Australian Government
Australian Transport Safety Bureau

Collision with terrain involving Lockheed Martin EC-130Q, N134CG

50 km north-east of Cooma-Snowy Mountains Airport (near Peak View), New South Wales, on 23 January 2020

ATSB Transport Safety Report
Aviation Occurrence Investigation (Systemic)
AO-2020-007
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Cover photo: Bidgee, Coulson Aviation (N134CG) Lockheed EC-130Q Hercules departing HMAS Albatross, 9 December 2019, under the Creative Commons Attribution-Share Alike 3.0 Australia license.

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Addendum

Page	Change	Date

Executive summary

What happened

On 23 January 2020, the crew of a Lockheed Corporation (now Lockheed Martin) EC-130Q large air tanker, registered N134CG, were conducting bushfire control operations in the Snowy Mountains region of New South Wales. After assessing the initial fire-retardant drop site at Adaminaby as not suitable, the crew accepted an alternate tasking to the Good Good (Peak View) fire-ground.

After conducting a partial retardant drop at Peak View, the aircraft was in a left turn and climbed for about 10 seconds to about 170 ft above the drop height. Following this, the aircraft was then observed descending. The aircraft was seen at a very low height above the ground, in a slight left bank, immediately followed by a significant left roll just before ground impact. The 3 crew were fatally injured and the aircraft destroyed.

What the ATSB found

The ATSB found that the forecast and actual weather conditions present in the Snowy Mountains region were hazardous, with strong gusting winds and mountain wave activity, producing turbulence. This was likely exacerbated by the fire and local terrain. Subsequently, the ATSB determined that the conditions were conducive to windshear and downdraft development at a time when the aircraft was most vulnerable, with a low airspeed and at a low altitude.

Despite an awareness of these conditions and that all other fire-control aircraft (including a Boeing 737 large air tanker) were not operating in the area at the time due to the weather conditions, the New South Wales Rural Fire Service (RFS) continued with their tasking of N134CG to Adaminaby without aerial supervision (birddog). In addition, they relied on the pilot in command to assess the appropriateness of the tasking but did not provide them all the available information to make an informed decision on flight safety. That information for the tasking to Adaminaby included details about actual hazardous environmental conditions, resulting in the cessation of local aerial operations, the birddog pilot declining the tasking due to the forecast weather conditions, and a report from the Boeing 737 crew that conditions precluded them from returning to the fire-ground.

The crew of N134CG were therefore very likely not aware that the birddog pilot had declined the tasking to the Adaminaby fire-ground, nor that the smaller fire-control aircraft had ceased operations in the area, due to the hazardous environmental conditions. While this was only one risk factor among others that would be considered by the crew when accepting a task, having this information would have allowed them to make a more informed decision about the weather conditions.

Nonetheless, the pilot in command of N134CG accepted the tasking to the Adaminaby fire-ground, which was subject to hazardous environmental conditions. After assessing the conditions as unsuitable at Adaminaby, the crew accepted an alternative tasking to continue to the Good Good fire-ground, which had the same weather conditions. The acceptance of these taskings was consistent with the operator’s practices to depart and assess the conditions to find a workable solution rather than rely solely on a weather forecast, which may not necessarily reflect the actual conditions at the fire-ground.

At the Good Good fire-ground, following a partial retardant drop and left turn, the aircraft was very likely subjected to hazardous environmental conditions including low-level windshear and an increased tailwind component. From a combination of witness video, and real-time position and flight path data, it was established that the aircraft’s climb performance degraded. Subsequently, while at a low height and airspeed, it was likely the aircraft aerodynamically stalled, resulting in a collision with terrain. In the limited time available, the remainder of the fire-retardant load was not jettisoned prior to the aircraft stalling.

The ATSB established that, while a safety management system was not required under Australian regulations at the time of the accident, Coulson Aviation's safety risk management processes did not adequately manage the risks associated with large air tanker operations. In particular, they had not conducted formal risk assessments of the hazards identified in their operations manual, and did not maintain a tool, such as a risk register, to track risk acceptance levels. Further, incident reports submitted through the safety reporting system were mainly related to maintenance issues, and therefore operational risks were less likely to be considered or monitored. This limited their ability to identify and implement control measures to manage the risks associated with their aerial firefighting operations.

It is critical that crews can differentiate between a low-risk and high-risk flight during the planning stage to establish the overall risk profile. While identifying it as a high-risk activity, Coulson Aviation had not identified a need for a pre-flight risk assessment for their firefighting large air tanker crews. This would have provided crews with predefined criteria to ensure consistent and objective decision-making with accepting or rejecting tasks, and include factors relating to crew, environment, aircraft and external pressures and factors.

There are a number of mitigators for windshear, including pilot training and procedures, and airborne detection systems. However, Coulson Aviation did not include a windshear recovery procedure in their C-130 Airplane Flight Manual. Further, it was noted that a briefing on windshear recovery was incorporated into the training syllabus, but there was no requirement to conduct a simulator-based low-level windshear recovery scenario. Combined, these strategies could provide crews with the experience needed to recognise the symptoms of windshear and practice a recovery procedure. In addition, Coulson Aviation had not assessed their fleet of C-130 aircraft for fitment with a windshear detection system. This increased the risk of a windshear encounter and/or delayed response to an encounter.

While the New South Wales RFS was not an aviation organisation or directly responsible for flight safety, they were closely involved in the aerial operation, being responsible for determining the task objectives and selecting aircraft for the task. The ATSB found that the RFS had limited large air tanker policies and procedures for aerial supervision requirements and no procedures for deployment without aerial supervision. In addition, they did not have a policy or procedures in place to manage task rejections, nor to communicate this information internally or to other pilots working in the same area of operation. Such policies and associated procedures would provide frontline personnel with the required steps to effectively and safely manage taskings, and provide guidance for decision-making.

It was also identified that, while not applicable to the accident crew, the RFS procedures allowed aircraft operators to determine when pilots were initial attack capable. This was inconsistent with their intention for pilots to be certified by the United States Department of Agriculture Forest Service certification process.

While not contributing to the accident, the aircraft's cockpit voice recorder did not record the accident flight. This resulted in a valuable source of safety information not being available to the investigation, which not only increased the time taken to determine contributing factors to the accident but also limited the extent to which important safety issues could be identified and analysed.

What has been done as a result

As a result of this investigation, Coulson Aviation have incorporated a windshear recovery procedure into their C-130 Airplane Flight Manuals and plan to introduce simulator-based recurrent windshear training. Related to the consideration of risk in aerial firefighting operations, they have also implemented a pre-flight risk assessment to be completed by the pilot in command prior to the first tasking of the day. They will also be introducing a three-tier risk management approach, of organisational risk, operational risk, and tactical/mission risk, to be utilised during the upcoming fire season in Australia. Further, Coulson Aviation have updated their pre-flight procedures to incorporate a cockpit voice recorder system check before each flight. Lastly, the Retardant Aerial Delivery System software was reprogrammed so that the system will not require re-arming between partial load drops where less than 100% was selected.

The ATSB has issued 2 safety recommendations to Coulson Aviation. These are to further consider:

- fitment of a windshear detection system to their C-130 aircraft to minimise the time taken for crews to recognise and respond to an encounter particularly when operating at low-level and low speed
- incorporating foreseeable external factors into their pre-flight assessment tool to ensure the overall risk profile of a tasking can be consistently assessed by crews.

The New South Wales Rural Fire Service advised the ATSB that they intend to take the following actions in response to this accident:

- Commissioned an independent report into the management of airspace in which aircraft are operating in support of fire-fighting activities.
- Formalise and establish a 'Large Air Tanker Co-ordinator' role description, to be positioned on the State Air Desk during heightened fire activity.
- Undertake an immediate audit, in conjunction with operators, of pilots qualified as initial attack capable and ensure appropriate records are accessible by RFS personnel.
- Undertake detailed research to identify best practice (nationally and internationally) relating to task rejection and aerial supervision policies and procedures as well as initial attack training and certification.
- Undertake a comprehensive review of RFS aviation doctrine to incorporate outcomes of the above-mentioned research into existing policies and procedures.
- Promulgate the revised doctrine detailing the task rejection policies and procedures and aerial supervision requirements to all operational personnel, pilots/aircrew and other key stakeholders. This is to be reinforced at the aviation operators briefing held annually prior to the bushfire season.
- Provide the National Aerial Firefighting Centre and national fire-fighting agencies with copies of the updated doctrine relating to these issues.

While the ATSB acknowledges the commitment to undertake reviews and research, at the time of publication, the New South Wales Rural Fire Service had not yet committed to adopting any safety action that would reduce the risk associated with the 3 identified safety issues to an acceptable level. As such, the ATSB has issued three safety recommendations to the RFS to take further action:

- to address the absence of policies and procedures for personnel to effectively manage and communicate task rejections on the basis of operational safety concerns
- to address the absence of policies and procedures regarding minimum aerial supervision requirements and the use of initial attack to assist frontline staff with making acceptable risk-based tasking decisions
- to address the ambiguity with the interpretation of 'initial attack' in the NSW and ACT Aviation Standard Operating Procedures with the intent of this requirement.

Safety message

As noted by the National Aerial Firefighting Centre, aerial firefighting has become a critical capability for the management and suppression of bushfires in Australia. To effectively achieve this, aircraft are flown at low altitudes and low airspeeds, often in challenging environmental conditions. This creates a high-risk environment, which requires a continued focus on risk mitigation.

Previous research conducted by the ATSB emphasised that any decisions made by tasking agencies during the management of an aerial campaigns (firefighting) could influence the level of risk of the operation. Therefore, if safety was to be maintained, this responsibility had to be shared between the tasking agency and the aircraft operator. This accident highlights the importance of having effective risk management processes, supported by robust operating procedures and training to support that shared responsibility.

While the identification of hazards is the initial step in safety risk management, conducting risk assessments, implementing risk mitigators, and having effective oversight of the process though a tool such as a risk register are critical aspects of this process. This provides the mechanism for organisations to consider the specific challenges associated with firefighting operations such as hazardous environmental conditions, and ensure they have the appropriate risk controls in place to support crew decision-making when conducting high-risk activities.

Further, the adoption of good systems for managing risk by the tasking agency could provide an effective additional layer of defences over and above that provided by each aircraft operator to protect against an incident or accident. This also ensures that one aspect of the operation does not compromise another aspect. This may include the development of procedures to support decision-making processes rather than personnel having to exercise judgement to the best of their abilities, based on their experience, skills and knowledge. This would include aspects such as tasking decisions, task rejection policies and procedures, and minimum aerial supervision requirements.

Contents

The occurrence

Overview

During the Australian 'black summer' of 2019-2020, the east coast experienced many severe bushfires. As part of the firefighting efforts, small and large aircraft were used for aerial fire suppression and intelligence gathering. The larger aircraft included large air tankers (LATs),[1] located at the Richmond Royal Australian Air Force (RAAF) Base, New South Wales (NSW). This included a United States-registered Lockheed Martin EC-130Q,[2] registered N134CG, operated by Coulson Aviation. On 23 January 2020, the aircraft was applying retardant for property protection in the Good Good fire-ground (near Peak View) in the Snowy Mountains region of NSW. While attempting to climb away after a partial fire-retardant drop, the aircraft collided with terrain. The 3 crew were fatally injured and the aircraft was destroyed.

Daily briefings at Richmond Base

On 23 January 2020, at about 0900 Eastern Daylight-saving Time,[3] the NSW Rural Fire Service (RFS) Richmond airbase manager (ABM)[4] had conducted a briefing with the crews of the air tanker and birddog[5] aircraft based there. The briefing included the current and anticipated fire activity and discussed fire-related weather conditions across the state. Following the briefing, the crews then remained on standby until they received a tasking from the RFS, with a contracted 15-minute departure time following the completion of retardant loading.

The operator of two LATs at Richmond, Coulson Aviation, reported[6] that they had also conducted their daily safety management system call between management and crews, which would typically discuss the operations to be conducted on the day, and any reported issues encountered in the previous 24 hours. However, as there were no notes taken for the call, the details of the conversation were unknown.

Fire situation in the Snowy Mountains region

On the day, the Snowy Mountains region in NSW had a severe fire danger rating,[7] due to high temperatures, strong winds and forecast thunderstorms. This region included the Adaminaby and Good Good fire-grounds, which were both under the control of the RFS Cooma Fire Control Centre (FCC).[8]

At about 1100, the Cooma FCC incident controller[9] made a phone call to the RFS State Operations Centre.[10] A number of senior personnel from the State Operations Centre were involved in the conference call. They discussed the escalating fire danger at the Adaminaby

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1 A large air tanker (LAT) is an aircraft with a minimum suppressant/retardant capacity of 3,000 US gallons (11,356 L).

2 The aircraft was initially built as an EC-130Q, however, all specialised military equipment had been removed, and it was considered to be the equivalent of a C-130H. Throughout the report, the aircraft is referred to as a C-130.

3 Eastern Daylight-saving Time (EDT): Coordinated Universal Time (UTC) + 11 hours.

4 The airbase manager was responsible for the supervision and coordination of airbase personnel, and the layout and operation of an airbase. There were 2 airbase manager's operating at Richmond on the morning of the accident.

5 Birddog aircraft were used to lead large air tanker aircraft across the fire-ground and provide guidance on the release of the water or fire suppressant (retardant or gel).

6 Provided by Coulson Aviation in response to the draft report on 10 July 2022.

7 The NSW RFS fire danger ratings provide an indication of the possible consequences of a fire and are based on predicted conditions including but not limited to temperature, humidity, wind, and the dryness of the landscape.

8 A FCC forms the administrative and operational base of the rural fire district or zone. The coordination and management of local brigade responses to fire and other incidents was undertaken through the FCC.

9 The incident controller was responsible for all aspects of an emergency response, including the objectives, operations, and application of resources of the FCC.

10 The State Operations Centre coordinated the NSW multiagency state-wide response and provided a variety of specialised resources to the FCC.

fire-ground, with rural properties under threat and concern the town would be impacted if containment lines did not hold. During that call, RFS personnel stated that there were strong winds, severe fire weather conditions, and that the smaller fire-control aircraft were not operating in the area due to the winds and poor visibility. There was also discussion as to whether a birddog aircraft had already departed to assess the conditions. However, a senior RFS officer stated they should send the Boeing 737 LAT aircraft irrespective, 'as it can bomb by itself if need be' and 'not wait for the birddog assessment'.

Consequently, the State Operations Centre tasked 2 LATs[11] and a birddog to the Adaminaby fire-ground: a Boeing 737 aircraft, registered N137CG, call sign 'Bomber 137' (B137); a Lockheed Martin C-130 aircraft, registered N134CG, call sign 'Bomber 134' (B134); and a Rockwell International 690-B aircraft (operating as a birddog). All 3 aircraft were based at the Richmond Base, about 316 km north-east of the Adaminaby fire-ground.

'B137' tasking to Adaminaby

Following the 1100 call, the tasking was communicated by the state air desk (SAD)[12] to the Richmond ABM. At 1120, the Cooma aerial operations manager log recorded that LATs were inbound, with no birddog. At about 1121, the crew of B137 had commenced taxiing at Richmond for another task to the north[13] when they were re-tasked to the Adaminaby fire-ground by the ABM. After the initial coordinates, location details, and information regarding the expected direction of the fire were provided, the pilot in command (PIC) of B137 requested details for the fire common traffic advisory frequency. The Richmond ABM was unable to provide these details immediately, but indicated the SAD 'want to get them in the air and down there'. The ABM also advised the crew of the objective to 'keep the fire out of Adaminaby', that 'the fire is burning towards the north-west', that there were no other aircraft in the area, and that it 'is very windy down there….take care'. The ABM further advised 'the birddog won't be down there'.[14] Therefore, the PIC was aware they would be operating as initial attack.[15] The aircraft subsequently departed at about 1127.

