air balloon. Hot-air balloons are most efficient in cooler temperatures, where less heat has to be generated to lift a given weight. Calm conditions are also preferred during the take-off and landing phases of flight. Ballooning therefore mostly takes place in the early morning and to a lesser extent in the evening.

3.9.2. The movement of a balloon over the ground is dictated by the direction taken by the mass of air it is in at the time; that is, the wind at that height. By applying heat to the envelope, the pilot of a hot-air balloon can climb in an attempt to find air that is moving faster or in a different direction. Similarly, by letting the air in the envelope cool, the balloon will descend. A pilot therefore has limited control over the direction of flight.

3.9.3. The activation of the burners does not cause a balloon to climb immediately. A number of factors can delay a climb. These include the rate at which heat is applied (one or 2 burners), the load carried and the ambient temperature. The delay can be in the tens of seconds. It also takes more energy and time to overcome descent inertia before the balloon starts to climb. In other words, if the balloon is descending when the pilot applies the burners, it will take more time to arrest the descent before the balloon begins to climb. If the ambient (outside) air temperature increases later in the morning, more energy will be required to increase the temperature of the air inside the envelope to maintain the temperature difference required for the balloon to fly.

3.9.4. The balloon is descended by allowing the air in the envelope to cool. However, a more rapid descent can be initiated using the venting system, for example the parachute valve. In stable flight pilots will therefore generally apply short bursts of heat to either maintain level or hold steady climbs and descents.

3.9.5. Most balloons, especially those with large baskets, have vents fitted to the side of the envelopes that permit the balloons to be rotated for landing, as described in paragraph 3.7.7. A pilot might also rotate a balloon in order to get a clear view ahead or to rotate an advertising logo towards a crowd. For some envelopes the turning vents are located close together, and if activated simultaneously they can propel the balloon forward, albeit at a slow speed. However, any venting will also cause the envelope to lose lift and descend.

3.9.6. In calm or very light wind conditions the basket normally stays upright during the landing. However, in stronger winds the basket can tip over and possibly drag along the ground. If that happens the pilot might activate the rip line to collapse the envelope and stop any further dragging.

3.9.7. The last fatal ballooning accident in New Zealand was on 19 October 1995, when a Cameron A210 balloon was overtaken by a squall line and ditched into the sea near North New Brighton, Christchurch (TAIC, 1995). Three passengers were drowned. The Commission has since investigated 3 other balloon occurrences, all involving contact with power lines, none of which resulted in injuries.[17]

3.9.8. A review of ballooning accidents internationally showed that the majority of fatal and serious injury accidents involved power lines. A United States study reviewed the records of 495 hot-air balloon crashes between 1964 and 1995. The crashes resulted in 92 fatalities and 384 serious injuries. A further 1057 individuals were either uninjured or received minor injuries (JAMA, 1998). The study showed that 27.7% of all crashes involved power lines and accounted for 44.6% of fatalities, and noted that “The odds of a fatality were more than 13 times greater when contacting a power line than when hitting the ground”.

3.9.9. A later study in the United States looked at 86 balloon crashes between 2000 and 2004, in which there were 5 fatalities (ASEM, 2006). Power line strikes were involved in 34% of the crashes. The study determined that the baskets suffered “so little damage in accidents where

[17] Transport Accident Investigation Commission Reports 97-007, 00-008 and 00-011.

passengers are seriously injured [that the] strength of the balloon appears to need little improvement".

3.9.10. A United Kingdom study of ballooning accidents between January 1976 and January 2004 found that the majority of accidents (83%) occurred during the approach and landing phase of flight (Hasham, 2004). Further, "power line collisions occurred in 34 accidents (35%) but adverse weather conditions accounted for only 8 of these". The study made reference to an article in The American Journal of Sports Medicine that stated that "collisions while the pilot is deflating the balloon have been associated with a significantly reduced risk of serious injury and death" (Marcus, 1981).

3.10. The regulator

3.10.1. On 10 November 2011 the initial issue of Civil Aviation Rule Part 115 Adventure Aviation – Certification and Operations came into effect to regulate activities such as commercial ballooning (CAA, 2011a) (see section 6, Safety actions. However, transitional arrangements meant that balloon operators were not required to comply until 1 May 2012. In the meantime balloon pilots were required to conform with Part 91 General Operating and Flight Rules (CAA, 2011b). If conducting commercial operations they had to comply with Part 61, Pilot Licences and Ratings (CAA, 2011c).

3.10.2. Every pilot was required to operate their balloon in accordance with the operating limitations specified in the flight manual or approved equivalent. Pilots were to ensure that safety briefings were given to passengers before each flight. Guidance on the content of the briefings was given in the flight manual and focused on entry to the basket, the landing position and the use of the holding ropes. Passengers were not to hold on to "hoses, valves or control lines". Civil Aviation Rule Part 91 required pilots to ensure that passengers were briefed on the procedures to be followed in the case of an emergency landing.

3.10.3. The AAIB and the BBAC were asked to comment on passenger briefing. The BBAC provided a typical operations manual for a company flying large balloons, and extracts from the BBAC training manual used by most private balloon pilots in the United Kingdom. The content was similar to that referred to in the previous paragraph, including the direction that passengers were not to interfere with the controls. One difference was that commercial balloon pilots were required to wear harnesses. Although "pilot incapacity through illness" was mentioned in the BBAC list of briefing topics, it advised that this was never actually discussed.

Licensing requirements

3.10.4. All commercial balloons are required to be registered and have type certificates issued. They are required to be maintained in accordance with their approved maintenance schedules. Commercial balloon pilots are required to hold commercial pilot licences (balloon) and current class 1 medical certificates and meet the currency requirement of 3 take-offs and landings in the preceding 90 days. They also need to complete 2-yearly flight tests.

3.10.5. In New Zealand, pilots engaged in private or non-commercial flights are not required to hold licences. This latter group is therefore not subject to any form of competency or currency requirements despite being potentially able to carry the same number of passengers as commercial operators. There is also no rating to cater for differences in balloon sizes and handling characteristics.

3.10.6. In contrast, balloon pilots in Australia are required to hold student, private or commercial pilot licences, and endorsements depending on the size of the envelope and passenger capacity. In the United Kingdom pilots are required to hold either private or commercial pilot licences. There is no size or rating endorsement for private pilots, but there is for commercial pilots. In the United States pilots are also required to hold private or commercial pilot licences, and also endorsements depending on size of the balloon.

Aviation-related concerns

3.10.7. Aviation-related concern (ARC) is the term used by the CAA for a category of information regarding an aviation-related activity that may have implications for safety. A concern can be raised by anyone and reported to the CAA through its website, or by email or telephone. For example, a person may allege or have witnessed low flying, improper maintenance or a near accident and is sufficiently concerned to let the CAA know.

3.10.8. ARCs are a safety net to catch information on activities that might not be reported under Civil Aviation Rule Part 12 Accidents, Incidents, and Statistics. At the time of the accident, once an ARC had been reported it was logged in the CAA's management information system, given a reference number and allocated to a CAA staff member for investigation. Regardless of the potential severity of the ARC, each concern was to be investigated and either closed off or referred to the most appropriate unit within the CAA for action. For example, a low flying complaint could be closed off as unproven or the incident referred to the enforcement unit for consideration of a prosecution. On 22 February 2012 CAA staff drew the Commission's attention to 2 ARCs that they thought might be relevant to the Commission's investigation. The 2 ARCs are described below.

3.10.9. On 16 November 2009, an ARC had been raised regarding "inadequate balloon testing" of another balloon flown by the pilot and maintained by the maintainer of ZK-XXF. The concern stated that the annual inspection was not being correctly carried out owing to a lack of proper equipment and that both the pilot and the maintainer were aware of this. Specifically, the maintenance action called for the completion of a porosity check using the manufacturer's porosity tester. It was alleged that the maintainer did not have access to or use the required piece of equipment.

3.10.10. The CAA records for this ARC noted that the initial review identified potential breaches of Civil Aviation Rules, including Part 43 General Maintenance Rule and Part 91 General Operating and Flight Rules. On 30 September 2010 an entry was logged against the ARC stating that, given the serious nature of the allegation, a "coordinated approach/visit" was suggested. The following entries referred to an unrelated ARC that had been incorrectly entered into the file. The final entry, made on 11 November 2011, stated "Assessed" but there was no close-off action recorded nor was the originating ARC referred to another unit for follow-up action.

3.10.11. On 8 February 2010 a different ARC concerning the pilot had been raised. The ARC stated that a balloon passenger had been told that their planned flight was cancelled because the pilot "appeared too 'pissed and/or high'[18] to perform his piloting duties for that flight". The ARC file recorded that by the following day 3 CAA staff members had been assigned to look into the ARC.

3.10.12. The next file entry on 25 August 2011 stated that the pilot and a crew member had been spoken to and both were "adamant that the incident never occurred", and that "considering the level of accusations within the ballooning community against certain individuals it seems likely that this incident may not be genuine. No further action required". The status of the ARC was changed to "Assessed" but there was no record of it being closed off.

Review of ARC processes

3.10.13. In view of the 2 ARCs lodged concerning the pilot and the balloon maintenance company, the Commission enquired into the CAA system for processing ARCs. The CAA advised that there had been a longstanding internal concern about its ARC management and processes. In particular the CAA was concerned about the initial recording of ARCs, the allocation of appropriate resources and the ad-hoc manner in which they were managed to logical conclusions. In 2010 a review of ARCs was initiated and a report produced titled "Aviation Related Concerns: Review of Processes and Procedures", dated 29 June 2010. The review found there was "a systemic failure in the CAA's internal management systems". The

[18] "Pissed" is understood to mean intoxicated or drunk. "High" is understood to mean under the influence of drugs.

treatment of ARCs varied and valuable information could be missed. A lack of resources was also identified.

3.10.14. A follow-on discussion paper, titled "The Processing of Aviation Related Concerns" was produced on 22 June 2011. The discussion paper identified that organisational change was needed to address the issues raised in the earlier report as well as recommendations from the Office of the Auditor-General on ARC processes. The draft recommendations contained in the discussion paper were subsequently superseded by the CAA's Regulatory Operating Model, produced in late February 2012. This in turn resulted in a new executive management policy on ARCs titled "Responding to Aviation Related Concerns" being released on 6 March 2012.

3.10.15. The new ARC policy created a centralised management system for ARCs. Information received by the CAA was to be directed to the Intelligence, Safety and Risk Analysis Unit for recording and the creation of an ARC work request. A dedicated position had since been established with that person being responsible for co-ordinating and managing all ARCs.

3.10.16. Following this accident, the CAA initiated an independent review of the ARC process generally, and used the 2 ARCs related to the pilot and the balloon maintainer as test cases. The final report was passed to the Commission on 19 December 2012.

3.10.17. In summary, the review found numerous systemic issues with the control and management of ARCs. The investigation of ARCs was supplementary to staff members' normal work and the number of ARCs received had continued to increase steadily, from 347 in 2009 to 897 in 2011. There had been no compensating increase in resources to help manage this increase and staff members allocated to ARC investigations were not given training on how to process an ARC to an effective conclusion.

3.10.18. The lack of resources and training had resulted in different standards of treatment of ARCs. In regard to the 2 ARCs related to this accident, the review found that the ARCs could have or should have been more thoroughly investigated.

3.10.19. For the maintenance-related ARC, the review found that the lack of action between November 2009 and June 2010 had resulted from "work pressures" but this had not been recorded. The opportunity to inform audit staff in preparation for their next audit of the maintenance provider had not been exercised because of a breakdown in communication. Further, the staff members concerned had not been aware of the linking function on the ARC computer management program that would have allowed them to view information about the maintenance provider and possibly adjust the scope of their audit accordingly.

