CORONER'S COURT
OF NEW SOUTH WALES

Inquest:	Inquest into the deaths of Emma Bowden, Heather Bowden-Page, Edward Cousins, Richard Cousins, William Cousins & Gareth Morgan
Hearing dates:	17 to 21 October 2022; 24 to 28 October 2022
Date of Findings:	26 May 2023
Place of Findings:	Coroner's Court of New South Wales, Lidcombe
Findings of:	Magistrate Derek Lee, Deputy State Coroner
Catchwords:	CORONIAL LAW – cause and manner of death, aviation fatality, de Havilland Canada DHC-2, Jerusalem Bay, Sydney Seaplanes, Airag Aviation Services, floatplane, engine exhaust system, magneto access panels, magneto cooling tubes, firewall breach, AN3-3A bolt, carbon monoxide exposure, ingress of carbon monoxide into aircraft cabin, chemical spot detectors, on board recording devices, recorded flight data, Australian Transport Safety Bureau, Civil Aviation Safety Authority
File number:	2018/1389; 2018/1393; 2018/1398; 2018/1399; 2018/1401; 2018/1404
Representation:	Ms S Callan SC & Ms J Davidson, Counsel Assisting, instructed by Ms A Doyle (Crown Solicitor's Office) Mr R McIlwaine SC & Mr D Roberts for Mr A Page, instructed by Ms S Kaurin (Shine Lawyers) Mr P Hornby for the Australian Transport Safety Bureau Mr R Wilson (Norton Wilson Lawyers) for Airag Aviation Services Pty Ltd & Mr J Land

Findings:

Emma Bowden died on 31 December 2017 at Jerusalem Bay, Brooklyn NSW 2083. The cause of Emma's death was the combined effects of multiple injuries and immersion.

Heather Bowden-Page died on 31 December 2017 at Jerusalem Bay, Brooklyn NSW 2083. The cause of Heather's death was the combined effects of multiple injuries and immersion.

Edward Cousins died on 31 December 2017 at Jerusalem Bay, Brooklyn NSW 2083. The cause of Edward's death was the combined effects of multiple injuries and immersion.

Richard Cousins died on 31 December 2017 at Jerusalem Bay, Brooklyn NSW 2083. The cause of Richard's death was multiple blunt force injuries.

William Cousins died on 31 December 2017 at Jerusalem Bay, Brooklyn NSW 2083. The cause of William's death was the combined effects of multiple injuries and immersion.

Gareth Morgan died on 31 December 2017 at Jerusalem Bay, Brooklyn NSW 2083. The cause of Gareth's death was multiple blunt force injuries.

Emma, Heather, Edward, Richard and William died whilst a passengers in aircraft registration VH-NOO piloted by Gareth which experienced aerodynamic stall while partway through a low level steep turn at a bank angle in excess of what was required. This caused the aircraft to descend and impact with the water in Jerusalem Bay.

There is no reliable evidence that an acute medical event or a chronic underlying medical condition involving the pilot, distraction of the pilot as a result of an unexpected event in the aircraft cabin, meteorological conditions, mechanical failure or pilot error caused or contributed to the accident.

Instead, cracks in the aircraft's exhaust collector ring allowed exhaust gases with high carbon monoxide concentrations to pass from the exhaust assembly into the aircraft cabin. Whilst the mechanism of carbon monoxide ingress into the cabin cannot be precisely determined it is most likely that holes in the magneto access panels left open by three missing bolts and gaps around an incorrectly oriented magneto access panel provided the route of entry. Exposure to carbon monoxide in the cabin resulted in an elevated carboxyhaemoglobin level in the pilot which impaired the pilot's ability to operate the aircraft safely, especially given the complexity of this task.

Recommendations pursuant to section 82, *Coroners Act 2009*	See Appendix A

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1. Introduction

1.1 On the afternoon of New Year's Eve 2017, Richard Cousins and his fiancé, Emma Bowden, boarded a seaplane at Cottage Point. Also on board the flight were Richard's two adult sons, Edward and William, and Emma's 11 year old daughter, Heather Bowden-Page. The group were enjoying a family holiday to Australia from the United Kingdom and had just finished lunch at a restaurant in Cottage Point with the intention of flying back to Rose Bay.

1.2 The seaplane took off at around 3:11pm with Gareth Morgan, an experienced seaplane pilot, in control of the aircraft. A short time later the aircraft unexpectedly turned into Jerusalem Bay which was not part of the typical flight path from Cottage Point to Rose Bay. Whilst in Jerusalem Bay the aircraft made a steep right turn. Partway through the turn, the nose of the aircraft dropped suddenly and it began descending before impacting with the water at around 3:14pm.

1.3 The impact caused significant damage to the aircraft and catastrophic injuries to the pilot and passengers. The aircraft began to sink below the surface. Despite the efforts of witnesses who were on watercraft in Jerusalem Bay at the time of impact, the pilot and passengers could not be extricated from the aircraft.

1.4 Emergency services were contacted and rescue and recovery efforts began a short time later. At around 5:00pm, New South Wales Police Force (**NSWPF**) divers confirmed that all the occupants of the aircraft were, tragically, deceased.

2. Why was an inquest held?

2.1 Under the *Coroners Act 2009* (**the Act**) a Coroner has the responsibility to investigate all reportable deaths. This investigation is conducted primarily so that a Coroner can answer questions that are required to be answered pursuant to the Act, namely: the identity of the person who died, when and where they died, and what was the cause and the manner of that person's death.

2.2 In some cases inquests are held so that evidence can be presented which may assist in answering some of the above questions. Inquests also tend to consider other questions that are typically associated with the manner of a person's death or, in other words, the circumstances surrounding that death. The events of 31 December 2017 raised a number of immediate questions, and others which arose during the course of the subsequent investigation conducted by both the NSWPF and the Australian Transport Safety Bureau (**ATSB**). These questions focused on the following matters:

(a) what caused an aircraft, piloted by an experienced pilot, on an otherwise routine flight to suddenly and unexpectedly deviate from its usual course;

(b) the operation of the aircraft in Jerusalem Bay and what contributed to the apparent loss of control of the aircraft and subsequent impact;

(c) the investigative process, in circumstances where critical evidence was discovered at a relatively late stage in the investigation, more than two years after the events of 31 December 2017; and

(d) whether appropriate consideration has been given to taking remedial action to mitigate against the likelihood of such a catastrophic event occurring again.

2.3 For all of these reasons, an inquest was required to be held.

2.4 In this context it should be recognised at the outset that the operation of the Act, and the coronial process in general, represents an intrusion by the State into what is usually one of the most traumatic events in the lives of family members who have lost a loved one. At such times, it is reasonably expected that families will want to grieve and attempt to cope with their enormous loss in private. That grieving and loss does not diminish significantly over time. Therefore, it should be acknowledged that the coronial process and an inquest by their very nature unfortunately compels a family to re-live distressing memories several years after the trauma experienced as a result of a death, and to do so in a public forum. This is an entirely uncommon, and usually foreign, experience for families who have lost a loved one.

2.5 It should also be recognised that for deaths which result in an inquest being held, the coronial process is often a lengthy one. The impact that such a process has on family members who have many unanswered questions regarding the circumstances in which a loved one has died cannot be overstated.

3. Recognition of the lives of the people who died

3.1 Inquests and the coronial process are as much about life as they are about death. A coronial system exists because we, as a community, recognise the fragility of human life and value enormously the preciousness of it. Understanding the impact that the death of a person has had on those closest to that person only comes from knowing something of that person's life. Therefore, it is important to recognise and acknowledge the lives of the people who died on 31 December 2017 in a brief, but hopefully meaningful, way.

3.2 **Emma Bowden** was born on 29 July 1969. She was known to have a very gregarious, open and generous personality and did very well at school. Emma retained many of her friends from school throughout her life. Emma loved meeting people and spending time with family and friends.

3.3 After obtaining a degree from the London College of Printing, Emma worked in graphic design and children's book publishing as a Deputy Art Editor before later becoming the Art Editor at OK! Magazine.

3.4 This job brought together many of Emma's favourite things. She loved to travel, was an intrepid cyclist, and enjoyed attending the cinema and theatre. Emma's sister, Rebecca, describes the job as being the perfect vehicle for Emma's ability to be cool, calm and collected, despite whatever was thrown at her.

3.5 After Heather was born, her aunt Rebecca observed that being a mum was "*very much front and centre*" to Emma's life. Rebecca describes Emma as being a very loving, careful and responsible mother.

3.6 In the Spring of 2015, Emma met Richard Cousins in Soho in London. They travelled frequently together and in August 2017 they bought a house with plans to start work on it in the new year. Emma had dreams of creating a big, loving family with a home for Heather and Richard's sons to share.

3.7 **Heather Bowden-Page** was born on 18 March 2006. Heather lived in London with her mother but also regularly visited her father, Alexander Page, at his home on a farm in the Czech Republic, where her brother Alfie lived and she kept a horse.

3.8 Shortly before travelling to Australia, Heather had started at a new school where she was passionately involved in a number of co-curricular activities. Heather was a keen member of the choir and involved in many different school clubs ranging from rugby to chess. She had become part of a program to mentor students, of which she spoke about with great pride, had started a school newspaper and played the lead role of Alice in *Alice in Wonderland*.

3.9 Heather was also a Girl Guide and was interested in arts and culture, especially music and film. Heather was a talented artist, in both painting and drawing, and had produced a number of short movies and music that she had created herself.

3.10 Heather had many plans for the future, with an ambition to study politics, philosophy and economics at Cambridge University. She wanted to follow a career path as an international civil servant or a politician, and was passionate about becoming a champion for social change, particularly in the area of education for socially excluded girls. Heather's hero was Malala Yousafazi.

3.11 Alexander describes his daughter as precocious, empathetic, loving, giving and firm in her convictions. Alexander recalls the last conversation he had with Heather on Christmas Day 2017 when she sounded very mature, happy and excited for the future. He heartbreakingly describes Heather as sounding content and very grown up, a credit to Emma and to herself, becoming the woman she was destined to be, and living her life to the fullest.

3.12 **Richard Cousins** was born in Leeds on 29 March 1959 and had two older brothers, Simon and Andrew. He obtained degrees in mathematics and statistics. Whilst at university, he met Caroline and they later married in 1982. Together, they had two sons, William and Edward. The family lived in the village of Hyde Heath in Buckinghamshire where they became part of the village community.

3.13 Richard spent a number of years working for the British Plaster Board and later occupied the position of CEO until overseeing its sale in around 2006. Richard subsequently became the CEO of Compass, the largest food/catering business in the world and he became a world leader in his field.

3.14 Sadly, Caroline died of cancer in August 2015. During this difficult time, Richard took great strength from his two sons.

3.15 After experiencing great depths of sadness at Caroline's passing, Richard's life took on a new purpose and optimism when he met and formed a relationship with Emma. Together, they bought a house in central London in August 2017, and were engaged with a plan to marry in July 2018.

3.16 Richard was known to be a lover of cricket. Indeed, the family trip to Australia in late 2017 included attending the Boxing Day Test in Melbourne.

3.17 **Edward Cousins** was born on 18 October 1994. During his Gap Year he taught at a school in a Palestinian refugee camp. He later graduated from St Andrews University, where he was the president of the martial arts club.

3.18 Edward enjoyed horse riding and had aspirations of becoming a police officer. Indeed, two weeks before his death, he passed the entrance requirements for his chosen career.

3.19 **William Cousins** was born on 29 April 1982. After attending university, William later worked as the press officer for Open Britain, a pro-EU organisation, and loved his job. His work involved writing speeches for Members of Parliament, a number of whom attended his memorial service.

3.20 William played cricket and the violin. Shortly before his death, William received a commendation from the Metropolitan Police for "*talking down*" a person contemplating self-harm from a bridge over the River Thames.

3.21 William and Edward are described by their uncle Simon as "*gentle giants*", and kind and compassionate young men.

3.22 **Gareth Morgan** was born in Sydney on 29 August 1973 to Dr Rusty Morgan and Mrs Orlis Morgan. He later moved to North Vancouver, Canada and obtained his aviation diploma from the University of the Fraser Valley.

3.23 Mr Morgan was a gifted athlete. As a child, he was a provincial record holder in the 80-metres hurdles and provincial pentathlon champion. Mr Morgan's mother describes him as someone who loved running, whether on the soccer field or track oval. Indeed, Mr Morgan played for the Canadian Under 19 soccer team and could have pursued a professional soccer career. He was also described as being at home on the ski slopes and hiking trails on the mountains close to his family home in North Vancouver.

3.24 Instead of a professional sporting career Mr Morgan instead chose to pursue a career in aviation, initially gaining experience flying seaplanes in northern British Columbia and remote First Nations communities in Canada, in the High Arctic and in Myanmar. Mr Morgan's mother describes his aviation career as a perfect fit for his adventurous spirit, love of nature and his sense of the importance of being at the helm when looking after others.

3.25 After flying seaplanes in Vancouver for a number of years, Mr Morgan returned to Sydney and commenced work with Sydney Seaplanes. Over the course of his career, he accumulated over 9,000 hours of flying in seaplanes. Relevantly, Mr Morgan had flown the Rose Bay to Cottage Point route over 780 times. Mr Morgan's colleagues had great respect for his professionalism and described him as very experienced, very careful and risk averse. Mr Morgan had a very good understanding of how weather conditions affected landing areas, take-off areas, and the operation of seaplanes in and around terrain and rivers.

3.26 Mr Morgan's father fondly recalls a trip with his wife to visit their son in the Republic of Maldives in February 2017. Mr Morgan spent a week with his parents and discussed his future plans of returning to Australia with a view to settling down, qualifying to fly as a first officer for Qantas, buying a house in Brisbane, getting married and having children.

3.27 Mr Morgan was of devout Christian faith, and spent time doing mission work in an orphanage in Mozambique, with the homeless in Vancouver, and building homes for the destitute in Mexico. Mr Morgan's mother notes that even with Mr Morgan's many accomplishments and accolades he remained completely without ego, and was a modest and gentle soul. She describes her son as connecting with people all over the world with his generosity, humanity, compassion and deep spiritual beliefs. Mr Morgan loved his family, friends, flying and God. Mr Morgan's mother said that there are not enough words to describe the depth of Mr Morgan's soul, the warmth of his smile and the clear blue of his eyes.

4. Background to the events of 31 December 2017

4.1 Mr Morgan commenced work as a pilot with Sydney Seaplanes in December 2011. He flew seaplanes regularly in this role until April 2014 when he left to undertake work in the Republic of Maldives. Mr Morgan recommenced working with Sydney Seaplanes in May 2017.

4.2 On 23 December 2017, Mr Morgan was landing a Cessna 208 aircraft at Rose Bay when it encountered unexpected boat wake. This caused the aircraft to become airborne momentarily before impacting the water. No persons on board were injured but the aircraft sustained damage to the landing gear and floats, rendering it unserviceable.

4.3 Although an internal review found that the incident was beyond Mr Morgan's control, and he was approved for a return to line flying, Mr Morgan expressed disappointment and regret regarding the incident. Notwithstanding, the Chief Pilot and other pilots at Sydney Seaplanes observed that the incident did not appear to adversely affect Mr Morgan.

4.4 Between 24 and 27 December 2017, Mr Morgan was not rostered to work. However, on 27 December 2017, Mr Morgan volunteered to fly to Proserpine, Queensland to pick up parts for the aircraft damaged four days earlier. Mr Morgan was then rostered to work between 28 and 30 December 2017, and piloted a number of flights in accordance with his schedule on these days.

5. The events of 31 December 2017

5.1 On 31 December 2017, Mr Morgan was rostered to work from 9:00am to 5:00pm. At 6:30am, Mr Morgan phoned a long-term friend in Canada whom he spoke to regularly. The conversation was normal and positive, and Mr Morgan talked about his future personal and career plans.

5.2 Mr Morgan's first flight of the day was scheduled for 10:00am. His roster was consistent with a standard busy day for Sydney Seaplanes during the summer, and Mr Morgan was used to the number of flights which would be flown that day. During the course of the morning, work colleagues, passengers and other people who interacted with Mr Morgan observed that he appeared normal, upbeat and happy.

Flight from Rose Bay to Cottage Point

5.3 At about 10:45am, Richard, Emma, Edward, William and Heather arrived at the Sydney Seaplanes terminal at Rose Bay via water taxi. They had previously booked a chartered fly-and-dine experience to Cottage Point Inn, a 20 minute flight by floatplane from Rose Bay.

5.4 At about 11:30am, the five passengers received a pre-flight safety briefing and then boarded a floatplane with Mr Morgan as pilot. This particular floatplane was a de Havilland Canada DHC-2 Beaver, registered VH-NOO and operated by Sydney Seaplanes. The flight was uneventful and VH-NOO arrived at Cottage Point shortly before 12:00pm.

5.5 Whilst the passengers had lunch at Cottage Point Inn, Mr Morgan conducted four flights in VH-NOO between Cottage Point and Rose Bay.

Weather conditions

5.6 According to the Bureau of Meteorology:

(a) there was no rain in the area;

(b) winds near the surface were from the east-north-east at about 15km/hour, moving around to the north; and

(c) the wind would have been flowing over the hills into the bay.

5.7 Based on wind strength, light turbulence could not be discounted but moderate turbulence was unlikely.

5.8 Nicholas Faubert, the pilot of another Sydney Seaplanes aircraft (registration VH-AAM) which departed Cottage Point shortly before VH-NOO in the afternoon, considered the weather conditions to be standard.

5.9 Witnesses in and around Jerusalem Bay reported good visibility, variable wind strength and calmer water conditions than in Cowan Bay (where choppy waves and some white caps had been reported).

Preparations for the return flight to Rose Bay

5.10 At around 1:53pm, Mr Morgan landed at Cottage Point. After securing VH-NOO at the pontoon and assisting his passengers to disembark, he bought some lunch from a kiosk.

5.11 At about 2:15pm, Mr Morgan was asked by Sydney Seaplanes to move VH-NOO off the pontoon so that VH-AAM could collect some passengers. Mr Faubert had known Mr Morgan since 2013. During this process, Mr Faubert found Mr Morgan to be in good spirits and health, and did not notice any irregular sounds or issues from VH-NOO as it moved off the pontoon.

5.12 Mr Morgan moved VH-NOO into Cowan Creek where he taxied with the engine running for up to 27 minutes. CCTV footage shows VH-NOO heading south on Cowan Creek over a 10 second period with the pilot's door ajar. Passengers on earlier flights that day had taken photographs which also showed the door to be ajar and window closed when the aircraft was commencing taxi. This was a common practice in light, non-air-conditioned aircraft especially during the summer.

5.13 At 2:46pm, VH-AMM left the pontoon and VH-NOO returned. Mr Morgan went into the restaurant to check whether the passengers were ready to depart for their scheduled flight at 3:00pm to return to Rose Bay.

The final flight of VH-NOO

6.1 At 2:57pm, the five passengers boarded VH-NOO. At 3:04pm, VH-NOO commenced taxiing towards the designated take-off area in Cowan Creek. During the seven minute taxi, the aircraft engine was running its lowest possible revolutions per minute (**RPM**) (as a matter of company policy and common operating procedures), and the fuel is at its richest in terms of concentration of carbon monoxide (**CO**) emissions.

6.2 At around 3:11pm, VH-NOO took off towards the north-north-east, becoming airborne shortly before passing Cowan Point. VH-NOO climbed straight ahead before commencing a right turn into Cowan Water. Photographs taken by one of the passengers indicate that the turn had a bank angle of 15 to 20 degrees. The last photograph was taken whilst VH-NOO was heading in a southerly direction towards Cowan Bay at an estimated altitude of 30 metres.