While en route, the crew contacted various fire centres to determine the correct ground-based contact, eventually communicating with the Cooma aviation radio operator (ARO), located at the Cooma FCC. At about 1155, B137 arrived overhead the Adaminaby fire-ground, but the crew were unsure of the actual planned location for the drop. After further discussion with the ARO, it was determined they were overhead the intended location.

Due to the weather conditions and ground-based fire-fighters in the planned drop area, the crew orbited for about 25 minutes. At interview, the PIC reported that, while assessing the conditions in the Adaminaby area, the aircraft encountered uncommanded rolls up to 45° angle of bank (due to wind) and they received a windshear[16] warning from the aircraft's onboard systems.[17] The PIC elected to operate on the upwind side of the hills to avoid lee side mechanical turbulence.[18] They

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[11] The tasking of B137 and B134 to Adaminaby was annotated in the Richmond ABM's log, which specifically noted that the birddog was not accompanying either aircraft, the conditions were 'windy', and for the crews to 'only do what they can do safely'. However, this log entry was at 1049, shortly before the phone call between the Cooma FCC incident controller and the RFS State Operations Centre where it was questioned if the birddog had already departed. These time discrepancies could not be resolved by the ATSB.

[12] The state level multiagency team located in the State Operations Centre responsible for coordination of aircraft operations.

[13] B137 was to be accompanied by a birddog for the tasking to the north.

[14] Where there was an urgency to dispatch aircraft due to the rapid spread or the impending impact of the fire, it was standard practice to launch the LATs at the same time, or ahead of, tasking the associated birddog.

[15] An air tanker initial attack certification allowed a pilot to conduct fire retardant drops without aerial supervision.

[16] Windshear is defined as a wind direction and/or speed change over a vertical or horizontal distance.

[17] B137 was fitted with both predictive and reactive windshear warning systems, and it could not be determined, based on the evidence available, which system provided the warning (refer to section titled *Windshear risk control systems*).

[18] Mechanical turbulence occurs due to frictional forces on the surface wind creating turbulent eddies. The intensity of the turbulence is largely dependent on the wind speed, surface roughness, and atmospheric stability near the surface.

also reported that the wind speed at the Adaminaby fire-ground was 50 kt at 800 ft above ground level (AGL) and about 37 kt at the fire-retardant drop height of 200 ft AGL. At about 1225, B137 departed the Adaminaby fire-ground, having successfully deployed a retardant load.

After completing the retardant drop, the PIC reported that they advised the Cooma ARO to cancel all the aircraft operating in the area, although it was not clear if the ARO had received that message. They also sent a text message to the birddog pilot assigned to the Adaminaby fire-ground indicating that the conditions were 'horrible down there. Don't send anybody and we're not going back'. During B137's return flight to Richmond, at about 1232, the PIC contacted the Richmond ABM and stated they were going 'to put themselves on hold', but would be available for other taskings. The ABM requested that they reload the aircraft with fire retardant in Canberra and return to Adaminaby. The PIC replied that they would not be returning to Adaminaby due to the weather conditions, as the 'winds were getting too strong and the visibility is down', and continued to Richmond. Subsequently, when the ABM communicated B137 PICs decision to the SAD, they indicated the weather was 'fairly dicey…probably won't go back'. There was some discussion as to the availability of other LATs to task to Adaminaby, however, the decision was made to wait for a report from B134 before any further tasking.

Birddog rejection of tasking

Meanwhile, at about 1137, the Richmond ABM contacted the SAD to confirm the dispatch of a birddog to Adaminaby. The birddog crew consisted of the birddog pilot and the LAT air attack supervisor.[19] The ABM had also noted in their log at 1130 and 1140 that they were intending to send the birddog to Adaminaby. The 1130 log entry also indicated that the incident air attack supervisor was not operating 'due to extreme wind conditions'. By the time of the 1137 phone call, B137 had already departed Richmond as initial attack and B134 was being prepared for departure, with the expectation from the RFS that both LATs would do multiple retardant drops. The ABM and SAD discussed that the 2 LATs would beat the birddog to the fire-ground, but it was considered unlikely 'they will get through as [it] will be too windy for them'.[20]

The birddog pilot reported having experienced moderate to severe turbulence in the Snowy Mountains region about 2 weeks prior, which resulted in an uncommanded roll up to 30–40° angle of bank. This, combined with a downdraft, required the pilot to execute an escape manoeuvre. On receipt of the tasking to Adaminaby, the birddog pilot reviewed the weather and concluded that the conditions were forecast to be worse than previously experienced, and therefore declined the task. The RFS reported the SAD log recorded the birddog declining the task to Adaminaby at 1204.

At about 1209, the ABM had a conversation with the SAD and discussed that the birddog pilot was 'questioning the weather conditions'. The SAD instructed the ABM to 'get them on their way, and then turn them around' (that is, rather than accept a rejection based on the forecast, they would prefer they re-assess the conditions in-flight). When the ABM communicated this to the birddog pilot, the pilot indicated to the ABM that B137 would arrive overhead Adaminaby shortly, and they could then report the actual conditions. At about 1235, following a report of the conditions from the PIC of B137, the ABM reportedly agreed that the birddog pilot had made an appropriate assessment to reject the task to Adaminaby.

The birddog pilot reported that they had not spoken to the crew of B134 following the receipt of the tasking on the day of the accident as they were both focussing on their pre-flight planning, which was normal practice. Subsequently, the birddog pilot accepted an alternate tasking at 1259.

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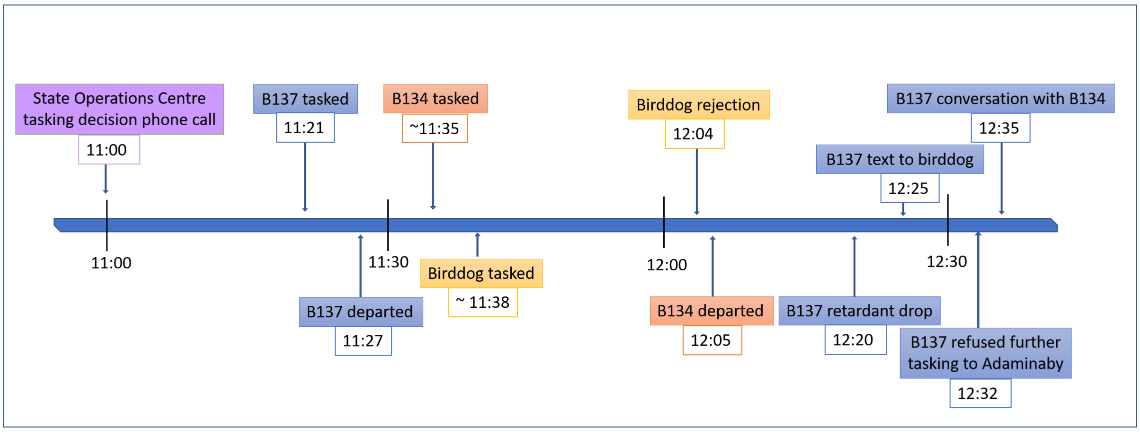
19 The air attack supervisor was a tactical command position, which ensured that aerial operations were consistent with the procedures and incident controller's intent.

20 From this conversation, it was unclear whether the term 'they' referred to all 3 aircraft, that is, B134, B137 and the birddog.

Figure 1 provides a timeline of the key communications regarding tasking allocation for B134, B137 and the birddog.

Figure 1: Timeline of tasking communications



Source: ATSB

'B134' tasking to Adaminaby

At about 1205,[21] while B137 was overhead the Adaminaby fire-ground, and about the same time the SAD logged the birddog rejection, B134 departed Richmond as initial attack. On board were the PIC, the copilot and flight engineer.

In response to the draft report, the RFS provided excerpts from the state operations controller (SOC) log.[22] An entry was written in the log by the SOC following the accident.[23] The SOC noted having been advised that the birddog had indicated it was 'not safe to fly' and that B137 was not returning to the area until the conditions had eased. However, B134 would continue with the PIC to make the 'decision of safety of bombing operations'. The RFS advised the ATSB that the SOC had the authority to cancel B134's tasking, but instead allowed it to proceed, with the intention of gathering additional intelligence to assist in determining whether further aerial operations would proceed. The RFS further reported that this indicated an ongoing intelligence gathering and assessment process by the SOC.

At about 1235, while returning to Richmond, the PIC of B137 heard the PIC of B134 on the Canberra approach frequency, and contacted them via their designated operating frequency. At that time, B134 was about 112 km north-east of Adaminaby, en route to the fire-ground (Figure 2). In this conversation, the PIC of B137 informed them of the actual conditions and that they would not be returning to Adaminaby. The PIC of B137 reported that they could not recall the specific details of the call, but that the conversation included that they were 'getting crazy winds' and 'you can go take a look' 'but I am not going back'. It was also noted that the PIC of B134 had asked several questions. It was reported by the majority of the operator's pilots that, despite receiving information from another pilot, they would have also continued with the tasking under these circumstances, to assess the conditions themselves.

At about 1242, the crew of B134 contacted air traffic control to advise them of the coordinates they would be working at, provide an 'ops normal'[24] call time, and confirm there was no reported

[21] The ABM log recorded the departure of B134 at 1140. This time discrepancy could not be resolved by the ATSB.

[22] The SOC maintains an overall awareness of the firefighting effort across the state ensuring information and warnings are being distributed and resources are being allocated where needed.

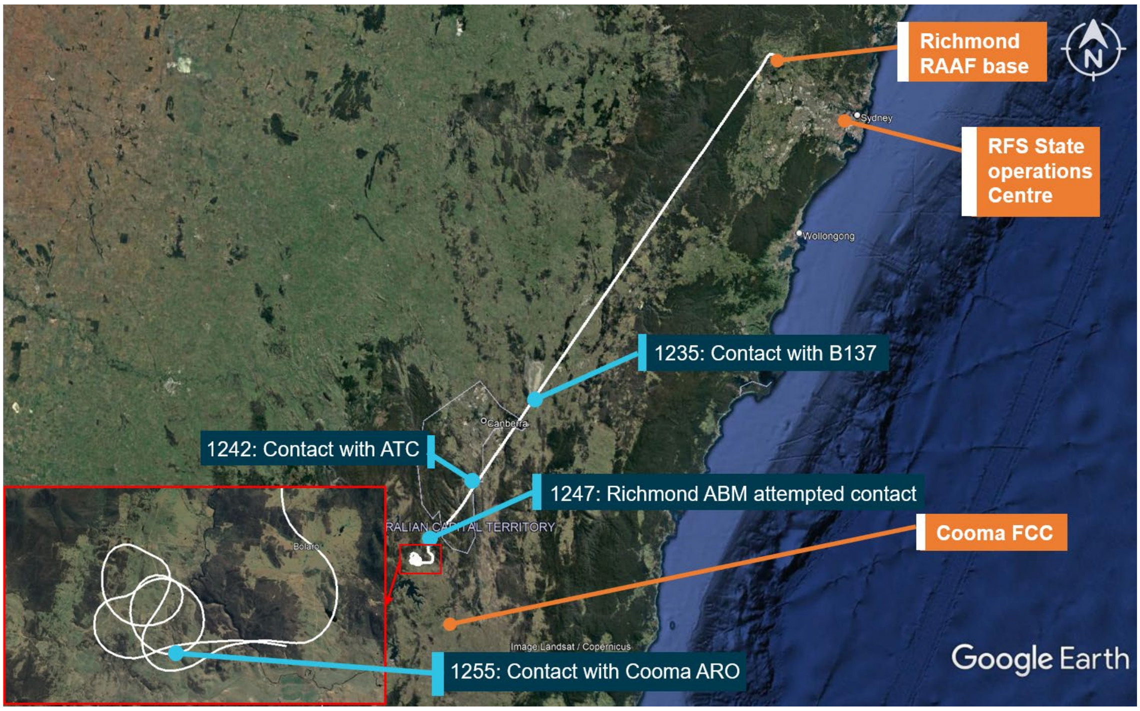
[23] The SOC's note was entered into the log following another note written at 1327. The log was provided to the ATSB at the time of the RFS response to the draft investigation report.

[24] 'Ops normal' call time provided the next expected transmission time from this aircraft to indicate operations were normal.

instrument flight rules[25] aircraft in the area. About 5 minutes later, the Richmond ABM also attempted to contact the crew of B134 to confirm 'ops normal', firstly by radio, and then by text to the PIC's mobile phone, but did not receive a response.

The automatic dependent surveillance broadcast (ADS-B) data showed that, after arriving at the Adaminaby fire-ground at about 1251, the crew of B134 completed several circuits at about 2,000 ft AGL.[26] At about 1255, the crew advised the Cooma ARO that it was too smoky and windy to complete a retardant drop at that location. The Cooma ARO then provided the crew with the approximate coordinates of the Good Good fire, about 58 km to the east of Adaminaby. The ARO further indicated that they had no specific requirements, but they could look for targets of opportunity, with the objective of conducting structure and property protection near Peak View.

Figure 2: Flight track of B134 (white line), timing and location of external communications, and key locations, with an inset detailing the circuits at Adaminaby



Source: Google earth, ADS-B data and radio calls, annotated by the ATSB

'B134' tasking to the Good Good fire-ground

At about 1259, the crew of B134 contacted air traffic control to advise that they had been re-tasked to the Good Good fire-ground, and provided updated coordinates. At about the same time, the RFS ground firefighters at the Good Good fire-ground, near Feeney's Road in Peak View, contacted the Cooma FCC and requested additional assets for property protection. They were advised that a LAT would be passing overhead in about 10 minutes. The firefighters acknowledged the intention of a LAT retardant drop and advised the Cooma FCC they would wait in open country on Feeney's Road, clear of any properties targeted for protection.

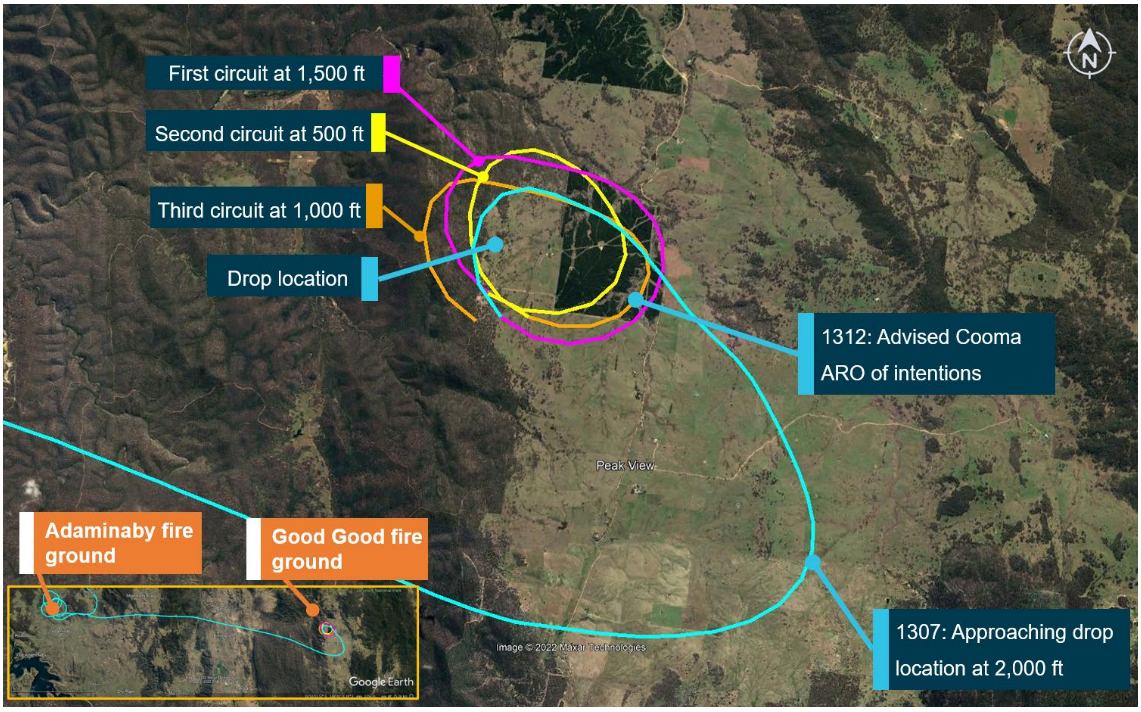
At about 1307, B134 arrived overhead the drop area (Figure 3). The drop area was located to the east of a ridgeline, with the fire on the western side of the ridgeline. The aircraft's recorded track data (SkyTrac) showed that the crew conducted 3 left circuits, at about 1,500 ft, 500 ft and 1,000 ft AGL respectively, prior to commencing the drop circuit (Figure 4). At about 1312, after conducting

[25] Instrument flight rules (IFR): a set of regulations that permit the pilot to operate an aircraft in instrument meteorological conditions (IMC), which have much lower weather minimums than visual flight rules (VFR). Procedures and training are significantly more complex as a pilot must demonstrate competency in IMC conditions while controlling the aircraft solely by reference to instruments. IFR-capable aircraft have greater equipment and maintenance requirements.