3.10.20. The review identified that the second ARC relating to pilot performance had initially been based on hearsay information and, according to a CAA staff member, the ballooning community "was rife with rumour and personality issues". Follow-up enquiries had been made with the Police but there had been nothing of substance to validate the ARC. The CAA had found that witnesses were reluctant to come forward and make statements so, following several informal interviews, and considering the quality of the information available, it had decided not to continue the investigation.

3.10.21. In conclusion the review noted that concerns previously identified had "been amply demonstrated with regard to the two ARCs considered". The underlying issues of co-ordination, management, resources and recordkeeping in respect of ARCs are being addressed, helped by the organisational changes made within the CAA, including additional staff.

4. Analysis

4.1. Introduction

4.1.1. This balloon accident rates as the worst single New Zealand aviation accident since the loss of a DC10 aeroplane on Mount Erebus, Antarctica in 1979. As at January 2012, it was also the second worst single hot-air balloon accident on record in the world.[19]

4.1.2. The flight started as a routine adventure flight. The weather was suitable for the flight and the take-off and early stages of the flight appeared to run routinely. Communications between the pilot and the ground crew were normal and none of the witnesses noticed anything unusual until the pilot yelled out shortly before the balloon struck the power lines.

4.1.3. The Commission found several areas for concern regarding the maintenance of the balloon, but it found no defect with the balloon that could have contributed to the accident.

4.1.4. Although there was no obvious defect that contributed to the accident, the issue of balloon maintenance standards and the regulatory oversight of those standards was a safety issue.

4.1.5. The CAA's system for handling reported ARCs was reviewed. Two ARCs had been lodged with the CAA: one about the pilot and one about the maintenance of the balloon ZK-XXF. The Commission was unable to determine if the accident would have been prevented had the CAA properly followed up these 2 ARCs. Nevertheless, proper follow-up of ARCs is important, so this safety issue is discussed also.

4.1.6. The focus of the following discussion is on how the balloon came to be at low level above the silage paddock and what caused it to strike the power line. Pilot performance is central to that discussion.

4.2. What happened

Landing site

4.2.1. The pilot had told his ground crew that the landing would probably be in the Somerset Road area. The predicted landing location would have been an estimate only. In light wind conditions the direction of the wind, and therefore the balloon's track, can vary significantly as a balloon descends through the levels. This was the case on 7 January. ZK-XXF approached the anticipated landing area initially in a south-east direction and then began drifting north-east across Somerset Road before changing direction again to drift south-west over the silage paddock towards Somerset Road. The report by one of the witnesses on Somerset Road of "an isolated gust of wind" from the north was consistent with the flight path of the balloon changing to a more southerly direction towards the farm track and dual-voltage power lines.

4.2.2. After entering the silage paddock the balloon descended to a few metres above the ground, which was just above the water spray from the sprinkler system. However, this paddock was unlikely to have been the pilot's intended landing area. There are 4 reasons for this:

1 The basket was not orientated for a landing in the direction in which the balloon was travelling. The landing side with the runners (support beams) was nearly 180 degrees out from the direction of flight as it initially crossed the paddock in a south-west direction.

2 There were several rows of sprinklers operating in the silage paddock and the pilot would have been unlikely to want either the passengers or the balloon to get wet.

3 The passengers were not in their braced landing positions and were still leaning over the sides of the basket as it crossed the silage paddock.

[19] On 13 August 1989, 13 people were killed after their balloon collided with another near Alice Springs, Australia. On 26 February 2013, 19 people were killed when their balloon caught fire over Luxor, Egypt.

4 The pilot had acknowledged the ground crew's report of the horse in another paddock over the road. If the pilot had intended to land in the silage paddock, that would have been the time to inform the ground crew.

4.2.3. The flight to this stage had taken nearly 45 minutes, and based on historical records there should have been ample fuel remaining to continue flying for another 45 minutes before low fuel quantity became a concern. There was also no rush to land at this time as there were suitable landing paddocks immediately across Somerset Road and farther on.

4.2.4. If the pilot did not intend to land in the silage paddock, there is the question of why he let the balloon descend to below the level of the dual-voltage power lines. These power lines not only ran adjacent to the balloon's initial path, but also ran across the Somerset Road border of the paddock. The balloon always therefore needed to climb over them before crossing Somerset Road in search of a better landing site.

4.2.5. The pilot may have wanted to stay at low level to land immediately after crossing Somerset Road. However, allowing the balloon to descend below the level of the power lines was not safe practice. There is a possibility that the pilot was giving the passengers the experience of flying at low level across the paddock, but again, to do so at such a low level would not have been safe practice. In any event, there was no evidence of any obvious concern or distress by the pilot, passengers or ground crew while the balloon was heading in a south-west direction across the silage paddock.

4.2.6. Until the balloon changed to a southerly direction there was probably ample time for the pilot to climb the balloon over the power lines running along Somerset Road. Once the direction changed more southerly towards the power lines running adjacent to the farm track, there was less distance and time for the balloon to out-climb them. It was at about this time that witnesses reported hearing the sustained operation of the burners. The first indication of anything untoward with the flight was when the pilot was heard telling his passengers to duck down. When exactly the pilot stopped the burners could not be confirmed, but it was probably just before the basket came into contact with the first wire and before the pilot's warning to his passengers, because witnesses described hearing this warning clearly rather than over the roar of the burners.

Did the pilot see the power line?

4.2.7. Wires generally and power lines in particular are a well known hazard for aircraft operating at low levels. Studies show they are also the single biggest cause of injury accidents involving balloons. The safety material available for balloonists emphasises the danger of wires and is consistent in the message that wires must be avoided. The flight manual for the Cameron A210 balloon devoted a section to contact with power lines. The pilot should also have been cautious of power lines, having been involved in a wire strike some 12 years previously.

4.2.8. Wires can be difficult to detect, especially single and small-diameter wires. The dulling of wires from exposure to the elements, certain lighting conditions and the presence of material such as lichen can act to camouflage wires. Figure 7 shows examples of a power line viewed from 2 different angles and demonstrates the potential difficulty in seeing wires. The poles, however, remain clearly visible.

Figure 7
Power lines

4.2.9. Balloon pilots should be aware of these factors and are taught to look for poles as an indication of the presence of wires. Once a wire is sighted, the pilot should maintain a safe height above it or, if at very low level, start a climb early enough to clear the obstacle with a good safety margin.

4.2.10. The pilot of ZK-XXF was familiar with the local area with its numerous power lines and had flown over the power line he later struck only 2 or 3 minutes earlier. A photograph taken by a passenger at the time clearly showed the power lines below the basket. The pilot had an unobstructed view ahead and, while he may have been facing away from the power lines when he operated the burners, he only had to turn slightly to see them.

4.2.11. The power lines, with their 6 wires and regularly spaced poles, should have been easily visible to the pilot as he crossed the silage paddock. For this and other reasons given above, it is highly likely that the pilot knew of and saw the power lines along the side and at the end of the silage paddock before allowing the balloon to descend below them.

Post contact with the power lines

4.2.12. As the balloon rose from beneath the level of the power lines, the nearest wire caught over the corner lip of the basket at the pilot's end. A second wire then caught lower down the basket. The pilot had applied both burners to initiate a climb. The balloon continued to rise and drift across the farm track, lifting the 2 wires and sliding along them towards Somerset Road as it did so.

4.2.13. If contact with a power line is imminent, pilots are advised to initiate a rapid descent so that any contact is with the envelope instead of with the basket. This is the instruction given in the balloon flight manual, so as to reduce the height of the basket above the ground and lessen the risk and severity of any injury. The accident would have been potentially survivable if an immediate descent had been initiated when the pilot first realised that the balloon was likely to hit the power lines. For some reason the pilot decided to try to out-climb the power lines instead. It is possible that he thought there was sufficient time or distance to enable the balloon to out-climb the power lines. If so, this comes down to a simple error in judgement.

4.2.14. Once the balloon was caught on the power lines the occupants were in extreme danger. A rapid deflation of the envelope at that point might still have risked an electric arc or shock to the occupants, but it would have been the more sensible option while ensuring that no-one touched the power lines or other metal objects. Instead the occupants reportedly grabbed the power line and tried to push it off the basket. This was always going to be difficult as the balloon was at that time still trying to climb. The likelihood of serious or fatal injury was almost certain once the balloon caught fire, but once it broke free and rapidly climbed the chances of survival were negligible.

4.2.15. Another instruction given in the flight manual is to shut off the fuel bottles and lines, and vent the fuel lines to reduce the risk of a fire. It was not possible to determine whether the pilot had turned off the 2 cross-feed valves as part of his normal fuel management or in response to the impending collision with the power lines. However, flight manual advice was to operate with the cross-feed valves closed unless otherwise required. The "as-found" condition would be consistent with this. One of the LPG cylinders that would otherwise normally have been open had been shut off and the other had not. It is possible that the pilot was in the process of shutting the system down but did not have time before the electrical arcing occurred. As it turned out, his action probably would have made little difference because the arcing ruptured one of the fuel cylinders, thereby providing fuel to a source of ignition. Heat from the ensuing fire caused the pressure relief valves on the other bottles to burst, adding more fuel to the fire.

4.2.16. The intense fire that developed below the mouth of the envelope would have heated the air inside it and increased the tendency for the balloon to climb. The 2 passengers jumping from the basket would have lightened the load and also caused a greater tendency for the balloon to climb. However, this was not considered a significant factor in comparison with the sustained use of the burners and the effect of the fire. The speed of the balloon's ascent once it broke free of the power lines was significantly higher than would have been expected had the load lightened by 2 passengers alone. The wires were calculated to have 4 m of free vertical movement before coming under strain. The ultimate tensile strength of the wires was 36.5 kilonewtons. The fact that the balloon lifted 2 heavy wires and one wire parted confirms that the balloon was generating a large amount of lift as it pulled the wires upward. The action of the 2 passengers in jumping from the basket was understandable in the circumstances and did not alter the outcome of the accident.

4.2.17. Once the balloon broke free of the power line, it continued to rise and drift west across the road. The fire spread to the envelope, which ultimately lost its ability to support the weight of the balloon. The envelope collapsed and separated from the basket shortly before it hit the ground.

Findings

1. The weather conditions were suitable for the balloon flight that morning.
2. The pilot allowed the balloon to descend below the level of power lines surrounding a paddock in which he did not intend to land. It could not be determined whether that action was deliberate or not, but it unnecessarily compromised the safety of the flight.
3. It was highly likely that the pilot knew the location of the power lines and had seen them before allowing the balloon to descend below their height.
4. A last-minute change in wind direction carried the balloon towards power lines that the loaded balloon was probably not capable of out-climbing. In any event, the pilot exercised poor judgement by attempting to out-climb the power lines, and the balloon collided with them.
5. Electrical arcing from the power lines punctured one of the balloon's LPG fuel cylinders, causing an intense fuel-fed fire that consumed the basket and increased the air temperature in the balloon envelope.
6. The pilot's initial application of the burners caused the balloon to climb. Heat from the basket fire and to a lesser extent 2 of the balloon passengers jumping from the basket increased the balloon's lift and caused it to break the power line that was restraining it. It then ascended rapidly and fell to the ground once the envelope caught fire.
7. Once a collision with power lines is imminent, the recommended action is for the pilot to descend the balloon rapidly. Had he done so there would have been a better chance of survival for the balloon's occupants.

4.3. Performance of the pilot

General

4.3.1. The pilot had accumulated more than 1000 hours of ballooning and had flown commercial balloon flights from his base in Carterton for nearly 15 years. He had also landed near the accident site, possibly even in the same silage paddock, several times before. He was therefore experienced and familiar with the local area.