6.3 Shortly after the right turn into Cowan Water, VH-NOO entered Jerusalem Bay and was seen to be flying below the height of the surrounding terrain. There are several uncommon features about the flight path of VH-NOO up to this point:

(a) The usual route from Cowan Water back to Rose Bay was along the coastline;

(b) Whilst there is an alternative route back to Sydney, known as the Coal and Candle Creek route, it is non-scenic and unlikely to have been chosen with tourist passengers on board. Further, the altitude of VH-NOO was too low for it to take the Coal and Candle route;

(c) There was no reason for VH-NOO to enter Jerusalem Bay as it is a dead end, surrounded on three sides by very high terrain. It is unlikely that a pilot would seek a suitable landing area within

Jerusalem Bay given that more viable landing options existed at Howletts Beach or Fishermens Beach, further along Cowan Water, which Mr Morgan was very familiar with. In addition, take-off and landing are ordinarily conducted into wind whilst landing in Jerusalem Bay would have involved landing with a tail wind.

6.4 VH-NOO flew along the southern shoreline for approximately 1.1 kilometres. When near the entrance to Pinta Bay VH-NOO suddenly entered a steep right turn at a bank angle estimated to be 80 to 90 degrees at a low level. This exceeds the estimated 50 degrees bank angle which is considered to be required to conduct that turn safely.

6.5 Further, it is considered that the only way to make this very sharp turn is to increase engine power together with various inputs on the wing controls. However, no witnesses reported hearing a significant change in engine sound consistent with such inputs. David Hitch, a member of Marine Rescue NSW, saw VH-NOO and did not hear any change in engine noise when it made the turn. A number of witnesses described the right turn as sudden and steep.

6.6 Whilst partway through the turn, VH-NOO entered an aerodynamic stall. Its nose dropped suddenly and it impacted with the water just before 3:14pm at a location approximately 1.2 kilometres from the end of Jerusalem Bay. Several witnesses describe VH-NOO being at least halfway through the turn before its nose dropped.

6.7 Witnesses also observed the aircraft to impact the water banked to the right in a nose-down position. The right wing tip and both float tips impacted the water first. The left wing and float tips separated from the fuselage and the aircraft became inverted. The right wing and remainder of the floats remained with the inverted and partially submerged main fuselage. The main wreckage drifted about 70 metres west into Jerusalem Bay before sinking near the entrance to Pinta Bay.

Rescue and recovery efforts

6.8 A number of witnesses were on boats and other water craft in Jerusalem Bay at the time of impact. Many responded immediately, diving into the water in an attempt to access the aircraft cabin. However, these efforts were unsuccessful as the cabin was already too deep, visibility was poor and there was no current movement from inside the aircraft.

6.9 The entire tail section and parts of both floats were initially above the water but had sunk within 10 minutes. A significant quantity of fuel leaked from the aircraft and was seen in the water. As the aircraft was sinking, witnesses attached a buoy and rope to the tail to mark the accident location.

6.10 The efforts and courage of those people who sought to render assistance should be recognised. There was a significant amount of aviation fuel in the water and a possibility that anyone in the water near the aircraft could have been dragged down as it sank.

6.11 Officers from the NSWPF Marine Area Command arrived on scene at 3:32pm, followed by Marine Rescue NSW and a rescue helicopter at 3:41pm. A perimeter was established and a NSWPF dive team arrived at the site at 4:36pm. VH-NOO was located at a depth of 13.7 metres.

6.12 The first NSWPF rescue dive commenced at 5:01pm. A short time later, NSWPF divers confirmed that all six occupants of VH-NOO were deceased. Mr Morgan was found in the front left pilot seat, Edward was in the front right seat, Richard and William were on a bench seat in their middle row, whilst Heather and Emma were in the rear bench seat. All of the occupants, with the possible exception of Richard, had their seatbelt clasps fastened. All were also wearing life jackets which had not been inflated.

6.13 By 7:00pm all of the occupants had been retrieved from the aircraft. The NSWPF maintained a perimeter around the aircraft until it was salvaged. On 4 January 2018, the aircraft was recovered in pieces under the supervision of the ATSB and later removed to a location controlled by the ATSB.

7. Post-mortem examinations

7.1 All six occupants were taken to the Department of Forensic Medicine where post-mortem examinations were conducted by forensic pathologists, Dr Elise Burger and Dr Rebecca Irvine.

7.2 **Emma** was found to have a fracture of the 4th lumbar vertebral body as well as some processes of the 3rd lumbar vertebra, a comminuted fracture of the proximal right femur, comminuted fractures of facial bones, a left frontal subgaleal haematoma and a small volume subdural haemorrhage. Immersion-related wrinkling of the skin on the hands and feet were noted, together with other features in keeping with retrieval from water.

7.3 **Heather** was found to have a horizontal fracture through the 3rd lumbar vertebral body and neural arch with associated fractures of the L2 neural arch and the right L1 transverse process, together with extensive fractures in the facial bones and fractures of the right lower ribs. Other features consistent with immersion were also noted.

7.4 **Edward** was found to have sustained a comminuted fracture of the left clavicle, fracture of the left scapula, left forearm fracture and left lateral malleolus fracture, together with features in keeping with retrieval from water.

7.5 **William** was found to have sustained fractures of the distal left femur and of the left fibula, a displaced fracture of the distal left forearm at the wrist, and extensive fractures of the facial bones, jawbone and frontal bones of the skull. Extensive subarachnoid, and some subdural, haemorrhage surrounding the brain were also noted.

7.6 Dr Burger noted that whilst Emma, Heather, Edward and William had sustained significant injuries, none of these injuries would have unequivocally caused immediate death. It was further noted that it would be impossible to determine the extent to which terminal drowning contributed to their deaths. Dr Burger ultimately opined that Emma, Heather, Edward and William all died from the combined effects of multiple injuries and immersion.

7.7 **Richard** was found to have sustained severe craniofacial fractures, multiple rib fractures, fracture dislocation of the lower thoracic spine, multiple pelvic fractures with right hip dislocation and multiple upper and lower limb fractures. Right haemopneumothorax, left haemothorax and haemopericardium were also identified.

7.8 **Gareth** was found to have sustained intracranial haemorrhage with fractures of the skull base, left orbit and mandible. Bilateral pelvic acetabular fractures (with right hip dislocation) and transverse processes of the long bar vertebrae were also identified, together with multiple bilateral rib fractures with pneumothoraces, and fractures of the right of the humerus and shoulder girdle. Subarachnoid haemorrhage and unorganised right subdural haemorrhage were found in the brain, as well as a basal skull fracture near the foramen magnum.

7.9 Dr Irvine found that there were no significant underlying conditions demonstrated at autopsy and, specifically, the heart was noted to be grossly normal. Routine toxicological analysis showed no detectable alcohol, drugs of potential abuse or common therapeutic drugs.

7.10 Dr Irvine noted that whilst Richard and Gareth had sustained grievous injuries, none of these would unequivocally have caused immediate death. Dr Irvine also acknowledged that drowning was a possible contributing factor to each death. Ultimately, Dr Irvine opined that both Richard and Gareth died from multiple blunt force injuries.

8. What issues did the inquest examine?

8.1 Prior to the commencement of the inquest a list of issues was circulated amongst the sufficiently interested parties, identifying the scope of the inquest and the issues to be considered. That list identified the following issues for consideration:

(1) What caused VH-NOO to crash into the water at Jerusalem Bay on 31 December 2017, in particular:

(a) whether the pilot became incapacitated during the flight by exposure to carbon monoxide (**CO**) or otherwise;

(b) the source of any exposure to CO and the mechanism by which it entered the aircraft cabin; and

(c) the adequacy of maintenance conducted on VH-NOO, particularly insofar as it related to the exhaust system, magneto access panels and use of bolts associated with those panels.

(2) The extent, prior to March 2020, of the investigation of the possibility of CO exposure by agencies involved in investigating the circumstances of the deaths (eg. NSW Health Pathology, the ATSB and the NSWPF) in particular:

(a) what consideration (if any) was given to the possibility of pilot incapacitation due to CO exposure;

(b) to the extent this was not considered, the reason(s) for this; and

(c) what prompted the further toxicology report obtained March 2020.

(3) The adequacy of remedial actions taken in response to the crash, in particular:

(a) the desirability of mandating the fitting of active electronic CO monitors (with associated alarms) to Australian passenger-carrying aircraft under 5,700 kilograms; and

(b) the desirability of mandating the fitting of flight recorders for Australian passenger-carrying aircraft under 5,700 kilograms.

(4) Whether carboxyhaemoglobin (**COHb**) toxicology screening should be conducted by NSW Health Pathology's Forensic Medicine Service as part of the standard autopsy toxicology screening in the case of any death during the operation of a carbon monoxide producing vehicle, vessel, aircraft or other machinery, where the cause of such death remains unknown at the time of other standard toxicology screening been conducted.

8.2 In order to assist with consideration of some of the above issues, opinion was sought from the following independent experts as part of the coronial investigation:

(a) Professor Steven Armfield, Professor of Computational Fluid Dynamics, Faculty of Engineering, University of Sydney (engaged by Airag Aviation Services Pty Ltd for the purposes of civil litigation);

(b) Dr Jeffrey Brock AM, a medical practitioner and senior specialist in aviation medicine for the Australian Army (engaged by the ATSB);

(c) Professor Con Doolan, Associate Dean, Academic Programs, Faculty of Engineering, UNSW (engaged by Sydney Seaplanes for the purposes of civil litigation);

(d) Emeritus Professor Olaf Drummer AO, forensic pharmacologist and toxicologist (engaged by Airag Aviation Services Pty Ltd for the purposes of civil litigation);

(e) James Fogg, a Licensed Aircraft Maintenance Engineer and former Chief Engineer (engaged by Sydney Seaplanes for the purposes of civil litigation);

(f) David Kuruvita, Aircraft Maintenance Engineer and Chief Pilot (engaged by Airag Aviation Services Pty Ltd for the purposes of civil litigation);

(g) Dr Judith Perl, a forensic pharmacologist (engaged by the NSWPF);

(h) Dr Michael Robertson, pharmacologist and forensic toxicologist (engaged by Sydney Seaplanes for the purposes of civil litigation);

(i) Dr Shelley Robertson, a forensic pathologist with a speciality on aviation medicine (engaged by the ATSB); and,

(j) Steve Swift, aeronautical engineer (engaged by Airag Aviation Services Pty Ltd for the purposes of civil litigation).

8.3 Each of the above experts provided reports which were tendered as part of the brief of evidence during the inquest. Some of the experts also gave oral evidence during the inquest.

8.4 Before considering each of the discrete issues examined by the inquest, it is first necessary to set out a number of matters relevant to this consideration. As the majority of these matters are non-controversial and were not in contest during the inquest, it is intended to only provide a summary in so far as they provide background and context to the discrete issues listed above.

9. VH-NOO

9.1 VH-NOO was a float-equipped de Havilland DHC-2 Beaver, a predominantly all-metal high-wing aircraft manufactured in 1963. Ventilation to the VH-NOO cabin was via circular snap events in both front fixed side windows, and by opening the pilot and front right sliding windows. Two vents were installed in the rear cabin roof above the passenger seats.

9.2 Sydney Seaplanes acquired VH-NOO in 2006. As at 31 December 2017, VH-NOO was one of two DHC-2 aircraft in its fleet of five.

9.3 VH-NOO was maintained in accordance with the operators a system of maintenance approved by the Civil Aviation Safety Authority (**CASA**) which consisted of the following:

(a) daily inspections;

(b) checks of the engine, airframe and float every 50 hours, known as A Checks;

(c) "periodic" checks of the engine and airframe every 100 hours or 6 months, known as B Checks;

(d) various other specialised inspections; and

(e) a requirement to comply with appropriate airworthiness directives and Civil Aviation Orders.

9.4 Apart from daily inspections, all maintenance on VH-NOO was conducted by Airag Aviation Services Pty Ltd (**Airag**), which held a valid CASA Certificate of Approval. Airag has been operating since the 1950s and maintaining DHC-2 aircraft since that time. Licensed aviation mechanical engineers (**LAME**) working for Airag carried out relevant maintenance work on aircraft.

9.5 On 6 November 2017, a B Check was carried out on VH-NOO) and certified by a LAME. A scheduled engine change was also carried out at this time. The replacement engine had previously been fitted to VH-AAM, another DHC-2 aircraft in the Sydney Seaplanes fleet. The engine had been disassembled, inspected and reassembled in the United States by a Federal Aviation Administration (**FAA**) approved repair station. Nil defects were found and the replacement engine passed a test run before it was fitted to VH-NOO.

9.6 On 11 December 2017, an A Check was carried out by a LAME. At this time, the engine, airframe, floats, and associated compartments were inspected, and the oil changed. Minor propeller leading edge repairs were carried out and a leak in the engine fuel primer system was rectified.

9.7 From the time of the engine change until the accident, VH-NOO had flown 85.9 hours. It had a total time in service of 21,872.5 hours.

10. Mechanical examination of VH-NOO following the accident

10.1 According to the ATSB, the purpose of its safety investigations is to enhance transport safety by identifying safety issues and facilitating safety action to address such issues, and providing information about occurrences and safety factors to facilitate learning within the transport industry. It is not a function of the ATSB to apportion blame or provide a means for determining liability.

10.2 VH-NOO came to rest on the floor of Jerusalem Bay. The main wreckage, comprising the cabin, table, engine, floats and right wing was located near the entrance to Pinta Bay. On 4 January 2018, wreckage of VH-NOO was recovered and transported to secure facilities at Bankstown Airport for mechanical and engineering examination. This was conducted by an ATSB team that included a LAME lead investigator, as well as a LAME senior investigator certified on the DHC-2 airframe.

10.3 The examination relevantly revealed the following:

(a) the oil filler cap in the cabin was not found in the wreckage with no evidence of oil residue in the immediate vicinity;

(b) the left front pilot door window snap event was found in the partially open position;

(c) the aircraft cabin was fitted with a disposable CO detector affixed to the instrument panel with no "date open" annotated on the front of the detector;

(d) the flap actuator was extended to a position consistent with "climb" flap of 15°;

(e) the rudder trim and elevator trim were in positions consistent with normal operations for the aircraft;

(f) no evidence of a bird strike or collision with an object prior to take-off or in-flight;

(g) no evidence of an in-flight breakup or pre-impact structural damage; and

(h) no foreign objects found obstructing the rudder pedals or the control column.

10.4 On 13 and 14 February 2018, an engine examination took place at separate maintenance facilities under the supervision of the ATSB. Members of the NSWPF, interested parties, representatives from CASA, insurance assessors and Covington Aircraft, the engine manufacturer from the United States, all attended examination as observers. The examination did not identify any pre-existing damage, conditions that may have contributed to the accident, or any issues with the engine indicative of engine failure. No evidence was identified indicating aircraft malfunction as the cause of the accident.

11. Mr Morgan’s experience as a pilot

11.1 Mr Morgan held a commercial and air transport pilot aeroplane license, a multi-engine instrument rating, float plane endorsement and instrument ratings. He had over 10,000 hours of total flying experience, 9,000 hours of which were on float-equipped aircraft, including the DHC-2. Mr Morgan had flown in Australia, the Republic of Maldives and in Canada, where he had operated over high terrain and to and from alpine lakes. Mr Morgan began flying the DHC-2 with Sydney Seaplanes in 2007, and had accrued about 535 hours on VH-NOO and 375 hours on VH-AAM.

11.2 In May 2017, Mr Morgan completed an operator proficiency check, an authorised landing area check (which included flying to Cottage Point), and a low level manoeuvring proficiency check (which included steep turns and recovery from an aerodynamic stall) with the DHC-2. Mr Morgan completed the same checks with a Cessna 208 Caravan (another float-equipped aircraft) in July 2017. Relevantly, Mr Morgan was rated highly in relation to operator proficiency checks including simulated engine failures after take-off and during cruise, having a high standard of proficiency in relation to preparation for flight and root knowledge, and having low level manoeuvring proficiency (including level steep turns in cruise configuration) at a high standard

11.3 Mr Morgan had significant experience operating at Cottage Point, having conducted at least 780 flights there, with the majority in the DHC-2.

11.4 Mr Morgan was described as having good aircraft handling skills and was known to be conservative with his decision-making, reliable, a steady operator who did not take risks and to have a very strong attitude to safety. Mr Morgan’s work colleagues described him as diligent, methodical, meticulous, safety “conscientious”, and a very experienced and safe pilot overall.

11.5 Mr Morgan was also known to have a regimented and consistent daily routine. He exercised regularly, ate healthily, and typically went to bed at 9:00pm if rostered for duty the following day. Relevantly, Mr Morgan’s phone records show that there was no late-night or early morning phone activity before 31 December 2017.

12. Mr Morgan's medical history

12.1 Mr Morgan's aviation medical records were provided by Transport Canada and CASA (which also included a medical assessment from the Republic of Maldives). These examinations and assessments found that Mr Morgan was fit and healthy, with no respiratory, cardiovascular or neurological issues, and no family history of heart disease under the age of 60 years.

12.2 The records also indicated that Mr Morgan had never experienced chest pain, palpitations or high blood pressure; been diagnosed with ischaemic or coronary heart disease; never experience symptoms of shortness of breath or coughing up blood; and never had frequent severe headaches, head injury, unconsciousness, fits, faints, blackouts, funny turns, dizziness, tremors or weakness of the limbs.

12.3 As part of Mr Morgan's annual medical examinations he was required to have specialist tests depending on his age, such as audio and eye examinations, an electrocardiogram (**ECG**) cholesterol testing and blood glucose testing. Several of Mr Morgan's ECG tracings were reported with a range of abnormalities. However, subsequent review by cardiologists determine the tracings to be within normal limits, and therefore acceptable for medical certification to fly. In addition, in 2016, Mr Morgan underwent an ECG, a stress test and magnetic resonance imaging of the heart. The results of these investigations indicated that Mr Morgan was fit for all types of duties and training. Mr Morgan was cleared as medically fit for his Aviation Medical Certificate on 7 March 2017.

12.4 As part of its investigation, the ATSB engaged Dr Brock to review the available medical information in relation to Mr Morgan. Dr Brock concluded that:

(a) Mr Morgan's medical history was unremarkable, with no abnormalities of any significance identified;

(b) Mr Morgan's family history raised no concerns about his medical fitness;

(c) the findings from the post-mortem examination did not identify any natural disease that could have caused or contributed to the accident; and

(d) the nature of the injuries sustained by Mr Morgan suggested that he was alive at the time of the impact, although it was not possible to determine if he was conscious or unconscious.

12.5 Notwithstanding the above, Dr Brock considered that the possibility of Mr Morgan experiencing sudden cardiac death or cardiac incapacitation on 31 December 2017 could not be entirely excluded. As a result, the ATSB engaged a specialist cardiologists to examine the relevant medical information. This examination found no cardiac abnormalities is to suggest that Mr Morgan experienced a sudden and incapacitating cardiac event.

12.6 Finally, analysis of Mr Morgan's DNA was also conducted. The results of this analysis were negative, and did not assist with diagnosing any pathological condition causing sudden cardiac death.

13. Human factors

13.1 Apart from Mr Morgan's training, qualifications, experience and piloting skills, human factors in aviation are relevant to investigating and understanding what may have caused an aviation accident. The ATSB describes these factors in this way:

> Broadly, human factors refers to the application of scientific knowledge, mostly from psychology, anthropology, physiology and medicine, to the design, construction, operation, management and maintenance of products and systems. The purpose of this application is to attempt to reduce the likelihood of human error and therefore the likelihood of negative outcomes for operating or using products or systems.
>
> From an investigation perspective, the purpose of applying human factors knowledge is to not only understand what happened in an accident or incident, but more importantly, why it happened.