[26] When conducting initial attack operations, crews complete several circuits to assess the hazards and drop conditions.

about 2 circuits, they advised the Cooma ARO of their intention to complete multiple drops on the eastern side of the Good Good fire, and that they would advise the coordinates after the first delivery.

Figure 3: B134's approach and circuits overhead the drop location; the inset shows the track from the Adaminaby to the Good Good fire-ground



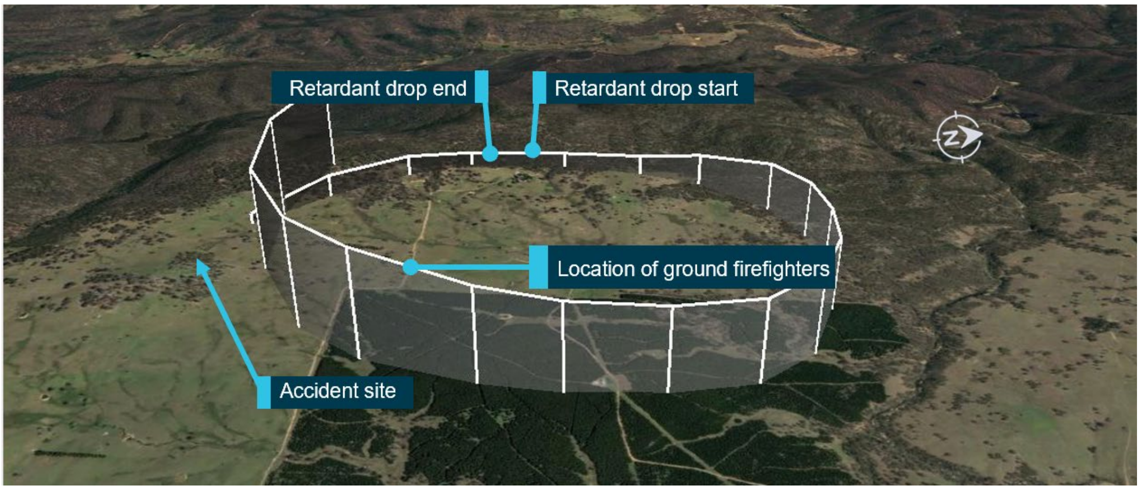
Source: Google earth and SkyTrac data, annotated by the ATSB

At 1315:15,[27] a partial retardant drop was conducted on a heading of about 190°, at about 190 ft AGL (3,600 ft above mean sea level). During the drop, about 1,200 US gallons (4,500 L) of fire retardant was released over a period of about 2 seconds. A ground speed of 144 kt was recorded at the time of the drop.

A witness video taken by ground fire-fighters captured the drop and showed the aircraft immediately after the drop in an initial left turn with a positive rate of climb, before it became obscured by smoke.[28] While being intermittently obscured by smoke, the aircraft climbed to about 330 ft AGL (3,770 ft above mean sea level). At about this time, ATSB analysis of the video showed that the aircraft was rolling from about 18° left angle of bank to about a 6° right angle of bank. Following this, the aircraft descended and about 17 seconds after the completion of the partial retardant drop, it was seen at a very low height above the ground, in a slight left bank. Video analysis and accident site examination showed there was no further (emergency) drop of retardant. Throughout this period, the recorded groundspeed increased slightly to a maximum of 151 kt. Shortly after, there was a significant left roll just prior to ground impact.

[27] All times in the report are referenced to the ADS-B data, with adjustments based on the recorded locations.
[28] From the witness video, it was unclear if the aircraft flew behind the smoke, or entered the smoke.

Figure 4: Accident circuit and location of the firefighters and retardant drop



Source: Google earth and SkyTrac data, annotated by the ATSB

At about 1315:37, the aircraft collided with terrain and a post-impact fuel-fed fire ensued. The 3 crew were fatally injured and the aircraft was destroyed.

A review of the Airservices Australia audio recording of the applicable air traffic control frequency found no distress calls were received by controllers prior to the impact.

Context

Crew information

Pilot in command

Experience

The pilot in command's (PIC) logbook, combined with the operator's records for the accident aircraft showed that the PIC had a total flying experience of about 4,010 hours, which included 3,010.3 hours in the C-130 aircraft and 994 air tanker drops. The PIC had also accrued a further 1,616.8 hours as a flight navigator.

The PIC commenced work in Australia on 1 December 2019. In the 30 days prior to the accident, the PIC had flown about 32 hours. In the 72 hours prior, the PIC had flown 4.5 hours, all of which were in B134. The accident flight was the first flight of the day.

The PIC was initially trained as a navigator and pilot in the United States (US) Air National Guard. During this time, the PIC gained experience in firefighting operations through the modular airborne firefighting system (MAFFS)[29] program. The PIC joined Coulson Aviation in 2015 on a part-time basis, before being employed full-time in 2017.

Qualifications

The PIC held a current airline transport pilot certificate with ratings for multi-engine land airplane including the EC-130Q, issued by the US Federal Aviation Administration (FAA) on 13 October 2017. The PIC's most recent flight instructor certificate with ratings for multi-engine and instrument aircraft was issued by the FAA on 6 April 2019. On 18 April 2019, the PIC's latest 'airplane pilot qualification card' was issued from the US Department of Agriculture, Forest Service,[30] for the C-130 aircraft, which included the authorised missions of:

- *low level* (below 500 ft above ground level)
- *mountainous terrain*
- *airtanker initial attack.*

An air tanker initial attack certification allowed a pilot to conduct fire retardant drops without the supervision of a birddog or air tactical (attack) supervisor.

At interview, other flight crew reported the PIC was 'methodical', 'conservative', who 'always did his due diligence' and was not considered to take unnecessary risks. It was also reported that Coulson Aviation pilots were not being paid per flight or by flying hours, and therefore that was not a motivational factor to accept a tasking. In addition, the PIC had recently resigned from the operator and accepted a US-based position.

Training

The PIC last completed training with Coulson Aviation in March and April 2019,[31] which included annual C-130 simulator training, and controlled flight into terrain awareness and crew resource management courses. In addition, the PIC completed 2 assessed training flights in the C-130 on 14-15 April 2019. The flight on 14 April included approach to aerodynamic stalls[32] in the circuit (with 50% flap) and drop (with 100% flap) configurations, and go-arounds with a full load (water).

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29 MAFFS were portable fire-retardant delivery systems that could be inserted in C-130 aircraft without major structural modifications to convert them to air tankers when needed.

30 When operating in the US as an air tanker, the aircraft was considered a public use asset, and the US Department of Agriculture Forest Service assumed the regulatory role, and defined and issued initial attack qualifications.

31 This was the operator's spring training period in preparation for the North American fire season.

32 Aerodynamic stall: occurs when airflow separates from the wing's upper surface and becomes turbulent. A stall occurs at high angles of attack, typically 16˚ to 18˚, and results in reduced lift.

The flight on 15 April included drop planning (hazards, tactics, ingress, egress, and dry run) and an emergency on the drop run. The drop run emergency was a simulated 'down air' [downdraft]. All the assessed sequences, which included jettison of the load during a (simulated) emergency condition,[33] were recorded as satisfactory.

Copilot

The copilot had joined Coulson Aviation in September 2019, after 20 years in the US military, including experience flying the C-130. The copilot's logbook combined with the operator's records showed a total flying experience of about 1,744 hours, of which about 1,364 hours were on the C-130. This was the copilot's first fire season, and they commenced work in Australia on 1 December 2019. Since the start of the fire season, the copilot had flown about 85 hours, with about 28 hours in the last 30 days and about 4.5 hours in the 72-hour period prior to the accident.

The copilot held a current airline transport pilot certificate and ratings for multi-engine land aircraft, including the EC-130Q (second-in-command privileges only), issued by the FAA on 7 November 2019. The copilot also held a flight instructor certificate with ratings for single, multi-engine and instrument aircraft, issued by the FAA on 14 August 2019.

The copilot's C-130 check flight with the operator was completed on 12 September 2019, and was assessed as satisfactory against the qualification standards for second-in-command. On 13 September 2019, the copilot completed the crew resource management and controlled flight into terrain awareness courses, and reviewed the US Department of Agriculture Forest Service's air tanker pilot training video.

On 16 September 2019, the copilot was issued with an 'airplane pilot qualification card' from the US Department of Agriculture Forest Service for the C-130, which included the authorised missions of:

- *low level* (below 500 ft above ground level)
- *mountainous terrain*
- *airtanker SIC* (second-in-command).

Flight engineer

The flight engineer joined Coulson Aviation in November 2019, after about 25 years in the US military. This was the flight engineer's first fire season. The flight engineer held a flight engineer certificate with a rating for turbo-propeller powered aircraft, issued by the FAA on 20 November 2019. On the flight engineer application form, the flight engineer reported accruing about 4,050 hours on the C-130. The flight engineer also held a mechanic certificate with ratings for airframe and powerplant, issued by the FAA on 2 June 2019.

The flight engineer's check flight was completed with the operator on 20 November 2019. In addition to this flight, the flight engineer completed 2 air tanker drops under supervision in Australia on 12 January 2020. The flight engineer commenced work in Australia on 13 January 2020.

72-hour prior history

In Australia, each crew member's roster cycle was 14 duty days followed by 2 rest days. The accident flight occurred on the PIC's 9th day, and the copilot's and flight engineer's 11th day of their respective current duty periods.

Table 1, based on the operator's records, details the crew's sign-on and sign-off times for the 3 days before the accident. On 23 January 2020, the crew signed on at 0900.

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[33] Although the emergency condition for the jettison was a simulated scenario, the pilot was still required to perform a live jettison of the load (water) in this training sequence.

Table 1: B134 crew working hours

	20 January	21 January	22 January	23 January
Sign-on	1000	0800	1000	0900
Sign-off	1800	1700	1900	-
Duty time	8 hours	9 hours	9 hours	-

Information from the crew's telephone and hotel records, in addition to work and flying duties, were used to determine their activities in the previous days. There were no indications of fatigue for the 3 crew members. However, there was insufficient information available to the ATSB about their sleep and non-duty activities to estimate fatigue levels with confidence.

Aircraft information

General information

The C-130 is predominantly an all-metal, high-wing aircraft, designed for military operations. The accident aircraft (Figure 5) was manufactured by the Lockheed Corporation (now Lockheed Martin Corporation) in 1981 and was powered by 4 Allison T56-A-15 turbopropeller engines, fitted with Hamilton Sundstrand 54-H60-91 4-blade propellers. The T56-A-15 is a constant speed engine, with a variable pitch propeller.

Previously owned by the US Navy, the aircraft was transferred to the US National Aeronautics and Space Agency in 1992 and later placed in storage. It was then re-purposed for firefighting activities by Coulson Aviation and registered in the restricted category.[34] At that time, Coulson Aviation became the type certificate holder and assumed the responsibilities of the aircraft manufacturer for the entire aircraft and any modifications made.

Initially registered as N130CG in 2018, this was later changed to N134CG in April 2019. Modifications to the aircraft included the installation of an avionics package and firefighting tank system, known as the Retardant Aerial Delivery System XXL (RADS).

[34] Restricted category in this instance referred to an aircraft type that had been manufactured in accordance with the requirements of, and accepted for use by, an Armed Force of the US and was later modified for a special purpose. It becomes a restricted category aircraft on entry to the civilian register.

Figure 5: N134CG

Source: Coulson Aviation

Retardant Aerial Delivery System XXL

The RADS included a 4,000 US gallon (15,000 L) tank system located within the aircraft's fuselage. The system was designed to deliver discrete quantities of retardant, dependant on the coverage factor[35] selected and the duration the doors remained open. This was controlled from the cockpit, with drop controls located on both the PIC and copilot yokes.

The drop quantity was manually controlled by the crew by setting the coverage factor and either selecting a pre-set percentage or setting 100%. The latter option allowed the crew to control the amount of retardant released by holding a button on the yoke until the desired amount was dispensed. The RADS system was designed that, if less than 100% volume was selected, the system would disarm after a partial load drop and the crew would need to re-arm the system to complete further releases. It was reported that the crew on B134 normally selected 100%.

The system also included a guarded emergency dump ('e-dump') switch, located in reach of all 3 crew members, which would fully open the doors and jettison the load in a period of about 2 seconds. Following an emergency dump, the doors would remain open until the RADS was reset by the crew.

Maintenance history

The aircraft had a total time-in-service of 11,888 hours and had accrued 683 hours of firefighting operations since the tanker conversion in 2018. The aircraft had a current certificate of airworthiness, and was maintained in accordance with an FAA approved program.

N134CG arrived in Australia in November 2019. The last daily inspection conducted on 22 January 2020, at the end of flying activities the day before the accident, identified the propeller

[35] Coverage factor refers to the amount of retardant released over a specified area. The higher the coverage factor, the larger amount of retardant dropped in the specified area.

anti-icing system on engine number 2 was unserviceable, and rectification had been deferred in accordance with the minimum equipment list.[36]

In addition to a maintenance requirement to perform engine power efficiency checks at 150-hour intervals, the operator reported pilots were required to perform power checks before every take-off. Operations were only permitted if a minimum performance requirement of 95% was met.

Weight and balance

The last weight and balance report for the aircraft, in April 2019, showed its basic empty weight was 75,794 lb (34,380 kg) and according to the RADS Airplane Flight Manual (AFM) supplement, the maximum take-off weight was 150,718 lb (68,365 kg). The aircraft flight and maintenance log indicated the PIC had the aircraft refuelled to a total of 34,000 lb (15,422 kg) at the completion of flying on 22 January 2020. The operational load monitoring system[37] indicated there was 35,514 lb (16,109 kg) of retardant on board prior to the accident drop, in addition to a 2,000 lb (907 kg) pallet of gel. This resulted in a take-off weight of about 147,308 lb (66,818 kg) and the centre of gravity being at the aft limit on departure from Richmond.

Using the operator's reported fuel consumption for air tanker drop missions of 5,000 lb/h (2,268 kg/h) for a 70-minute flight, and the retardant drop of 10,764 lb (4,882 kg), the estimated post-drop weight was 130,656 lb (59,265 kg). The centre of gravity remained close to the aft limit. This was consistent with reports from the operator's other crews that the location of the RADS tank in the aircraft meant there was no appreciable change in the centre of gravity following a retardant drop.

Aerodynamic stall

Stalling

An aircraft's wing is said to be 'aerodynamically stalled' when the airflow over the wing separates from the wing; that is, the airflow no longer follows the contour of the top surface of the wing. This results in a rapid loss of lift, which balances the weight of the aircraft, and the aircraft will rapidly descend. An aerodynamic stall will also normally result in the nose of the aircraft pitching down, often with a left-wing drop.