4.3.2. The pilot's medical certificate had lapsed 6 weeks before the accident. He subsequently flew 9 flights, not including the accident flight, with an expired medical certificate. CAA Rules required pilots to maintain current medical certificates as part of their licences (CAA, 2011). He had previously been made aware that his certificate was about to expire but there was no evidence found to show that the pilot was in the process of renewing it. Undertaking the flight knowing that he did not have a current Class 1 medical certificate as required by Civil Aviation Rules displayed a certain disregard for the authority of those Rules.

4.3.3. The pilot was, however, considered to be healthy and not suffering from any ailment that would have prevented him flying. The medical examiner was aware that the pilot suffered from gout and he believed this would not have precluded him from issuing a class 1 medical certificate.

Cannabis

4.3.4. Pilots, like other persons in safety-critical roles in aviation and other transport modes, need to be able to discharge their duties free of performance-impairing substances, such as those contained in drugs and alcohol. Cannabis is a known performance-impairing substance. The Commission obtained the test results for blood samples taken from the balloon pilot. The samples were not optimal. They were taken 3.5 days after the time of death and included a mixture of other body fluids. The samples obtained could not therefore be considered as "whole blood". They were, however, good enough to analyse for performance-impairing substances such as cannabis, provided the appropriate caveats were considered.

4.3.5. The pilot's urine was also tested for the presence of cotinine, a substance found in the urine of tobacco smokers. This test was negative, showing that it was highly unlikely the pilot had smoked regular tobacco on the morning of the flight. The pilot also was not known by his friends and colleagues to smoke regular tobacco.

4.3.6. The active ingredient of cannabis is THC. The sample analysed revealed a THC level of 2 micrograms per litre of blood (fluid obtained). This was well above that normally considered possible for passive ingestion (inadvertent ingestion by being in the same room as others who are smoking cannabis, for example [Mason, 1983 and Morland, 1985]).[20] This indicates that the pilot had deliberately consumed the drug at some point prior to the accident.

4.3.7. Three experts in forensic toxicology gave their opinions on the pilot's post-mortem toxicology results. ESR and Dr Robertson gave their opinions based on the pilot being an occasional user of cannabis, and the Police expert based his opinion on the assumption that the pilot was a "chronic" user of cannabis, which was an assumption he made from the information he was given, that the pilot was a "long-term regular" user of cannabis. It is not clear whether the terms "chronic user" and "long-term regular user" mean the same thing. In fact, it is a subjective assessment as to how much cannabis a person needs to consume, and how often, for the label of "chronic user" to apply.

4.3.8. Under "normal smoking conditions", a blood THC level of 2 micrograms per litre 70-80 minutes after use would be possible, based on an infrequent user smoking one or part of one cannabis cigarette.[21] On this basis, the level shown in the tests was consistent with the pilot smoking the equivalent of one cannabis cigarette up to 4-6 hours before the accident.

4.3.9. The Police expert said that if the pilot was a regular "chronic" user of cannabis, such a level of THC in the blood could be reached due to the post-mortem redistribution of THC from body fatty tissue. He said that in that case it would be possible that the pilot had not ingested cannabis on the morning of the flight.

4.3.10. On reviewing the medical opinions the Commission accepts the premise that the more often a person smokes cannabis, the higher the likelihood of post-mortem THC readings being attributed to post-mortem redistribution. That is because the more a person smokes cannabis greater will be the accumulation of THC in the body fatty tissue before it can be eliminated from the body through natural processes. Therefore, if the pilot was a frequent user of cannabis, it would be possible that such a level would have remained from previous use. Conversely, if the pilot was an infrequent user of cannabis, such a level would indicate more recent use.[22] The test results could therefore be the result of both longer-term and recent use.

4.3.11. The pilot's friend reported that he had not observed the pilot smoking cannabis the night before the accident, nor was the pilot observed by his partner smoking cannabis at home the previous evening or before he left home on the morning of the flight. That is not to say that he could not have done so at some time on his own, but both his friend and his partner said that he had not displayed any signs of having smoked cannabis the evening before the flight.

4.3.12. The 2 ground crew and the photographer, all of whom had worked with the pilot for many years, did not see the pilot smoking on the morning of the flight. Each agreed that there were

[20] The research papers suggest that to start showing a positive result for THC the pilot would have needed to be in a small, unventilated room or motor vehicle on the morning of the accident with several people who were smoking cannabis.

[21] The 70- to 80-minute timeframe is the time from when the pilot was observed smoking on the balcony to the time of death.

[22] Police expert's opinion, Appendix 3. ESR and Dr Robertson's opinions Appendix 4.

occasions during the morning when they were not with the pilot. It is possible therefore that the pilot smoked cannabis at some time that morning, unseen by them.

4.3.13. One of the ground crew and the photographer were nevertheless adamant that the pilot did not smoke before the flight. They believed this because they did not notice him being under the influence of cannabis and did not notice the distinctive smell of cannabis on the pilot. The 3 were aware that the pilot socialised with a group that regularly used cannabis. One of the 3 had seen the pilot use cannabis in his presence, and another suspected he had used cannabis before. However, all 3 said it would have been out of character for the pilot to smoke cannabis before a flight, especially in view of the passengers and other people assembled that morning.

4.3.14. The pilot was not averse to flouting rules. He had continued to operate his commercial balloon venture despite his medical certificate having expired some 6 weeks previously. There are 2 other considerations that could also have altered his normal behaviour:

- the pilot was about to lose a significant portion of his income with the return of the balloon to its owner. While he reportedly accepted this, it was the first topic he raised with the 2 ground crew and the photographer on the morning of the flight, and he was not happy about it
- the pilot was known to suffer from gout, and was seen to be limping that morning. Gout was a condition that may have affected his behaviour.

4.3.15. The 2 witnesses who saw the pilot smoking on the balcony of the shed shortly before the flight made their reports only after they became aware that the pilot had tested positive for THC. One of them was made aware of the results at a Police briefing before the public release of the Commission's interim report on the accident. She reported what she had seen to the Police immediately after the briefing.

4.3.4 The 2 witnesses did not know what the pilot was smoking and both assumed he was smoking a regular cigarette. After making their reports, the 2 witnesses were interviewed separately, initially by the Police, then by the Commission.

4.3.16. The 2 witnesses were standing about 25 m from the pilot and had a clear view of him on the balcony. Their observations were consistent. They saw the pilot taking something to his mouth and smoke then rising from it. They did not see the pilot drinking from the cup he held. Tests made of the pilot's urine were negative for the substance of cotinine, which means that if the pilot was smoking, he was not smoking regular tobacco.

4.3.17. It has not been possible to determine with any certainty how often the pilot used cannabis. It is possible that he used it more than "occasionally" as described by those 2 witnesses who were close to him – the partner and the friend. Neither could be emphatic on that point because neither was with the pilot all of the time. Similarly for the 2 ground crew and photographer, as none of the 3 was with the pilot all of the time.

4.3.18. On the balance of probabilities the THC level of 2 micrograms per litre of blood resulted from both longer-term and recent use. On reviewing the evidence available, it was highly likely that the pilot smoked cannabis on the morning of the flight. The pilot was only on the balcony for a limited time, so it was possible that he smoked part of a cigarette only. These conclusions are supported by the following 3 points:

- 2 witnesses observed the pilot smoking on the balcony shortly before the flight
- the pilot was not known to smoke regular cigarettes and his urine tested negative for cotinine, which is normally found in the urine of someone who has smoked regular tobacco
- the pilot was known to use cannabis, including in the company of others.

4.3.19. It has been suggested that subtle cognitive impairment could develop in chronic users over several years. Solowij et al examined cognitive functioning in a group of 9 long-term cannabis users (Solowij, 2008). Their findings suggested that long-term cannabis use may impair the efficient processing of information.

4.3.20. Given that it was highly likely that it was cannabis the 2 witnesses saw the pilot smoking, it was only about 25 minutes before commencing the flight and about one hour and 35 minutes to the time he was landing the balloon in the Somerset Road area. These times are well within the 1.5-4 hours that the subjective symptoms of cannabis intoxication are known to last.

4.3.21. The opinion of the Commission's expert was that cognitive impairment at or around the time of the accident, and its contribution to the cause of accident, could not be excluded. ESR noted that symptoms of cannabis intoxication usually peak 10-15 minutes after smoking cannabis and last 1.5-4 hours. The degree of cognitive impairment cannot be determined as the effects vary from person to person. Nevertheless, cognitive impairment of the pilot could not be excluded given the carry-over effect of cannabis from both recent and longer-term use. The extent to which longer-term use could cause cognitive impairment would depend on the frequency of use.

4.3.22. Studies have shown that the greater the judgement and skills required in performing a task, the greater would be the impairment. Flying low level across the paddock; replying to a radio call; preparing to land in variable wind conditions; and dealing with a sudden change in flight path would have all combined to put the pilot under some pressure to make quick and correct decisions.

4.3.23. The sections above refer to a number of errors in judgement by the pilot, namely:

- allowing the balloon to descend over the silage paddock and continue at a height below the level of the power lines – rather than maintain a safe height
- his reaction to the last-minute change of direction towards the adjacent power lines, in not descending and landing
- his response once the balloon had collided with the power lines, in not initiating an emergency descent.

4.3.24. Cognitive impairment could typically contribute to these types of error. Although it cannot be concluded definitively that the cause of the accident was the pilot smoking cannabis, the possibility that it did contribute to the accident could not be excluded.

4.3.25. Pilots, others involved in the aviation industry and the public all need to be aware of the dangers associated with the use of performance-impairing substances. The same principle applies to all transport modes and activities involving complex tasks requiring attention and mental co-ordination.

ARCs relating to the pilot

4.3.26. The CAA had longstanding concerns about the handling of ARCs, and had undertaken several reviews in the previous 3 years. The latest independent review of ARCs highlighted a number of systemic issues. The CAA accepted the findings of the review and has initiated changes in the management of ARCs. The ARC lodged in February 2010 claiming this balloon pilot had been unfit to conduct a flight was examined in depth by the review's author, who found that follow-up enquiries made by CAA staff had been appropriate for the information received.

4.3.27. It was not possible to say whether a more rigorous follow-up of the concern by the CAA would have prevented the 7 January 2012 accident. What the case emphasises, however, is the importance of the CAA responding to ARCs as quickly, completely and robustly as possible. ARCs provide valuable information about risk, and the CAA needs to ensure that this information is acted upon, focusing particularly on those commercial operations that may put the lives of members of the public at risk. While the CAA-initiated independent review concluded that the CAA had acted appropriately, this case serves as a strong reminder that this must be an area of ongoing focus for the CAA.

4.3.28. Had the CAA undertaken a more prompt and co-ordinated response to the February 2010 ARC it could have identified a potential safety risk and a range of preventive actions.

Other accidents where performance-impairing substances were involved

4.3.29. As noted in paragraph 3.6.4, the Commission has investigated 6 occurrences in the past 10 years, including in the rail and marine modes, where crew members were found to have taken performance-impairing substances in the hours or days leading up to the accidents. The aviation accidents included another Part 119 adventure activity (TAIC, 2010), and a commercial air transport flight (TAIC, 2005). While substance impairment could not be identified as a primary cause in these accidents, the use of these substances by personnel responsible for performing safety-critical tasks is a transport-wide safety issue.