13.2 Kerri Hughes, Manager, Transport Safety from the ATSB, referred to the view expressed by a leading academic authority in aviation that "*flying an aircraft is one of the greatest challenges to the quality of capabilities of humans as it involves the knowledge of how to control the vehicle that defies the natural forces of gravity*". Ms Hughes explained that similarly, the International Civil Aviation Organization (**ICAO**) considers that piloting an aircraft "*requires the utilisation of a complex set of physical and cognitive skills*" and that "*interference with any aspect of these skills and the coordination may have serious personal and public safety consequences*".

13.3 As to the physical and cognitive skills that a pilot is required to utilise, Ms Hughes referred to the following:

(a) the operation of an aircraft around three axes;

(b) management of flight controls;

(c) processing available information from flight instruments;

(d) scanning internal and external environments from within and outside the cockpit;

(e) identifying terrain features, interpreting weather conditions, and maintaining a level of situational awareness; and

(f) what actions to take to avoid an emergency situation, and what actions to take in the event of an emergency situation.

13.4 Dr Stuart Godley, Director, Transport Safety from the ATSB, gave evidence of some of the neurocognitive skills required to fly an aircraft, including decision-making, mental flexibility, planning, workload management, concentration, perceptual motor skills, memory and situational awareness. He explained that pilots will be conducting a variety of tasks simultaneously, and that some of these tasks will be automatic whilst others will involve some controlled processing.

13.5 Dr Godley went on to explain the difference between two types of processing:

(a) rule-based or procedure based processing which do not require high levels of mental resources because of a pilot's training and experience in such situations where memorised rules can be applied; and

(b) knowledge-based processing where no rules apply and it is necessary to "*resort to slower, more effortful error prone processes of thinking*".

13.6 Dr Godley went on to explain the unevenness of pilot workload across flight, where there is "*more going on*" in some phases of flight than in others. Dr Godley gave evidence that "*the most critical phases of flight, in terms of the chance of an accident, are take-off and initial climb and the approach and landing*". He explained that excellent situational awareness is essential for these phases and described the following:

> So pilots need to cope with a higher workload in these phases, which in turn means that the pilot's information processing abilities must be perfect to be able to capitalise on the advantages of their expertise that they bring to flying and navigating, communicating and comprehension of the aircraft systems.

13.7 Ms Hughes gave evidence that when flying into a confined area a pilot would acquire information, process the information and then embark upon decision-making. As to each of these three stages, Ms Hughes explained:

(a) Acquiring information: a pilot "*would be scanning outside for attitude and roll information against the horizon to maintain orientation, scanning inside the cockpit to determine the aircraft's current state and performance, scanning the terrain and water for indicators of possible turbulence, judging the aircraft's proximity to the terrain, judging the distance between the terrain, identifying local features for navigation, scanning to identify any low level hazards, scanning outside for potential escape routes, observing the wind direction and speed and listening to the engine noise, listening to passengers and keeping an ear out for any radio calls*".

(b) Processing information: "*relying on memory from experiences and training to recognise that the aircraft's current state does or does not meet the expectations in terms of pitch, roll and yaw, relying on the pilot's memory from experiences and knowledge to determine if the aircraft's actual performance matches the expected performance, mentally calculating the angle of bank required to safely conduct a turn within the distance available between the surrounding terrain, recognising if local features are or aren't consistent with what was observed, assessing how any hazards will affect the aircraft's flight path, relying on memory and calculations from experience, training and knowledge to plan the most appropriate escape option, considering the aircraft's current state and performance, calculating any effects of wind direction and speed changes to the aircraft's flight path and air speed and assessing if the engine noise is as expected*".

(c) Decision-making: making regular adjustments to the flight controls, adjusting the trim and engine power settings, making configuration changes to match the phase of flight, "*changing the aircraft's position using the geographical features to ensure that the intended flight path is flown, changing the aircraft's flight path to avoid any wind or turbulence influences from the* *surrounding terrain, reacting to changes in the aircraft's motion to sudden changes in the wind, deciding the most appropriate course of action to exit the confined area, positioning the aircraft so that there is enough room to turn around, deciding when to commence a turn and coordinating a turn, including a steep turn, which will require the concurrent manipulation of all three flight controls and adjusting engine power to prevent a loss of altitude and air speed, all the while maintaining situational awareness*".

14. Unexpected features of the final flight

14.1 The ATSB considered a number of scenarios to explain why VH-NOO entered Jerusalem Bay and the totality of the accident sequence:

(a) There is no evidence that VH-NOO deviated from its intended route as a result of a request from one of the passengers. A number of Sydney Seaplanes pilots reported that such requests predominantly came from local passengers wanting to see their residences rather than international passengers. Further, Sydney Seaplanes reported that it would be uncharacteristic for Mr Morgan to deviate off track due to a passenger request. By way of example, during a flight several weeks before the accident, Mr Morgan had declined a request by one of the owners of Sydney Seaplanes to deviate from the standard flight path;

(b) Although the passengers had a water taxi pre-booked to depart Rose Bay at 3:45pm, and Mr Morgan had a return flight to Cottage Point scheduled for 4:00pm, there were no immediate time pressures;

(c) Although Mr Morgan had switched between flying the DHC-2 and the Cessna 208 it was considered that because the aircraft are so different, and Mr Morgan had daily experience switching between the aircraft, that this was not causative of the accident;

(d) Although there was some turbulence present, the weather conditions were otherwise standard for seaplane operations;

(e) The time between the initial turn in Cowan Water to where the last photograph was taken to the steep turn in Jerusalem Bay was about 47 seconds. If Mr Morgan had been distracted during that turn, there was sufficient time for him to respond and react appropriately by landing the aircraft or turning earlier in Jerusalem Bay. The ATSB did not consider that pilot distraction could explain the totality of the accident, especially given Mr Morgan's flying experience in the DHC-2, and the fact that he (like all Sydney Seaplanes pilots) was trained and assessed in handling low-level engine failures after take-off;

(f) There was no evidence that suggested a sudden incapacity due to an acute or chronic medical condition on Mr Morgan's part;

(g) Although Mr Morgan had his seatbelt fastened at the time of impact, the right seat passenger in the middle row had unfastened his seatbelt for reasons unknown at some time during the flight. Notwithstanding, there was no evidence to indicate that Mr Morgan had been distracted or incapacitated by a passenger, either intentionally or inadvertently during the flight (see also further below). There was nothing untoward with the behaviour of the passengers and based on their character descriptions, it would be unexpected for them to interfere with the operation of the aircraft without reason. Further, a number of Sydney Seaplanes pilots and other experienced DHC-2 pilots informed the ATSB that in the event of inadvertent passenger interference there was still sufficient room in the cockpit for the pilot to operate the aircraft without any issues;

(h) Relevantly, there was evidence to indicate some level of flight control input by Mr Morgan (aft back pressure and rudder input) - as distinct from a passenger taking the controls - for the aircraft to make it part way through the final steep turn in Jerusalem Bay before it stalled.

15. Operation of Sydney Seaplanes & initial outcome of the NSWPF investigation

15.1 Investigating police formed the view that VH-NOO was operated in accordance with the Sydney Seaplanes Operations Manual and complied with all other relevant regulatory requirements. An audit of Sydney Seaplanes conducted by CASA on 19 September 2017 concluded that the company was compliant with activities observed during the audit, and that they were conducted in a professional and confident manner.

15.2 Aaron Shaw, the co-founder, Chief Executive Officer and Managing Director of Sydney Seaplanes, describes the company's culture as being conservative and safe. He described the approach of how Sydney Seaplanes conducted business in the following ways:

> So we were always apply a conservative approach to things like, and particularly, weather. So if there was ever any doubt around how the weather would play out in Rose Bay or any of our destinations, then we would cancel flights. Others would - other operators would still fly; we wouldn't.
>
> […]
>
> [T]o summarise, we had a view that if you wouldn't push your own family on a plane off the dock, then you wouldn't push anyone's [off it], and so that was really the way the business operated for as long as I was involved in it and to this day.
>
> […]
>
> [W]e had a sort of a policy internally that if anyone wasn't comfortable to go to any destination, even if the company was happy to go, there was a no fault, no blame policy. So if a pilot didn't feel like their particular skills or experience was suitable to go to a particular destination on any given day, then they could do that even if the company was happy to operate that day.

15.3 The NSWPF also investigated the circumstances surrounding the landing in Rose Bay on 23 December 2017 involving Mr Morgan. Andy Gross, former Chief Pilot for Sydney Seaplanes, and Mr Shaw both spoke to Mr Morgan following the incident and provided him with reassurance in response to his apology. Mr Shaw gave evidence that the incident did not cause him to have any concerns regarding Mr Morgan's abilities as a pilot.

15.4 By December 2018, investigating police had formed the view that there was no logical explanation for VH-NOO entering Jerusalem Bay having regard to the following matters:

(a) it was almost in the complete opposite direction to the intended flight path for VH-NOO;

(b) it was unlikely that Mr Morgan would have acceded to a passenger request to divert the flight into that area;

(c) it was also unlikely that a passenger would have made such a request given that the area was not of scenic interest;

(d) It was not an area that a pilot would enter due to its terrain and difficulty of climbing out of the bay; and

(e) a number of Sydney Seaplanes line pilots commented that, given his experience, Mr Morgan would have been more than capable of dealing with any mid-flight emergency and would not have flown into the bay or, if he had done so, would have turned or landed in a safe manner.

15.5 Overall, the police investigation reached the conclusion that something had happened to Mr Morgan shortly after the commencement of the right hand turn, and that he was incapacitated at the time of the accident.

16. Dislodgement of oil filler cap during the flight

15.1 One hypothesis which emerged as to the cause of VH-NOO entering Jerusalem Bay and/or performing the part steep right turn is that the oil filler cap in the aircraft cabin became dislodged, representing a source of distraction for Mr Morgan. In other words, if the cap had become dislodged it could have potentially caused a hot oil spill or prompted a reaction from a passenger, thereby distracting Mr Morgan. The oil filler cap for a DHC-2 is usually located inside the cabin in the area of the front passenger seat footwell. As noted above, the oil filler cap was not recovered from the VH-NOO wreckage.

15.2 Ms Hughes gave evidence that the ATSB did not conduct any investigations as to how long it might take to resolve a situation where the oil filler cap accidentally dislodged, such as locating the cap or blocking the oil tank. However, Ms Hughes gave evidence that the purpose of the oil filler in the cockpit is so that the cap can be removed in flight and the aircraft refuelled. Ms Hughes explained:

> So that means that there should be no issue if the cap came off in flight, that would not cause any immediate concern for a pilot, and there was sufficient time for the pilot to land in Jerusalem Bay or even turn earlier.

15.3 Relevantly, Mr Bosworth gave evidence that when the wreckage of VH-NOO was examined, no oil was found in the cabin. Further, Mr Bosworth explained that the dipstick attached to the cap is 12 inches long, and expressed the view that oil cap would not be dislodged unless it was deliberately removed by a person.

15.4 Mr Bosworth gave evidence that the ATSB considered that the oil filler cap was dislodged at impact for the following reasons:

(a) The oil tank compression damage and deformation as a result of a high energy impact, although the ATSB did not conduct a study as to the degree of compression damage or take any measurements to quantify how much pressure would have been required to cause such damage;

(b) A number of photos taken by passengers of VH-NOO in the days preceding, and on, 31 December 2017 show the oil filler cap to be consistently at the 10 o'clock position, which Mr Bosworth assumed was a locked position; and

(c) Mr Bosworth considered it possible that "some sort of dynamic sequence" such as movement of a passenger or a seat or some other part of the aircraft moving forward might have twisted the oil filler cap and caused it to become dislodged.

15.5 In addition, Mr Bosworth did not consider that it was possible for oil to come out of the oil filler neck as the oil tank was not pressurised and the oil was not in the neck of the filler, but rather 8 to 12 inches below in the tank.

15.6 Similarly, Mr Gross explained that unscrewing the cap requires a half-turn mechanism, and that once unscrewed it might become dislodged by a few centimetres but remain on top of the oil filler due to the dipstick. Mr Gross went on to express this view:

So, it would be impossible that the - you know, very unlikely that the actual cap would – and dipstick itself would come out of that hole of the oil filler neck there. So, it would take somebody, you know, intentionally removing it for that to occur.

15.7 Mr Gross went on to describe a situation where an oil filler cap become dislodged as a "*non-event*". Mr Gross gave evidence that any distraction course would be "*fairly minor*" and that a proficient pilot familiar with the aircraft (such as Mr Morgan) would have been able to operate the aircraft in a stable fashion and keep orientation on their surroundings "*quite easily*". In addition, Mr Gross explained that as part of routine pilot training and assessment, emergency situations such as low level engine failures following take-off are dealt with, which is a more significant distraction to a pilot than a dislodged oil filler cap.

15.8 Finally, Ms Hughes gave evidence that any question of possible distraction needed to be considered in the context of the whole accident sequence. She explained:

> [I]f there was a distraction, that doesn't explain why the aircraft didn't continue climbing although it was still in the climb configuration; why the pilot didn't land earlier or turn earlier if they believed there was an issue; or even, coming to that final steep turn, the fact that such an excessive steep turn, more than what was required and more than what the aircraft was capable of performing, was performed or conducted by a very experienced pilot who had a significant amount of experience in that area, knew that the terrain was rising, and the fact that they had a lot of experience flying that particular aircraft type.

16.1 Mr Swift considered it unlikely that the oil filler tap could have been blasted off from impact forces and/or lifting and recovery of the wreck.

16.2 Mark Leadbeatter, a senior surveyor and adjuster within the aviation insurance market, inspected the wreckage of VH-NOO on 22 March 2021. During that inspection he took a number of photographs of the oil tank and the oil filler neck, and found no marks present indicating that the oil filler cap had been forced off during the impact sequence. Mr Leadbeatter also noted that the oil tank had been punctured by firewall deformation which would have relieved any possible internal pressure build up.

16.3 Ireneuz Cieslar is the Chief Engineer at Airag and a commercial pilot. Mr Cieslar referred to an incident in August or September 2019 when he was seated in the front passenger seat of a Sydney Seaplanes aircraft which was having a newly installed or modified compass tested. Upon the pilot starting the engine, a large amount of oil escape from the filler neck and spilled onto Mr Cieslar's pants. From his experience Mr Cieslar concluded that human error may result in an oil filler cap not being secured between flights. From this experience, Mr Cieslar expressed the view that on 31 December 2017 an unsecured oil filler cap could become dislodged causing oil to escape from the filler neck onto the lower leg(s) of the front seat passenger.

16.4 Stephen Krug is the owner and Chief Pilot of a seaplane charter company with 33 years of experience flying DHC-2 aircraft. Mr Krug referred to two incidents in 1995 and 1998 when he was flying a DHC-2. On each occasion an unsecured oil filler cap became dislodged, causing oil to spill onto a passenger's leg.

16.5 Mr Cieslar and Mr Krug both expressed the view that an event of this kind may cause even a careful and skilful pilot become distracted, either by shifting their attention to the passenger or the passenger accidentally or intentionally interfering with the controls of the aircraft. Mr Cieslar and Mr Krug also both expressed the view that due to the absence of any damage to the oil filler neck and tank, it is unlikely that the impact of the crash generated an explosive force to dislodge the oil filler cap. However, Mr Cieslar acknowledged that he did not have sufficient expertise to form a confident opinion on this issue.

16.6 Mr Kuruvita acknowledged that there are many documented cases of oil filler cap release during flight on the DHC-2. He stated that it is conceivable that even a prudent and diligent pilot may forget to replace the cap after topping up oil between flights. Mr Kuruvita surmised that an oil filler cap that was not repositioned correctly could be dislodged by "*pressure built up in the oil tank assisted by vibrations generated by take-off*", and that this could result in oil being discharged from the tank together with exhaust smoke, causing panic and distress to passengers. Mr Kuruvita opined that such a scenario is a likely cause of distraction for Mr Morgan and the passengers during the take-off and climb stages on 31 December 2017.

16.7 It was submitted on behalf of Airag that the evidence of Mr Krug, Mr Cieslar, Mr Leadbetter and Mr Kuruvita should be preferred to that of Mr Bosworth, Ms Hughes and Mr Gross.

16.8 **Conclusions:** The evidence established, anecdotally, that it is possible, although very rare, for an oil filler cap in a DHC-2 to become accidentally dislodged during flight. However, the evidence from Mr Cieslar and Mr Krug regarding such events is based upon the cap not being secured after oil was topped up between flights. Whilst Mr Kuruvita theorised that even a diligent pilot could be prone to such human error, this was not based on any actual experience of such an occurrence.

16.9 The evidence also established, anecdotally, that in the event of an oil filler cap becoming dislodged during flight oil may be expelled from the tank and trigger a response from the pilot or a passenger which may amount to a distraction. In such a scenario the question which arises is whether such a distraction might be significant enough to interfere with the pilot's safe operation of the aircraft.

16.10 The critical evidence in respect of both of the above matters is Mr Morgan's known qualities and competencies as a pilot. The evidence established that Mr Morgan was a very experienced and skilled pilot who was known to be diligent, methodical, meticulous and very safety conscious.

16.11 These qualities suggest that it would be unlikely that Mr Morgan left the oil filler cap on VH-NOO unsecured between flights. This is supported by the photographic evidence gathered by the ATSB which shows the oil filler cap to be in the same position, which is presumed to be the secured position, in the days preceding the flight. It is also unlikely that if the cap had been left unsecured by another person that this would have escaped Mr Morgan's attention on 31 December 2017. It should also be noted that no oil was found in the cabin of the VH-NOO wreckage, making the possibility of oil escaping from the tank unlikely. However, even if the cap had become dislodged during the accident flight the evidence from Mr Gross, who was well familiar with Mr Morgan's proficiency as a pilot, is that this would not have posed a significant distraction to Morgan so as to cause him to operate VH-NOO in the manner observed by witnesses.

16.12 There is therefore no reliable evidence to suggest that the oil filler cap on VH-NOO became dislodged during the accident flight. There is also no reliable evidence to suggest that in the unlikely event of such dislodgement occurring it posed a distraction of such significance to cause Mr Morgan to operate the aircraft in manner that was contrary to his usual safe flying practice.

17. Post-mortem analysis for carbon monoxide

17.1 CO is a colourless, odourless and tasteless gas. It is produced from the exhaust gases in transport vehicles. When inhaled, CO is absorbed into the bloodstream where it binds with haemoglobin to form COHb. The effect is to reduce the oxygen carrying capacity of blood, decreasing the delivery of oxygen to vital organs including the heart and brain.

17.2 In October 2019, when the ATSB was finalising its draft report, a query was raised by Dr Brock regarding the possibility of CO exposure. Until this date, the ATSB had understood that analysis for CO was part of routine toxicology conducted as part of the post-mortem examination process. This led to enquiries being made of NSW Health Pathology which confirmed that CO testing had not in fact been performed.

17.3 Such testing was subsequently undertaken in relation to the retained blood samples for each of the occupants of VH-NOO. In December 2019 it was determined that Mr Morgan had a COHb level of 11% saturation. Further analysis in March 2020 revealed that Heather and Richard had COHb levels of 10% and 9% saturations, respectively, whilst the remaining passengers had 4% saturations.