The aerodynamic characteristics of an aircraft wing are such that the airflow will separate and the wing stalls when the angle of attack, the relative angle between the wing and the airflow, reaches a critical value. The C-130H did not have an angle of attack instrument, however, this could be referenced to an equivalent airspeed. The airspeed at which a stall occurs is not fixed to a single value, and varies depending on the flap setting, aircraft weight, and load factor.[38] The stall speeds are typically presented in the AFM (refer to section titled *Aircraft performance*).

The C-130 aircraft has 4 wing mounted engines driving propellers. The placement of the propellers forward of the wings results in the propeller slipstream providing a relative airflow over each of the wings in addition to the forward speed of the aircraft, which varies in strength with the power produced. This is known colloquially as a 'blown lift' wing and results in the stall speed lowering as power is increased. For the C-130, the published power-on stall speed with 50% flap is based on maximum power. Therefore, the stall speed will be higher when less than maximum power is applied. The higher power-off stall speeds are based on idle engine power.

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[36] A minimum equipment list is a list that identifies items, subject to specific conditions, which may have been unserviceable at the commencement of a flight, and is approved by the FAA.

[37] The operational load monitoring system transmitted various parameters in-flight, including the status of the RADS tank at the start and completion of the drop. The system was introduced to monitor the actual structural loads in the firefighting operational environment, and therefore to better manage the maintenance regime and monitor the structural elements of the aircraft. It was introduced after multiple in-flight break ups of firefighting aircraft.

[38] The load factor is the ratio of the normal acceleration to the acceleration due to gravity. All else being equal, this is equivalent to the ratio of the lift to the weight.

Stall characteristics of the C-130

A C-130 discussion paper (Mizell, 2009), based on data obtained during US Air Force testing, described the aircraft as having a 'very good natural stall warning... However, once in a stall, the plane becomes much less predictable'. In a clean (no flap) power-off stall:

> The flying characteristics of the plane are very benign all the way up to full stall. A significant buffet was experienced 10 knots prior to stall. 3 knots above stall, a deterring buffet was experienced, giving a clear signal to the crew that stall was imminent. Immediately before stall, a yaw acceleration was detected by the data, but nearly imperceptible to the crew.

However, the 50% flap and 100% flap power-on stall 'present a much larger hazard..'. Specifically, the paper noted that:

> Similar to 0% flap, but with less buffet warning, the left wing stalls first resulting in large, uncontrolled bank excursions and subsequent nose low attitudes. In some cases, the aircraft remained uncontrollable until the bank exceeded 100 degrees and the nose approached 75 degrees down. This caused massive altitude loss and overspeed of airframe components.
>
> The approach to stall at 50% and 100% configurations also exhibited high descent rates.

The accident aircraft was not fitted with a stall warning system, nor was one required or available. However, according to the C-130 pilots consulted during the investigation, the aircraft had a noticeable pre-stall buffet through the rudder pedals and control column, and this was reported as being distinct from a turbulence-induced buffet, which could be felt throughout the aircraft. In addition, the flight controls become less effective at these lower speeds, described by pilots as 'sluggish' and 'unresponsive'. The Lockheed Martin AFM also indicated that:

> With flight idle power, stall warning buffet initially occurs at 4% to 15% above stall speed, depending upon configuration, and progresses to moderate or heavy buffet at the stall. The greatest stall warning airspeed margin exists in the takeoff and approach configuration and less margin exists in the landing and cruise configurations. The stall of the C-130 is characterized by either a mild pitch down or a mild roll-off to the right or left depending on slightly unequal power settings.

Stall recovery

The Lockheed Martin AFM described the recovery actions for a stall as:

> If in climbing or bank attitude, immediately drop the nose, level the wings, and apply power to limit loss of altitude. Move controls smoothly, and avoid abrupt actions. Avoid diving the airplane, and avoid abrupt or accelerated pull-up after recovery.

While the ATSB did not find a published procedure in the operator's AFM (refer to section titled *Operating documents*) for stall symptoms and recovery actions, their C-130 pilots all reported that approaches to stall (start of the buffet) training[39] was conducted in the aircraft on an annual basis in various configurations. According to the operator's *Company Operations Manual* (COM),[40] training for approaches to the stall were conducted in the clean, take-off and landing configurations.[41] The recovery procedure referred to both low altitude (ground contact imminent) and higher altitude (ground contact irrelevant) scenarios.

The C-130 pilots' descriptions of the symptoms and recovery actions were consistent with the manufacturer's published material, with some additions specific to their operation. These included the addition of load jettison and flying the aircraft towards their pre-briefed escape route from the release point. Although their recovery descriptions for a pre-stall buffet, following a fire-retardant

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[39] Approach to stall training is conducted for pilots to recognise the incipient stall symptoms. Fully developed stall training was not practically trained in the aircraft due to the significant height loss and potential unusual attitudes when the C-130 entered a stall.

[40] The COM was developed to contain the procedures, instructions and information required by CASA for the conduct of operations for all the operator's aircraft in Australia.

[41] The clean configuration refers to 0 flap and gear retracted, take-off refers to 50% flap and landing gear down, landing configuration refers to 100% flap and landing gear down.

drop, was to apply maximum power by pushing the power levers full forward, this was not a procedure that could be practically trained in the aircraft. The engine power was managed manually, therefore, pushing the power levers full forward during training could result in an over-torque or over-temperature condition for the engines. However, they reported they would apply as much power as needed and as quickly as possible in a real low-level stall situation.

Aircraft performance

Stall speeds

The aircraft stall speeds were contained in the respective performance charts in the Lockheed Martin AFM. The ATSB calculated the power-on and power-off stall speeds for an aircraft weight of 131,000 lbs (59,420 kg), in level flight and with 50% flap at 83 kt (IAS) [42] and 101 kt (IAS) respectively. This configuration and attitude were considered most representative of the aircraft state just prior to the observed descent (refer to sections titled *Weight and balance, Wreckage and impact information*, and *Recorded information* sections), noting that a pitch-up attitude, any bank angle above 0° and a decreasing flap setting would increase the stall speed. It was a standard operating procedure for the crew to calculate the power-off stall speeds at the take-off weight for 0-flap, 50% flap and 100% flap, for 0° and 45° angle of bank for each flight. A 25,000 lb (11,340 kg) weight reduction from a jettison of the remaining fire retardant would have reduced the power-on stall speed to 76 kts.

Turbulence will also affect an aircraft's stall speed. According to the Bureau of Meteorology, moderate turbulence is associated with a load factor increase of 0.5 to 0.99 G[43] with appreciable changes in attitude and/or altitude, while severe turbulence is associated with a load factor increase of 1.0 G to 1.99 G with large abrupt changes in attitude and/or altitude. Turbulence was forecast (refer to section titled *Bureau of Meteorology forecasts*) and likely experienced (refer to section titled *Bureau of Meteorology analysis*) at the accident location. Applying the moderate turbulence load factors as boundary conditions to the 50% flap power-on stall speed at 59,420 kg produced a range of 101-117 kt (IAS). Similarly, for severe turbulence, this produced a power-on stall speed range of 117-143 kt (IAS) at 59,420 kg.

Regarding turbulence, the airspeeds limitation section of the operator's AFM stated that:

> The aircraft should not be operated in conditions of severe turbulence [actual conditions] because gusts can be encountered that may impose excessive loads. However, if flight in severe turbulence cannot be avoided, flight should be in the range of 65 knots above the power-off stall speed (not to exceed 180 KIAS) for the operating gross weight.[44]

Emergency climb performance

The aircraft's emergency climb performance with maximum power at 131,000 lb (59,420 kg) and 50% flap was about 1,500 ft/min. With a reduced weight from a jettison of the remaining fire retardant, the emergency climb performance would have increased to about 2,250 ft/min, representing a 50% improvement. This was the absolute best rate of climb that could have been achieved.

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[42] Indicated airspeed is the airspeed read directly from the airspeed indicator in the cockpit. This speed is an important value for the pilot as it is the indicated airspeeds that are specified in the AFM for important performance information such as stall speeds.

[43] G load: the nominal value for acceleration. In flight, g load represents the combined effects of flight manoeuvring loads and turbulence and can have a positive or negative value.

[44] This was consistent with the limitations published by the original manufacturer.

Meteorological information

Bureau of Meteorology forecasts

A Bureau of Meteorology graphical area forecast was issued at 0924 and was valid for the time of the flight. It forecast moderate mountain wave activity[45] above 3,000 ft above mean sea level (AMSL) and severe turbulence below 8,000 ft AMSL in the area of operation from Richmond to Cooma. This included the Adaminaby and Good Good fire-grounds. In addition, a SIGMET[46] issued at 0947, and valid for the flight, forecast severe turbulence[47] below 10,000 ft AMSL for the area. Of note, when commenting on the general nature of forecasts, some of the operator's pilots indicated that they could be broad and cover a large area of the state, which may not accurately reflect the actual conditions over the fire-ground. The only operational limitation cited at interview by the pilots were related to thunderstorm activity.

The aerodrome forecast for the Cooma-Snowy Mountains Airport,[48] located 50 km south-west of the accident site was amended at 0948. It indicated wind speeds of 25 kt, gusting to 48 kt, with a mean wind direction of 300° from 1100 and visibility reduced to 8,000 m in light showers. Severe turbulence below 5,000 ft AGL was forecast from 0900-1500. A PROB30[49] for visibility reduced to 2,000 m in blowing dust and a broken[50] layer of cloud at 1,000 ft AGL was forecast for the period 1100–1700.

At 1012, the Richmond airbase manager (ABM) sent a text message to the air tanker and birddog pilots to advise them of an airport warning at Richmond for wind gusts in excess of 35 kt between 1000 and 1700.

Observations of the weather in the area

Other fire-control aircraft

On the day of the accident, several fire-control aircraft, primarily consisting of fixed-wing Air Tractors (single-engine air tankers) and Bell 206 helicopters, were operating from the Polo Flat airstrip, located 33 km south-west of the accident site. The Cooma Fire Control Centre (FCC) aviation radio operator (ARO) received reports of strong winds in the area from the fire-control pilots in the early morning. This included winds of 30-40 kt at 0839, 40-50 kt at 0902, and 52 kt at 0937. The ARO recorded in their operations log that, due to the weather conditions, all fire-control aircraft had departed the area or landed by 1030.

In addition, the crew of B137 reported that the wind conditions at Adaminaby at about 1200 were 50 kt at 800 ft AGL and about 37 kt at 200 ft AGL.

Witness reports

Following the accident, the ATSB received multiple witness reports of the weather conditions at Peak View. They all consistently reported very strong winds from the north-west, with gusts up to 43 kt recorded at ground level. One resident noted that, although the prevailing wind was from the

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[45] Mountain waves form above and downwind of topographic barriers when strong winds blow with a significant vector component perpendicular to the barrier in a stable environment. If air is being forced over terrain, it will move downward along the lee slopes, then oscillate in a series of waves as it moves downstream, sometimes propagating long distances downwind.

[46] Significant meteorological information (SIGMET): a weather advisory service that provides the location, extent, expected movement and change in intensity of potentially hazardous (significant) or extreme meteorological conditions that are dangerous to most aircraft, such as thunderstorms or severe turbulence.

[47] Severe turbulence can result in large abrupt changes to an aircraft's attitude and/or altitude, and potentially a momentary loss of control.

[48] The Cooma-Snowy Mountains Airport has an elevation of 3,106 ft AMSL.

[49] PROB30 means 30 per cent chance of forecast conditions occurring.

[50] Cloud cover: in aviation, cloud cover is reported using words that denote the extent of the cover – broken indicates that more than half to almost all the sky is covered.

north-west, the direction and strength at ground level were also being influenced by the local terrain.

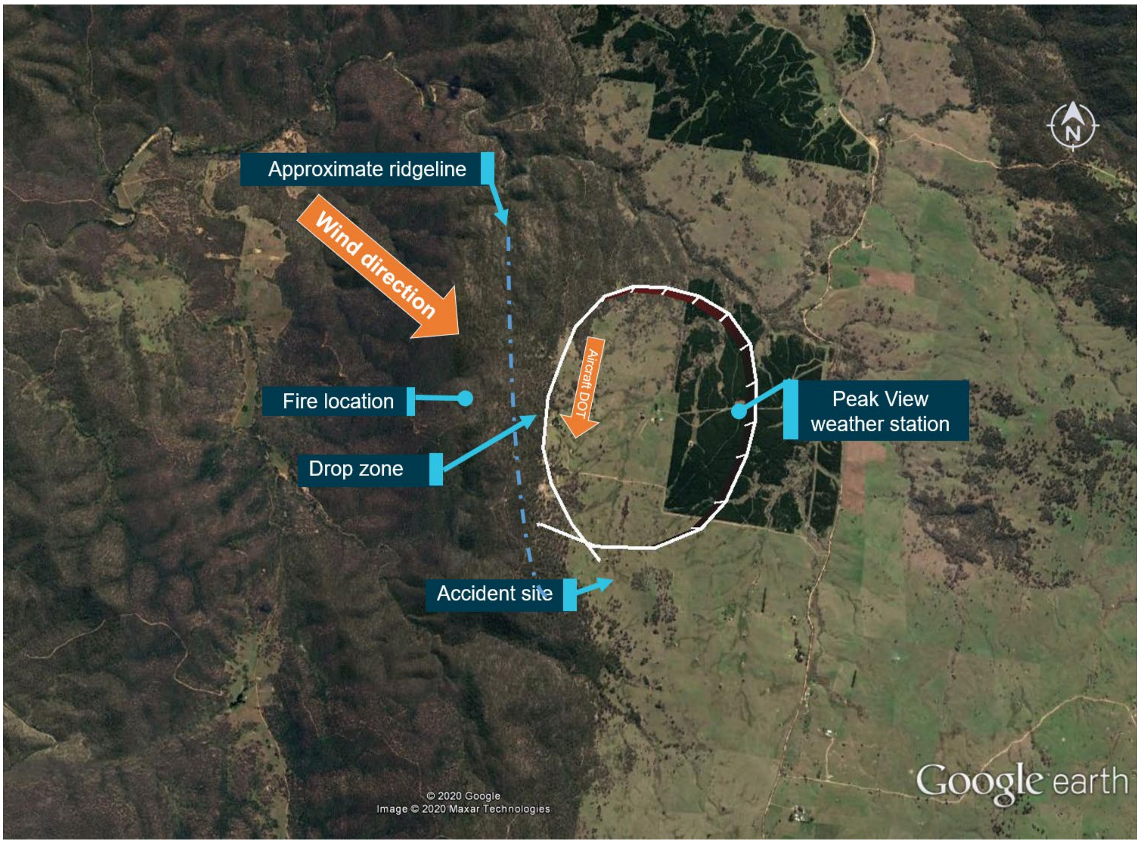
Glider pilots familiar with the area commented that, due to the local terrain, the area was often subject to turbulence and rotor conditions (refer to section titled *Mountain wave activity*). It was also a well-known area for mountain wave activity and that on the day of the accident it was a 'terrible wave day'.

Weather station recorded conditions

About 12 minutes prior to the accident, the Cooma-Snowy Mountains Airport weather station indicated a wind speed of 25 kt, gusting to 39 kt, from a direction of 320°. The visibility was 6,000 m, with a QNH[51] of 1002 hPa, and temperature of 26 °C.

A personal weather station at Peak View, located about 1.3 km from both the drop and accident sites (Figure 6), recorded the conditions twice per hour. At about 1309 (7 minutes prior to the accident), the station recorded a mean wind of 15 kt from the west and a peak gust of 32 kt from the north, a temperature of 30 °C, and a QNH of 995 hPa.[52] At about 1330 (14 minutes after the accident), the station recorded a mean wind of 16 kt from the west and a peak gust of 42 kt from the north-west.