4.3.30. On 8 March 2011, in its report on a collision between a jet boat and a jetski, (TAIC, 2009), the Commission made a recommendation to the Secretary for Transport regarding substance impairment in the maritime sector. The recommendation referenced persons in charge of any craft, but the same could apply to a person who has responsibilities or duties to do with safety-critical activities within the rail and aviation industries. The recommendation and the reply on behalf of the Secretary for Transport are shown below:

> Until legislation is made setting limits for and testing of alcohol and other performance impairing substances for recreational and commercial boat drivers, the risk of alcohol-related accidents will be elevated.
>
> It is recommended that the Secretary for Transport address this safety issue by promoting appropriate legislation to set maximum allowable levels of alcohol and other performance impairing substances for persons in charge of recreational and commercial craft, and supporting legislation to allow testing for such levels in these cases. (005/11)

4.3.31. On 16 March 2011 the Manager Maritime and Freight of the Ministry of Transport replied to the recommendation:

> The recommendation is that the Secretary for Transport promote legislation to set limits and establish a testing regime to address the risk of recreational and commercial boating accidents due to the use of alcohol or other performance-impairing substances.
>
> Recreational and commercial boating is one of three areas of transport activity where no alcohol and drug limits or testing regime yet exists. The introduction of such a regime in any of these areas would be a major policy decision for government that would need to be informed by a thorough understanding of the problem and the policy options. The Ministry therefore intends to develop a report to government on the feasibility of a compulsory post-accident and incident drug and alcohol testing regime for the aviation, maritime and rail transport sectors.
>
> Accordingly, implementation of recommendation 005/11 would only be practicable once the relevant policy work has been undertaken by the Ministry, and then only if the results indicated that a drug and alcohol testing regime is a feasible option.

4.3.32. The Commission notes that this proposed action fell short of what the Commission recommended, namely, that legislation should set maximum allowable levels of alcohol and other performance-impairing substances. Post-accident and -incident testing on its own will not act as a sufficient deterrent unless it can be backed up with potential enforcement measures. The Commission believes there should be a zero tolerance to impairment by drugs and alcohol in the transport sector, and random or targeted testing should be included in the range of measures to promote safer work practices.

4.3.33. On 22 March 2012, in its report on a loss of control and crash involving a skydiving plane at Fox Glacier aerodrome (TAIC, 10-010), the Commission made another recommendation to the Secretary for Transport as follows:

> The use of performance impairing substances is known to have a detrimental effect on the ability of people to safely operate in critical transport environments. The Commission recommends that the Secretary for Transport promotes the introduction of a drug and alcohol detection and deterrence regime for persons employed in safety critical transport roles (011/12).

4.3.34. On 3 May 2012 the General Manager Aviation and Maritime of the Ministry of Transport replied, in part:

> I accept the specific recommendation 011/12 directed to the Secretary for Transport.
>
> I also urge the Commission to note the existing health and safety in employment regulatory regime, where drugs and alcohol are specifically mentioned in the definition of "hazard". This regime already places obligations on both employers and employees.
>
> Since the Fox Glacier accident the Minister of Transport has approved a new Rule Part 115 that entered into force in November 2011. The Rule requires adventure aviation operations to be certified by 1 May 2012. Adventure aviation organisations, including commercial parachuting, now face the risk that their safety certification can be suspended and removed for safety violations. This gives such operators a stronger incentive to ensure they address alcohol and drug taking safety risks in their organisations.
>
> Over the next two years the Government will be considering rule amendments that would require aviation organisations to introduce safety management systems. This would require certificated operators to assess and mitigate all safety risks relevant to their operation. This risk of intoxication of personnel by drugs and alcohol would clearly be a safety risk that we would expect both operators and the Civil Aviation Authority (when certifying and auditing aviation organisations) to be actively addressing under an SMS regime. Decisions will also be made in the near future to ensure that the Civil Aviation Authority is resourced to transition to the ICAO-endorsed SMS approach which has widespread industry support.
>
> Whilst recognising that where the illegal use of drugs is involved, changing individual behaviour will be challenging, the Ministry will encourage the Civil Aviation Authority to step up its effort to alert the aviation community through education of the risks that drugs pose to the safety operation of aviation undertakings. This will require an on-going effort.
>
> As you are aware, the Ministry has developed a Transport Regulatory Policy Statement that specific rule changes may not always be the best interventions to achieve desired safety outcomes. Non-regulatory interventions can often be more appropriate. In this regard we appreciate the Commission's recommendation to promote a drug and alcohol detection and deterrence regime, rather than to implement a regime.
>
> The Ministry of Transport has in the past sponsored an inter-agency Substance Impairment Group. This looked at whether or not compulsory random drug and alcohol testing, and specific breath alcohol limits, should be required by regulation in the aviation, marine and rail transport modes. In part because of a lack of data, we were not convinced at that time that the costs would outweigh the benefits. We will, however, monitor international experience in this regard and, in particular, the recent relevant changes in the Australian aviation regime.

4.3.35. The Commission notes with concern the possibility that performance-impairing substances (cannabis) contributed to this accident – one of New Zealand's worst aviation disasters. While acknowledging the benefits of some of the steps outlined above in response to previous recommendations, the Commission firmly believes that the risk of performance-impairing substances contributing to future transport accidents and incidents will remain unacceptably high until legislation is introduced to deal properly with this safety issue.

Findings

8. The pilot did not have a current medical certificate as required by Civil Aviation Rules. This was unlikely to have contributed to this accident in any way, but it did show a disregard for complying with the rules.

9. The pilot had a post-mortem THC blood level of 2 micrograms per litre. This was likely the result of 2 factors: the pilot smoking cannabis shortly before the flight (considered highly likely), and residual THC from his having ingested cannabis over a longer term that redistributed into his blood after he died. It was not possible to determine if either factor contributed more or less to the toxicology result.

10. The accident was caused by errors of judgement by the pilot. The possibility that the pilot's performance was impaired as a result of ingesting cannabis cannot be excluded.

11. The long-term and recent ingestion of performance-impairing substances such as cannabis by crew of any transport vehicle is a serious safety issue that needs to be addressed as a matter of priority.

4.4. Balloon maintenance and performance

4.4.1. Ballooning in New Zealand is a small-scale activity, with 74 balloons recorded on the CAA aircraft register, including numerous small 2- and 4-person balloons, and some that have not flown for extended periods of time. As a result ballooning has attracted less attention from the CAA, which had little in-house expertise in the maintenance of balloons at the time of the accident. The CAA had therefore delegated the responsibility for the initial inspection for the certificate of airworthiness to more experienced maintenance engineers. This was the case with the accident balloon ZK-XXF and its predecessor ZK-EMB.

4.4.2. The delegation of balloon inspections still meant that the CAA retained the responsibility for ensuring that the documentation submitted for approval and the issuing of certificates was correct. The documents submitted by the maintenance provider for the accident balloon contained errors that had not been identified by the CAA. Similar certification errors were found with some other balloons as well.

4.4.3. Balloons are obviously different from other aircraft types; nevertheless, they still need to be rigorously maintained. The Commission found no evidence of any mechanical or envelope defect that contributed to the accident. The flight proceeded normally. The pilot reported no issues. The burners were seen and heard to be operating and the balloon was seen to begin climbing just before and after contact with the wires. In spite of the fire and impact damage, the balloon was found to be in good working order.

4.4.4. However, the maintenance performed on ZK-XXF, namely the documentation, was substandard. The Commission was concerned that this could have extended to other balloons, so it published an urgent recommendation to the Director of Civil Aviation to address this safety issue. (Refer to section 7, Recommendations, and section 6, Safety actions).

4.4.5. The ARC on the practices of the balloon maintainer, had it been followed through properly by the CAA, should have identified the need for the CAA to improve its oversight of that part of the balloon industry much sooner than when this accident occurred. However, as stated earlier, nothing in the maintenance procedures for this balloon contributed to the accident. The safety actions taken by the CAA in its handling of ARCs has addressed that safety issue.

4.5. Balloon safety

4.5.1. The Commission examined the design and construction of balloons, and the emergency equipment and procedures, and tested those factors against the survivability of this accident.

4.5.2. Balloon envelope material has improved with the introduction of increasingly stronger, tear-resistant fabrics. Envelopes can last longer, sustain greater heat damage and better endure the effects of the sun and moisture than previously. There are required tests to monitor the condition and performance of the balloon envelope.

4.5.3. The basket, meanwhile, has changed little, with cane and wicker continuing to be the principal materials used in construction. These materials are lightweight and provide both strength and flexibility. They are able to absorb the repeated knocks of a landing and sliding along the ground and often tipping over. The drawback is that cane, which is normally varnished, has limited fire-resistant qualities. Fire-resistant materials are usually a stipulation for enclosed commercial transport vehicles where opportunities for passenger escape can be limited. The concept is to try to limit the spread of fire long enough to enable opportunities for both fire-fighting and escape.

4.5.4. In this case the electrical arcing and the ensuing LPG-fed fire were intense. There are not many materials available that would be resistant to fires of that intensity and still be suitable for balloon baskets. In these situations the primary defence against this type of fire is first avoiding the electrical arcing, and second starving the fire of fuel. LPG is highly flammable and the design of the fuel system was so that the entire system could be closed off. This situation where one of the LPG bottles was punctured by the electrical arcing was unusual. The ensuing fire would have been almost uncontainable, even if the basket had been constructed from fire-retardant material.

4.5.5. The balloon was required to be fitted with a fire extinguisher and one was found in the wreckage with the safety pin still in place, which indicated it had not been used. Photographs taken on the morning of the accident show that it had been stowed centrally in the pilot's compartment next to the passenger compartments. Passengers might have been able to reach the extinguisher, but would have firstly needed to know it was there and then needed to lean over the basket partition to reach it.

4.5.6. The initial location and intensity of the fire may have prevented the occupants reaching the extinguisher. Regardless, the New Zealand Fire Service investigator who assisted the Commission considered that the extinguisher would have had little or no effect in containing the very hot fuel-fed fire. These types of extinguisher were designed to extinguish or contain smaller fires. In different circumstances, having the basket constructed from fire-retardant material could have slowed the spread of a small fire and increased the chance of the balloon occupants extinguishing it. Manufacturers of balloon baskets should consider this when designing future baskets.

4.5.7. The pilot gave 2 briefings to the passengers before the flight. The first was a general welcome with a description of the balloon, the preparation for the flight and how to enter and exit the basket. The second briefing was a safety briefing, which normally included practising the landing position and where to place the hands, and instructions to not attempt to vacate the basket until instructed by the pilot. According to experienced ballooning pilots in New Zealand and overseas, a balloon pilot would not normally brief passengers on the emergency equipment available or how to operate the control lines. It would be common, especially in single-compartment baskets, to instruct passengers not to interfere with the control lines, as the incorrect use of the controls could be fatal.

4.5.8. There is an argument that had the pilot become incapacitated by the initial electrical arcing, a passenger could have descended the balloon using the emergency deflation cord had they been instructed in its use. This would need to be balanced with the risk of a passenger panicking and pulling the cord at an inappropriate time.

4.5.9. The Commission could identify no obvious improvements in the design and operation of balloons in general that might have improved the chances of survival of the balloon occupants in this accident.

4.5.10. The emergency services received multiple notifications of the accident and responded promptly, reaching the accident site within 6 minutes. This was a good response. A faster response would not have improved the survivability of this accident.

4.5.11. There is no requirement to hold a licence for private ballooning in New Zealand. This was not a factor in this accident because the pilot was experienced and held a commercial balloon licence. However, the absence of a private balloon licence, with its associated requirements for theoretical and practical examinations and medical standards, is at variance with International Civil Aviation Organization guidelines and those of other countries with similarly developed histories of ballooning. Fortunately new balloon pilots usually seek guidance and training from experienced pilots and operate within an association of balloonists that provides some supervision. The Director of Civil Aviation has issued an NPRM seeking to introduce a mandatory private balloon licence and a balloon instructor rating, which should address this safety issue (see section 6 for details).

4.5.12. Civil Aviation Rule Part 115 Adventure Aviation – Certification and Operations came into effect on 10 November 2011, about 2 months before this accident. Transitional arrangements meant that balloon operators were not required to comply until May 2012, about 4 months after the accident. The Commission has concluded that, for the reasons given in this section, the regulatory oversight of the ballooning industry was not sufficient for its size and the potential risk to the public, for both private and commercial balloon operations. The introduction of Rule Part 115 should provide a good mechanism for balloon operators to improve the safety of operations, and for the CAA to maintain appropriate oversight of the industry.