17.4 These results prompted the following investigation by both the ATSB and NSWPF:

(a) in March 2020, the VH-NOO wreckage was further examined to identify possible methods of CO ingress into cabin;

(b) interviews were conducted with Airag personnel regarding maintenance of VH-NOO, and relevant associated documents were obtained;

(c) opinions were sought from medical experts regarding the likely symptoms and effects of CO exposure at the levels reflected from the analysis results;

(d) the ATSB conducted research into academic literature relating to medicine, clinical toxicology, aviation, mining and industrial health and safety, particularly in relation to the effects of low level CO exposure. This led the ATSB to refer in its final report to the following statement issued by the UK Civil Aviation Authority in 2020:

> The physiological effects of CO poisoning are cumulative and take a very long time to disburse. Even a low level of CO ingestion below the level that causes immediate physical symptoms will cause a progressive reduction in blood oxygen levels, which will reduce pilot performance and potentially cause permanent damage to the brain, heart and nervous systems. It is therefore a mistake to assume that a cockpit contaminated with very low levels of CO is acceptable.

(e) the ATSB reviewed accident and incident reports, rather than relying solely on controlled studies, to gain a real-life understanding of how CO would affect an individual, and particularly the cognitive demands placed on a pilot in the aviation context. Ms Hughes gave evidence that the literature indicated that this cognitive impairment resulting from low-level exposure to CO could be more extensive than previously reported and influence aspects of memory, coordination, orientation, attention and concentration.

Relevantly, the ATSB refer to a number of similar incidents, including one in December 2019 which involved a Cessna 172 (a piston engine aircraft, like the DHC-2). In this incident, the pilot observed a localised discolouration on a CO chemical spot detector and experienced memory loss, confusion, a numbness/tingling sensation in the extremities, chest pains and mildly blurred vision. The crew all reported experiencing nausea, headaches, fatigue and light-headedness. An observer reported experiencing chest pains, fatigue and breathlessness, whilst a communications officer reported vomiting. Blood samples taken about three hours after the incident revealed that the pilot and communications officer had COHb levels of 1.2%, whilst the observer had a COHb level of 1%. Whilst dehydration and possible motion sickness may have exacerbated the crew symptoms, the physical symptoms and cognitive effects likely resulted from closure to elevated CO levels in the aircraft cabin.

18. Possible ingress of CO into the cabin of VH-NOO

18.1 The ATSB readily determined that heating sources and smoking could not reasonably explain the COHb levels detected in the occupants of VH-NOO. This left consideration of whether exhaust gases could account for the COHb levels.

18.2 The ATSB considered that at a minimum, Mr Morgan would have been exposed to CO for about 30 minutes, accounting for the 27 minute taxi on Cowan Creek and the accident flight itself. To achieve a COHb saturation level of 11% in this period of time required a CO concentration in the cabin of at least 500 parts per million (**ppm**).

18.3 The ATSB also recognised that Mr Morgan may have been exposed to CO on earlier flights on 31 December 2017 when the engine of VH-NOO was running. This amounted to up to 200 minutes of exposure, and would require lower CO concentration levels in the cabin to achieve a COHb saturation level of 11%.

Source of carbon monoxide

18.4 In March 2020, the ATSB conducted an examination of the engine exhaust system for VH-NOO as research has shown that the most common sources of CO exposure in aircraft are attributed to the engine exhaust systems. This examination found that some of the exhaust manifold segments were significantly deformed as a result of the accident, with a number of cracks or partial fractures identified on these segments. Further, the manifold was cracked in several locations prior to the accident. These fractures were examined microscopically in circumstances where it was important to distinguish between pre-existing cracks and damage that occurred as a result of the accident.

18.5 The examination revealed that most of the fractured segments on the exhaust system had two visibly distinct regions:

(a) those with more contaminated surface represented cracks which had existed prior to the accident; and

(b) the less contaminated surface represented cracks that occurred during the accident.

18.6 Chemical analysis of the fracture surface contaminations and the discolouration of areas adjacent to the cracks, particularly at the number 7 cylinder exhaust range, indicated fuel combustion by-product. The ATSB therefore concluded that at least one of these cracks, which had existed prior to the accident, had resulted in the leaking of exhaust gases.

18.7 The ATSB was unable to determine the age of the pre-existing cracks and the speed at which they developed. Therefore, it cannot be determined whether any of these cracks would have been visible at the last routine maintenance inspection for VH-NOO. Whilst the B Check conducted on 6 November 2017 included an inspection of the engine exhaust system (with no issues identified), it is possible that these cracks emerged following this check.

Breach of the firewall

18.8 Identification of the exhaust system cracks provides evidence of a potential source of CO (from engine exhaust gases) leaking out of the exhaust system into the engine bay. The question that arises is how CO may have entered the cabin from the engine bay.

18.9 VH-NOO was fitted with a main firewall between the accessory bay and the cabin, and an accessory firewall between the accessory bay and the engine. The ATSB noted publications from the FAA and Transport Canada regarding the significant hazard or risk that exists from CO entering aircraft cabins through openings in a firewall.

18.10 When the main firewall was examined, a number of features were noted:

(a) two out of four bolts were missing from the left magneto access panel, which is on the pilot's side of the cabin;

(b) one out of four bolts was missing from the right-hand magneto access panel;

(c) the three missing bolts left holes through which gas could pass, with the combined area of the holes being 53 mm^2;

(d) the five bolts present consisted of an AN3-3A bolt, two AN3 bolts fitted with a "*butterfly*" modification, an unidentified wing-head screw, and a stainless steel Phillips head screw. Regulation 42.420 of the *Civil Aviation Safety Regulations 1988* (Cth) provides that only standard parts are to be fitted to aircraft unless otherwise provided by the Regulations. The standard parts for use in magneto access panels are AN3-3A bolts.

(e) the left magneto access panel was positioned upside down, although at the time of the examination it was unclear whether this would have allowed the panel to "*sit flat*" or "*bow out*" so as to allow gas to pass through the entire circumference of the panel as well as through the holes where bolts were missing.

AN3-3A bolts

18.11 Mr Bosworth gave the following evidence regarding the particular characteristics required for an AN3-3A bolt:

(a) it is made from high tensile alloy steel plate to provide the strength necessary to hold a component onto a firewall, with a cadmium plate, which also offers strength and protection;

(b) the diameter of the thread should equate to the diameter of the matching nut plate;

(c) the length of the threaded section is specified for the thickness of the firewall, the thickness of the magneto access panel and the length of the nut plate;

(d) the unthreaded section is specified as the thickness of the firewall;

(e) the specific standard of the pitch (how many threads) is used in application where sealing is necessary; and

(f) the grip length is important to prevent vibration and loosening of the bolt to ensure that the magneto access panel remains secure and sealed.

18.12 Mr Bosworth gave the following evidence regarding the use of non-standard bolts in the magneto access panels:

> [C]ertainly with those bolts, they don't have all the properties that a specified bolt has, and part of that is anti-vibration properties and diameter which in one case would mean it doesn't mate with the thread in the nut-plate as well, so more likely loose, so not knowing what the other two were but there's certainly more likelihood of a bolt coming loose due to vibration during aircraft operations, yes.

18.13 Ultimately, the ATSB did not make a finding that the three missing bolts were a contributing factor because they have not been found. Notwithstanding, Mr Bosworth explained that the bolts used to secure the magneto access panels on the main firewall were worn, meaning that they do not work as effectively as unworn bolts, thereby increasing the risk of the bolts either not tightening securely or coming loose during operations.

19. Exemplar testing conducted by the ATSB

19.1 On 20 May 2020, the ATSB used an exemplar aircraft to conduct testing of cabin in a number of scenarios. The exemplar aircraft was an earlier model DHC-2 provided by Sydney Seaplanes, with features that were not identical to VH-NOO but were considered to be "*relatively close*" by the ATSB insofar as the engine bay, accessory bay, cabin, doors and window positions were concerned.

19.2 Whilst Mr Shaw was present at the exemplar testing, together with a LAME, neither the NSWPF or Airag had a representative at the testing. Mr Bosworth gave evidence that the absence of other interested parties "*wasn't that big a consideration at the time*" and that he did not feel that there was a conflict of interest. He explained that the ATSB did not have an obligation to "*invite people*" and drew a distinction between other testing of a destructive nature in which available physical evidence would be changed and there would be occasions to invite directly involved parties to be present. Mr Bosworth also gave evidence that the exemplar aircraft was only available at short notice and that there may have been health risks to additional attendees given that the testing was conducted during the COVID-19 pandemic and involved attendees being potentially exposed to CO.

19.3 The testing was not intended to precisely replicate the conditions during the taxi or flight of VH-NOO. Indeed, the testing was conducted entirely on the ground. Rather, the testing sought to determine a number of matters:

(a) a baseline CO level in the cabin which could then be used to compare CO levels under varying conditions;

(b) whether CO could enter the cabin where there was an exhaust crack and firewall breach; and

(c) observe the impact of various ventilation effects, such as scoop vents and having the cabin doors open, on CO levels in the cabin.

19.4 To conduct the testing, an exhaust leak was simulated in both the engine bay and the accessory bay. During the pre-test briefing, the LAME present suggested removing a connecting sleeve from the exhaust, as this would likely not create a sufficient leak, and instead using an extension hose from the exhaust tailpipe into the engine and accessory bay cowlings. Panelling on the aircraft exterior was loosened to allow for an extension hose to be inserted into the exhaust tailpipe, which then entered the engine bay and subsequently (in a separate series of tests) the accessory bay. The CO concentration level was measured at the outlet of the simulated exhaust leak and was found to be greater than 500 ppm.

19.5 Mr Bosworth gave evidence that the testing was not intended to replicate the exhaust leak size and exact conditions which might have been found on VH-NOO. Rather, the intent was to establish whether an exhaust leak of approximate comparative size, could affect CO levels in the cabin, compared to a baseline level of the exemplar aircraft.

19.6 The testing relevantly found that:

(a) elevated CO levels in the cabin only occurred when both a simulated exhaust leak and missing magneto access panel bolts were present, but not when only one of these factors was present in isolation;

(b) CO was more evident at the pilot's position and was exacerbated when the pilot's door was ajar with a simulated exhaust leak in the engine bay; and

(c) when the magneto access panel bolts were reinstalled, CO levels in the cabin reduced by more than 80% despite the exhaust leak remaining and regardless of the position of the pilot's door.

19.7 The ATSB acknowledged a number of limitations with the exemplar testing and its results:

(a) it was not representative of the operational and environmental conditions of the accident flight as all of these conditions could not be safely tested;

(b) an attempt was made to simulate taxi speed with the engine in the idle position;

(c) the testing was intended to simulate an exhaust leak rather than *the* actual exhaust leak;

(d) in response to a criticism that the testing was not representative of the ventilation effects of the engine and accessory bay cowlings, Mr Bosworth explained that the cowlings were not removed when the exhaust leak was simulated; and

(e) the ATSB did not specifically measure pressure but operated on the assumption, based on principles of aerodynamics, that air was flowing from a high-pressure area to a low pressure area, creating a pressure differential.

20. Conclusions reached by the ATSB

20.1 In its final report of 29 January 2021, the ATSB relevantly reached the following conclusions:

(a) the accident was not survivable due to the combination of impact forces and the submersion of VH-NOO;

(b) Mr Morgan had no pre-existing medical condition that could explain the accident;

(c) there was no indication of any mechanical or structural issue with VH-NOO that would have precluded normal operation;

(d) the aircraft weight (which was calculated on the basis of information provided by the passengers) did not contribute to the accident despite the being underestimated by at least 26 kilograms, resulting in VH-NOO being just below the maximum take-off weight when departing Cottage Point;

(e) Mr Morgan's ability to safely operate the aircraft was likely significantly degraded by exposure to CO;

(f) pre-existing cracks in the exhaust combined with the breach in the firewall from the missing bolts in the magneto access panels allowed elevated levels of CO to enter the cabin, with a rapid flow of air including exhaust gases coming through the bolt holes as a result of the pressure differential between the engine/accessory bay and the cabin;

(g) whilst it was possible some CO ingress could have occurred through a combination of the deteriorated condition of the gasket and one of the magneto access panels being incorrectly oriented, the foot wells in the cabin were unlikely to have provided a source of ingress for CO into the cabin;

(h) the amount of CO in the cabin, and Mr Morgan's elevated COHb level, was likely exacerbated by the pilot's door being ajar on the prolonged taxi, as well as the short flight itself prior to impact; and

(i) although two of the passengers (Richard and Heather) also had elevated COHb levels and were likely experiencing the effects of CO exposure which may have given rise to an event in the cabin causing pilot distraction, without recorded evidence from within the cabin it is not possible to determine whether this contributed to the aircraft entering Jerusalem Bay.

20.2 Ultimately, the ATSB concluded that the unexpected events during the final flight and the indications of some level of flight control input from the pilot in the final steep turn was consistent with Mr Morgan controlling the aircraft but with a deterioration in performance. This would have included a level of confusion, and a degradation in coordination, manual dexterity, alertness, reaction time, and visual disturbance. As no other plausible explanation could be found to explain the totality of the accident sequence from the turn in Cowan Water to the final steep turn in

Jerusalem Bay, the ATSB concluded it was likely that CO exposure had a detrimental effect on Mr Morgan's ability to accurately and safely operate VH-NOO.

21. Did Mr Morgan become incapacitated by exposure to CO or otherwise

21.1 There was no dispute as to the presence of COHb in the blood samples of each of the occupants of VH-NOO. However, several issues arose as to the reliability of the analysis conducted on the samples.

Integrity of analysis method

21.2 First, Mr Morgan's blood sample came from heart blood rather than femoral blood. Professor Drummer gave evidence that heart blood is more likely than peripheral blood to contain methaemoglobin (oxidised haemoglobin). This is significant because methaemoglobin has the potential to elevate the reading for COHb when analysis takes place, regardless of the analysis technique. Professor Drummer considered some artifactual effect of methaemoglobin to be likely although this could not be quantified.

21.3 Second, a hemoximeter was used to measure the COHb levels but this instrument is designed for higher COHb measurements (such as those found in CO toxicity from car exhausts) where readings are typically between 50 and 70%. Professor Drummer noted one study which indicates that the hemoximeter often overestimates CO readings when compared to readings by gas chromatography. Professor Drummer also noted that Mr Morgan had relatively low haemoglobin levels which can lead to artifactual errors in oximetry results. Dr Perl agreed that gas chromatography is considered the gold standard for analysis and that there could be some doubt regarding the accuracy of the hemoximeter measurements but indicated that any variation could not be estimated.

21.4 Third, Professor Drummer found the variation in COHb levels to be surprising given the small size of the aircraft cabin. Professor Drummer also noted that whilst oxyhaemoglobin was detected in the samples from the passengers, it was not detected in Mr Morgan's sample. However, Professor Drummer acknowledged that he does not hold any expertise regarding aircraft ventilation and had not performed any studies regarding CO exposure in confined spaces.

21.5 Fourth, a delay of approximately two years in analysing the relevant blood samples for COHb was not ideal. However, having regard to the way the samples were collected and stored, the experts agreed that any uncertainty was less material that other considerations bearing upon the reliability of results.

21.6 Gas chromatography is not used to perform CO analysis in any forensic toxicology laboratory in Australia or New Zealand. This is because it is a more sophisticated test involving a longer process (and substantially more expensive) than oximetry where a result can be obtained within minutes. Professor Drummer expressed the view that in order to be certain of any COHb reading for Mr Morgan's blood, the sample would need to be sent to an overseas laboratory for testing. However, Professor Drummer had no experience with any case where this had been required and described it as a very rare situation.

21.7 Ultimately, Professor Drummer gave evidence that he could have "*no confidence*" that the COHb results are accurate and whether the readings were close to endogenous (because all humans contain small amounts of COHb - usually less than 2% - as a result of our natural metabolism) or whether the readings were slightly elevated due to some form of CO ingress into the cabin.

21.8 Dr Perl expressed this view as to the presence or absence of CO in the cabin:

> Well, I would agree that the variability in all the readings would - could be explained by other variations. And I indicated that in my report, that age and health status and the amount of haemoglobin - all those factors could impact on the actual reading. But the fact that all of the passengers had carbon monoxide in them, some of whom I wouldn't expect to have anywhere near the amounts that were reported, particularly the child - then I would have to say that I would consider that it's probably more likely that there was carbon monoxide in the cabin.

21.9 On the same issue, Dr Robertson expressed this view:

> Yes, I agree with Dr Perl in that whilst the absolute accuracy of the result may be slightly variable, they all appear to have - all the people in the cabin appear to have elevated carbon monoxide levels for one reason or another. And as Dr Perl said, particularly the child to have an elevated level is - indicates, I believe, that there was carbon monoxide in the cabin.

21.10 Professor Drummer referred to a simulation study conducted on behalf of Airag which showed very low exposure to CO would have occurred and would not have elevated the COHb level of Mr Morgan by more than 2%, and even less for the passengers. This was based on Professor Drummer's assumption that CO exposure levels of 10 ppm (for taxiing) and 5 ppm (in flight) are correct. On Professor Drummer's calculations, if Mr Morgan had been exposed to these CO levels over 104 minutes during taxi and 122 minutes during flight, this would not have elevated his COHb to more than 2%.

21.11 On the alternative assumption that 11% COHb was accurate, Professor Drummer used a nomogram to calculate that approximately 100 ppm over approximately 200 minutes of taxiing flight would be needed to achieve a COHb level of 10%, although these estimates using the nomogram could only be approximate. However, Dr Perl did not consider the nomogram calculation to be useful because in her view it assumed a baseline level of zero which was unrealistic.

Effects of CO exposure

21.12 Professor Drummer referred to a number of studies which suggest that adverse effects on cognitive and neuropsychological functions do not occur until COHb levels reach above 10%, with some studies suggesting the threshold to be 18 to 20%. Professor Drummer also noted that other studies have found that there are no obvious detriments in a range of cognitive functions such as the ability to think, reason and make judgements at a COHb level of around 10%.

21.13 In summary, Professor Drummer expressed the view that there is mixed evidence that healthy persons with a COHb level of around 10-15% following acute exposure to CO have any significant deficits in short-term memory, psychomotor tracking, information processing and reaction time. He agreed with Dr Perl that at lower levels symptoms may develop which are not reported or necessarily observable by others. Professor Drummer also agreed that none of the studies to which he referred necessarily simulate the task of flying.

21.14 Dr Robertson gave evidence that whilst the effects of CO exposure can vary between individuals, a COHb reading of around 10% may result in dizziness, headache, loss of concentration, visual disturbances, and loss of, or inability to, carry out complex tasks. Dr Robertson noted that as the levels of CO and COHb increase, these effects may be exacerbated to the point where loss of consciousness can occur and subsequently death. As to the studies referred to by Professor Drummer concerning the effects of CO exposure at high COHb concentrations, Dr Robertson explained:

> I believe that the - the tests that we've just been discussing really only looks at one or two aspects of - of the total tasks needed to fly a plane safely. And I think that there are many more and whether other studies have been - have looked at this - I'm not familiar with them. But there is such a wide range of tasks that are necessary or involved in flying a plane accurately, it's difficult to test them with very simple – in laboratory tests, I would imagine.

21.15 Dr Perl gave evidence that she was unaware of any study which considered the effects of CO in the context of actual flight performance. However, her opinions were based on inferences that she thought were available having regard to the work that she specialises in, namely the effects of substance consumption on the task of driving. Dr Perl explained that the more complex the task becomes, the more likely there is a degree of adverse effect of a substance on performance. Dr Perl therefore expressed the view that the COHb level of the identified in Mr Morgan likely resulted in some impairment but that it is not possible to be definite about this.