Figure 6: Accident circuit with predominant wind direction, direction of travel (DOT), and terrain



Source: Google earth, Peak View weather station and SkyTrac data, annotated by the ATSB

Bureau of Meteorology analysis

The Bureau of Meteorology analysed the conditions on the day and indicated that a cold front was approaching the accident location, with hot and strong north to north-westerly winds ahead of the

51 QNH: the altimeter barometric pressure subscale setting used to indicate the height above mean sea level.

52 This was the average and peak speed recorded for the previous 10 minutes.

front. High resolution weather model data indicated the winds at 5,000 ft AMSL were about 45 kt from the north-west, increasing in strength with height up to 80 kt from the north-west at 10,000 ft AMSL.

Gusting winds had produced some areas of blowing dust, which likely reduced visibility. Bushfire smoke in the area had also affected visibility. While nearby observations at the Cooma-Snowy Mountains Airport showed intermittent reductions in visibility, it was noted that measuring equipment may not have accurately reported visibility in smoke conditions. Therefore, it was likely that the actual visibility was lower than that reported by the instruments.

The strong winds over the terrain likely resulted in severe turbulence and mountain wave development. Satellite imagery of cloud formations confirmed the presence of mountain wave activity during the day. The conditions in the area at the time were generally favourable for mountain wave development, however, they were unable to determine the severity of this from the data available.

The Bureau of Meteorology considered that the conditions at the Cooma-Snowy Mountains Airport were likely representative of the general conditions experienced at the accident location. Further, their analysis of the weather conditions in the area was consistent with what was forecast on the day.

Accessing meteorological information

For operations in NSW, following the briefing with the Richmond ABM each morning, the crews would return to their own operational areas until they received a tasking from the RFS. On receipt of a tasking, crews would conduct their flight planning. It was reported that the operator’s crews used an electronic flight bag (their company issued iPad including the Foreflight app) to submit their flight plan to Airservices Australia, which also provided access the required weather forecasts. While specific weather data access could not be confirmed, as the flight plan had been submitted, it was considered very likely that the crew of B134 would have also accessed the relevant weather information at that time.

In addition, the operator outlined that conditions at a fire could change rapidly, and when the fire was an hour or more flight time away, reported weather conditions were likely to be inconsistent with the actual conditions on arrival.

Weather systems: Mountain waves and windshear

Mountain wave activity

Mountain waves[53] are the result of flowing air being forced to rise up the windward side of a mountain range, then as a result of certain atmospheric conditions, sinking down the leeward side (ATSB, 2009). Immediately downwind of the range there is a strong downdraft followed quickly by an updraft, which produces the wave motion. According to Underdown and Standen (2003), mountain waves can develop when the wind direction is near perpendicular to a continuous mountain range and at a speed of 15 kt or more[54] at the summit, and increasing with height in a stable atmosphere. Aircraft may encounter severe turbulence in mountain wave systems.

Rotors or eddies can also be found embedded in mountain waves. Their formation usually occurs where wind speeds change in a wave or where friction slows the wind near to the ground. Often these rotors will be experienced as wind gusts or windshear (ATSB, 2009). According to the FAA (1997), localised gusts of 50 kt, with downdrafts greater than 1,500 ft/min, are not unusual in mountain wave systems. Although this phenomenon is usually forecast reasonably well by the

53 Also known as lee wave or standing wave systems.
54 Other publications may cite higher values up to 25 kt.

Bureau of Meteorology, many local factors may also affect the formation of mountain wave activity.

When discussing the consequence on aircraft performance, the ATSB's safety publication *Mountain wave turbulence* noted that (ATSB, 2009):

> Many dangers lie in the effects of mountain waves and associated turbulence on aircraft performance and control. In addition to generating turbulence that has demonstrated sufficient ferocity to significantly damage aircraft or lead to loss of aircraft control, the more prevailing danger to aircraft in the lower levels in Australia seems to be the effect on the climb rate of an aircraft.

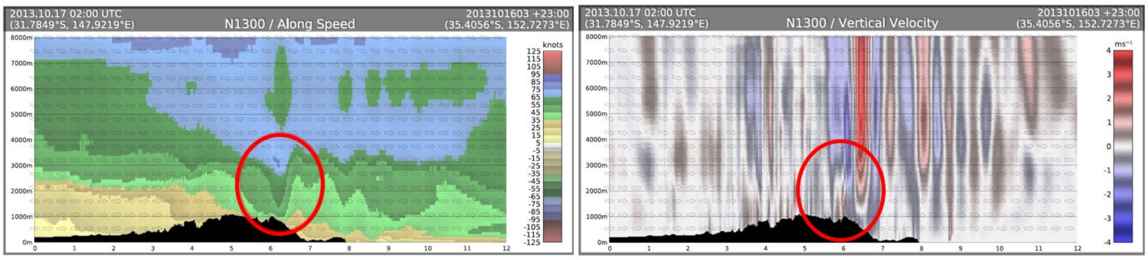
Study of mountain waves associated with bushfires

According to the Bushfire and Natural Hazards Cooperative Research Centre,[55] one of the most challenging situations in fire management was when relatively benign weather conditions were expected, but a severe fire eventuated. In December 2016, the centre released Hazard note issue 24: *Fire escalation by downslope winds.* The note, authored by specialists from the Bureau of Meteorology, investigated the meteorology of unexpected severe fire behaviour associated with mountain wave activity and identified 3 relevant bushfires. A detailed case study of the New South Wales (NSW) Blue Mountains fires of October 2013 was undertaken, focussing on 17 October at 1300. Of interest was the behaviour of the winds in the vicinity of the State Mine fire.

Figure 7 shows a cross-section of the horizontal wind speeds (left image) and vertical wind speeds (right image) along a section passing from the north-west to the south-east through the State Mine fire-ground. The red circled region in the left image shows strong horizontal winds extending downwards towards the surface in the vicinity of the fire. Downwind (to the right) of the fire are oscillations (left image) in the wind speeds and alternating bands of ascending and descending air (right image), both of which are characteristic features of mountain waves. The note described mountain waves as:

> Mountain waves are oscillations that can occur when the wind blows across a mountain or hill. They are somewhat similar to water flowing over a rock in a stream, but are much more complex because their existence and amplitude is sensitive to the atmospheric temperature structure (stability) and vertical variation of the wind (wind shear). They often lead to strongly accelerated flow attached to the lee slope of the mountain or hill, known as downslope winds…

Figure 7: North-west to south-east cross section of fire, illustrating horizontal (left image) and vertical (right image) wind speed changes, with the fire located near the number 6 on the horizontal axis



Source: Bushfire and Natural Hazards Cooperative Research Centre

While the purpose of the note was to consider the wind effect on the severity of a fire, this has potential implications for firefighting aircraft, particularly if low-level windshear was present. As a comparison, at position 1 on the horizontal axis (left image), the wind speed band of 45–55 kt would not be encountered until reaching a height greater than 8,000 ft (2,450 m) above the surface. However, at the fire-ground at position 6, these wind speeds could be encountered within a few hundred feet above the surface. The note also highlighted that this research revealed

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55 Formed in 2013, the Bushfire and Natural Hazards Cooperative Research Centre is a national research centre funded by the Australian Government.

features at the location of the fire-ground that might not have been captured or possibly filtered out of broader-scale forecasts.

Windshear

Windshear is defined by the Bureau of Meteorology (2014) as a 'wind direction and/or speed change over a vertical or horizontal distance'. It is always present in turbulent air, but can also occur without turbulence being present. This phenomenon becomes particularly significant when an aircraft is abruptly displaced from its intended flight path and substantial corrective action is required by the pilot. More so, at lower levels and low speed, such as during take-off and landing. The hazards are a rapidly changing headwind and tailwind, strong side gusts, and a change in lift on the wings, all during a time when an aircraft is most vulnerable (Minor, 2000). Specifically, the Bureau of Meteorology (2014) noted that:

> During the climb-out and approach phases of flight, aircraft airspeed and height are near critical values, rendering the aircraft especially susceptible to the adverse effects of wind shear.
>
> Aircraft taking-off may be significantly affected by changes in headwind and tailwind components which create changes in the amount of lift experienced. A decrease in the vertical headwind component, or an increase in the tailwind component, will result in a reduction in airspeed, and in extreme cases the resulting loss of lift may be enough to cause the aircraft to stall or fly into the ground.

Likewise, the adverse effects on aircraft performance from low-level windshear was also discussed by Bowles (1990), when analysing airborne forward-looking windshear detection systems:

> The hazard of windshear arises principally from its deceptive nature: In a windshear situation, from a microburst[56] or any other source, the pilot may be confronted with a performance-increasing headwind, followed a few seconds later by a powerful, performance-decreasing tailwind. To cope with the headwind, the pilot may take actions to prevent the plane from climbing. These actions are then compounded by performance loss caused by the tailwind and downdraft, so that it may be impossible to avoid ground impact.
>
> Depending on crew action, a typical low altitude windshear may result in reduced airspeed and rate-of-climb, which often result in significant altitude loss and possible ground impact. Full performance capability depends on two key factors: timely recognition and appropriate response.

Windshear controls

Aviation specific windshear research

In 1985, the FAA contracted a consortium of aviation specialists to study windshear. As a result of that work, a windshear training aid was developed. The aid provided an effective means of training crews to minimise the windshear threat through avoidance, cockpit recognition, and recovery techniques. This included the 1988 publication *Pilot windshear guide* (FAA advisory circular 00-54). This outlined the limitations in pilot avoidance, with a reliance on visual indications, which can be complicated by marginal weather, and reports from other aircraft in high density traffic areas.

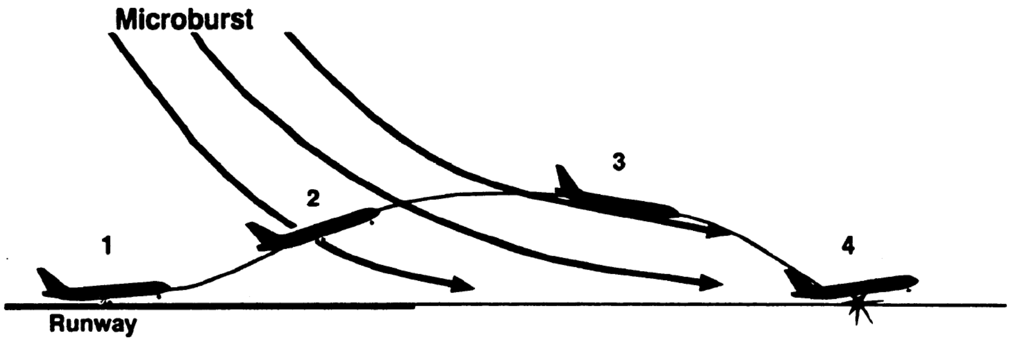
According to the advisory circular, between 1964 and 1986, there were at least 32 air transport accidents and incidents in which windshear was identified as a contributing factor, resulting in over 600 fatalities. There was also evidence to suggest that this figure was underestimated as it did not include undocumented 'close calls' and general aviation statistics.

Generally, the research showed that only 5 to 15 seconds may be available for the crew to recognise and respond to a windshear encounter. In describing a typical encounter shortly after take-off, with windshear encountered prior to a stabilised climb (Figure 8), for the first 5 seconds

56 A small, localised severe downdraft generally associated with a thunderstorm, which induces a horizontal burst of damaging wind at the surface, as the air hits the ground and spreads out.

the take-off appeared normal, with early trends in airspeed, pitch attitude, vertical speed and altitude appearing normal. However, as airspeed decreased, pitch attitude was reduced, limiting performance capability, and resulting in a loss of altitude.

Figure 8: Effect of a windshear encounter on the aircraft flight path during take-off



Source: US Federal Aviation Administration

The timeframe mentioned above was consistent with windshear research reported by Tsukagoshi (1999) conducted following a 1993 Douglas DC-9-41 hard landing accident in Japan following windshear during the landing approach (while crossing the runway threshold in Japan). Following the occurrence, the Japan Federation of Flight Crew Unions established a project to obtain objective and quantitative data on flight crews' reactions to windshear. The research was supervised by Dr Sado Horino from Kanagawa University, Japan, and was conducted on a DC-9 flight simulator at Northwest Aerospace Training Corporation near Minneapolis, US.

Eight DC-9 pilots completed 35 test approaches to land on the simulator. Windshear was encountered at random heights, from 50 ft to 900 ft. Of particular note, the results demonstrated that the average recognition time for a windshear encounter was about 5.5 seconds. Recognition time was defined as the time between the windshear encounter and when the pilot first moved the elevator control.

Windshear risk control systems

Windshear avoidance, based on pilot awareness and training, cannot be 100% effective. There are also limitations in recognition and recovery procedures, as this requires the aircraft to have entered the windshear condition, which can potentially exceed the aircraft's performance capability, regardless of pilot actions. Therefore, ground-based and airborne detection systems have also been introduced to reduce the hazard of an inadvertent windshear encounter (Bowles, 1990).

Ground-based low-level windshear alerting systems were developed and introduced at selected airports, predominantly in the US. However, there were 2 prominent windshear accidents in the 1980s (a Pan Am Boeing 727 on 9 July 1982; and a Delta Airlines Lockheed L-1011 on 2 August 1985), which prompted the FAA, in 1988, to mandate the use of airborne windshear detection systems for passenger aircraft.

The initial airborne windshear detection systems were reactive systems, which relied on the aircraft performance instruments, combined with attitude, angle of attack and accelerometer inputs. According to FAA advisory circular 25-12, *Airworthiness Criteria for the Approval of Airborne Windshear Warning Systems in Transport Category Airplanes*, even reactive systems 'provide a valuable service in the detection, timely annunciation, and confirmation of a potentially hazardous windshear condition generally in advance of human pilot recognition time'. With the development of digital signal processors in the 1990s, weather radar with forward-looking (predictive) windshear detection became possible and the first system was certified by the FAA in 1994. The requirement was to provide at least 10 seconds advance warning to the crew of a microburst. These systems used doppler weather radar and the moisture in the atmosphere to collect wind velocity data. Therefore, drier air would reduce the reflectivity and windshear warning time.

An article published by Honeywell Aerospace (2019), *Radar Corner: Understanding Airborne Windshear Detection Systems, Part One*, emphasised that 'It is the advanced warning time that saves the aircraft'. This time allowed the pilot to increase engine power, and retract the flaps and landing gear, thereby increasing the aircraft's energy state and climbing, so that the windshear encounter would occur at a higher, 'more survivable altitude'. The article further indicated that, during studies evaluating windshear recovery manoeuvres, it was found that when a windshear recovery manoeuvre was delayed by 5 seconds, the average altitude loss increased by 300 ft.

Another study on *Wind-Shear System Cost-Benefit Analysis* (Hallowell and Cho, 2010) reviewed the effectiveness of various detection systems, as the FAA considered the options for managing aging systems and evaluating new systems. The study also considered windshear mitigation strategies, which were categorised into 3 groups: pilot recognition and recovery training, airborne (aircraft systems), and ground-based systems.[57] While noting the difficulties in determining the effectiveness of pilot training in recognition and avoidance, for comparative purposes, this was estimated to be effective about 25% of the time. Conversely, while only measured in simulated environments, the effectiveness of predictive windshear (airborne) systems had often exceeded 95%, although this may be reduced in dry environments.

Notably, Hallowell and Cho (2010) identified that each of these categories provided their own advantages, with the greatest benefit achieved when multiple categories were combined. It also noted that air taxi and aerial work operations, which included firefighting aircraft, operated at low-level and low-speed outside the ground-based protection areas more frequently than air transport. Further, airborne systems including both reactive and predictive windshear systems, were not routinely available on air taxi, aerial work or general aviation aircraft.