Findings

12. The regulatory oversight of commercial ballooning in New Zealand was not sufficient to ensure a safe and sustainable industry for the New Zealand public.

13. It is a safety issue that a person without any prescribed training, knowledge or medical certificate can take non-paying passengers for a balloon flight.

14. The basic design and safety of the balloon were adequate and improvements in the design would not have altered the outcome of this accident.

5. Findings

5.1. The weather conditions were suitable for the balloon flight that morning.

5.2. The pilot allowed the balloon to descend below the level of power lines surrounding a paddock in which he did not intend to land. It could not be determined whether that action was deliberate or not, but it unnecessarily compromised the safety of the flight.

5.3. It was highly likely that the pilot knew the location of the power lines and had seen them before allowing the balloon to descend below their height.

5.4. A last-minute change in wind direction carried the balloon towards power lines that the loaded balloon was probably not capable of out-climbing. In any event, the pilot exercised poor judgement by attempting to out-climb the power lines, and the balloon collided with them.

5.5. Electrical arcing from the power lines punctured one of the balloon's LPG fuel cylinders, causing an intense fuel-fed fire that consumed the basket and increased the air temperature in the balloon envelope.

5.6. The pilot's initial application of the burners caused the balloon to climb. Heat from the basket fire and to a lesser extent 2 of the balloon passengers jumping from the basket increased the balloon's lift and caused it to break the power line that was restraining it. It then ascended rapidly and fell to the ground once the envelope caught fire.

5.7. Once a collision with power lines is imminent, the recommended action is for the pilot to descend the balloon rapidly. Had he done so there would have been a better chance of survival for the balloon's occupants.

5.8. The pilot did not have a current medical certificate as required by Civil Aviation Rules. This was unlikely to have contributed to this accident in any way, but it did show a disregard for complying with the rules.

5.9. The pilot had a post-mortem THC blood level of 2 micrograms per litre. This was likely the result of 2 factors: the pilot smoking cannabis shortly before the flight (considered highly likely), and residual THC from his having ingested cannabis over a longer term that redistributed into his blood after he died. It was not possible to determine if either factor contributed more or less to the toxicology result.

5.10. The accident was caused by errors of judgement by the pilot. The possibility that the pilot's performance was impaired as a result of ingesting cannabis cannot be excluded.

5.11. The long-term and recent ingestion of performance-impairing substances such as cannabis by crew of any transport vehicle is a serious safety issue that needs to be addressed as a matter of priority.

5.12. The regulatory oversight of commercial ballooning in New Zealand was not sufficient to ensure a safe and sustainable industry for the New Zealand public.

5.13. It is a safety issue that a person without any prescribed training, knowledge or medical certificate can take non-paying passengers for a balloon flight.

5.14. The basic design and safety of the balloon were adequate and improvements in the design would not have altered the outcome of this accident.

6. Safety actions

6.1. General

6.1.1. The Commission classifies safety actions by 2 types:

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

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

6.1.2. Safety actions addressing safety issues identified during an inquiry

6.2. Maintenance

6.2.1. As a result of the urgent safety recommendation described in section 7, on 21 February 2012 a safety inspection team from the CAA commenced an inspection of the 5 maintenance providers approved to work on balloons, starting with the maintainer for ZK-XXF. The inspection team found that while most balloon maintenance providers were adhering to good maintenance practices and generated no concerns, there were "various levels of performance in respect of adherence to the manufacturer's maintenance manual and [Civil Aviation Rules]". The CAA report said that one maintenance provider in particular had not appeared to meet the required standards. The reasons cited included:

a. a lack of direct supervision of maintenance being performed by unapproved repair and test agencies prior to certification of that maintenance in the maintenance records

b. an incorrect application of the "grab test". This was mitigated in part by the provider's knowledge and experience

c. incorrect records stating that a porosity check had been completed

d. the incorrect technique used for the fuel system inspection.

The CAA report made 2 recommendations in respect of the above maintenance provider: firstly, "that a further in depth inspection/audit is conducted"; and secondly, that "consideration be given to whether re-inspection is required to validate the aspects of maintenance that have not been conducted in accordance with the manufacturer's maintenance manual".

6.2.2. As a result of the inspection, the Inspection Authorisation document for the principal of the maintenance provider was suspended until the completion of a "section 15a investigation". This referred to section 15a of the Civil Aviation Act 1990 and the "Power of the Director to investigate holder of aviation document… if the Director believes, on reasonable grounds, that it is necessary in the interests of civil aviation safety and security".

6.2.3. On 6 March 2012, at the request of the Director of Civil Aviation, an investigation team was formed to gather information regarding the exercise of the privileges of the personal aviation documents held and the maintenance practices carried out by the maintainer. The team found that:

> While most of the issues identified during the investigation were not seen as individual safety risks, the number and variety of issues is concerning.
>
> Common themes are a lack of discipline in completing records, a lack of checking of records prior to signing the release to service and a lack of checking the resulting loose leaf entry records.

At about this time the Inspection Authorisation for the maintenance provider's principal expired and was not renewed. As a result the CAA required the maintenance provider to put in place a number of changes and quality management initiatives.

6.2.4. On 27 June 2012 a safety audit of the maintenance provider was undertaken. The audit team identified 2 minor and 2 major findings. The major findings related to an expired part and fluid, and missing documentation for another part, all held in the bond store. Other than recommending a "thorough audit" of the bond store items, no additional action was recommended.

6.3. Drugs and alcohol

6.3.1. On 5 October 2012 the CAA issued NPRM 13-01 regarding the establishment of a specific drug and alcohol programme for adventure aviation operators. The notice called for submissions on the proposed changes. Three written submissions were received.

6.3.2. On 12 November 2012 the Minister of Transport approved the changes to Part 115 Adventure Aviation – Certification and Operations, including the addition of new Rule 115.62 Drug and Alcohol Programme. The new Rule required an adventure aviation operator certificate applicant to:

> Establish a drug and alcohol programme for monitoring and managing the risks relating to the use of any drug, or consumption of alcohol by-
>
> (1) any crew member;
> (2) a tandem master;
> (3) a ground crew member;
> (4) any other person whose work directly affects the safety of an adventure aviation operation.

6.3.3. Adventure aviation operator certificate applicants are also required to include within their expositions the details of their drug and alcohol programmes, and the means of ensuring that adventure aviation operations did not take place were people referred to above found to be impaired by such substances. The new Rules applied to new certificate applicants, while current certificate holders as at 15 December 2012 were required to amend their expositions by 15 March 2013. In the meantime all certificate holders were required to have available the details required by the new Rules.

6.4. Ballooning

6.4.1. On 29 November 2012 the CAA issued NPRM 09-02, Part 61 Pilot Licences and Ratings, Docket 4/CAR/4. The NPRM included the introduction of a private pilot licence (balloon) and a balloon instructor rating. The final date for submissions on the NPRM was 11 January 2013. The new balloon licence and rating were proposed to be in effect within 12 months of the new Rule being approved.

6.4.2. On 22 April 2013 the CAA issued a new flight test standards guide for the commercial pilot licence (balloon) and biennial flight reviews for licensed balloon pilots. These brought commercial balloon pilots in to line with other commercial licence holders.

6.5. ARCs

6.5.1. The CAA advised the Commission that in response to the review of ARCs a range of actions had been taken to address "underlying issues of coordination, management, resource allocation and record keeping". These included:

- Additional fulltime dedicated resource assigned for the management and coordination of ARC investigation;
- Additional resources allocated to the oversight of adventure aviation, including commercial ballooning, and General Aviation sport and recreation activity;

- Enhancement of safety analysis capability to support intelligence led, risk based interventions across the CAA;
- The development and promulgation of the CAA Regulatory Operating Model and the supporting Regulatory Tools Policy to provide clear and consistent direction to all staff on priorities for safety interventions and to support decision making on these. Collectively these support a more proactive and focused approach to identifying and managing safety risk — one that is intelligence led and risk-based. They also support the use of a broader regulatory toolkit to influence safety outcomes — the right tools used in the right way at the right time;
- The development of enhanced policies to support the consistent and coordinated management of ARCs across the CAA that reflect the Regulatory Operating Model and the Regulatory Tools Policy;
- Restructuring has resulted in what was the General Aviation Group now sitting within the Operations and Airworthiness Group (previously the Airlines Group) to support a more consistent approach to management decision making and performance management;
- Intensive training has been provided to managers to support professional performance management practices. This includes training on setting performance objectives and is designed to improve the quality of staff performance objectives. Further support as required in the form of refresher training and one-on-one coaching for managers has been undertaken by senior Human Resources staff, and improved documentation for 2012/13 Performance Review and Development agreements was developed.

  More generally in respect of the adventure aviation sector the following developments and activities have occurred since January 2012 that contribute to enhanced levels of safety in that sector:

- The introduction of Civil Aviation Rule Part 115 - *Adventure Aviation – Certification and Operations*. This came into effect in late 2011 and resulted in all adventure aviation operations involving hot air balloons, hang gliders, paragliders, tandem parachuting, and parachute drop aircraft to be certificated by 1 May 2012. Microlight aircraft adventure operations required certification from1 Nov 2012 and those involving gliders must be certificated by 1 May 2013. The rule requires operators to have appropriate management systems, structures, and operating procedures in place to ensure compliance with the relevant safety standards, employees are appropriately qualified, and trained, equipment is appropriate to the task and properly maintained, and key people are fit and proper to undertake their responsibilities;
- Audits of all Part 115 Operators on their compliance with existing obligations they have under the Health and Safety in Employment (HSE) Act 1992 to manage hazards posed by a drug or alcohol impaired employee;
- Amendments to Rule Part 115 to add specific requirements for Operators to manage the hazards posed by substance impairment.

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.

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.

Recommendations

7.3. On 15 February 2012 the Commission made the following urgent safety recommendation:

The Commission recommends that the Director of Civil Aviation:

(a) conduct an urgent check on all maintenance organisations and licensed engineers approved to maintain hot-air balloons to ensure that their balloon maintenance practices fully comply with Civil Aviation Rules, and

(b) satisfy himself that all New Zealand-registered hot-air balloons are airworthy. (001/12)

7.4. On 17 February 2012 the Director of Civil Aviation replied in part:

> I accept the thrust and intent of the recommendations made by the Commission. However, with respect to recommendation (b), I cannot accept it as it is written, as it goes beyond the scope of my responsibilities as Director of Civil Aviation under the Civil Aviation Act. The Act is clear about the respective responsibilities and accountabilities of participants: in particular for those who operate aircraft. Those individuals are responsible and accountable for ensuring aircraft are airworthy.
>
> Notwithstanding my comments above about recommendation (b) I can advise the following:
>
> The CAA [Civil Aviation Authority] initiated a safety investigation into the maintenance practices associated with balloon ZK-XXF on 15 February 2012
>
> The CAA investigation will also examine maintenance practices associated with other balloons maintained by the maintenance provider of ZK-XXF
>
> The CAA investigation will identify any other issues associated with the maintenance practices, and thus airworthiness, of balloons in New Zealand
>
> The CAA investigation is being undertaken as a matter of urgency, with an initial report from the investigation team due on 29 February in relation to the first bullet point.
>
> The CAA views the issues identified by the Commission very seriously and will act swiftly to address any deficiencies found in maintenance practices that place in doubt the airworthiness of hot air balloons operated in New Zealand. As a consequence of the advice received from the Commission, the CAA has amended the Terms of Reference for its investigation to more expressly address the maintenance and airworthiness issues of all hot air balloons as the third stage of the investigation.