21.16 Professor Drummer agreed that in considering any possible cause of the crash, regard needs to be had to the totality of all the evidence and that one piece of evidence (such as the COHb level for Mr Morgan) cannot be considered in isolation. Professor Drummer agreed that if all other possible causes of the accident had been ruled out then it was important to determine the accuracy of the COHb reading and whether CO exposure affected pilot performance. Dr Perl expressed the view that determination of whether CO exposure could have caused impairment of performance resulting in the accident was "*basically dependent on there being no other factor*" which contributed to the accident. Dr Robertson similarly agreed with Dr Perl that in the absence of anything such as Mr Morgan having an underlying medical condition or experiencing a medical event that may have contributed to the loss of safe flying, she considered his COHb level to be a contributing factor to the accident.

21.17 It was submitted on behalf of Airag that it cannot be said that, based on the COHb tests that were undertaken, CO exposure caused the accident. This is because of the lack of evidence as to the quality and duration of any CO in the cabin of VH-NOO, the absence of any evidence which indicates that CO at 500 ppm entered into the cabin, the uncertainty as to the precise levels of COHb in Mr Morgan's blood, the mixed evidence as to the effects of CO exposure and the results of Professor Armfield's exemplar testing.

Alternative hypothesis to pilot incapacitation due to CO exposure

21.18 In his report, Mr Kuruvita relevantly expressed the following opinion in relation to what he referred to (on instructions) as the "Unusual Flight", that is, the phase of the flight on 31 December 2017 shortly after the shallow right turn just east of Little Shark Rock Point up until the point of impact in Jerusalem Bay:

> [T]he conduct of all stages of the [accident flight] was consistent with [Mr Morgan] being coherent and unaffected by CO Impacts. The evidence is consistent with [Mr Morgan] dealing with and working to manage an in-flight situation and doing his best to control the Aircraft and make a safe landing. I believe the most likely in-flight situation was the release of the oil cap and evacuation of oil into the cabin. A competent, skilful and unimpaired pilot would have done the same as [Mr Morgan] appeared to do […] I believe several related and unrelated in-flight issues that the evidence above illustrates have created a scenario that left [Mr Morgan] in control of the Aircraft with very few options. In a safety management system this is known as the "swiss cheese effect" to result in a fatal aircraft accident.

21.19 It was submitted on behalf of Airag and Mr Land that Mr Morgan was in control of VH-NOO during the flight up to the point of aerodynamic stall, but that he was otherwise distracted as he was making decisions. The issue of possible distraction has already been dealt with above. As to the issue of whether Mr Morgan was in control of VH-NOO up to the point of aerodynamic stall, the following matters should be noted:

(a) Mr Kuruvita accepted during is oral evidence that after VH-NOO completed the 270 degree turn in Cowan Water instead of Mr Morgan searching for somewhere to land, as Mr Kuruvita put it, it is open to conclude that Mr Morgan was "*affected by something impacting his concentration or his ability to fly the plane*";

(b) Mr Kurita accepted that the 270 degree turn could be explained by Mr Morgan suffering from reported symptoms of CO exposure such as dizziness or visual disturbance, confusion, sensory disturbance or altered mental state;

(c) Mr Kuruvita gave evidence that if Mr Morgan was suffering the symptoms described immediately above he may not have been actively making a decision to land the aircraft;

(d) Mr Kuruvita agreed that he was speculating about why Mr Morgan did not land the aircraft in Cowan Water;

(e) Mr Kuruvita accepted the possibility that Mr Morgan flew VH-NOO into Jerusalem Bay whilst suffering reported symptoms of CO exposure as described above; and

(f) Mr Kuruvita ultimately gave evidence that he accepted the possibility that the "Unusual Flight" could be explained by Mr Morgan suffering reported symptoms of CO exposure as described above. Mr Kuruvita sought to quality his evidence by indicating that he considered the flight time of approximately two minutes to be a "*very short period of time*" for Mr Morgan to suffer such symptoms. However, Mr Kuruvita acknowledged that he was making an assumption regarding the duration of time in which reported symptoms of CO exposure could develop, and not purporting to advance an unqualified opinion on this issue.

21.20 **Conclusions:** The evidence established a number of limitations associated with the analysis methodology to detect and quantify COHb levels in the post-mortem blood samples of each of the occupants of VH-NOO. Most significantly, the COHb level for Mr Morgan may have been artifactually elevated although this cannot be quantified. Further, the COHb results generally may have been elevated due to the use of a hemoximeter for measurement rather than gas chromatography.

21.21 As to this last matter, the evidence established that gas chromatography is not used in a forensic toxicology setting in Australia and that instances of its use in overseas laboratories to verify results obtained from a hemoximeter are exceedingly rare. Therefore, the prevalence of the use of a hemoximeter (due in part to the cost and the time it takes to produce a result) for COHb analysis suggests a degree of reliability.

21.22 Whilst there is a degree of variance in the COHb levels for each of the occupants of VH-NOO which does not appear to be dependent upon the seating configuration within the cabin, there is no direct evidence which suggests that this variance renders any result to be unreliable. Indeed, as both Dr Perl and Dr Robertson observed, the detection of COHb in a child (in the case of Heather) tends to support the conclusion that CO was present in the cabin of VH-NOO on 31 December 2017.

21.23 Whilst there is mixed evidence regarding the threshold at which COHb might adversely affect the neurocognitive functioning of individuals, the COHb level detected for Mr Morgan needs to be considered in context in two ways. First, as both Dr Perl and Dr Robertson explained, the complex and multifaceted tasks that are involved with flying aircraft cannot be tested in a laboratory setting, and the performance of such tasks are more likely to be adversely affected by exposure to a substance such as CO. The human factors described by the ATSB are relevant in this regard. Second, the evidence establishes that Mr Morgan was unlikely to have been affected by an acute medical episode or an underlying chronic medical condition which impaired his ability to control the aircraft.

21.24 There is also no evidence that mechanical failure, the meteorological conditions on the day or pilot error contributed to or caused the accident. Further, given the appropriate concessions made by Mr Kuruvita, there is no reliable evidence to support an alternative hypothesis that Mr Morgan was in control of VH-NOO, and unaffected by any symptoms of CO exposure, up to the point of aerodynamic stall. In the absence of such factors which might otherwise explain the cause of the accident, the identification of CO within the aircraft cabin and its effects on Mr Morgan's capacity to pilot the aircraft safely carries greater emphasis.

21.25 Having regard to the above matters, it is most likely that Mr Morgan became impaired by exposure to CO on 31 December 2017. This impairment compromised his ability to pilot the aircraft in a manner commensurate with his training, skills and experience and resulted in the accident.

22. The adequacy of the maintenance conducted on VH-NOO

Systems of maintenance at Airag

22.1 David Pyett had been the sole director of Airag since about 1999. He looked after "*corporate affairs*" but only worked there one or two days a month. Mr Pyett gave evidence that on other occasions he attended Airag not for any business purpose but rather in a personal capacity, stating:

> I have an old airplane out there which I go out and play with.

22.2 Mr Pyett also gave evidence that he had "*been trying to get away from it for years*" and explained:

> I just don't enjoy it and somebody has to be the director. Nobody else wants to be, so I have to do it.

22.3 Mr Pyett was not qualified as a LAME and was not in charge of technical, mechanical or certification work at Airag. These were the responsibilities of the Chief Engineer (who in 2017 was Tony Pitt). Mr Pyett gave evidence that from a corporate perspective, he did not give any direction to the Chief Engineer regarding technical, mechanical or certification aspects of the business; the Chief Engineer did not seek guidance regarding any of these aspects; and the Chief Engineer was effectively "*running his own show in terms of supervision*".

22.4 The maintenance process involved Sydney Seaplanes providing work packs to Airag to perform maintenance facility purchase orders. These work packs included what were effectively sheets photocopied from the Sydney Seaplanes' System of Maintenance (which was a document approved by CASA and required to be followed by Airag).

22.5 John Land was a LAME working for Airag between 1986 and 2020. Mr Land had worked on DHC-2 amongst other aircraft since 1971. Mr Land took direction from the work packs in relation to the maintenance tasks required.

Engine firewall inspection

22.6 The right magneto in VH-NOO was replaced in November 2016, with the left magneto replaced in April 2017. The left magneto was most recently disturbed by Mr Land on 8 to 9 June 2017 due to the report of a rough running engine. However, Mr Land gave evidence that he did not access the magneto via the magneto access panel but rather through the accessory bay cowling.

22.7 Mr Land did not check the magnetos during the B Check in November 2017 because he said this would have been done by Covington when the engine was sent to the United States in about July 2017. At this time, Mr Land inspected and sandblasted the exhaust system.

22.8 As part of the B Check in November 2017, Mr Land signed off an inspection of the main firewall for cracks and structural damage. However it was not recognised that the left hand side magneto access panel had been installed upside down. Mr Land suggested that in April 2017 when he replaced the left magneto, he asked someone at the Rose Bay terminal to assist him in replacing the magneto access panel. Mr Land guessed that this was a person from Sydney Seaplanes named John Klemis. However, Mr Shaw gave evidence that Mr Klemis did not commence working for Sydney Seaplanes until December 2017.

22.9 During the A Check in December 2017, Mr Land did not check for any missing bolts. He gave evidence that when looking from the accessory bay side it is not possible to tell whether there are any missing bolts in the magneto access panel without purposefully shining a torch and looking for this. Mr Land also inspected the exhaust as this was part of his usual practice when conducting an A Check but did not observe any cracks.

22.10 Mr Land was the last person at Airag to inspect the exhaust system. He gave evidence that if he had seen cracks he definitely would have done something about them. Mr Land gave evidence that Mr Pitt only supervised his work "*outside the engine realm*". He said that it was his decision alone as to how to undertake maintenance on the engine of aircraft, including what parts were used and what parts would be replaced, and whether they were standard or non-standard parts.

Magneto access panel bolts

22.11 Mr Land accepted that there were missing bolts in the magneto access panel, and that this was likely because they were non-standard AN3-3A bolts. Mr Land gave evidence that he had been introduced to the use of non-standard AN3-3A bolts at an early stage in his work and had used them ever since for many years whilst performing engine work as a LAME. Mr Land described the modification as having a wing nut attached to the bolt because "*it was an easy method of screwing in the magneto access panel to the firewall to try and eliminate tooling*". By this Mr Land meant that the bolts could be tightened by hand, rather than using a spanner which might be accidentally dropped or bumped when working in rough conditions if an aircraft was on the water.

22.12 Mr Land gave evidence that the non-standard AN3-3A bolts were manufactured at Airag by what he described as welding a tab to the top of a bolt. According to Mr Land these modified bolts were specifically only used on magneto access panels.

22.13 Mr Land described the practice of using non-approved bolts in this way:

> It - it kind of originated at Airag, that I remember. We - you know, we all had them. Other engineers had them. I had them and it was just - I was just told that's the - it was legal - legal to use them because it had been modified and as far as, when I asked [my former Chief Engineer], he suggested that there might have been an engineering order made because he thinks that [another Chief Engineer] wouldn't have let us use them if it wasn't certified.

22.14 Mr Land gave evidence that it was not until about two weeks before the inquest that he spoke to a former Chief Engineer because he was so concerned about using non-standard bolts throughout his career. Mr Land said the Chief Engineer assured him that he would not have been permitted to use the non-standard bolts without an engineering order. Mr Land explained that it was not until he saw or read the final ATSB report that he considered there might be some relationship between the accident and his use of non-standard bolts. Notwithstanding, Mr Land said that he did not seek any clarification regarding use of the bolts until two weeks before the inquest because he had been "*pretty stressed over the whole matter*".

22.15 Mr Land gave evidence that he replaced the left magneto access panel in VH-NOO on 4 April 2017 when the aircraft was on the water, and that he replaced all of the bolts using modified AN3-3A bolts together with one Phillip's head screw. This is because, in effect, Mr Land ran out of modified AN3-3A bolts and he "*wanted to fill the hole up*". Mr Land asserted that the Phillip's head screw would be secure because he had previously used them on aircraft panelling. Mr Land gave evidence that he considered it important to make sure there were bolts (or screws) in all the holes because of what he had been told over the years regarding the leakage of "*fumes and different things like that*".

22.16 Mr Land gave evidence that he intended to replace the Phillip's head screw with a AN3-3A bolt later but forgot to do so. He agreed that approaching his work with the assumption that it met appropriate safety standards unless something was visibly wrong may not represent good and safe work practice. Mr Land also gave evidence that it would have been helpful to his work as a LAME if some degree of guidance had been provided by the Chief Engineer to undertake some testing or examination to ensure that such assumptions (for example about whether parts had been securely fastened) were indeed correct.

22.17 As to the orientation of the magneto access panel, Mr Fogg and Mr Swift agreed that the aircraft's maintenance manual produced by the manufacturer provided official guidance regarding this issue. Mr Fogg gave evidence that where this manual fails to provide guidance, a LAME would instead seek guidance from the manufacturer in the aircraft's Illustrated Parts Catalogue (**IPC**). Mr Swift considered this approach to be "*risky*" because an IPC is not approved by airworthiness regulators, unlike maintenance manuals. Mr Swift was prepared to accept that whilst an IPC should not be used for that purpose it is capable of providing a LAME with some guidance regarding the orientation of a magneto access panel.

22.18 Mr Fogg and Mr Swift agreed that the modified bolts on the magneto access panel were adequate in terms of strength. However, Mr Fogg considered that at least two of the bolts did not have equivalent functionality to a AN3-3A bolt in terms of required locking ability to remain in place. Mr Swift expressed the following view (which Mr Fogg agreed with):

> I think I take a broader view of these bolts in that, if they are not the bolts, if they're not clearly the bolts that are listed in the IPC then I think you have to suspect their performance and, you know, I think that there are a number of features of a bolt which, if you're not sure that it's an AN3 bolt, would be questionable.

Magneto cooling tubes

22.19 The purpose of magneto cooling (or blast) tubes is to deliver or duct cool fresh air into the magnetos so they do not overheat. The left and right magnetos each have a cooling tube. A standard magneto cooling tube is constructed of aluminium.

22.20 When the wreckage of VH-NOO was inspected by representatives of Sydney Seaplanes in May 2021, a section of orange flexible tube was found loose in a wooden box together with some black plastic tube. A question arose in the mind of Mr Shaw whether the magneto colling tubes in VH-NOO were constructed of something other than aluminium. This is significant because if the tubes did not fit snugly or had fallen out of position (by virtue of their construction) this gives rise to a further potential method of CO ingress.

22.21 This question was answered by Mr Land who gave evidence that during a B Check prior to the removal of the engine from VH-AAM (which was later sent to Covington in the United States and re-installed in VH-NOO) he noted that the section of the right magneto cooling tube that runs through the engine bay was in particularly poor condition. As a result, Mr Land fitted a length of heavy duty black concertina rubber hose as a substitute.

22.22 In August 2017, this hose was removed from VH-AAM and inspected by Mr Land in November 2017 during the engine build-up for VH-NOO. Mr Land found the hose to be in good condition and concluded it was an effective and safe substitute for the aluminium tube. Therefore, he reinstalled it in the engine for VH-NOO. Mr Land explained:

> […] I substituted that piece that I used prior and I put that in place because I knew it was sufficient - there was a practical way to substitute a metal piece of inner pipe for the plastic - well, I call it plastic, it was some other material - and I had a complete flow right through without any obstruction whatsoever, because I actually, just to reassure myself, because I didn't have time to go and get these other ones sorted, because I'd had a box full of them, they were all deteriorated and I know there's no excuse, but that's what I did and I even rammed air down both sides so that I knew that it was safe to use and I knew that the cold air running through the tubes was cold ram air […]

22.23 Mr Land gave evidence that there "*was a little bit of pressure*" to get the aircraft back to flying condition and that he did not have time to get another one made or sorted. His intention was to replace the black hose with an aluminium tube at the next B Check. He said that he did not consider that the hose would do a better job, but rather that "*it would do the same job*", whilst acknowledging that the use of non-standard parts was contrary to his obligations as a LAME.

22.24 Mr Land gave evidence that he similarly used an orange coloured hose for the left magneto cooling tube running through the engine bay during the engine build-up in November 2017. Mr Land checked these tubes during the A Check in December 2017. He gave evidence that he did so because he was concerned that, as a non-standard part, there was a risk that they were getting too close to the exhaust and might be affected by the heat of the engine. Mr Land acknowledged that he misled Mr Pyett or Mr Pitt regarding the use of a non-standard part because he did not tell them about it, and that, in hindsight, he should have consulted Mr Pitt about this. Instead, Mr Land explained that he "*took that on my own back through my own experience that it was a safe thing to do*".

22.25 Mr Fogg and Mr Swift agreed that the magneto cooling tubes should be constructed of aluminium, and that:

> Failure to supply cooling out of the magnetos creates a risk of overheating and causing a reduction in their performance or failing completely and a magneto having failed potentially resulting in a loss of engine power during operations.

22.26 Mr Fogg and Mr Swift agreed that a requirement of a B Check inspection was to make sure that the forward and aft sections of the magneto access tubes were installed. Mr Fogg considered that a LAME should be able to find that without a forward section, the magneto cooling tubes on a DHC-2 would not be working properly. Mr Swift agreed with the opinion expressed by Fogg but allowed for the possibility of "*human factors*" meaning that "*you're more likely to find something that's broken or cracked but if something is completely missing that's I think a little bit more forgivable*".

22.27 Both Mr Fogg and Mr Swift gave evidence that they would have concerns about the use of a plastic tube and a concertina rubber hose as part of the magneto cooling tube assembly due to its heat characteristics and because of the heat characteristics in the area where it would be installed. Mr Swift acknowledged that his concerns may be allayed by appropriate testing to show whether a non-aluminium tube could comply with the relevant airworthiness standard. However, Mr Fogg explained his approach if he, whilst maintaining a DHC-2, came across a flexible tube similarly installed as part of the magneto cooling tube assembly:

> It would be to check, knowing that it was supposed to be an aluminium tube, I'd be looking for any prior approval for it being substituted and I'd be looking through either a marking around the area or failing that in a record in the aircraft logbooks or even speaking to the operator or the owner of the aircraft.

22.28 Professor Armfield and Professor Doolan agreed that gas in the accessory bay would have a higher CO concentration if the forward magneto tubes were missing, if the engine bay CO concentration was high and if there was flow through the magneto cooling tubes from the engine bay into the accessory bay. Both experts also agreed that the flow rate of CO through the boltholes would also be higher, assuming that there was flow into the cabin from the accessory bay. However, Professor Armfield acknowledged that he had not measured the losses directly. Professor Doolan expressed the view that the extent of the losses, and whether they would be greater or lesser in the way that Professor Armfield described, is unknown.

Existence of any policies and guidance at Airag

22.29 Mr Pyett gave evidence that at the time the magneto access panel bolts were installed on VH-NOO, he was not aware of any company policy regarding the use of modified or non-standard bolts or whether he had provided training to Mr Land regarding the use of such bolts. Mr Pyett said that he was unaware of any training generally provided by any Airag Chief Engineer to Mr Land. Mr Pyett ultimately agreed that there was no Airag policy at the relevant time in relation to the use of modified or non-standard bolts.

22.30 However, according to Mr Pyett at some stage after December 2017, changes were made so that the Airag Chief Engineer ensures that modified materials are not used "*without obtaining the correct, what you might call, paperwork*". However, this change has not been produced in the form of a policy document or statement made by the Chief Engineer and appears, according to Mr Pyett, to relate only to oral instructions.

22.31 Mr Pyett also gave evidence that he was unaware of Airag having any company policy, distinct from the systems of maintenance requirements for particular jobs, regarding having its engineers check for exhaust cracks, or the installation and use of materials in magneto cooling tubes. He also said that he was unaware of Airag providing any training to its LAMEs regarding checking for cracking in exhaust manifolds, or checking of magneto cooling tubes. Unlike the provision of oral instructions by the Chief Engineer regarding the use of non-standard bolts, Mr Pyett gave evidence that he was unaware of similar oral instructions being provided regarding checking for exhaust cracks and magneto cooling tubes.