While there are limitations to reactive and predictive systems, where these systems were fitted to firefighting aircraft, and warnings had activated in the low-level environment, several pilots reported at interview this had a positive effect on their management of the situation. In addition, in 2018, Lockheed Martin developed a civil-certified firefighting air tanker, which was a variant of the C-130J. The LM-100J 'FireHerc' had numerous advanced features that provided increased situational awareness and modern safety features to protect and guide crews through challenging flight conditions. Of most relevance to this investigation was the inclusion of warning systems with visual and aural alerts for windshear detection.

The accident aircraft was not fitted with a windshear detection system as it was built in 1981, prior to such technology becoming available. Likewise, the operator's other C-130 aircraft did not have this system. Retrofitted systems suitable for the C-130 have since become available.[58] However, the operator advised that they had not considered installing these systems into their C-130 fleet. Further, it was not required by regulation or contract to be installed.

On 10 July 2022, in response to the draft report, Coulson Aviation advised that aerial firefighting operate in very dry environments conducive to active fires. Therefore, with minimal or nil moisture present in the atmosphere it could be concluded that a forward-looking windshear detection system would provide little to no advance warning of a windshear event. They further indicated that their crews were highly experienced in recognising windshear events and crew reaction times would be as timely, if not quicker than a reactive-based system. The operator further advised that this statement was based on 'rational conclusion' based on experience supported by informed opinion. The ATSB was unable identify any research that supported this comment.

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[57] As ground-based systems were not relevant to firefighting operations, this has not been discussed any further.

[58] These predictive systems rely on a minimum moisture level to detect windshear. The performance specifications for minimum threshold moisture on the system available to be retrofitted to the C-130 were the same as the system fitted to B137.

Lockheed Martin Airplane Flight Manual

The Lockheed Martin AFM contained a section on adverse environmental conditions, which defined windshear as 'any rapid change in wind direction or velocity that results in an airspeed change of more than 10 knots'. Severe windshear was defined as 'a rapid change in wind direction or velocity causing airspeed changes greater than 15 knots, or vertical speed changes greater than 500 fpm [ft/min]'.

The AFM also warned pilots that severe windshear, particularly those with downdrafts, could exceed aircraft performance capability. It was considered to be most dangerous at low levels when encountering a decreasing headwind (or increasing tail wind) such as during take-off and approach. At these times, the aircraft is at low-level and low speed, and the initial reaction of the aircraft will be a drop in indicated airspeed and a decrease in pitch attitude, resulting in a loss of altitude.

By 2010, the Lockheed Martin AFM had introduced a recovery procedure for severe windshear encountered during approach to land as:

> 1. Announce a go around.
>
> 2. Set maximum power and select a go around (G/A) flight director mode, if applicable. Best initial pitch attitude will be a function of the conditions. If ground impact is a concern, rotate above the G/A flight director cue, as necessary, to target threshold speed until safe altitude above the ground is reached.
>
> 3. The co-pilot will monitor and call sink rate (VVI/VSI) and airspeed as appropriate.
>
> 4. The navigator/engineer will monitor and call out radar altimeter.
>
> 5. If flaps are at 100%, transition to 50% flaps after assuring continued positive rate of climb at no lower than Obstacle Clearance Speed.
>
> 6. Do not retract the landing gear until recovery is complete with positive climb rate and increasing terrain separation.
>
> 7. When clear of the wind shear, adjust pitch and power for normal climbout.
>
> 8. When conditions permit, report the encounter with ATC.

Coulson Aviation's Airplane Flight Manual and Company Operations Manual

On 10 July 2022, in response to the draft report, Coulson Aviation stated that the precursors that generally defined windshear would be routinely encountered in normal aerial firefighting operations due to the hot, dry, and windy conditions that lead to most bushfires. Therefore, the procedures, experience, and training to deal with, and respond to these conditions were in-built for their aerial firefighting operations. However, the ATSB noted that there was no windshear recovery procedure published in the operator's AFM, nor did it contain a section on adverse environmental conditions.

The manual did contain a warning associated with the go-around procedure, which was described by the operator's pilots as similar to the post-retardant drop climb out:

> Retracting flaps from 100 percent to 50 percent will increase stall speed. Without proper power and attitude corrections, sink rate will also increase. This is particularly noticeable at lower than normal airspeeds. If safe altitude and airspeed are not attained, inadvertent touchdown and/or stall may occur.[59]

The COM contained information on windshear in the departure procedures section, which stated:

> …wind shear may create a severe hazard for aircraft below 1,000 ft…the best defence is to avoid downdrafts altogether as it could be beyond you or your aircraft's capability… If wind shear is

[59] This was in accordance with the manufacturer's published procedure.

> encountered, prompt action is required. In the EC-130Q/L382G, the recovery requires full power and pitch attitude consistent with the maximum angle of attack for the aircraft.

The majority of the crew interviewed provided accounts of personal experiences with either a real or simulated windshear event in the low-level airdrop environment. It was noted that in-aircraft training was conducted by the operator for emergency scenarios with a focus on jettisoning the retardant. These descriptions were consistent with the manufacturer's procedures for windshear recovery, with additional consideration of jettisoning the load if aircraft performance did not improve after maximum power was applied.

Coulson Aviation windshear training

A review of the operator's C-130 simulator training syllabus noted there was no specific training item for a low-level windshear recovery scenario. The syllabus only noted that a briefing on recovery from windshear was to be conducted.

The operator conducted yearly training that consisted of ground school, simulator training, and in-aircraft flight training. Included in the ground school training were 'consider the load' discussions, where if there was an emergency or performance concern, they could jettison the load to improve aircraft performance. Further, in-aircraft training was conducted where each PIC completed a 'consider the load' scenario, with a focus on jettisoning the retardant. Any applicable emergency or non-normal event could be used for this purpose, which at times included a simulated 'down air' (downdraft) scenario.

At interview, it was noted by at least one pilot that the air drop[60] scenario was quite different between the firefighting and military scenarios, and that standardisation for completing these operations occurred through the operator's yearly training sessions.

On 10 July 2022, in response to the draft report, Coulson Aviation indicated that the response to a downdraft was consistent with the windshear escape manoeuvre for most large aircraft, with the added protection of being able to jettison the load to increase aircraft performance. In addition, the operator emphasised that the majority of their C-130 crews were current or former military pilots, where windshear recovery training was conducted on a bi-annual basis. Therefore, the operator considered their pilots to be 'extremely familiar' with the procedure.

Wreckage and impact information

Accident site

The accident site was located on slightly sloping, partially wooded terrain, near Peak View, 50 km north-east of the Cooma-Snowy Mountains Airport. The wreckage trail (Figure 9) was approximately on a heading of 100°, with the initial impact at an elevation of about 3,440 ft AMSL. The debris trail began at the lower end of the slope, with the wreckage distributed linearly over about 180 m.

60 An air drop is generally defined as a delivery of cargo, supplies or personnel by parachute from an aircraft in-flight.

Figure 9: Accident site overview showing the wreckage trail

Source: ATSB

Wreckage examination

The ATSB's on-site examination of the wreckage, damage to the surrounding vegetation, and ground markings, all indicated that the aircraft initially impacted a tree in a left wing down attitude of about 55°, before colliding with the ground. An intense post-impact fuel-fed fire destroyed the aircraft. The ATSB's on-site examination also found (Figure 10):

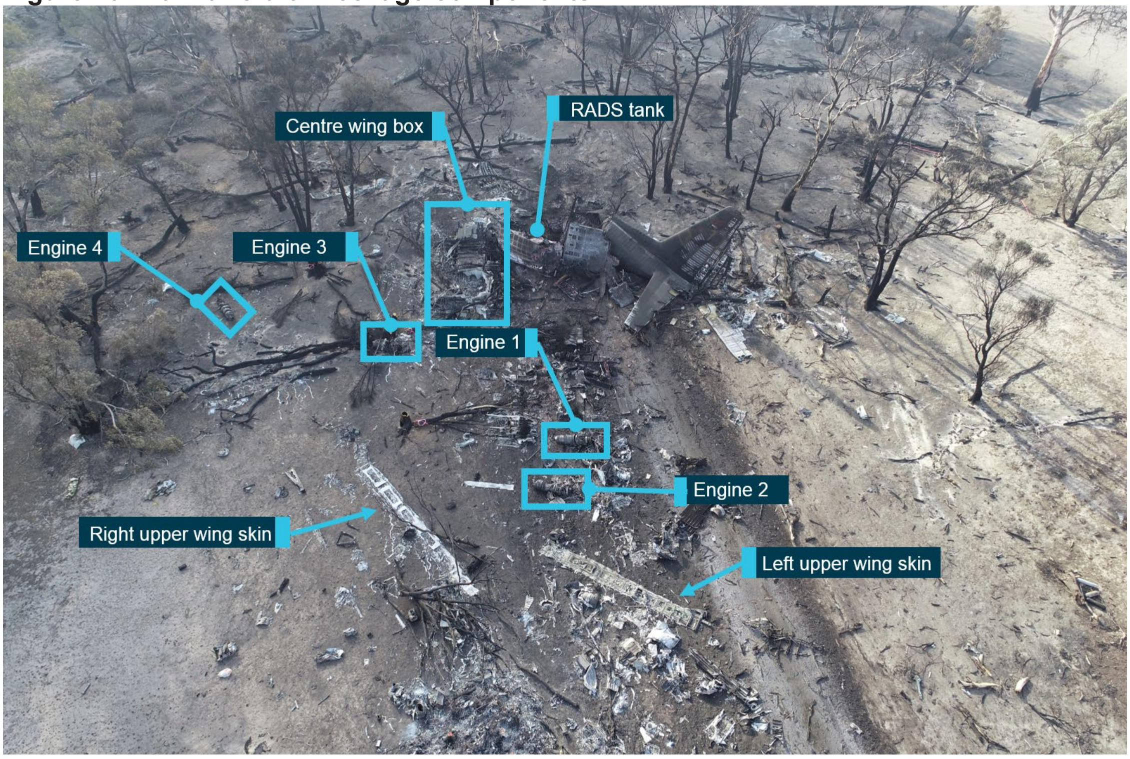
- no pre-existing airframe issues
- all major sections of the aircraft's structure were identified and there was no evidence of an in-flight break-up or pre-impact structural damage[61]
- the cockpit and associated avionics were identified about two-thirds of the way along the wreckage trail
- the cockpit and forward section of the airframe had separated from the fuselage, was inverted, and had been destroyed in the impact and fire
- sections of the wing skin, leading edge spar, wing tips and portions of the wings were identified along the wreckage trail, having fragmented during the impact sequence, and sustained further damage during the fire
- all flight control surfaces were identified, however, flight control continuity could not be established due to the impact and fire

[61] In July 2018, the aircraft manufacturer published service bulletin 382-57-97 to address accelerated structural fatigue for C-130 aircraft performing air tanker operations.

- the vertical and horizontal stabilisers had remained attached to the aft section of the fuselage
- the 4 engines and 16 propeller blades were located on-site and some of the propeller blades remained attached to the propeller hubs, while others had detached through impact forces
- there were varying degrees of damage observed across the 4 engines, likely due to the impact sequence of each engine, with the damage indicating the engines were rotating at impact.

The RADS tank remained upright, with no fire retardant identified between the drop area and the initial impact location. However, a large amount of retardant was located in the wreckage near the tank. The system was badly damaged, with the doors fragmented throughout the wreckage, and its operational state could not be established.

Figure 10: Main aircraft wreckage components



Source: ATSB

Aircraft configuration

The aircraft was equipped with 4 trailing edge flaps. All flaps had separated from the aircraft during the impact sequence. On-site measurements of the flap screw jacks indicated the flaps were set at 50% at impact. This was consistent with the expected setting following a retardant drop. Due to the extent of damage, the elevator, aileron, and rudder trim settings could not be established.

Fuel testing

Fuel samples were retained from the 2 fuel tankers that last serviced the aircraft and from the refuelling storage tank at Richmond. The fuel samples were independently tested by a commercial fuel company for correct specifications, with nil abnormal indications found. In addition, there were no reports of fuel quality concerns with any other aircraft using the same fuel source.

Engine and propeller examinations

With the assistance of the Australian Army, the engines, partial remnants of the reduction gearboxes, and propeller assemblies and blades were transported to a secure hangar at Richmond Royal Australian Air Force (RAAF) Base for further examination. The engine manufacturer attended the inspections, where it was confirmed that all engines were rotating at impact, and there were no noted pre-existing issues. As power changes were controlled by changes to the propeller blade pitch while maintaining a constant engine speed, the engine power levels were determined from the blade pitch angle at impact.

During the propeller hub assembly inspection, measurements of the internal components were recorded. The ATSB consulted the propeller manufacturer to determine the propeller blade angles at impact, and establish engine power levels. The propeller manufacturer concluded the following:

> The calculations indicate that, based on the operating conditions estimated by the ATSB,[62] all the propellers were absorbing power from their respective engines and were producing positive thrust. The horsepower computed for each of the four engines are within the normal operating range for the T56 engine installed on this aircraft.

Recorded information

General information

The aircraft was not fitted with a flight data recorder, nor was it required to be by Australian or US regulations. However, there were devices on board that recorded information relevant to the flight path, as well as data that was transmitted in real time. Further, 2 firefighters located near the accident had videoed the aircraft. An analysis of these sources are presented below.

Witness video

Two firefighters were located on Feeney's Road (800 m from the accident site), and both videoed the aircraft during the retardant drop. One video was taken in the landscape orientation and had a duration of 18 seconds. This video captured the drop and stopped as the aircraft was descending (Figure 11: 1315:15 to 1315:33). The other video was taken in the portrait orientation and was 37 seconds in duration. It captured the aircraft descending into the drop zone and ended after the aircraft impacted with terrain (1315:05 to 13:15:42). Collectively, the videos captured the aircraft from 10 seconds prior to the retardant drop, the drop, and the 5 seconds after the drop when the aircraft became obscured by smoke and was only intermittently visible (Figure 11). From the witness video, it was unclear if the aircraft flew behind the smoke, or entered the smoke. Seventeen seconds after the drop, the aircraft was seen at low-level, followed by the collision with terrain and post-impact fire.

The videos were analysed by the ATSB using commercial camera tracking software[63] to estimate the aircraft's flight path and attitude. The RAAF Aircraft Research and Development Unit also analysed the video to evaluate the aircraft attitude. These analyses indicated that:

- at 1315:15 (commencement of the drop), the aircraft was at a left bank angle of 10°, with a pitch of 0°
- at 1315:17 (end of the drop), the aircraft was at a left bank of 17° and a pitch-up of 6°
- at 1315:21, the aircraft reached its maximum left bank of 31°and maximum pitch-up of 12°
- at 1315:22 and 1315:23, the aircraft was obscured by smoke and the attitude could not be determined

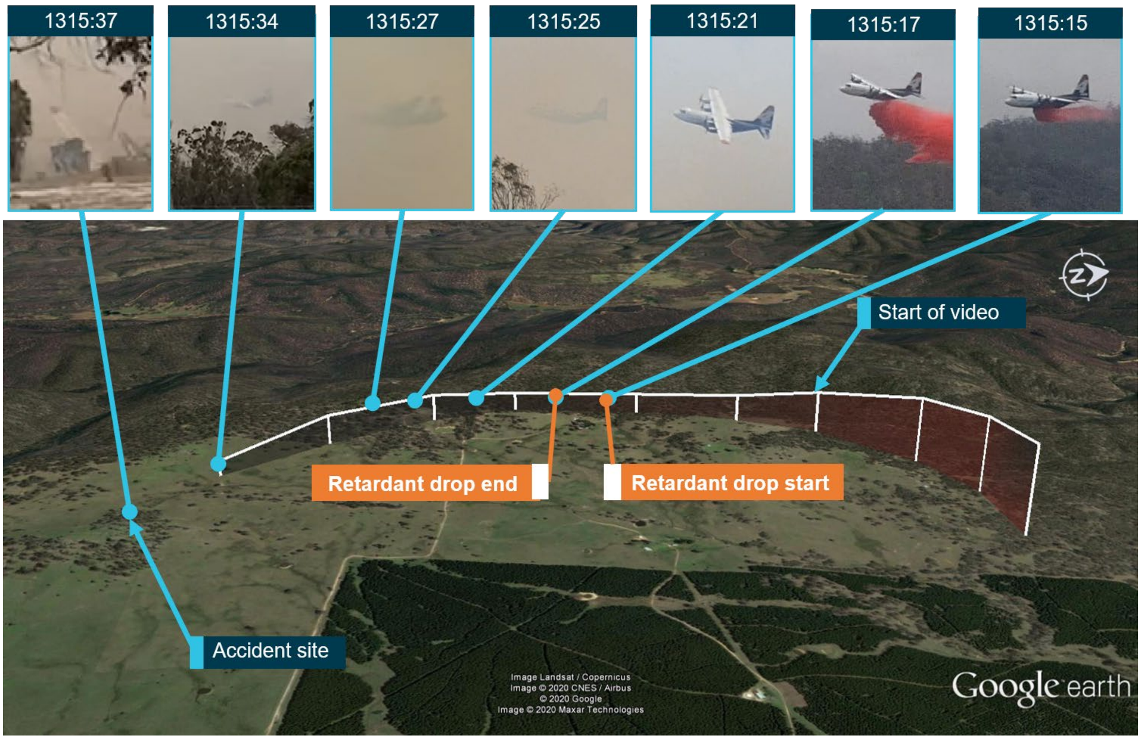
[62] To calculate thrust, the ATSB provided the propeller manufacturer with a true airspeed range of 110–135 kt to account for a tailwind component in the range 15–40 kt at impact.