7.5. On 11 October 2013 the Commission made the following recommendation to the Secretary for Transport:

The post-mortem toxicology results for the pilot in the Carterton hot air balloon showed that he had a positive result for tetrahydrocannabinol (a constituent of cannabis). It was likely that this was due to 2 factors: first, the pilot smoking cannabis shortly before the accident flight; and, second, residual tetrahydrocannabinol, from ingesting cannabis over a longer term, redistributing in the pilot's blood after his death.

The Commission found that the accident was caused by errors of judgement by the pilot. It also found that it could not exclude the possibility that the pilot's performance had been impaired as a result of ingesting cannabis.

This is not the first time that the Commission has inquired into occurrences where persons operating aircraft, vessels or rail vehicles, or where persons performing functions directly relevant to the operation of these, have tested positive for performance-impairing substances such as illicit drugs and alcohol. The Commission is increasingly seeing more occurrences where the use of performance-impairing substances is a feature.

Unless this safety issue is properly addressed, further occurrences where the use of performance-impairing substances is a contributing factor will occur. Legislative or regulatory reform in this area is necessary.

The Commission, therefore, recommends that the Secretary for Transport complete, as a matter of priority, all necessary work that will support the introduction of appropriate legislation or rules that will:

- prescribe allowable maximum levels for alcohol
- prohibit persons from operating an aircraft, vessel or rail vehicle if they are impaired by drugs
- require operators to implement drug and alcohol detection and deterrence regimes, including random testing
- prescribe post-occurrence testing requirements for drugs and alcohol.

This legislation or these rules should apply:

- across the aviation, maritime and rail transport modes
- to persons operating an aircraft or a marine craft for recreational purposes. (012/13)

7.6. On 21 October 2013, the Secretary for Transport replied:

> Below is the Ministry's response to the final recommendation, noting at this date that I have not seen the final report.
>
> I wish to note that the determination of the need for legislation or rules is a matter for the Minister of Transport, rather than the Secretary for Transport. The Ministry's response to the recommendation is prepared with this in mind.
>
> I also note that the inquiry's findings conclude that the accident was caused by errors of judgement by the pilot, but include the possibility that the pilot may not have been impaired. Before I respond to the recommendation I would like to take this opportunity to comment on relevant work in the transport sector.
>
> *Drug and alcohol impairment in the aviation, maritime and rail sectors*
>
> Alcohol and drug impairment in the transport sector is an issue that the Ministry takes very seriously. Impairment in driving is one of the largest causes of serious road crashes in New Zealand, contributing to about a third of all road deaths every year.
>
> The impact of drug and alcohol impairment on the aviation, rail and maritime sectors has been an area of focus for the Ministry. Following the review of safety practices within the adventure and outdoors commercial sectors conducted by the previous Department of Labour, in August 2012 the Government agreed to amendments to aviation and maritime rules to improve safety in these sectors. These amendments are now in force and include a requirement for adventure activity operators to include a description of how they will manage the safety risks associated with drug or alcohol impairment in their relevant safety plans (Organisational Management Systems for aviation and Safe Operational Plans for maritime).

To assist maritime operators, Maritime New Zealand has produced safety guidelines for managing risks related to alcohol and other drugs for raft and jet boat operators. The Maritime Transport Amendment Bill 2013, which has had its third reading and will come into force in the next few weeks, will implement the internationally applicable alcohol limit for merchant seafarers established by the 2010 amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1995 (STCW).

The Civil Aviation Authority has worked closely with adventure aviation operators to support the development and implementation of drug and alcohol management policies that include testing. A detailed advisory circular for adventure aviation operators outlines the expectations for drug and alcohol monitoring and management, and what acceptable policies should include.

Many transport operators, particularly those involved in transporting members of the public, already have drug and alcohol management policies in place in the workplace. Operators regard this as good business practice and meeting the duties of employers and employees set out in the Health and Safety in Employment Act 1992. Some operators that are involved in safety sensitive activities, such as Air New Zealand, Qantas, KiwiRail and Maersk Line have also introduced drug and alcohol policies involving testing regimes.

Statistics from the New Zealand Drug Detection Agency show that the number of workplace drug tests carried out in New Zealand increased 31 percent between 2011 and 2012, with an increase in alcohol tests of 32 percent over the same period. These results suggest that employers in safety sensitive areas, including transport, are taking workplace safety very seriously.

Drug testing on the road

The drug driving regime has been in force for just under four years. The Ministry has a project on its work programme to investigate developments in drug screening and testing technologies (and associated issues) that have occurred over this time. This work is due to take place during 2014.

Post accident testing

Aviation, maritime, and rail legislation does not currently provide for transport agencies, the Commission, or Police (except in relation to the STCW alcohol regime for international or large domestic vessels) to conduct toxicological tests following an accident. Only when a fatality occurs can a Coroner test for the presence and level of drugs and alcohol in the deceased as part of the post mortem investigation.

As a result there is a lack of New Zealand data to quantify the extent of alcohol and drug use in the aviation, maritime, and rail sectors, and its links to accidents and incidents. In comparison, the road sector's drug and random alcohol testing regime provides the necessary data to develop an understanding of the links between drug and alcohol use and accidents and incidents.

Compulsory post accident testing would provide valuable data on alcohol and drug use within the aviation, maritime and rail sectors in New Zealand. Aggregated data from the test results would inform future policy options, including the potential introduction of maximum limits and testing requirements, as noted in the Commission's recommendation.

In order to establish whether there is a case for a compulsory post accident drug and alcohol testing regime, the Ministry has commissioned the New Zealand Institute of Economic Research (NZIER) to investigate and report on:

- criteria to determine which accidents (and incidents) should be covered
- who should be tested
- the agency responsible for undertaking the testing
- the testing procedures to be used (with reference to current national and international standards) in order to safeguard the integrity and accuracy of the testing

- an offences and penalties regime for refusing to be tested or interfering with test results or samples
- the agency responsible for the data collection
- the cost of implementing a compulsory regime
- the legislative changes required to give effect to a compulsory regime.

Once we have the NZIER report, we will brief the Minister of Transport on the options. We expect to be able to do this in December 2013. The Minister may then need to take a paper to Cabinet regarding any further work.

Response to recommendation

This brings me to the Ministry response to your recommendation that the Ministry completes the work necessary to support the introduction of legislation or rules that will:

1. Prescribe allowable maximum levels for alcohol;
2. Prohibit persons from operating an aircraft, vessel or rail vehicle if they are impaired by drugs;
3. Require operators to implement drug and alcohol detection and deterrence regimes, including random testing; and
4. Prescribe post occurrence testing requirements for drugs and alcohol.

The completion of the first three parts of the recommendation is dependent on the fourth, prescribing post occurrence testing requirements for drugs and alcohol. As I have discussed earlier in this letter, the Ministry of Transport is already undertaking work, as a matter of priority, to determine the case for a compulsory post accident testing regime.

We will be able to confirm the next steps for post accident testing once the Minister has considered our advice. Of course we will keep the Commission informed of the progress of the post accident testing proposal, as well as any other work that relates to the Commission's recommendation.

Finally, like the Commission, the Ministry also believes there should be zero tolerance of operator impairment where members of the public are being transported by sea, rail and air. We feel very deeply for the families of those who lost their lives in this accident.

8. Key lessons

8.1. Both long-term and recent use of cannabis may significantly impair a person's performance of their duties, especially those involving complex tasks. Under no circumstances should operators of transport vehicles, or crew members and support crew with safety-critical roles, ever use it.

8.2. Power lines are a well-recognised critical hazard to hot-air balloon operations. Balloon pilots should give them a wide margin and if they ever inadvertently encounter them, they should follow the balloon manufacturers' advice and best industry practice to mitigate the possible consequences.

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Appendix 1: ESR reports

ESR Report dated 23 May 2012:

The following items were delivered by [courier] on 11 January 2012:

TOX121281/1	Blood
TOX121281/2	Blood
TOX121281/3	Urine
TOX121281/4	Urine
TOX121281/5	Liver
TOX121281/6	Stomach Contents

The items were not destroyed during analysis.

ANALYSIS

The blood and urine were analysed for the presence of alcohol. This analytical technique will also detect other volatile compounds including those associated with decomposition.

The blood was analysed for the presence of the majority of medical drugs that affect the mind, alter mood or cause sleep.

The blood was analysed for a range of common analgesic medication.

The urine was screened for evidence of the use of amphetamine type stimulants, opiate type drugs, cocaine and cannabis.

The blood samples were analysed for the presence of tetrahydrocannabinol (THC), the active constituent of cannabis.

The urine samples were analysed to determine the levels of THC-acid, the main metabolite formed after cannabis use.

RESULTS and INTERPRETATION

Alcohol

TOX121281/1	Blood	Not detected
TOX121281/3	Urine	5 milligrams per 100 millilitres

Low levels of alcohol may be due to means other than deliberate ingestion.

Volatile compounds associated with decomposition were also detected. It is therefore possible that any blood and urine alcohol concentration existing at the time of death was changed by microbial action prior to sampling. Microbial action can cause increases or decreases in blood and urine alcohol concentrations.

Tetrahydrocannabinol (THC)

TOX121281/1	Blood	Approximately 2 micrograms per litre
TOX121281/2	Blood	2 micrograms per litre

Under normal conditions a blood THC level of 2 micrograms per litre would be consistent with [the pilot] smoking the equivalent of a single cannabis cigarette within 5 hours prior to death. Blood THC levels may remain elevated for a longer period if cannabis is used frequently.

THC-acid (the main metabolite of THC)

TOX121281/3	Urine	130 micrograms per litre
TOX121281/4	Urine	120 micrograms per litre

THC-acid is an inactive metabolite of THC. Urine levels can not be used to indicate any degree of intoxication.

Urinary levels of drugs cannot be interpreted by themselves because the levels can be significantly affected by the amount of fluid a person drinks and when they last urinated. The period of time that THC-acid can be detected in urine varies from days to weeks and depends on the frequency of the use of cannabis.

No medical drugs that affect the mind, alter mood or cause sleep were detected in the blood.

No common analgesic medication was detected.

There was no evidence in the urine for the use of amphetamine type stimulants, opiate type drugs or cocaine.

The urinary screening test indicated the possible use of cannabis. This is consistent with the presence of THC in the blood.

COMMENTS

Tetrahydrocannabinol (THC)

Cannabis cannot be easily classified as a sedative or stimulant since it can have different effects in different people and its effects generally vary over time. Its main psychological and behavioural effects are euphoria and relaxation, an impairment of perception and cognition, and loss of motor coordination.

Subjective symptoms of cannabis intoxication usually peak 10 to 15 minutes after smoking cannabis and last 1.5 to 4 hours.

Blood THC levels produced by smoking a cannabis cigarette and the rate at which the levels decrease vary widely between individuals and are dependent on a number of factors. These factors include frequency of use, smoking technique and experience, and size and potency of the cannabis cigarette.

Blood THC levels are generally a poor indicator of cannabis intoxication. It is not usually possible to determine whether a subject was intoxicated based on blood levels alone. Because of the degree of trauma sustained I cannot be confident that the level of THC detected in the blood sample accurately reflects the level present immediately prior to death. However, a level of 2 micrograms per litre indicates recent use and it is possible that [the pilot] was affected by the drug at the time of the crash.

Peak levels of THC-acid occur in the urine within 6 hours after smoking cannabis. Because THC is absorbed into fatty tissues and slowly excreted as THC-acid, high levels of THC-acid may be detected in the urine of frequent users for several days.

ESR Report dated 26 October 2012

The following items were delivered by [courier] on 11 January 2012:

TOX121281/1	Blood
TOX121281/2	Blood
TOX121281/3	Urine
TOX121281/4	Urine
TOX121281/5	Liver
TOX121281/6	Stomach Contents

The items were not destroyed during analysis.