22.32 Mr Pyett gave evidence that as a matter of "*general policy*", Airag would not condone the use of non-authorised parts for magneto cooling tubes. However, Mr Pyett was unable to say whether this policy had been reproduced in a document. Rather, Mr Pyett again gave evidence that it formed part of oral instructions that he "*probably*" asked the Chief Engineer to give, although he could not recall specifically giving such instructions or when they might have been given.

22.33 Ultimately, Mr Pyett explained the response by Airag to any changes in policies or procedures it had made since December 2017 in this way:

> I think the position that I'm trying to express here is that Airag had good standards, it complied with the various requirements, regulations and standards and manuals, and again I say that that's what we still do. We have made some recommendations to the people, but we have not changed or done anything different because I disagree with the ATSB.

22.34 **Conclusions:** On 4 April 2017, Mr Land replaced the magneto access panel in VH-NOO using modified AN3-3A bolts and one Phillip's head screw. This represented both a continuation of a practice that Mr Land had followed over may years whilst working as a LAME for Airag, and a departure from accepted practice in using standard and approved parts. The evidence established that the performance of such non-standard bolts would be questionable. Indeed, Mr Land accepted that the three missing bolts from the magneto access panel were most likely modified AN3-3A bolts.

22.35 Mr Land's actions on 4 April 2017, and the practice adopted at Airag more generally in relation to the use of non-standard AN3-3A bolts, did not represent adequate maintenance work. So much is clear from Mr Land's own concerns about any relationship between the accident and his use of non-standard AN3-3A bolts which led him only two weeks before the inquest to seek reassurance from a former Chief Engineer.

22.36 Similarly, Mr Land did not use approved parts for the magneto cooling tube assembly. This decision was made by Mr Land because he considered it safe to do so, without approval from Mr Pyett or the Airag Chief Engineer. This decision was not informed by any testing as to the suitability of such a non-standard part, and was not documented or reported to Airag or Sydney Seaplanes. This change to a typical magneto cooling tube assembly potentially led to an increased CO concentration in the accessory bay, meaning a potentially higher flow rate of CO from the accessory bay through the boltholes into the cabin.

22.37 The evidence also established that Mr Land at times approached his maintenance work with potentially flawed assumptions that it was consistent with safe and adequate work practices, without actually verifying whether this was the case. To this extent, Mr Land did not receive adequate guidance or training from the Chief Engineer or another person at Airag, including Mr Pyett. This tends to reflect the absence of a robust system of work practices where relevant policies (particularly in relation to the use of modified parts and materials, and maintenance work on engine exhaust systems) were not documented and readily available to maintenance staff.

22.38 Having regard to the above matters, and the conclusions reached below regarding the capacity for CO to enter the cabin, it is necessary to make the following recommendations.

22.39 **Recommendation 1:** I recommend to the Chief Executive Officer, Airag Aviation Services Pty Ltd that Airag institute a written policy for its staff, requiring removal and installation of firewall access panels on DHC-2 aircraft to be inspected for conformity by its Chief Engineer, and a test for the presence of carbon monoxide to be conducted prior to the aircraft being returned to service.

22.40 **Recommendation 2:** I recommend to the Chief Executive Officer, Airag Aviation Services Pty Ltd that Airag institute a written policy for its staff requiring that following maintenance work being conducted on the engine exhaust system of a piston engine aircraft, whether scheduled or unscheduled, a test for the presence of carbon monoxide is conducted.

22.41 It was submitted on behalf of Airag that it now performs a test for the presence of CO where maintenance work is conducted on the engine exhaust system of a piston engine aircraft. However, as the submission is silent regarding whether this practice is reflected in a written policy, and in the absence of any evidence to demonstrate such practice occurring, the apparent practice of Airag currently does not detract from the necessity of the recommendations being made.

22.42 It was submitted on behalf of Sydney Seaplanes that:

(a) Airag and its staff "*have consistently denied their substandard and illegal maintenance had any causation relating to this accident*";

(b) Airag "*continues to trade with no punitive action against the organisation and those that work within it*";

(c) "*[n]either CASA or the Police [have taken] any action*"; and

(d) any recommendation made pursuant to the Act "*should include a significant fine against Airag, with license suspension against Airag, Mr Land and Mr Pitt*".

22.43 It is readily acknowledged that Sydney Seaplanes was not legally represented during the inquest and that therefore there may be some misapprehension about the functions and purpose of an inquest, and the coronial jurisdiction generally. However, for clarity it is important to note the following matters:

(a) allegations of wrongdoing, negligence or criminal conduct, and apportionment of blame are matters which are wholly incongruous with the nature and purpose of the coronial jurisdiction;

(b) a Coroner has no power to take punitive action against an individual or organisation or to determine issues of liability – these are matters dealt with in other jurisdictions and administrative forums and by regulatory agencies; and

(c) whilst the Act provides for certain powers (pursuant to section 78) for a Coroner to suspend an inquest and refer a matter to the Director of Public Prosecutions for consideration to be given to the initiation of criminal proceedings, the inquest did not receive any evidence to suggest that the provisions of section 78 ought to be engaged.

23. What was the source and mechanism of entry of any carbon monoxide ingress into the cabin?

23.1 It was not in dispute that CO is produced by the engine combustion process and was present in the exhaust system for VH-NOO.

Divergences of opinion

23.2 Professor Doolan opined that CO travelled from the engine bay into the cabin by the following mechanism:

(a) the propeller pushes air into the engine bay and mixes with exhaust gas that leaks from any cracks in the exhaust system;

(b) this mixture, which contains CO, is pushed through the dishpan into the accessory bay;

(c) from here, the mixture transfers into the cabin through the boltholes in the magneto access panel left by the dislodgement of the bolts that ought to have been secured to the panel;

(d) as the CO concentration in the cabin is directly proportional to the mass flow rate of CO into the cabin, this raises the level of CO in the cabin;

(e) missing magneto cooling tubes will cause the mass flow rate of CO through the boltholes to be higher, which in turn raises the level of CO in the cabin; and

(f) gaps around the magneto access panel will also cause the mass flow rate of CO through the boltholes to be higher, which in turn raises the level of CO in the cabin.

23.3 In essence, Professor Armfield expressed an opinion that was divergent from the opinion expressed by Professor Doolan in these respects:

(a) from exemplar testing that he conducted, the cabin pressure was greater than the pressure in accessory bay (and not the converse as formulated by Professor Doolan) meaning that air flow from the cabin would be driven into the accessory bay, rather than vice versa;

(b) friction losses (caused by propellor wash travelling through the cylinder bank and cooling fins) and the accessory bay cowling outlet geometry combine to reduce pressure in the accessory bay meaning that it is always at a negative pressure;

(c) flow rate of any CO through the boltholes, whether increased by missing magneto cooling tubes or gaps around the magneto access panels, will only occur when the pilot's door is ajar as this creates pressure in the accessory bay that is greater than the cabin pressure, meaning that the positive pressure differential drives air from the accessory bay into the cabin; and

(d) even if air flow was driven from the accessory bay into the cabin, the mixing and dilution of the cabin air would reduce the concentration of CO in the cabin.

Areas of agreement

23.4 Notwithstanding the above, there were a number of areas of agreement between Professor Doolan and Professor Armfield in their oral evidence. These areas are summarised as follows:

(a) the rate of CO production increases at higher engine RPM but the concentration of CO decreases when the engine is operating closer to its design point where the balance of air and fuel is at its most efficient;

(b) wind speed and aircraft speed may impact on whether the pressure differential across the firewall is positive or negative – for example, Professor Doolan explained that if the RPM of the propeller is low and the forward speed of the aircraft is very low or zero (such as whilst taxiing) these factors may have a measurable effect;

(c) during flight with an RPM of 1800 to 2000 and a high velocity slipstream, it is unlikely that wind speed would be able to disrupt the slipstream and propeller wash as a wind speed of that magnitude would affect the stability of the aircraft;

(d) a higher CO concentration measured in the cabin than in the accessory bay means that CO must be entering the cabin by sources other than the firewall – however, Professor Doolan gave evidence that he could not rule out another effect such as an unsteady flow effect or pulsating flow occurring across the firewall which could reduce pressure in the accessory bay and pump CO through the firewall;

(e) as air from the propeller has mass and significant velocity primarily directed towards the cabin it will have significant momentum directed towards the cabin;

(f) in principle, it is possible for momentum from the propeller to push a mixture of exhaust gas (including CO) and air in the engine bay towards the direction of the cabin, resulting in the mixture being pressed against the dishpan and then pushed through into the accessory bay due to the porosity of the dishpan - however, Professor Armfield expressed doubt that the degree of stagnation pressure could be equal to the total pressure immediately downstream of the cooling fins;

(g) CO may pass from the accessory bay into the cabin by two mechanisms: diffusion (where a substance such as carbon and oxygen molecules will naturally move from an area of higher concentration to one of lower concentration) and flow through the boltholes which is created by the momentum in the flow (created after passing through the dishpan and air exiting from the magneto cooling tubes) directed towards the firewall;

(h) gas in the accessory bay will have a higher concentration of CO if the forward magneto tubes are missing, the engine bay CO concentration is high and if there is flow through the magneto cooling tubes from the engine bay into the accessory bay;

(i) there is some uncertainty regarding whether removal of the forward magneto cooling tubes affects pressure in the accessory bay as this would be dependent upon further detailed analysis and measurements; and

(j) Assuming there is flow going through the accessory bay into the cabin through the boltholes, gas in the accessory bay will have a higher concentration of CO if the forward magneto cooling tubes are missing and the flow rate of CO through the boltholes will be higher, resulting in a higher volume of CO being transported into the cabin.

Additional factors relevant to differential pressure

23.5 Professor Doolan expressed some doubt regarding Professor Armfield's opinion that friction losses and the accessory bay cowling outlet geometry means that, with the pilot's door closed, the pressure in the accessory bay will be less than cabin pressure. Professor Doolan explained

> [I]s it always going to be less than the cabin pressure, I'm not so sure because of the effect of the flow over the cabin itself and the influence of the door being ajar, particularly at low RPM, such as 500 RPM, because there are some measurements that indicate that the pressure is different, is positive across the firewall.

23.6 Professor Doolan gave evidence that the two factors raised by Professor Armfield did not change his opinion because whilst they will slow down the passage of gas they will not stop it from coming through the firewall. Professor Doolan explained that if the gas has some momentum there is potential for it to stagnate against the magneto access panels resulting in localised areas of higher pressure that could push the gas through the firewall. Professor Doolan noted that this is "*highly dependent on the operating condition of the aircraft*" but ultimately opined that "*under some conditions*" it is theoretically possible for there to be higher pressure in the accessory bay than in the cabin.

23.7 Professor Armfield gave evidence that he did not disagree with the opinion expressed by Professor Doolan. However, he considered that the specific geometry of the cowlings in the engine bay always shows a negative pressure in the engine bay.

23.8 Professor Doolan described the mechanism by which CO can enter the cabin through the boltholes in this way:

> [M]y assumption was that the cabin would be at around an atmospheric pressure and the stagnation pressure upstream would have to be higher because it would start with the gas at about an atmospheric pressure's that's been accelerated by the propeller's immigrant momentum and then it's stopped again, so it would - my assumption was that that energy would result in a higher pressure across the - a higher pressure upstream of the cabin and create a positive pressure difference across the firewall.

23.9 In reaching this opinion, Professor Doolan gave evidence that he was "*intrigued*" by the results of the exemplar testing conducted by Professor Armfield which indicated a negative pressure differential across the firewall. In this regard, Professor Doolan acknowledge that he may not have taken into account the additional effect of the flow of the slipstream around the aircraft affecting cabin pressure.

Results from exemplar testing conducted by the ATSB

23.10 As to the results obtained from the exemplar testing conducted by the ATSB (namely, that the highest concentrations of CO were observed with the magneto access panel bolts removed and an exhaust leak was simulated into the accessory bay), Professor Doolan gave evidence that there must have been a positive pressure differential across the firewall. He explained:

> [T]here must a pathway from the accessory bay to the cabin, so given that the exhaust is placed into the accessory bay and the CO concentration rises in the cabin there must be a pathway. The most obvious one are the holes or the missing boltholes, or inaccurately attached panels to the firewall so, yes, it seems to be the most obvious pathway, it's not to say there couldn't be another one, but on the face of it, it seems to be the right one.

23.11 Professor Armfield considered that one reason for the difference in the results obtained from his exemplar testing to the exemplar testing conducted by the ATSB was that by raising the front of the cowling of the accessory bay in order to pass exhaust gases into the accessory bay this changed the aerodynamics and pressure of the accessory bay cowling. Professor Armfield considered this to be "*a point of concern*" that "*would need to be looked at more closely*". Professor Doolan agreed with the views expressed by Professor Armfield but noted that only a relatively small proportion of the exhaust bay cowling flow would be affected and that it would be important to quantify the amount of the effect.

23.12 Both Professor Armfield and Professor Doolan agreed that apart from a pathway for exhaust gases from the accessory bay into the cabin (assuming a positive pressure difference across the firewall), there could be potentially other pathways such as a vent scooping air mixed with CO from the slipstream very close to the fuselage and penetrations going from the underfloor duct into the cabin. However, both experts agreed that there is insufficient data and measurements regarding these potential pathways.

23.13 As to the differences in results between the two exemplar tests, both Professor Armfield and Professor Doolan agreed there are challenges associated with understanding the differences in the results. Such understanding would be informed by a close comparison of the results with precise details regarding how the testing was conducted. Professor Armfield explained:

> I would like to get into it more deeply because obviously I would like to understand why [the ATSB] results are different to the results we obtained and all I can point out at the moment is what I can are differences in what they did and what we did that may affect it and also in how it's more difficult to compare their results to their baseline and compare their results to our results because of these changes as they go through the results, so I can't give you any more detailed explanation than that as to why there are these differences. I mean clearly, they've got different results to what we got.

23.14 Advisory Circular 20-32B issued by the FAA regarding the detection and prevention of CO contamination in aircraft provides the following:

> Many light aircraft cabins are warmed by air that has been circulated around the engine exhaust pipes. A defect in the exhaust pipes or cabin heating system may allow carbon monoxide to enter the cockpit or cabin. The danger is greatest during the winter months and any time the temperature is such that use of the cabin heating system becomes necessary and windows and vents are closed. **But there is danger at other times, too, for carbon monoxide may enter the cabin through openings in the firewall** and around fairings in the area of the exhaust system. [emphasis added]

23.15 Notwithstanding the differences of opinion expressed by Professor Armfield and Professor Doolan, both experts agreed that the above advisory circular should be followed.

23.16 **Conclusions:** The opinions expressed by Professor Armfield and Professor Doolan establish that there is a pathway for exhaust gas containing CO to travel through the accessory bay, across the firewall via boltholes in the magneto access panels and gaps around a misoriented magneto access panel, and into the cabin. This pathway is dependent on pressure in the accessory bay being higher than cabin pressure. Such a positive pressure differential across the firewall may be achieved by effects such as the pilot's door being ajar, an unsteady flow effect or pulsating flow occurring across the firewall which could reduce pressure in the accessory bay, and stagnation of the gas mixture at the firewall with its momentum driven by the propeller converted into pressure.

23.17 Whilst the evidence identified potential limitations with the exemplar testing conducted by the ATSB, there is insufficient evidence to conclude that these potential limitations render the results unreliable. As Professor Doolan noted, the results achieved from the testing are consistent with the most obvious pathway for CO to enter the cabin across the firewall through boltholes in the magneto access panels. Whilst the evidence also identified other potential pathways for CO to enter the cabin, which are not dependent upon a positive pressure differential across the firewall, these pathways have not been the subject of analysis, testing or measurement.

23.18 The issue of any pathway of CO into the cabin is therefore not without an element of uncertainty. So much is clear from the divergencies in some aspects of the expert evidence and the different results from the exemplar testing that has been performed. It is also evident that the existence of a positive pressure differential across the firewall is dependent upon operating conditions of an aircraft. In this regard, the taxiing of VH-NOO with the pilot's door ajar on 31 December 2017 is consistent with such an operating condition.

23.19 Therefore, having regard to this matter, and the likely higher concentration of CO in the accessory bay if the forward magneto cooling tubes were missing, it is more probable than not that exhaust gases containing CO entered the cabin of VH-NOO across the firewall via the boltholes in the magneto access panels and gaps around the misoriented magneto access panel. There is support for this conclusion in that, despite the differences in their opinions, both Professor Armfield and Professor Doolan expressed the view that an FAA advisory circular warning of the danger of CO entering an aircraft cabin through openings in a firewall ought to be followed.

24. The extent of the investigation of the possibility of CO exposure

Assumptions made regarding toxicological analysis for CO

24.1 Up until late 2019, neither the NSWPF or the ATSB had given consideration to the effects of CO exposure as being a possible cause of pilot impairment or incapacitation which resulted in loss of control of the aircraft and the subsequent crash.

24.2 As for the NSWPF approach, Detective Sergeant O'Keefe explained:

> Generally, unless there's some specific reason for us to suggest something out of the normal, we would just rely on the toxicology as performed at the autopsy

24.3 Detective Sergeant O'Keefe went on to explain that in this regard, the NSWPF relies "*[t]o a huge extent*" on the expertise and judgement of forensic pathologists regarding toxicology testing.

24.4 The six autopsy reports authored by Dr Burger and Dr Irvine, and issued by the Department of Forensic Medicine, all contain a summary of the results of an analytical toxicology report performed for each of the occupants of VH-NOO, with the toxicology report being annexed to the autopsy report. Also annexed to the autopsy report is a document with the following title:

> FORENSIC TOXICOLOGY LABORATORY
> Report Attachment for Drugs/Poisons detectable in blood.
> The list below shows some of the drugs which can be detected in blood by LC QTQF MS and Immunoassay screening techniques. **For any drug not on the list or for targeted analysis please contact the laboratory**. [emphasis added]

24.5 Below this title is a list of drugs with numerical thresholds at which each drug can be detected. Carbon monoxide is not contained in the list.

24.6 Mr Bosworth gave evidence that the ATSB investigative team thought that CO had been tested for as part of routine toxicological analysis performed as part of the post-mortem examination process. However, once the autopsy and toxicology reports became available in late 2018, the ATSB did not verify or confirm that such analysis had in fact been conducted. Mr Bosworth explained that there were two factors which put the ATSB, as he described it, "*off the trail*":

> Well, probably the first one is it's not mentioned in the summary. Like, if it was highlighted as an issue, we would have chased it down at that time. So in our thought we thought it was tested, so that if it had been an issue, it would have been in the summary report without looking closely at the toxicology of what was tested. The other thing was the carbon monoxide detector which was found in the - the passive carbon monoxide detector found in the cabin, we weren't quite familiar with the operation of that even though it was quite simple, it changes colour, and the carbon monoxide detector in question, obviously, went under water in the accident and then was retrieved, and our consideration there was, okay, we've got to consider what happened to it afterwards. Our consideration was if there was a carbon monoxide detector, that would have been the defence for carbon monoxide. So that flavoured our thought on carbon monoxide, I suppose. Then when we did obviously looked a bit further, we could look back more closely on photos during the accident - not

the accident flights but just flights leading up to the accident flight that day and the day before and have a look at what the actual detector was showing to show that it was actually unserviceable.

24.7 Prior to 2020, the ATSB investigators did not have full knowledge of the way the CO spot detector worked and, more particularly, what the indicators on the detector actually meant. The ATSB considered that the beige colour of the CO spot detector from VH-NOO was a normal colour, indicating that no CO was present, whereas the colour was actually bleached on the spot detector and it was not serviceable. Instead, if the detector had a red colour it meant that no CO was present but if the colour turned black it indicated the presence of CO.