[63] SynthEyes is a program for 3D camera tracking, also known as match-moving. It required a minimum number of visible reference point to resolve the attitude and path.

- at 1315:25, the aircraft was at a left bank of 18° and a pitch-up of 8°
- at 1315:26, the aircraft was at a left bank of 5° and a pitch-up of 6°
- at 1315:27, the aircraft was at a right bank of 6° and pitch-up of 5°.

From 1315:27 the aircraft was obscured by smoke, and the attitude could not be determined using SynthEyes. The general attitude could be determined from basic photogrammetry at limited points from this time.

Figure 11: Aircraft attitude and approximate flight path at key times



Source: Google earth and SkyTrac data, annotated by the ATSB

For about 10 seconds after the completion of the drop, a positive rate of climb was achieved, with the aircraft climbing about 170 ft (to 3,770 ft AMSL) from the drop height. Following this, the aircraft was then observed descending. At 1315:34, the aircraft was seen at a very low height above the ground, in a slight left bank, immediately followed by a significant left roll just before ground impact. The elevation of the terrain, while undulating, also increased by about 40 ft from the drop site to the accident site.

The footage was also used to review aircraft control and configuration changes, such as flap positions and aileron movement. Shortly after the drop, the flap position was assessed as being 100%, consistent with the operator's AFM supplement drop procedure. However, further assessments could not be made due to limitations with the video quality, visibility, and aircraft attitude. At various points in the video, both left and right aileron movement could be seen, but actual deflections could not be determined.

The videos also provided a general understanding of the low-level wind conditions at the time, with significant audible and visual movement of the surrounding trees and smoke, and blowing dust at ground level. It was also noted that there was no video evidence of any retardant being dropped between the initial drop location and the impact site.

Operational load monitoring system

Aerial firefighting contract requirements in the US required the aircraft be fitted with an operational load monitoring system (OLMS), predominantly for monitoring aircraft loading during operation. The OLMS was located behind the centre wing section in the fuselage and recorded data at a rate of 32 Hz (32 times per second). This recording device had no impact or fire protection, and was destroyed in the accident sequence.

Six months of historical data for B134 was made available to the ATSB, to allow for a comparison of the available accident flight data with previous flights. This review identified that the pitch and angle of bank data was not recorded correctly by the OLMS. Therefore, only the flap retraction timing and duration, and the vertical speed (rate of climb/descent) could be compared. While there was no comparable data available for flights with the entire accident crew, a review of the PIC's recent flights and comparison with other crews indicated that the flap retraction was generally initiated between 2.5 and 5.5 seconds (with an average of 3 seconds) after the drop was completed. It also showed that the actual flap retraction from 100% to 50% flap took about 4-5 seconds and was completed, on average, about 7-8 seconds after the drop.

The rate of climb post-drop varied between 500 ft/min and 2,400 ft/min, with the majority of the flights between 1,100-1,500 ft/min. These variations were possibly related to weather patterns, terrain limitations, and the operational requirements, which were unique to each drop.

SkyTrac and automatic dependent surveillance broadcast (ADS-B) data

Aerial firefighting contracting requirements in Australia required the aircraft to be fitted with a tracking capability. The aircraft was fitted with SkyTrac, a system that could transmit the aircraft's position in real-time, and was monitored by the NSW Rural Fire Service (RFS). The SkyTrac unit was recovered from the wreckage and transported to the ATSB's technical facility for examination and download. The Canadian Transportation Safety Board assisted in the conversion of the downloaded data.[64] The SkyTrac unit recorded data at 5 second intervals.

Data broadcast by the automatic dependent surveillance broadcast (ADS-B) equipment fitted to the aircraft for air traffic control purposes was also obtained from various providers. This system determined the aircraft's position using GPS and then broadcast this information, along with pressure altitude,[65] ground speed,[66] and other data, at regular intervals. ADS-B data was transmitted every 0.5 seconds, however, not all transmissions were available, with gaps of up to 5 seconds during the accident flight. Aside from the difference in recording intervals, the data provided for the common parameters across both sources was identical.[67] Table 2 shows the parameters recorded by SkyTrac and ADS-B.

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[64] The SkyTrac unit was a Canadian built device, and the intellectual property had been provided previously to the Canadian Transportation Safety Board.

[65] The ADS-B data had output the pressure altitude and barometric vertical speed, both of which were derived from the air data computer, an avionics component which calculates airspeed and altitude trend data, based on the aircrafts pitot-static system. Pressure altitude is the altitude referenced to the international standard atmosphere, at 1013.25 hPa, atmospheric pressure at mean sea level.

[66] Ground speed is the speed of an aircraft relative to the surface of the Earth.

[67] ADS-B data recorded an additional ground speed of 132 kt immediately prior to impact, however, this was not used in the performance analysis.

Table 2: SkyTrac and ADS-B recorded parameters

SkyTrac	ADS-B
• time	• time
• latitude and longitude (position)	• latitude and longitude (position)
• ground speed	• ground speed
• track	• track
• GPS altitude (AMSL)	• pressure altitude
	• vertical rate of climb/descent

Airspeed calculations

Using the ground speed from the SkyTrac and ADS-B data, and the weather observations from Peak View, the wind speeds of 15, 30 and 40 kt from the north-west were used to estimate the aircraft's true airspeed.[68] These values were consistent with a review of the aircraft ground speed in the drop planning circuits. These circuits showed a periodic variation consistent with the aircraft flying into, and then with, the wind, and indicated that the wind speed was likely of a magnitude of 20-40 kt from a north-westerly direction during their drop planning circuits.

The calculated true airspeed values were then converted to a computed calibrated airspeed (CAS)[69] using temperature and pressure data also from Peak View. The airspeed calibration charts in the operator's C-130 AFM showed that there was a negligible difference between the CAS and indicated airspeed at the airspeed range being considered. Therefore, the CAS was equivalent to the indicated airspeed that would have been presented to the crew on the airspeed indicator.

The data showed a limited increase in the ground speed from 144 kt at the start of the drop, to 149 kt during the post-drop climb-out period, to a maximum of 151 kt just prior to the collision with terrain. However, the CAS (Figure 12) can be seen to be significantly lower, and with a much smaller increase during the climb. In the last 15 seconds of the available data, the calculated CAS was between 100 and 123 kt.

Vertical speed

From the SkyTrac data, a positive rate of climb was recorded for the 10 seconds following the drop, with the aircraft climbing to about 170 ft above the drop height, which was consistent with the witness video. The derived vertical speed,[70] while noting its limitations (as described above for the operational load monitoring system), increased from zero at the end of the drop to about 1,000 ft/min in the 8-10 seconds after the drop, then decreased to about 0 over the next 5 second period. At the last data point, the aircraft was descending at about 2,000 ft/min.

Aircraft track

From both SkyTrac and ADS-B data, the retardant drop was conducted on a track of about 190°. The aircraft was then turned through 160° as the climb rate peaked, with the last recorded track of 133°, about 3 seconds prior to impact.

The recorded ground speed, calculated CAS, track, derived vertical rate, and altitude for the last 30 seconds of flight is shown in Figure 12.

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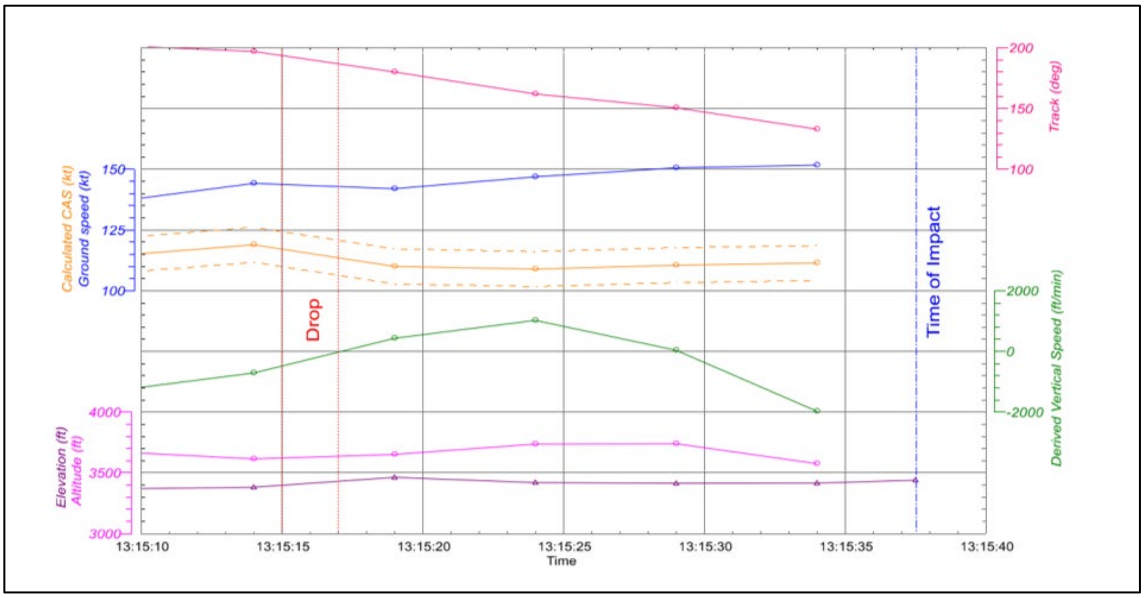
68 True airspeed is the airspeed of an aircraft relative to the air through which it is moving.

69 The calibrated airspeed (CAS) is indicated airspeed corrected for installation and instrument errors.

70 The SkyTrac vertical speed data was derived from the time and altitude information.

Figure 12: Recorded flight path data, derived airspeed, and rate of climb for the last 30 seconds of flight



Source: SkyTrac and Geoscience Australia digital elevation data, annotated by the ATSB

Low pressure spike

Prior to the drop, the ADS-B pressure altitude was, on average, about 250 ft above the SkyTrac GPS altitude (Figure 13), which was consistent with the QNH on the day. It was noted that there was a small increase in the ADS-B pressure altitude immediately following the drop. This was consistent with the RADS tank doors closing on previous drops, but this returned to about a 250 ft difference with the GPS-based SkyTrac altitude.

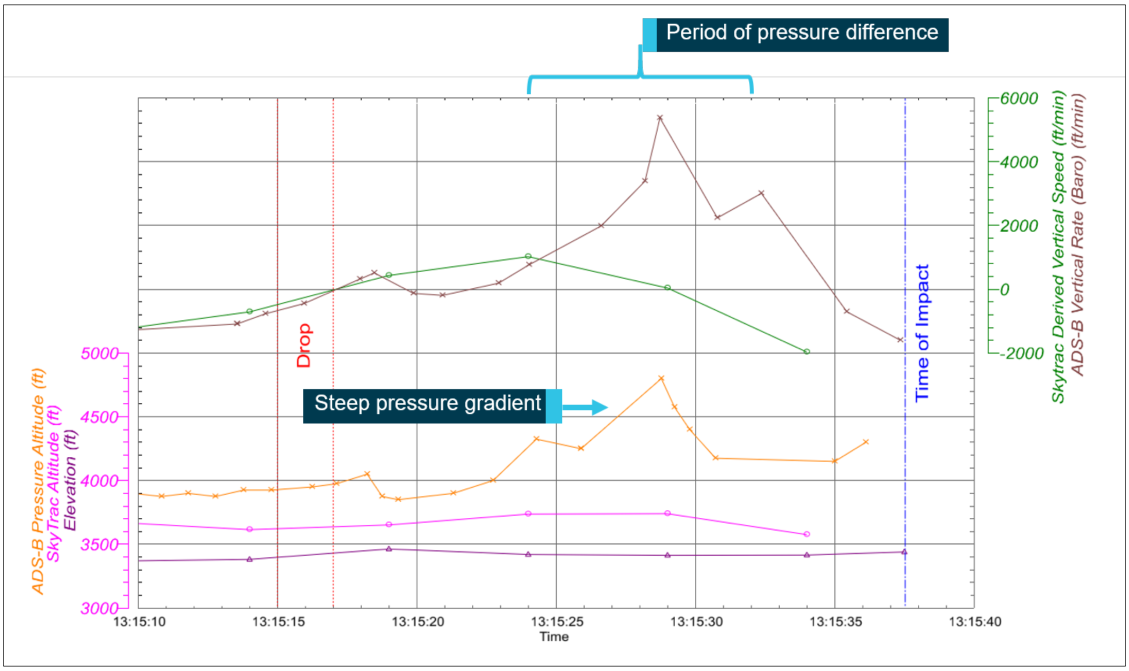
However, at about 1315:24, the ADS-B pressure altitude and the vertical rate began to diverge significantly, with a low atmospheric pressure spike at about 1315:29. This was identified by an abrupt increase in both the pressure altitude[71] and barometric vertical speed. In comparison, the SkyTrac GPS-based derived vertical speed showed a smaller increase, which correlated with the SkyTrac altitude.

As there were several data points associated with this spike, this was considered more likely to be associated with a real event, rather than an erroneous reading. The abrupt rise and fall in these parameters suggested the aircraft encountered a region of low pressure, relative to the surrounding air, with a steep pressure altitude gradient during the climb-out.

The reason for the localised pressure change could not be determined by the ATSB. Aircraft configuration changes (the RADS tank doors opening or closing, and flap changes) were excluded based on a review of the historical OLMS data. Several other potential factors were considered, including localised turbulence, wind gusts, terrain effects, temperature changes, and fire driven changes associated with smoke plumes. However, limitations in the available evidence prevented a determination.

[71] A higher-pressure altitude results in a decrease in aerodynamic performance.

Figure 13: Comparison of SkyTrac and ADS-B altitude and vertical rate data showing the low-pressure spike



Note: ADS-B pressure altitude shown as recorded references the international standard atmosphere QNH rather than actual QNH.
Source: ADS-B and SkyTrac, annotated by the ATSB

Cockpit voice recorder

The cockpit voice recorder (CVR) fitted to the aircraft was a solid-state memory Universal Avionics Model CVR-30B, part number 1603-02-03 (Figure 14). CVRs are designed on an endless loop principle, with the oldest audio continuously overwritten by the most recent audio. In this case, the CVR recorded crew and cockpit audio for a duration of at least 30 minutes. While the aircraft was not required to be fitted with a CVR under the US or Australian regulations, it was a contract requirement with the US Department of Agriculture, Forest Service (USFS).