ANALYSIS, RESULTS and INTERPRETATION

The blood and urine were analysed for evidence of the use of tobacco by the presence of nicotine, the main active component of tobacco, and the presence of cotinine, the main metabolite of nicotine.

No nicotine or cotinine were detected in the blood or urine.

Nicotine levels in blood are generally low even immediately after smoking and levels drop rapidly. Nicotine has a plasma half life of 24 to 84 minutes (average 40 minutes). The half life of a drug is the time it takes for the level in the blood or plasma to drop by half.

I would not expect to detect nicotine in the blood unless it was at a level that might be associated with toxicity.

Cotinine has a longer plasma half life than nicotine, ranging from 14 to 21 hours (average 16 hours). I don't know if I would detect cotinine in blood after use of a single cigarette, but I would expect to detect it in the blood of a regular tobacco smoker.

Levels of nicotine and cotinine in the urine of regular tobacco smokers is higher than blood levels. I would expect to detect both components in the urine of a person who has recently smoked tobacco. Cotinine can also be detected in the urine of people passively exposed to tobacco smoke.

Appendix 2: Dr Robertson's opinion dated 4 June 2012

My name is Shelley Diane Robertson and I am a legally qualified medical practitioner in Australia practising as a Specialist in Forensic Medicine and Pathology. I obtained the degrees of Bachelor of Medicine and Bachelor of Surgery from the University of Melbourne in 1978, Bachelor of Laws from the University of Melbourne in 1995. I hold a Fellowship of the Royal College of Pathologists of Australia by examination in General Pathology, a Diploma of Medical Jurisprudence in Forensic Pathology from the Worshipful Society of Apothecaries, London, a Fellowship of the Australian College of Legal Medicine and a Fellowship of the Faculty of Forensic and Legal Medicine, Royal College of Physicians, London. I have also obtained a post-graduate Diploma of Aviation Medicine and a Masters Degree in Health Sciences (Aviation Medicine) from the University of Otago, New Zealand. I held the appointments of Consultant Senior Pathologist, Victoria Institute of Forensic Medicine, Honorary Senior Lecture in Forensic Medicine, Faculty of Medicine, Monash University for over 20 years. I currently hold the position of Honorary Senior Fellow, Department of Pathology, Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne. I provide a forensic aviation and pathology consulting service call "Forensair".

In over twenty years of specialist Forensic Pathology practice, I have performed in excess of 10,000 medico-legal death investigations, including investigations of homicide and accident victims, cases of suicide, natural and suspicious death. My expertise in forensic pathology includes evaluation of injury patterns and interpretation of results of toxicological analysis and bloodstain patterns. I have given expert evidence in the fields of forensic medicine and pathology in the Coroner's Court, Magistrate's, County and Supreme Courts of Victoria and other states. I undertake teaching of medicine, pathology, law and aviation related subjects at undergraduate and postgraduate levels.

On June 4, 2012, at the request of Dr Robin Griffiths, I reviewed the following materials relating to the accident:

1. National News Report dated 7/1/2012 covering Hot Air Balloon crash in which there were 11 fatalities, Wairarapa, New Zealand.
2. Report of Toxicological analysis performed on specimens obtained from [the pilot] prepared by [ESR toxicologist].
3. Report of autopsy carried out on Unidentified Male, DVI number 01-0601 by [Forensic Pathologist] at Wellington Hospital, 10 January 2012.
4. Supplementary report identifying Unknown Male DVI no. 01-06-01 as [the pilot].
5. Electronic communication from Dr Rob Griffiths stating further analysis of urine sample of [the pilot] showed THC level of 120-130μg/l [micrograms per litre].

On the basis of the above materials, I make the following comments:

1. Summary of Circumstances

The deceased, [name deleted], was the pilot of a Hot air Balloon which departed for a sight-seeing flight from an area near Carterton, New Zealand on the 7/1/2012 with 11 persons (pilot and 10 passengers) on board. Approximately 45 minutes later, the balloon was seen to collide with powerlines, catch fire and crash to the ground, killing all eleven persons. The bodies of the deceased were recovered and Disaster Victim Identification procedures undertaken. The remains of the pilot, [name deleted], were autopsied by forensic pathologist [name deleted] and cause of death was given as "Multiple blunt force and thermal injuries". Toxicological analysis was performed on specimens from the deceased, [name deleted], collected at autopsy and the results from ESR Laboratories showed the presence of THC (active cannabis metabolite) in blood at a level of 2 μg/l. No other drugs or alcohol were identified in blood. A very low level of ethanol was detected in urine along with other volatile compounds which suggest post-mortem alcohol production as part of the process of decomposition rather than ingestion of ethanol. Subsequent testing of urine sample from the deceased showed a THC level of 12—130 μg/l.

2. Opinion

In general I agree with the comments regarding interpretation of the results of toxicological analysis made by [name deleted] of ESR Laboratories. She states "Because of the degree of trauma sustained I cannot be confident that the level of THC detected in the blood sample accurately reflects the level present immediately prior to death." Interpretation of THC levels in post-mortem blood specimens is problematic, particularly (as in the present case) if the specimen is suboptimal (ie cavity blood from an extensively traumatised body). Other factors include the possible post-mortem redistribution of THC in blood (from tissue stores of the compound). The finding of a level, however of 2 μg/l (2 micrograms per litre) in blood, strongly suggests recent use of cannabis by the deceased in the hours prior to the accident. This is supported by the presence of THC-acid in the urine.

The effects of cannabis use in an individual are extremely variable and include such factors as history of usage (that is, chronic as opposed to 'one-off'). Some research suggests that a blood level of 5 μg/l and above causes cognitive impairment however blood levels of THC tend to decline quite rapidly after use (several hours) whilst studies have shown (specifically flight simulator studies in pilots) that cognitive deficits can persist at least up to 24 hours following cannabis use (the 'carry-over effect'). This leads to the conclusion that direct correlation of cognitive impairment with blood levels of THC is also problematic.

The testing of the blood and urine specimens obtained from the deceased, [name deleted] by ESR Laboratories was directed at the active metabolite of cannabis, that is Δ9-THC. Levels of this compound give the best indication of recent usage, unlike the inactive metabolite, 11-nor-Δ-tetra hydrocannabinol-9-carboxylic acid (THC acid) which can persist in blood and urine for days following cannabis use and has not been demonstrated to correlate with cognitive impairment at all.

3. Conclusion

In conclusion, the pilot of this hot-air balloon, which crashed resulting in the death of all persons on board, was shown to have the active metabolite of cannabis in blood at a level of 2 μg/l. Whilst this level may not accurately reflect the actual blood level at the time of death, it strongly suggests recent cannabis use (4-6 hours prior to death). This in turn suggests that at the time of use (within the 4-6 hour time-frame) the blood levels of THC would have been much higher and the likelihood of cognitive impairment also high. Cognitive impairment at or around the time of the accident cannot be excluded, given the 'carry-over' effect of cannabis.

The testing of the specimens by ESR Laboratories and the report issued including the comments by [name deleted] appear to be entirely appropriate.

Appendix 3: Police expert's report (undated)

My name is [name deleted] and I am a Regional Forensic Pathologist to the National Forensic Pathology Services of New Zealand.

My qualifications are Bachelor of Medicine and Bachelor of Surgery and Obstetrics and Gynaecology (Trinity College, Dublin, Ireland 1999).
Ph.D (Medical Toxicology, Trinity College, Dublin, Ireland 1994).
Fellow of the Royal College of Pathologist (London) 2010.

I completed three Fellowships in Miami-Dade in Forensic Pathology 2006-2009 and was admitted to a fellow of the National Association of Medical Examiner's (USA 2010).
I currently work out of the Department of Forensic Pathology, Auckland City Hospital.
As a Forensic Pathologist, my primary expertise is in determining the cause of death and in the delineation of patterns of injury and their causation and putting any findings into context. I have expertise in forensic toxicology and the interpretation of post-mortem toxicology results. This is a particular area of professional interest.

REQUEST

At the request of [the Police], I have reviewed the post-mortem toxicology results for [the pilot] who was the pilot of a hot air balloon that crashed killing all 11 people on board on the 7th of January 2012. I have been asked to give an opinion on the significance / meaning of the finding of tetrahydrocannabinol (THC) in [the pilot's] blood and THC-acid (THCCOOH) in his urine.

DOCUMENTS REVIEWED TO FORM THIS OPINION

1. The autopsy report of [the pilot] carried out by [the pathologist] on the 10th of January 2012.

2. The photographs taken at the time of the autopsy.

3. The toxicology reports from [ESR], dated 14th of March and 23rd of May 2012.

4. An opinion provided by Dr Shelly Robertson of Forensair dated the 4th of June 2012.

5. A job sheet entitled "Operation Enoka" from [the Police] dated the 31st of July 2012

SPECIFIC INFORMATION PROVIDED BY [THE POLICE]

1. [The pilot] was known to smoke cannabis on a regular basis and has done so for a prolonged period of time (i.e. more than months).

2. [The pilot] was not known to smoke cigarettes.

3. [The pilot] was an experienced balloon pilot and had an impeccable safety record over 10 years.

4. A witness has stated that she saw [the pilot] smoking what looked like a cigarette shortly before the balloon took off.

REVIEW OF AUTOPSY REPORT AND AUTOPSY PHOTOGRAPHS

The salient points taken from the autopsy report by [the pathologist] and the review of the autopsy photographs were that [the pilot] suffered multiple blunt force traumas with extensive tissue disruption and burns. The body was in a moderate state of decomposition and had abundant post-mortem larvae activity.

The samples retrieved for toxicology testing were fluid containing blood from chest cavity and urine.

CRITICAL POINTS TO CONSIDER AND LIMITATIONS INFLUENCING THE INTERPRETATION OF POST-MORTEM TOXICOLOGY RESULTS

1. The decedent's exposure to drug(s) in question: chronic; intermittent; naïve.
2. Sample site.
3. Ante-mortem interval.
4. Post-mortem interval.
5. Pharmacokinetics and pharmacodynamics of the drug(s) in question.
6. Post-mortem re-distribution.
7. Condition of the body at time of sampling.
8. The context of the case, on a case by case, basis.
9. What is the specific question to be answered.

TOXICOLOGY RESULTS (summary)

Blood- Tetrahydrocannabinol (Δ9-THC)- 2 micrograms per litre.
Urine- Tetrahydrocannabinol-acid (11nor- Δ9-THCCOOH)- 120-130 micrograms per litre

As per [ESR] dated 23rd of May 2012

OPINION

1. The information as provided supports the fact that [the pilot] was a chronic user of cannabis

2. The information provided can not prove or exclude that [the pilot] had ingested cannabis in the hours prior to the Balloon crash.

3. The information can not prove the notion that [the pilot] was under the influence of cannabis at the time of the crash.

COMMENT

The subject of post-mortem toxicology is a specialized area of forensic toxicology in where the rules and assumptions that apply to the principles of pharmacokinetics and pharmacodynamics in the living require special precaution and interpretation. Most, if not any, of these assumptions cannot be applied to post-mortem interpretation. To give a full and complete review of the subject with extended medical and scientific explanation and references would require the production of a voluminous thesis above and beyond that required for a Ph.D. This report will attempt to capture the main issues in layman's language.

Cannabis is one of the most widely used drugs worldwide. Like alcohol, it is known to have a plethora of effects and affects on the human body (this is called pharmacodynamics) with some people showing euphoria and docile states to some who become paranoid and aggressive. Chronic use, similar to alcohol, can induce a degree of tolerance but unlike alcohol, chronic cannabis use results in metabolites (when taken the body causes chemical changes to assist in eliminating it from the body, this is called pharmacokinetics) accumulating within various tissues of the body. Cannabis is known to be lipophilic (that is to say it dissolves better in fat than it does water). The more you ingest cannabis, the more that becomes sequestered within fat stores of the body.