Discovery of the absence of CO analysis

24.8 Dr Brock gave evidence that when he received the autopsy reports from the ATSB in late 2018 he noted that they did not contain any reference to CO analysis. Dr Brock explained that he "*parked*" this issue, expecting to receive some further information from NSW Health Pathology. Dr Brock gave evidence that it was his expectation that the toxicology results and measurement of any CO levels would follow completion of the autopsy report "*because they are normally done in aviation accidents in most other jurisdictions as a routine*".

24.9 Although Dr Brock gave evidence that he raised these expectations with Mr Bosworth, Mr Bosworth could not recall having a conversation with Dr Brock in October or November 2018. Further, Mr Bosworth gave evidence that he assumed that he would have chased up any evidentiary material if Dr Brock indicated that he was waiting for it. However, even if Dr Brock had mentioned the outstanding toxicology results for the presence of CO, Mr Bosworth explained that this matter was not "*high enough in my priority list to follow-up with at that time because I didn't*".

24.10 However, no further information was forthcoming at that time, and it was not until the end of 2019 when Dr Brock was considering a draft of the final ATSB report that he realised "*we still had not seen a carbon monoxide result*". Dr Brock accepted "*some responsibility perhaps allowing that time to have elapsed*". Dr Brock's realization prompted Mr Bosworth to review the post-mortem material. Upon doing so, Mr Bosworth realised that no analysis for CO had been performed, or that if the analysis had been performed then the ATSB did not have the results, and he informed Dr Brock of this.

24.11 **Conclusions:** Routine toxicological analysis was performed in relation to the post-mortem blood samples from each of the occupants of VH-NOO. This analysis did not include detection of carbon monoxide. This was stipulated in an annexure to each of the autopsy reports, together with instructions to contact the forensic toxicology laboratory for targeted analysis of any drug not listed in the actual autopsy report.

24.12 Whilst the absence of routine analysis for CO as part of the post-mortem examination process was set out in the autopsy report provided to both the NSWPF and ATSB, both agencies operated under the mistaken assumption that such analysis had in fact been carried out. This assumption was not unreasonable having regard to the evidence of both Detective Sergeant O'Keefe and Mr Bosworth, which established that investigators rely heavily upon the expertise of forensic pathologists in determining whether there may be a natural, traumatic or toxicological contribution to the death of a person in a transport-related context. In addition, a lack of complete understanding on the part of the ATSB about the functionality of a CO spot detector also led to an assumption regarding the unlikelihood of CO being a potential contributing factor to pilot impairment.

24.13 Although the absence of any toxicology analysis for CO was first recognised in late 2018, regrettably no action was taken at this time to advance this issue. The evidence is unclear whether this recognition by Dr Brock was drawn squarely to the attention of Mr Bosworth. However, Mr Bosworth frankly acknowledged that even if his attention had been drawn to the issue, the question of pilot incapacitation due to CO exposure did not, at that time, feature prominently in the consideration by the ATSB of possible causes of the accident. It was not until the issue was raised again some 12 months later that definitive steps were taken to confirm whether any toxicological analysis for CO had been performed and, as matters eventually transpired, to arrange for this to occur.

24.14 There is no evidence that the delay in analysing the post-mortem blood samples for the presence of CO adversely affected, or compromised, the investigations conducted by the ATSB and NSWPF. Whilst the delay was not ideal, the expert evidence establishes that the blood samples were adequately stored so as not to detract from the reliability of the analysis results (particularly when compared to other limiting factors described above).

24.15 Notwithstanding, the delay in analysis was significant in at least three other respects. First, the delay meant that further investigation was required which affected the timeliness in which answers could be provided to the relatives of the occupants of VH-NOO about the circumstances of the accident. The impact of the discovery of "new" evidence at a late stage in the investigation and consequent delay in the publication of the ATSB final report on the emotional well-being of relatives experiencing a traumatic bereavement process cannot be underestimated. Second, the delay was particularly challenging for Mr Morgan's parents because until the analysis results raised the possibility of impairment due to CO exposure, it may have been suggested that Mr Morgan's actions and competency as the pilot may have been causally related to the accident. Third, whilst safety bulletins were issued by the ATSB and CASA reminding operators about the dangers of CO exposure, this did not occur until almost two and a half years after the accident, with other flights operating in the intervening period.

Possibility of routine testing for CO

24.16 Dr Lorraine Du Toit-Prinsloo, Chief Pathologist and Clinical Director, Department of Forensic Medicine, gave evidence that CO testing is requested as part of the post-mortem examination process by the case forensic pathologist where the information provided indicates the possibility that CO exposure could have contributed to, or caused, the death of a person. This typically involves cases involving exposure to fire, certain workplace-related fatalities and situations where an individual may have intentionally exposed themselves to CO.

24.17 Whilst Dr Du Toit-Prinsloo considered that routine CO testing should not be done in all cases, she considered that it would be consistent with good clinical practice for CO testing to be conducted in relation to aircraft fatalities given that the possible presence of CO may be important in determining the cause of a person's death. Dr Du Toit-Prinsloo also gave evidence that she had conducted a literature review which did not indicate that CO testing is routinely conducted in relation to motor-vehicle accidents. Dr Du Toit-Prinsloo was unable to comment in relation to boating related fatalities due to the absence of available data.

24.18 Dr Du Toit-Prinsloo explained that if a recommendation were to be made that CO screening be conducted in all instances of aircraft fatalities, this would be implemented by a memorandum being distributed by the chief forensic pathologist to relevant staff to ensure awareness and adherence.

24.19 Dr Du Toit-Prinsloo also explained that at the time that the post-mortem examination is performed in relation to a transport-related death (which is typically within days of the death being reported to the Coroner), the ATSB has not completed its investigation. However, Dr Du Toit-Prinsloo agreed that there was value in earlier engagement between the ATSB and NSW Health Pathology so that information can be provided by an investigator to a forensic pathologist, particularly in relation to whether, for example, CO testing is indicated in a particular case.

24.20 **Conclusions:** The evidence establishes that investigating agencies and NSW Health pathology recognise the value in earlier engagement between investigators and forensic pathologists regarding testing and analysis that may be conducted in cases of aviation fatality, informed by evidence gathered from such investigations. Such recognition carries increased emphasis where regulatory agencies in Australia and abroad have had cause to issue safety bulletins highlighting the risks of CO exposure in aircraft.

24.21 Further, this case highlights the importance of using testing and analysis to rule in or rule out any possible toxicological contribution where a death occurs during the operation of a CO producing vehicle, vessel, aircraft or other machinery. Finally, the evidence also establishes that such testing and analysis is considered to be good clinical practice in such instances.

24.22 Having regard to the above matters, it is necessary to make the following recommendation.

24.23 **Recommendation 3:** I recommend to the Chief Executive, NSW Health Pathology that carbon monoxide screening be conducted as part of standard toxicology testing by the NSW Health Pathology Forensic and Analytical Science Service in all deaths resulting from aviation incidents, subject to an appropriate biological sample from the deceased person(s) being available.

25. Has adequate remedial action been taken in response to the accident?

Sydney Seaplanes

25.1 Before recommencing DHC-2 flights on 31 January 2018, Sydney Seaplanes installed a stall warning system to their other DHC-2 aircraft. Following the issue of the ATSB preliminary report, Sydney Seaplanes undertook the following further remedial action:

(a) GPS tracking devices were installed on all aircraft to provide real-time positioning information and flight data;

(b) all aircraft were fitted with active electronic CO detectors connected to the aircraft communication system so that audible alerts can be heard through headsets;

(c) all pilots completed underwater escape training;

(d) the company worked with its external human factors training provider to develop a module for its pilots as part of the company's human factors training program recognising the effects of CO and how it affects human physiology;

(e) changes were made to the DHC-2 system of maintenance in relation to checks of the exhaust system, amendment to the 100 hourly B Check inspection and examination of magneto access panels and CO testing; and

(f) a new maintenance provider has been directed that the removal and installation of the magneto access panels must be classified as a critical maintenance operation task which will require certification by a LAME, a conformity inspection and CO testing.

25.1 **Conclusions:** It is evident from the above that Sydney Seaplanes has taken appropriate and extensive remedial action since 31 December 2017 to ensure the safety of its staff and passengers, and to mitigate against the possibility of another similar event to that of 31 December 2017 occurring again.

Airag

25.2 Mr Pyett gave evidence that he would provide an instruction to Airag staff that a CO test be conducted when maintenance panels are adjusted and returned. However, there is no evidence that Airag intends to introduce or implement any written policy in this regard.

25.3 There is otherwise no evidence that Airag has undertaken any substantive remedial action since 31 December 2017. This appears to be due to the fact that Airag denies any responsibility for factors giving rise to the crash.

25.4 **Conclusions:** The remedial action taken by Airag since 31 December has been extremely limited and, in essence, confined to oral instructions which are lacking in detail and which have not been reduced to writing or developed into any robust policy. Notwithstanding the view taken by Airag to the findings of the ATSB final report, the evidence suggests that the response by Airag is antiquated and not informed by contemporary practices. The response also does not demonstrate an attitude and approach to supervision and safety that is consistent with the expectations of industry.

ATSB

25.5 In July 2020, the ATSB issued two safety advisory notices to aircraft maintainers, operators and owners of piston engine aircraft:

(a) the first notice was a reminder of the importance of conducting detailed inspections of exhaust systems and firewalls with consideration for potential CO exposure; and

(b) the second notice strongly encouraged operators and owners to install a CO detector with an active warning to alert pilots and passengers to the presence of elevated CO levels in the cabin.

25.6 **Conclusions:** Given the findings of the ATSB final report, both safety advisory notices were strongly indicated and appropriate.

CASA

25.7 In July 2020, CASA issued Airworthiness Bulletin (**AWB**) 02-064 which included the following recommendations:

(a) aircraft maintenance engineers conduct thorough inspections of exhaust systems with a view to finding potential CO poisoning points/cracks;

(b) approved modifications and maintenance actions/service that include access panels and attachments to firewalls be re-sealed following all disturbances to prevent CO ingress into the cabin;

(c) aircraft be fitted with small electronic CO detectors as these are relatively more affordable and allow for continual CO monitoring with audible and visual warnings when required - if only the placard-type CO detector is available, this should be placed in the field of view of the pilot and regularly checked to ensure it is not faded from UV exposure or contamination; and

(d) operators of piston engine aircraft should be aware of degenerative effects of CO, noting that lengthy engine run ups and taxi periods with tail or crosswinds can draw the exhaust into the cabin. Pilots should therefore ensure adequate fresh air ventilation is available to them and that the aircraft is directed into the wind.

25.8 On 19 October 2020, CASA released version 2 of AWB 02-064 which replaced the recommendation for fitting aircraft with small electronic CO detectors with a strong recommendation that pilots wear personal CO detectors .

25.9 On 3 October 2021, CASA released version 3 of AWB 02-064 which included additional information from the ATSB report but did not change any of the version 2 recommendations.

CO detectors

25.10 In its final report the ATSB recommended that CASA mandate the carriage of CO detectors in piston engine aircraft, particularly for passenger carrying operations. The report identified as a contributing factor that there was no regulatory requirement from CASA for piston engine aircraft to carry a CO detector with an active warning to alert pilots to the presence of elevated levels of CO in the cabin.

25.11 David Punshon, CASA Manger, Continued Operational Safety, gave evidence that CASA is aware of approximately 8,365 single piston engine aircraft in operation in Australia. CASA had regard to the following factors in deciding not to mandate CO detectors:

(a) a low failure rate for exhaust systems in piston engine aircraft; and

(b) no other international civil aviation authority has mandated the use of CO detectors for the general aviation piston engine fleet.

25.12 Mr Punshon gave evidence that using the FAA's Small Aircraft Risk Assessment (**SARA**) assessment process, a number of factors (including the one year and 20 year failure rate) are plotted against a particular chart that has the risk levels and boundaries on the rate of occurrences with the aim to determine whether it will become an unsafe option.

25.13 Mr Punshon explained that mandating CO detectors would have required a regulatory response through legislative process, with part of the process involving consideration of economics and whether there is appropriate benefit to the industry and the public. However, in relation to the specific question of mandating CO detectors, Mr Punshon explained:

> Well, that process wasn't engaged, because when you start looking at the failure rates and the economics, the safety case doesn't come through as being relevant to drive for a legislative change.
> […]
> The cost of the detectors would be they're about, the ones I looked at that all were mounted in the dash, are around $1,200 Australian converted for US dollars, there were two examples I looked at. The economic cost isn't very high, but the benefit gained from the risk analysis when you look at the failure rates is not that significant.

25.14 Mr Punshon accepted that the data that informs failure rates is dependent on the quality and quantity of information that CASA receives. Mr Punshon explained that this information is usually provided by maintainers and when considering the accident rates over a 20 year period, the only accident as a consequence of CO exposure was the 31 December 2017 incident.

25.15 Mr Punshon accepted that whilst CASA's own defect database included 11 reports over 22 years, the ATSB recorded 30 instances in the period between 2011 and 2022. This indicated that CASA was not receiving enough adherence from industry regarding its obligations to report. However, Mr Punshon explained that even after conducting analysis of all the available data the results fell "*below the threshold for triggering any sort of regulatory reaction or even advisory material*". Mr Punshon explained that this analysis only assesses the risk of CO entering the cabin of an aircraft, and not the consequences of such an occurrence. This is because the only consequence that CASA is aware of is the one involving VH-NOO.

25.16 The response by CASA to the ATSB stated that "*rather than the full introduction of additional safety mechanisms as a belated safety defence mechanism*" the emphasis should be on the root cause of an accident, which CASA regarded as inadequate maintenance in the case of VH-NOO. Mr Punshon referred to an airworthiness directive (**AD**) already being in place and therefore "*there was already elements to deal with that issue that should have prevented it occurring*". However, Mr Punshon acknowledged that prevention did not occur in the case of VH-NOO.

25.17 Mr Punshon explained that the October 2021 AD which strongly recommended that pilots wear personal CO detectors, was issued to "*provide people self-awareness and some level of their own personal responsibility*". Mr Punshon described this as part of the education process and trying to encourage people so that regulatory action was not required. He described the process in this way:

> It's a graded response rather than going full - hard at the start, the idea is to build up to it and see whether that makes a change.

25.18 However, Mr Punshon explained that there had been no further graded response on the part of CASA other than with the issuing of the versions of AWB 02-064, but that it would be an ongoing process that does not remain "*stagnant or static*". Mr Punshon explained that since October 2022:

> [W]e've looked at the data again and seen if any changes, we've got hold of the ATSB data to see whether that provides any different view in the terms of the risk assessment. We've been back looking at the responses from other nationally with us [sic], or aviation authorities and seeing that their positions have changed, and none of that's changed.

25.19 Mr Punshon was asked about whether another occurrence involving CO ingress into an aircraft cabin, the consequence of which was injury or fatality, would elevate the failure rate to trigger a regulatory response. He explained that this would require consideration of a number of variables such as causal factors, the specific features of a component or issue which may have contributed to the occurrence, what occurrences may have occurred since the last analysis performed by CASA, and what may have occurred in other jurisdictions and responses taken by regulatory authorities in these jurisdictions. However, even taking these matters into account, Mr Punshon frankly acknowledged:

> To be honest I'd say it would take probably unfortunately a number of accidents, hopefully not fatal, to trigger the risk level to be in the range where regulatory action would be required.

25.20 Further, Mr Punshon acknowledged that an additional occurrence of the kind involving VH-NOO with the same fatal outcome would not be sufficient in terms of a risk analysis performance exercise, to trigger a regulatory response.

25.21 It would be unsurprising that in the views of many, most particularly the families of the occupants of VH-NOO, a real risk of injury or fatality to a single person should be enough to trigger a regulatory response. However, Mr Punshon explained the challenges faced by CASA in this regard:

> It's always a concern, but it's very difficult to make an informed and logical approach. If we don't have a data driven decision making process, people will refer to it as being an emotive response with no justification and that has been used by the industry previously. By having some sort of data driven decision making process, it becomes more supportive of the decision but not necessarily the only factor that drives the decision but it certainly helps give you a direction in which to take the decision.

25.22 Mr Punshon also referred to other considerations involving the mandating of CO detectors such as initial resistance from industry which would require "*a reasonable amount of effort, to use the words, win them over*", and concerns regarding false indications in CO detectors resulting in pilots becoming complacent about genuine indications. Mr Punshon gave evidence that if a CO detector kept producing "*nuisance triggers*" this could lead to complacency, although he agreed that even if there was a false indication which caused a pilot to land an aircraft it would be "*better to be safe than sorry*". Mr Punshon gave evidence that he was aware of a report produced by the FAA which considered what type of CO detectors work best in aircraft cabin and that CASA continued to monitor study data as to whether the type of detector may be a factor in the number of false indications.

25.23 Notwithstanding, Mr Punshon acknowledged that any concerns about perception of an emotive response would be less if research demonstrated underreporting in incidents of CO exposure, and that the rationale of permitting a regulatory response may be more accepted by industry if this were to be explained.

25.24 Mr Punshon also acknowledged that according to SafeWork Australia the maximum recommended exposure to CO over an eight hour period is 30 ppm. In contrast, the certification for the DHC-2 is 50 ppm. Notwithstanding the difference in these figures, Mr Punshon acknowledged that in terms of risk assessment taking into account current research, it would be "*a good idea*" for a pilot to have an active CO meter. Mr Punshon explained that this is why CASA produced the advisory bulletin.

25.25 Although CASA was not regarded as a sufficiently interested party at the inquest, an opportunity was extended to CASA to provide a response in relation to a number of suggested recommendations made by Counsel Assisting in their closing submissions. In relation to a recommendation that CASA reconsider the appropriateness of mandating the carrying of CO detectors, CASA considered it significant that the ATSB final report provides no detailed analysis or data relied upon in support of their original recommendation.

25.26 However, CASA expressed a willingness "*to engage in further discussions with the ATSB as to the data it has relied upon so as to better understand the basis for the ATSB recommendation, and in turn conduct a reconsideration as to whether mandating CO detectors is appropriate and within*

CASA's remit". CASA also expressed a willingness to develop and implement a program for the voluntary installation of CO electronic detectors in piston engine aircraft.

25.27 In addition, CASA noted that based on the number of fatal events and occurrences the safety benefit of mandating the carrying of CO detectors is "*extremely low which indicates it is not warranted to mandate a potentially unreliable system and diverse range of CO detectors into aircraft*". CASA observes that mandating such a system may introduce other unintended consequences, including pilot complacency as described by Mr Punshon.

25.28 **Conclusions:** It can be accepted that the type of emotive response described by Mr Punshon that a fatal occurrence may elicit does not often align with regulatory decision-making driven by raw data, risk assessment thresholds and economics. Further, inquests are often faced with the challenging task of determining whether a single adverse event provides a sufficiently informed evidentiary foundation for the making of a necessary or desirable recommendation which may have wide reaching implications well beyond the particular circumstances of that event. In addition, there are typically many considerations, about which an inquest has not received any evidence, that may be impacted by the implementation of such recommendations.

25.29 In this case, the evidence indicates that whilst CASA has indicated a graded response approach to the issue of CO detectors, no steps have been taken beyond the issuing of different versions of an AWB and promoting the issue of CO events in its own publications. It is clear that there are likewise many considerations which inform the original recommendation made by the ATSB in this regard. Given that CASA has expressed a willingness to engage with the ATSB regarding these considerations, it is necessary to make the following recommendations.