Cannabis is metabolised to several compounds but mainly to forms called Δ9-tetrahydrocannabinol or THC (has pharmacological activity) and 11-nor- Δ9-tetrahydrocannabinol or THCCOOH (has no pharmacological activity).

If I was to recommend one scientific paper that gives some insight into the complexities associated with interpreting cannabis and its metabolites in living humans, I would suggest a paper co-authored by Martin Huestis etal. (1). Work is currently underway, and has been for sometime, in Australia by Prog Olaf Drummer on the post-mortem changes to cannabis (personal communication with Prof Drummer). This work is finding similar variations with cannabis in post-mortem samples under much more controlled conditions that what we have in this case. Huestis et al's paper clearly demonstrates that when known chronic users are sequestered into a clinical environment and deprived of cannabis for seven days, their blood and urine levels of THC and THCCOOH vary considerably including an apparent increase, despite abstinence. Similarly Drummer et al. have looked at Cannabis in post-mortem samples and have found a similar oscillation in blood values from the same patient over 48-72 hours (personal communication).

The essences of this paper, and others that are out there, compel you to be cautious when considering the post-mortem result.

After death the human body undergoes a process of decomposition which involves breaking-down of tissues resulting in the release of stored metabolites (for some drugs and not all). This is particularly relevant to lipophilic compounds and THC is one such metabolite. Given the fact that [the pilot's] remains lay for two days in the summer sun exposed to the elements, the sample that is labelled blood cannot be considered anything near to whole blood as you may understand the term blood. It was a sample consisting of an admix of blood, fat, proteins, and decompositional fluid among under substances (as given by the toxicology results under volatiles).

As pointed out above under "Critical Points to Consider when Interpreting Post-mortem Toxicology", you must consider whether the person is a naïve user, intermittent or chronic user of a drug. When looking at a value of 2 micrograms per litre (that is 2 parts THC per million) of THC in such a sample under these conditions, you can not draw a firm conclusion of acute exposure in a person known to be a chronic user of cannabis, as was [the pilot]. The 2 micrograms may well be stored THC from previous exposures that re-distributed and / or leached from fat stores during decomposition. It is entirely possible that if a blood ample was drawn from [the pilot] minutes before he lifted off that morning, it may have shown levels of THC less than 2 micrograms per litre in his blood.

You can infer that it represents recent use in a person known not to take cannabis or to take it on an infrequent basis. You simply cannot infer that it represents recent use in a chronic user. The THCCOOH in the urine is known to be detectable for many days after the last exposure in a chronic user, up to 10-13 days after last use.

The suggestion, by Dr Shelley Robertson in her conclusions, that the level of 2 micrograms of THC in [the pilot's] blood strongly suggests recent cannabis use and that in turn this suggests that his blood levels would have been much higher in 4-6 hours before death is erroneous and fails to take into consideration critical facts (i.e. [the pilot] was a chronic user).

Equally the suggestion by [ESR] in her report that the result of 2 micrograms per litre suggests recent use has no scientific reliance (a fact she points out).

Their suggestions cannot be disproven beyond scientific and medical certainty due to problematic delay between the incident and the recovery of the post-mortem samples. In the four days between the incident and retrieval of the blood sample on which the toxicity is based, the vital information that may have answered this pivotal question was irretrievably lost.

In order to address the allegation that [the pilot] was smoking either a cigarette or something else just before the balloon took off, I requested that cotinine (found in urine of tobacco smokers) be looked for in his urine and this proved negative supporting the assertion that [the pilot] did not smoke tobacco. Therefore it remains to be considered that if [the pilot] was smoking cannabis (pure cannabis) that morning, was he such a cavalier character that he would have openly smoked cannabis in full view of his ground crew let alone his passengers immediately prior to take off?

CONCLUSIONS

The toxicology results from the decomposing samples taken from [the pilot] three days after the balloon crash support the established fact that he was a chronic smoker of cannabis (THCCOOH in urine) and he did not smoke tobacco. The results do not prove that he smoked cannabis on the morning of the flight. It is entirely probable that he did not smoke cannabis for several days prior to the incident. There is no definitive evidence to suggest he was under the influence of THC at the time of the incident and the THC found may well have resulted from post-mortem redistribution. The THC does not prove recent use in a chronic user (i.e. within a 4-6 hour timeframe).

If there is still a question as to whether [the pilot] smoked cannabis in full view of ground crew and customers that morning then these results cannot disprove it beyond doubt. The other circumstances, context and established behaviours of [the pilot] that morning may prove decisive as these results may simply reflect the known fact that [the pilot] was a chronic smoker of cannabis.

Reference:

1. Do Δ-Tetrahydrocannabinol Concentrations Indicate Recent Use in Chronic Cannabis Users. Marilyn Huestis co-author. Addiction. 2009 December; 104(12): 2041-2048.

Appendix 4: Review of toxicology report results

The ESR provided further comment as follows;

Δ9-Tetrahydrocannabinol, also known as THC, the active constituent of cannabis, was found in [the pilot's] blood sample at a level of 2 micrograms per litre. 11-Nor-9-carboxy-Δ9-tetrahydrocannabinol, also known as THC-acid, the main urinary metabolite of THC, was detected in [the pilot's] urine sample at a level of 120 to 130 micrograms per litre. THC-acid is an inactive metabolite, it has no effect on a person.

These findings could be consistent with [the pilot] smoking cannabis 90 minutes prior to his death. However, use of cannabis at an earlier time cannot be ruled out.

Under normal circumstances, a blood THC level of 2 micrograms per litre would indicate recent use of the drug, anywhere from 0.5 to 5 hours of the sample being taken, if a single fairly low potency cannabis cigarette had been smoked. Levels may be expected to remain elevated for longer if more than the equivalent of a single cigarette is smoked, if the cannabis is more than average potency or if cannabis is used frequently.

THC is a lipophilic drug. It moves rapidly from a watery medium like blood, to tissues that contain fat. When cannabis is smoked, blood THC levels peak during the time the cigarette is being smoked. The levels drop rapidly as the THC is distributed into the tissues.

There have been many studies conducted on THC levels following smoking cannabis. Most of the reported smoking studies have analysed plasma rather than whole blood. The plasma/blood ratio of THC is between 1.5 and 2. That means a THC plasma level of 2 micrograms per litre is equivalent to 1 to 1.3 micrograms of THC per litre in whole blood.

The length of time THC may be detected depends, among other things, on the potency of the cannabis. These smoking studies involved smoking cannabis with potencies of 1.75% and 3.55%, which are likely to be lower than the current average potency of cannabis. These studies also used volunteers who had no THC in their plasma prior to smoking. A number of studies, summarised in a paper by the same author found that THC plasma levels declined below 2 micrograms per litre within 6 hours (equivalent 1 to 1.3 micrograms per litre of whole blood). Considering the results of nine separate smoking studies a level of 2 micrograms of THC per litre of blood could occur anywhere from 0.5 to 5 hours after smoking.

New Zealand drivers who have been found impaired due to cannabis use, and failed to satisfactorily complete an impairment test conducted by Police, had THC blood levels ranging from 0.2 to 36 micrograms per litre (average 5.8 micrograms per litre).

If cannabis is smoked frequently, such as daily, THC will accumulate in the body tissues. How much accumulates will depend on how frequently the drug is used and the potency of the cannabis.

In this case, the blood sample provided for analysis had been taken at autopsy from the body cavity, 3.5 days after the time of death. Due to the time delay and the degree of trauma, it is likely that the analytical sample was not representative of the blood immediately prior to death. Some decomposition and mixing with other body fluids is likely to have occurred.

Decomposition and/or the mixing of blood with other body fluids may have resulted in an increase or decrease in the THC level as detected in the sample analysed compared with the level in the blood immediately prior to death. The possible effect that any decomposition and mixing with other body fluids might have had on the level of THC detected, will depend on how often [the pilot] smoked cannabis.

If he was an infrequent user of the drug, less than once a week, I would not expect THC to accumulate in the body tissue. Therefore, there would not be THC from previous use in the body tissue to be released into the body cavity fluid during the degradation of tissue following death.

If he used the drug more frequently, I can't rule out the possibility that THC stored in tissue from previous use has resulted in elevation of the THC level in the sample analysed.

The level of THC-acid in [the pilot's] urine indicates that it is possible he used cannabis more than infrequently. If [the pilot] was an infrequent user of cannabis, and had not used cannabis in the previous week, he should not have had a significant residue of THC-acid in his urine.

Peak levels of THC-acid in the urine don't usually occur until at least 3 hours after use [11, 12]. A level of 120 micrograms of THC-acid per litre of urine is high for very recent use of cannabis by someone with no THC-acid already present in the urine. In an ESR cannabis smoking study, THC-acid urine levels remained below 50 micrograms per litre, even after 7 hours, in those participants whose urine was drug free prior to smoking. Those participants whose urine was not drug free prior to smoking, achieved higher THC-acid urine levels within an hour, some comparable to [the pilot's] THC-acid urine level.

Urinary THC-acid levels are of limited use because urine is always changing in concentration. For example, if someone drinks a lot of fluid, their urine would be more dilute than someone who drinks less fluid. If urine is dilute, any drug levels will be lower. To take this into account, the urine strength can be measured by the amount of creatinine present. Creatinine is a waste product of muscle metabolism found in human urine. Creatinine is excreted at a fairly constant rate, that is, about the same amount of creatinine is expelled from the body every day and this amount is relatively independent of the amount of fluid intake.

Drug levels can be adjusted to take into account the urine strength. The adjusted results are called "normalised levels for THC-acid". The normalised level is the ratio of the THC-acid level over the creatinine level.

[The pilot's] creatinine level was 926 micrograms per litre, therefore a level of 120 micrograms of THC-acid per litre of urine would be normalised to 130 micrograms per litre.

In a reported study of the urinary excretion profiles of frequent and infrequent cannabis users, infrequent users were found to have THC-acid levels above 100 micrograms per litre for up to two days after use. Frequent users maintain THC-acid levels over 100 micrograms per litre for four or more days.

If [the pilot] was a very infrequent user of cannabis, use less than once a week, I would not expect such a high level of THC-acid in his urine so quickly after use. Such a level may be expected if there was already THC-acid in the urine from previous use. And if he had used cannabis frequently enough for THC-acid to be present in his urine prior to his most recent use of the drug, it is possible THC was present in his tissues which may have elevated the level found in the cavity blood.

Dr Robertson commented as follows:

At the time of compiling my original opinion regarding this case I was unaware that the deceased, [the pilot was likely to have been a chronic user of cannabis. As I stated originally "Interpretation of THC levels in post-mortem blood specimens is problematic, particularly (as in the present case) if the specimen is suboptimal (ie cavity blood from an extensively traumatised body). Other factors include the possible post-mortem redistribution of THC in blood (from tissue stores of the compound)". If in fact he was a chronic user, the issue of post-mortem redistribution of THC is very likely to influence the blood level of THC determined at post-mortem and recent use may not necessarily be implied.

I was also unaware of the witnessed account of the deceased smoking prior to the flight. I agree that the urine negativity for nicotine and cotinine strongly suggests that what was being smoked was not tobacco.

In summary, I conclude that an active metabolite of cannabis (THC) was detected in the blood of the deceased, [the pilot] and whilst the actual blood level prior to the accident and the time of usage cannot be clearly determined by this result, the facts remain that the deceased was a cannabis user and cognitive impairment at or around the time of the accident and its contribution to the cause of the accident, cannot be excluded, given the ‘carry-over ’effect of cannabis.

(The Police expert declined to make further comment in response to the invitation.)

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