25.30 **Recommendation 4:** I recommend to the Chief Executive Officer, Civil Aviation Safety Authority, that further engagement occur with the Australian Transport Safety Bureau to better understand the basis for the ATSB recommendation that carbon monoxide detectors in piston engine aircraft, particularly for commercial passenger carrying operations, be mandated. Such engagement should give rise to further consideration being given by CASA as to the appropriateness of such mandatory action, including monitoring study data to determine what types of carbon monoxide detectors function most reliably in piston engine aircraft cabins.

25.31 **Recommendation 5:** I recommend to the Chief Executive Officer, Civil Aviation Safety Authority, that pending reconsideration mandating the installation of carbon monoxide detectors, CASA develop and implement a specific program for regularly promoting the voluntary installation of electronic carbon monoxide detectors in piston engine aircraft, involving regular and appropriate communication to aircraft owners and maintainers.

Fitment of on-board recording devices

25.32 In its final report the ATSB also recommended that CASA mandate the fitment of an on-board recording device for certain small passenger carrying aircraft such as VH-NOO. Mr Shaw gave evidence that Sydney Seaplanes had not fitted such recorders in its fleet because of the cost (approximately $75,000) and because such recorders would take up considerable space in areas that would otherwise be used to store baggage, with the DHC-2 not having been designed for such recorders to be installed. Mr Punshon gave evidence that he was aware that improvements in technology mean that there are recording devices that are more suitable for fitment in small aircrafts, because they are not designed for the higher loads and impact forces that can be associated with larger transport aircraft.

25.33 In accordance with relevant guidelines issued by the International Civil Aviation Organisation (**ICAO**), flight data recorders and cockpit voice recorders are required for aircraft that have 10 or more seats and are turbine powered. However, the ICAO has not issued any guideline or recommendation regarding the use of such recorders in aircraft of less weight and different construction. However, Mr Punshon explained that he was aware of a panel that was considering this issue. Mr Punshon gave evidence that internationally, Transport Canada has formed a task force to consider whether fitment of lightweight data recorders ought to be recommended, but that the FAA was not planning to take any action this time. In terms of the approach of CASA, Mr Punshon explained:

> As neither of them have progressed to making a decision to amending the legislation along with ICAO, we are watching what they do to see whether there's any changes.
> […]
> [I]f [ICAO] change their guidelines then CASA will amend - review those changes because we're a signatory to the ICAO as a member, and so we tend to follow their guidelines and practices that they publish.

25.34 Mr Punshon gave evidence that flight recorders for aircraft under 5,700 kilograms are not an operational safety issue and relevant only to an accident investigation. Whilst pointing out that such an investigation might take several years, Mr Punshon acknowledged that if a recorder survived an accident then it may provide information that is relevant from an operational safety perspective.

25.35 Mr Punshon gave evidence that the costings for fitment of a single flight recorder ranged from approximately $11,500 up to approximately $43,000. If such recorders were to be fitted in both piston and turbine aircraft across the general aviation fleet (approximately 13,812 aircraft) the total cost, factoring in maintenance costs, would be between $175-$600 million.

25.36 Mr Punshon gave evidence that voluntary fitment of a flight recorder could provide data to a commercial operator to inform their safety management system, train pilots, maintain the aircraft and improve their operation. In other words, the data would have direct value on the day-to-day operation of the operator from a safety perspective, and not just for accident mitigation. Mr Punshon referred to a division within CASA concerning stakeholder engagement which could assist with educating the industry on the benefits of flight recorders. In this regard, Mr Punshon was receptive to the idea of CASA working with the ATSB to promote voluntary installation of such recorders to demonstrate the benefit in doing so from the perspective of both agencies.

25.37 CASA observed that:

(a) the ATSB did not provide a cost benefit analysis to support mandating the fitment of such devices;

(b) there are a number of considerations involved with the fitment of such devices including the cost and expense involved, the reliability of such devices, the survivability of such devices in an accident, and difficulties associated with the retrofitting of such devices;

(c) an operator is unable to access information from these devices;

(d) CASA would also be unable to access this information as the recordings of persons on the flight deck of an aircraft would be regarded as restricted information pursuant to the *Civil Aviation Act 1988*; and

(e) the only organisation that would benefit from the fitment of such devices would be the ATSB (assuming that a device is still functional following an accident).

25.38 Consistent with Mr Punshon's evidence that information obtained from a recorder which was still functional after an accident from a operational safety perspective, CASA observed the need for the ATSB to provide an appropriate analysis demonstrating a measurable improvement in the outcomes of their investigation, "*particularly demonstrating those active investigations in the past that would have been able to be concluded if onboarding recording equipment was available*".

25.39 Notwithstanding the above, CASA expressed a willingness to engage in discussions with the ATSB as to the feasibility of developing a program for promoting the voluntary installation of on-board recording devices.

25.40 **Conclusions:** The available evidence has not been able to establish whether the utility of information derived from on-board recording devices for commercial passenger-carrying aircraft with a maximum take-off weight of less than 5700 kilograms extends beyond accident investigation. This is because there may be legislative impediments to the use of such information for other purposes, and because use of the information primarily depends upon it been preserved in the event of an accident.

25.41 However, the evidence of Mr Punshon at the least establishes the potential for the information to be used beyond accident investigation by, for example, informing the day-to-day conduct of an operator from a safety perspective. Clearly, further engagement is required between ATSB and CASA to determine whether these considerations ought to give rise to mandating the fitment of such devices for certain aircraft. In the meantime, CASA has indicated a willingness to engage with the ATSB regarding the feasibility of developing a program for promoting the voluntary fitment of such devices.

25.42 Having regard to the above matters, it is necessary to make the following recommendations.

25.43 **Recommendation 6:** I recommend to the Chief Executive Officer, Civil Aviation Safety Authority, that further engagement occur with the Australian Transport Safety Bureau to better understand whether a cost benefit analysis exists to support mandating the fitment of on-board recording devices in commercial passenger-carrying aircraft with a maximum take-off weight of less than 5,700 kilograms. Such engagement should give rise to further consideration being given by CASA as to the appropriateness of such mandatory action.

25.44 **Recommendation 7:** I recommend to the Chief Executive Officer, Civil Aviation Safety Authority, that pending further consideration by CASA of mandating the fitment of on-board recording devices in small passenger-carrying aircraft under 5,700 kilograms, further engagement occur with the Australian Transport Safety Bureau to devise a program for promoting the voluntary installation of such devices in such aircraft.

25.45 **Recommendation 8:** I recommend to the Chief Commissioner, Australian Transport Safety Bureau that the ATSB engage with CASA to address the issue of whether fitment of on-board recording devices in small passenger-carrying aircraft under 5,700 kilograms will demonstrate a measurable improvement in the outcome of investigations conducted by the ATSB, particularly in relation to whether the absence of such devices has resulted in the non-identification of safety issues which continue to present a hazard to current and future passenger carrying operations.

26. Findings pursuant to section 81(1) of the Act

26.1 It was submitted on behalf of Airag and Mr Land that the "*Court should make an open finding as to the cause of the [accident]*". An open finding is typically returned at the conclusion of an inquest when the available evidence does not allow a Coroner to make findings in accordance with section 81(1) of the Act. Here, there is sufficient evidence to make findings in relation to each of the matters set out at section 81(1)(a), (b) and (c), namely the identify of each person that died, the date and place of their death, and the cause and manner of their death.

26.2 To the extent that the submission refers to the cause of the accident as being part of the manner of death for the pilot and passengers of VH-NOO there is sufficient evidence, for the reasons set out above for a finding to be made in this regard.

26.3 Before turning to the findings that are required to be made, I would like to acknowledge, and express my gratitude to Ms Sophie Callan SC and Ms Joanna Davidson, Counsel Assisting, and their instructing solicitor, Ms Amber Doyle from the Crown Solicitor's Office. The Assisting Team has provided exceptional assistance during the conduct of the coronial investigation and throughout the course of the inquest. I am extremely grateful for their commitment and tireless efforts, particularly having regard to the complexity of issues involved in this coronial investigation, and for the empathy and compassion that they have shown during all stages of the coronial process.

26.4 I also thank Detective Sergeant O'Keefe for his role in conducting a comprehensive investigation and for preparing the initial brief of evidence.

26.5 The findings I make under section 81(1) of the Act in relation to the death of **Emma Bowden** are:

Identity
The person who died was Emma Bowden.

Date of death
Emma died on 31 December 2017.

Place of death
Emma died at Jerusalem Bay, Brooklyn NSW 2083.

Cause of death
The cause of Emma's death was the combined effects of multiple injuries and immersion.

Manner of death
Emma died whilst a passenger in aircraft registration VH-NOO which experienced aerodynamic stall while partway through a low level steep turn at a bank angle in excess of what was required. This caused the aircraft to descend and impact with the water in Jerusalem Bay.

There is no reliable evidence that an acute medical event or a chronic underlying medical condition involving the pilot, distraction of the pilot as a result of an unexpected event in the aircraft cabin, meteorological conditions, mechanical failure or pilot error caused or contributed to the accident.

Instead, cracks in the aircraft's exhaust collector ring allowed exhaust gases with high carbon monoxide concentrations to pass from the exhaust assembly into the aircraft cabin. Whilst the mechanism of carbon monoxide ingress into the cabin cannot be precisely determined it is most likely that holes in the magneto access panels left open by three missing bolts and gaps around an incorrectly oriented magneto access panel provided the route of entry. Exposure to carbon monoxide in the cabin resulted in an elevated carboxyhaemoglobin level in the pilot which impaired the pilot's ability to operate the aircraft safely, especially given the complexity of this task.

26.6 The findings I make under section 81(1) of the Act in relation to the death of **Heather Bowden-Page** are:

Identity
The person who died was Heather Bowden-Page.

Date of death
Heather died on 31 December 2017.

Place of death
Heather died at Jerusalem Bay, Brooklyn NSW 2083.

Cause of death
The cause of Heather's death was the combined effects of multiple injuries and immersion.

Manner of death
Heather died whilst a passenger in aircraft registration VH-NOO which experienced aerodynamic stall while partway through a low level steep turn at a bank angle in excess of what was required. This caused the aircraft to descend and impact with the water in Jerusalem Bay.

There is no reliable evidence that an acute medical event or a chronic underlying medical condition involving the pilot, distraction of the pilot as a result of an unexpected event in the aircraft cabin, meteorological conditions, mechanical failure or pilot error caused or contributed to the accident.

Instead, cracks in the aircraft's exhaust collector ring allowed exhaust gases with high carbon monoxide concentrations to pass from the exhaust assembly into the aircraft cabin. Whilst the mechanism of carbon monoxide ingress into the cabin cannot be precisely determined it is most likely that holes in the magneto access panels left open by three missing bolts and gaps around a misoriented magneto access panel provided the route of entry. Exposure to carbon monoxide in the cabin resulted in an elevated carboxyhaemoglobin level in the pilot which impaired the pilot's ability to operate the aircraft safely, especially given the complexity of this task.

26.7 The findings I make under section 81(1) of the Act in relation to the death of **Edward Cousins** are:

Identity
The person who died was Edward Cousins.

Date of death
Edward died on 31 December 2017.

Place of death
Edward died at Jerusalem Bay, Brooklyn NSW 2083.

Cause of death
The cause of Edward's death was the combined effects of multiple injuries and immersion.

Manner of death
Edward died whilst a passenger in aircraft registration VH-NOO which experienced aerodynamic stall while partway through a low level steep turn at a bank angle in excess of what was required. This caused the aircraft to descend and impact with the water in Jerusalem Bay.

There is no reliable evidence that an acute medical event or a chronic underlying medical condition involving the pilot, distraction of the pilot as a result of an unexpected event in the aircraft cabin, meteorological conditions, mechanical failure or pilot error caused or contributed to the accident.

Instead, cracks in the aircraft's exhaust collector ring allowed exhaust gases with high carbon monoxide concentrations to pass from the exhaust assembly into the aircraft cabin. Whilst the mechanism of carbon monoxide ingress into the cabin cannot be precisely determined it is most likely that holes in the magneto access panels left open by three missing bolts and gaps around a misoriented magneto access panel provided the route of entry. Exposure to carbon monoxide in the cabin resulted in an elevated carboxyhaemoglobin level in the pilot which impaired the pilot's ability to operate the aircraft safely, especially given the complexity of this task.

26.8 The findings I make under section 81(1) of the Act in relation to the death of Richard Cousins are:

Identity
The person who died was Richard Cousins.

Date of death
Richard died on 31 December 2017.

Place of death
Richard died at Jerusalem Bay, Brooklyn NSW 2083.

Cause of death
The cause of Richard's death was multiple blunt force injuries.

Manner of death
Richard died whilst a passenger in aircraft registration VH-NOO which experienced aerodynamic stall while partway through a low level steep turn at a bank angle in excess of what was required. This caused the aircraft to descend and impact with the water in Jerusalem Bay.

There is no reliable evidence that an acute medical event or a chronic underlying medical condition involving the pilot, distraction of the pilot as a result of an unexpected event in the aircraft cabin, meteorological conditions, mechanical failure or pilot error caused or contributed to the accident.

Instead, cracks in the aircraft's exhaust collector ring allowed exhaust gases with high carbon monoxide concentrations to pass from the exhaust assembly into the aircraft cabin. Whilst the mechanism of carbon monoxide ingress into the cabin cannot be precisely determined it is most likely that holes in the magneto access panels left open by three missing bolts and gaps around a misoriented magneto access panel provided the route of entry. Exposure to carbon monoxide in the cabin resulted in an elevated carboxyhaemoglobin level in the pilot which impaired the pilot's ability to operate the aircraft safely, especially given the complexity of this task.

26.9 The findings I make under section 81(1) of the Act in relation to the death of **William Cousins** are:

Identity
The person who died was William Cousins.

Date of death
William died on 31 December 2017.

Place of death
William died at Jerusalem Bay, Brooklyn NSW 2083.

Cause of death
The cause of William's death was the combined effects of multiple injuries and immersion.

Manner of death
William died whilst a passenger in aircraft registration VH-NOO which experienced aerodynamic stall while partway through a low level steep turn at a bank angle in excess of what was required. This caused the aircraft to descend and impact with the water in Jerusalem Bay.

There is no reliable evidence that an acute medical event or a chronic underlying medical condition involving the pilot, distraction of the pilot as a result of an unexpected event in the aircraft cabin, meteorological conditions, mechanical failure or pilot error caused or contributed to the accident.

Instead, cracks in the aircraft's exhaust collector ring allowed exhaust gases with high carbon monoxide concentrations to pass from the exhaust assembly into the aircraft cabin. Whilst the mechanism of carbon monoxide ingress into the cabin cannot be precisely determined it is most likely that holes in the magneto access panels left open by three missing bolts and gaps around a misoriented magneto access panel provided the route of entry. Exposure to carbon monoxide in the cabin resulted in an elevated carboxyhaemoglobin level in the pilot which impaired the pilot's ability to operate the aircraft safely, especially given the complexity of this task.

26.10 The findings I make under section 81(1) of the Act in relation to the death of **Gareth Morgan** are:

Identity
The person who died was Gareth Morgan.

Date of death
Gareth died on 31 December 2017.

Place of death
Gareth died at Jerusalem Bay, Brooklyn NSW 2083.

Cause of death
The cause of Gareth's death was multiple blunt force injuries.

Manner of death
Gareth died whilst piloting aircraft registration VH-NOO which experienced aerodynamic stall while partway through a low level steep turn at a bank angle in excess of what was required. This caused the aircraft to descend and impact with the water in Jerusalem Bay.

There is no reliable evidence that an acute medical event or a chronic underlying medical condition involving Gareth, distraction of Gareth as a result of an unexpected event in the aircraft cabin, meteorological conditions, mechanical failure or pilot error caused or contributed to the accident.

Instead, cracks in the aircraft's exhaust collector ring allowed exhaust gases with high carbon monoxide concentrations to pass from the exhaust assembly into the aircraft cabin. Whilst the mechanism of carbon monoxide ingress into the cabin cannot be precisely determined it is most likely that holes in the magneto access panels left open by three missing bolts and gaps around a misoriented magneto access panel provided the route of entry. Exposure to carbon monoxide in the cabin resulted in an elevated carboxyhaemoglobin level in Gareth which impaired his ability to operate the aircraft safely, especially given the complexity of this task.

27. Epilogue

27.1 The sudden and unexpected deaths of six people in a single event is truly heartbreaking. There is no doubt that the deaths of the pilot and passengers of VH-NOO was extraordinarily tragic and untimely, and that their loss is still very deeply felt by all of their family members and loved ones.

27.2 On behalf of the Coroners Court of New South Wales, I offer my sincere and respectful condolences, to the relatives, loved ones and friends of Emma, Heather, Edward, Richard, William and Gareth for their devastating loss.

27.3 I close this inquest.

Magistrate Derek Lee
Deputy State Coroner
26 May 2023
Coroners Court of New South Wales

Inquest into the deaths of Emma Bowden, Heather Bowden-Page, Edward Cousins, Richard Cousins, William Cousins & Gareth Morgan

Appendix A

Recommendations made pursuant to section 82, *Coroners Act 2009*

To the Chief Executive Officer, Airag Aviation Services Pty Ltd (Airag):

1. I recommend that Airag institute a written policy for its staff, requiring removal and installation of firewall access panels on DHC-2 aircraft to be inspected for conformity by its Chief Engineer, and a test for the presence of carbon monoxide to be conducted prior to the aircraft being returned to service.

2. I recommend that Airag institute a written policy for its staff requiring that following maintenance work being conducted on the engine exhaust system of a piston engine aircraft, whether scheduled or unscheduled, a test for the presence of carbon monoxide is conducted.

To the Chief Executive, NSW Health Pathology:

3. I recommend that carbon monoxide screening be conducted as part of standard toxicology testing by the NSW Health Pathology Forensic and Analytical Science Service in all deaths resulting from aviation incidents, subject to an appropriate biological sample from the deceased person(s) being available.

To the Chief Executive Officer, Civil Aviation Safety Authority (CASA):

4. I recommend that further engagement occur with the Australian Transport Safety Bureau to better understand the basis for the ATSB recommendation that carbon monoxide detectors in piston engine aircraft, particularly for commercial passenger carrying operations, be mandated. Such engagement should give rise to further consideration being given by CASA as to the appropriateness of such mandatory action, including monitoring study data to determine what types of carbon monoxide detectors function most reliably in piston engine aircraft cabins.

5. I recommend that pending reconsideration mandating the installation of carbon monoxide detectors, CASA develop and implement a specific program for regularly promoting the voluntary installation of electronic carbon monoxide detectors in piston engine aircraft, involving regular and appropriate communication to aircraft owners and maintainers.

6. I recommend that further engagement occur with the Australian Transport Safety Bureau to better understand whether a cost benefit analysis exists to support mandating the fitment of on-board recording devices in commercial passenger-carrying aircraft with a maximum take-off weight of less than 5,700 kilograms. Such engagement should give rise to further consideration being given by CASA as to the appropriateness of such mandatory action.

7. I recommend that pending further consideration by CASA of mandating the fitment of on-board recording devices in small passenger-carrying aircraft under 5,700 kilograms, further engagement occur with the Australian Transport Safety Bureau to devise a program for promoting the voluntary installation of such devices in such aircraft.

To the Chief Commissioner, Australian Transport Safety Bureau (ATSB):

8. I recommend that the ATSB engage with CASA to address the issue of whether fitment of on-board recording devices in small passenger-carrying aircraft under 5,700 kilograms will demonstrate a measurable improvement in the outcome of investigations conducted by the ATSB, particularly in relation to whether the absence of such devices has resulted in the non-identification of safety issues which continue to present a hazard to current and future passenger carrying operations.

Magistrate Derek Lee
Deputy State Coroner
26 May 2023
Coroners Court of New South Wales