Figure 14: N134CG cockpit voice recorder

Source: ATSB

The CVR was recovered from the aircraft and transported to the ATSB's technical facility in Canberra on 25 January 2020 for examination and download. Thirty-one minutes of audio data was successfully downloaded. However, the audio was from a previous flight when the aircraft was operating in the US. No audio from the accident flight was recorded on the CVR.

Inertia switch

The power supply to the CVR was fitted with an inertia switch. Inertia switches are designed to stop the recording function by removing power to the CVR when a pre-set deceleration force was detected. The recovered audio was of crew training flights undertaken on 7 May 2019 near Sacramento McClellan Airport, California. The audio included 4 landings conducted as part of that training. The recording ceased immediately after the fourth landing, and the post-landing taxi and engine shutdowns were not recorded. It was likely that the inertia switch was activated during this landing and consequently disconnected power to the CVR.

Pre-flight testing

Following installation in an aircraft, supplemental material related to the operation of the CVR must be attached to the approved AFM. The supplement for the accident aircraft indicated that the CVR conducted a self-test at power up, and the status of the system would be presented to the crew on the CVR control unit, located on the copilot side console. A CVR system check for crew was also included in the operator's AFM supplement, but was not included in their pre-flight checklists. None of the operator's C-130 flight crew interviewed were aware of the need to check this system status prior to flight.

CVR maintenance

A review of the aircraft's maintenance logs indicated that the underwater locating beacon attached to the front of the CVR was replaced on 24 December 2019. This was a self-contained, replaceable unit, and a full maintenance service check was not required with this replacement. A maintenance check was conducted yearly, and had last been performed in February 2019.

Medical and pathological information

Pilot in command

The PIC held a first-class medical certificate that was issued on 5 September 2019 by the FAA, with a limitation to wear corrective lenses. The PIC's aviation medical records were provided for the period 2013 to 2019. Overall, these examinations reported no significant medical conditions or abnormal physical findings. Of note, the PICs last electrocardiogram (ECG),[72] conducted as part of their annual medical examinations, showed indications of an inter-atrial conduction delay,[73] while previous ECGs noted sinus bradycardia.[74] Otherwise, the ECGs were considered normal and were 'cleared' by the FAA medical officer.

The PIC was reported to be fit and active, with no known medical conditions. On the morning of the accident flight, the PIC's behaviour appeared normal and there was no evidence to indicate any concerns regarding their general health. While limited, the post-mortem examination did not identify any pre-existing medical conditions that could have contributed to the accident nor detect any commonly used drugs or alcohol. Due to limited blood samples, carbon monoxide testing could not be conducted.

Copilot

The copilot's most recent first-class medical examination was issued on 17 July 2019 with no limitations. The copilot's aviation medical records were provided for 2018 and 2019. The records reported no significant medical conditions or abnormal physical findings. The records noted that they were taking prescribed medication to lower blood cholesterol and reduce the risk of heart disease. The copilot's last ECG noted several common anomalies,[75] but it was 'cleared' by the FAA medical officer.

The post-mortem examination identified narrowing and areas of calcification[76] in both the left anterior descending artery and right coronary artery of the heart. However, the muscle layer of the heart showed no identifiable scarring and there was no indication of an acute coronary artery occlusion (blockage). While no other evidence of significant natural disease was identified, the examination concluded that, the significance of the narrowing, in the absence of any evidence to indicate a blockage in the heart, was unclear. In addition, toxicology testing did not detect the presence of any alcohol, or common medications and illicit drugs. Carbon monoxide testing could not be conducted due to the lack of a suitable sample material.

Flight engineer

The flight engineer's most recent second-class medical examination was issued on 27 August 2019 with no limitations. From their 2019 aviation medical records, there were no reported medical conditions or abnormal physical findings that could have affected aircraft operations. While limited, the post-mortem examination did not identify any pre-existing medical conditions that could have contributed to the accident. The toxicological analysis identified traces of a commonly used over-the-counter antihistamine. Carbon monoxide testing could not be conducted due to the lack of suitable sample material.

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72 An ECG detects heart problems by measuring the electrical activity generated by the heart as it contracts. ECGs from healthy hearts have a characteristic shape. If the ECG shows a different shape it could suggest a heart problem.

73 Interatrial conduction delay is an electrical abnormality, which is very prevalent in general hospital patients with sinus rhythm (such as sinus bradycardia), and is considered a marker of an electromechanical dysfunction in the left atrium.

74 Sinus bradycardia was a slower than normal heart rate typically resulting from good physical fitness, taking medications, or from a heart blockage.

75 The ECG anomalies noted were commonly found in the general population and did not necessarily represent a medical condition.

76 Calcification causes the artery walls to become more hardened.

Aviation medical specialist

The ATSB engaged an aviation medical specialist to review the crew's aviation medical records and post-mortem examinations. Noting the limited evidence that could be collected from the examinations due to the nature of the accident, the specialist concluded that:

- As best as could be determined, there was no suggestion of in-flight incapacitation.
- The copilot's examination identified that 2 of the arteries in their heart showed evidence of narrowing and calcification, but there was no pathological evidence of acute coronary occlusion. The copilot had been taking prescribed medication to treat elevated cholesterol levels for several years. This medication was approved for use by flight crew in both the US and Australia. Further, the copilot's blood pressure readings and last ECG tracing were all within normal limits.
- The detection of the antihistamine and the reported concentration could not be used to determine with any certainty if the flight engineer was using the medication at the time of the accident or during non-flying periods. This was considered an 'incidental' finding.
- While any exposure to carbon monoxide from the fires could not be determined in this case, limited research on a small cohort of ground fire-fighters many years earlier, determined that carboxyhaemoglobin[77] levels of around 6% were indicative of fire-ground exposures. This level, had it been present in the crew, was not likely to have caused in-flight incapacitation.

Test and research

Reconstruction flight

On 24 January 2021, at about 1300, the operator reconstructed the flight path from the drop location to the accident site. The intention was to record the perspective and challenges of the terrain, while acknowledging the lack of bushfire smoke and environmental conditions. The flight was in a Cessna Citation 550 (business jet), with the Director of Flight Operations on board. They flew the path twice, firstly at 3,665 ft AMSL and then at 3,610 ft AMSL (noting the accident flight path was at about 3,600 ft AMSL). They noted that, as they turned toward the drop exit and were flying towards the accident site, they experienced an airspeed decay, even as engine power was increasing. While this was not considered 'extreme' on the day, it was 'a bit surprising'. Further, they stated that the path flown by the crew of B134 from the drop to the accident site was into slightly rising terrain.

At the time of the flight, the METAR[78] for the Cooma-Snowy Mountains Airport recorded wind was 13 kt at 250°, with the direction varying between 200° and 290°. However, at 1143, a SPECI[79] recorded winds of 15 kt gusting to 29 kt at 260°, and the aerodrome forecast issued from 1200 indicated winds of 14 kt gusting to 25 kt at 270°.

C-130 simulator testing

Purpose

A series of tests were undertaken in a simulator representative of the accident aircraft, the RAAF C-130J-30 full flight mission simulator. The purpose of the testing was to determine if, and under what conditions, wind speeds representative of the strength and prevailing direction reported on the day of the accident could potentially affect aircraft performance. In particular, if the airspeed of

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[77] When carbon monoxide is absorbed into the bloodstream, it readily binds with haemoglobin to form carboxyhaemoglobin. This reduces the oxygen carrying capacity of the blood and in turn decreases the release of oxygen to the tissues.

[78] A METAR is a routine report of meteorological conditions at an aerodrome.

[79] A SPECI is a special report of meteorological conditions, issued when one or more elements meet specified criteria significant to aviation.

the simulator could decay to the power-on stall speed given the accident flight profile, of a climbing turn from 200 ft AGL. In addition, tests were also conducted to evaluate the effect following a weight reduction of 25,000 lbs (11,340 kg), from a jettison of the remaining fire retardant.

The testing was performed by RAAF Aircraft Research and Development Unit C-130 qualified test pilots (QTPs), supported by the simulator fidelity manager, under the direction of the ATSB. There were no recordings available of the accident crew's actions. Therefore, the testing was limited to attempting to replicate the known flight path and aircraft attitude, with crew inputs (configuration and power setting changes) described as typical by the operator's crew. The accident site and drop location were in the simulator database, which enabled a recreation of the accident flight profile from the start of the drop to be used for the tests. The intent was not to recreate the accident flight in full, or review the crew's potential response to the situation, but focussed on the aircraft performance in the environmental conditions.

Aircraft differences

Access to a C-130H model simulator was limited, with none located in Australia and restrictions imposed by the COVID-19 pandemic. However, a C-130J model simulator was offered to the ATSB. The C-130H (accident aircraft) and the C-130J were both listed on the same FAA Type Certificate. A discussion of the differences and limitations was held with the RAAF's Aircraft Research and Development Unit chief of flight test, which considered the airframe, engines, aircraft controls, wings, aircraft systems and modelling limitations. The primary differences with respect to the aircraft were that the C-130J simulator had:

- a longer airframe affecting some aircraft handling qualities
- significant upgrades to the propulsion units
- stall speeds likely to be slightly lower
- aural and visual stall warnings, tactile stall warning (stick shaker) and stall avoidance (stick pusher) systems (not installed on the H model).

As control effectiveness was not being tested, the differences in aircraft handling qualities were of little impact to the proposed assessment. Similarly, an equivalent thrust level could be used to determine the necessary power settings, and limited to the available C-130H levels. To characterise the potential differences in stall speeds, a series of tests were completed, documented in the *Results* below. The stick shaker and stick pusher functions were both turned off during testing.

Simulator limitations

The ATSB also considered the limitations of the simulator, noting that they are designed for flight training, with the following being of most importance:

- it had a pre-programmed stall characteristic of a 50° left wing drop
- the stall was not considered to be well modelled
- complex weather phenomena such as mountain waves and rotors could not be modelled
- pre-programmed windshear models had a tailwind of 60 kt
- wind gusts could be modelled, but the timing of the gusts could not be controlled.

As the test objectives were to characterise the flight profile with wind speeds that could reduce the airspeed to the stall speed, the pre-programmed stall behaviour and modelling did not impose any limitations on the assessment. As the pre-programmed windshear model was in excess of the planned test conditions, the simulator fidelity manager developed a method to simulate windshear using the wind gradient tool. This resulted in the wind magnitude changing linearly, proportional to the altitude increase. This also required the test runs to commence in level flight at the drop height of 200 ft AGL, rather than from a descent profile to avoid a pre-drop windshear disrupting the climb-out test profile. A consequence of this methodology was that, on the occasions the simulator entered a pre-stall sink, it exited the windshear condition, which allowed it to recover airspeed and fly-away.

Test summary

The planned test criteria included constant winds of increasing strength, windshear of increasing strength, followed by the addition of turbulence[80] and gusts to each of these base conditions. Three thrust settings were calculated, based on the calculated true airspeeds (refer to section titled *SkyTrac and automatic dependent surveillance broadcast (ADS-B) data*) and propeller blade angles (refer to section titled *Engine and propeller examinations*) considered to provide reasonable boundary conditions.

Fourteen test profiles were developed, which included:

- Three initial tests to establish the equivalent power settings, and comparison of the stall values against the C-130J and C130H flight manuals. It also included the development of the flight profile for the QTPs to practice using the pitch changes, bank angles and heading changes provided by the ATSB.
- Eight profiles were planned for the QTPs to fly the accident profile under various wind conditions. These conditions included constant wind speed environments of varying strengths, windshear environments of varying strength, followed by the addition of turbulence and wind gust profiles.
- Three profiles were developed to test the effect on the stall speed of a reduction of 25,000 lbs, simulating the emergency dump of the remaining fire retardant.

Multiple flight runs were then undertaken for each test profile by 2 QTPs.

Results

The RAAF simulator for the C-130J-30 demonstrated stall speeds comparable to those published for the C-130H at the approximate weight of the accident, 131,000 lb (59,420 kg), in the unaccelerated level flight condition. The power-off stall speeds were 98 kt (simulator) and 101 kt (C-130H), and power-on stall speeds were 82 kt (simulator) and 83 kt (C-130H).

The simulator provided useful insight into the potential for a significant loss of airspeed to occur when a combined maximum wind speed (mean wind plus gust) of 50 kt was used as the control variable. Although this was greater than the surface wind speed recorded at Peak View of 43 kt, it was consistent with the pilot reports from the smaller fire-control aircraft earlier on the day of the accident.

The key outcomes from the simulator testing were:

- A constant strong (40 kt) north-westerly wind resulted in a small loss of airspeed during the climb-out, with minimum airspeeds of about 113 kt IAS, and a ground speed of about 160 kt. There were no aural stall warnings activated, the pilots reported no indications of any pre-stall buffet or other warnings, and was a notably higher ground speeds than the accident flight.
- A moderate (15 kt) north-westerly wind, combined with a 15 kt windshear, a 25 kt windshear and a 35 kt windshear during the climb-out resulted in an airspeed decay to between 98 kt and 104 kt, with intermittent aural stall warnings. The pilots also reported the controls were less responsive in the higher wind speed scenarios, indicative of approaching the stall.
- A moderate (15 kt) north-westerly wind, with +10 kt gust and +25 kt windshear during climb-out produced similar ground speeds to the accident flight. This consistently resulted

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80 The review of the data post-testing showed the maximum g load applied when modelling severe turbulence was 0.3 G. This was significantly less than the expected additional load factor (0.5-1 G). Therefore, the impact on the stall speed was lower than expected, and is not discussed in the results.

in the airspeed decaying into the stall speed region between power-on (82 kt IAS) and power-off (98 kt IAS) with repeated stall warnings. The minimum airspeed was in the range 84–98 kt IAS and the ground speed was in the range 141–151 kt.

- When simulating an emergency dump of the remaining fire retardant, the rapid weight reduction, if made after the aural stall warning activation,[81] but prior to aerodynamic stall, reduced the stall speed. The simulator exited the stall warning/pre-buffet stall regime and improved the performance as expected.

Aerial firefighting in Australia

Overview

The National Aerial Firefighting Centre (NAFC) was formed by the Australian States and Territories in 2003 to provide a cooperative national arrangement for combating bushfires by facilitating the coordination and procurement of specialised firefighting aircraft.

The NAFC contracted aircraft on behalf of all the states and territories, with leasing arrangements allowing for aircraft to be moved around the country to address the prevailing bushfire risk. For each aircraft, a state or territory then assumed primary responsibility, and managed the operation and deployment of that aircraft.

As detailed in the *National Aerial Firefighting Strategy 2021–26* (National Aerial Firefighting Centre, 2021), firefighters operate in an escalating risk environment frequently challenged by 'changing fuel, vegetation and vulnerabilities'. At the same time, they strive to meet the community, government, and media expectations for protecting lives, properties, and the environment. This has resulted in:

> …situations where aerial assets can provide effective support are increasing, and with them, community expectations. Meeting these expectations is a risk. Aerial firefighting has grown from 'just another tool in the toolbox' to a point where the community expect firefighting aircraft over every fire (especially 'their' fire).

Consequently, aerial firefighting has become a critical capability for the management and suppression of bushfires in Australia. To effectively achieve this, aircraft are flown at low altitudes and low airspeeds, often over inhospitable terrain with reduced visibility from smoke. This creates a high-risk environment, which 'requires an enduring focus on training, compliance, and risk mitigation' (National Aerial Firefighting Centre, 2021).

Operating environment and limitations

In 2020, although born out of the 2019-2020 bushfires, an inquiry into Australia's national natural disaster coordination arrangements was conducted. The final report, *Royal Commission into National Natural Disaster Arrangements*, was published in October 2020. The report noted that the effectiveness of aerial firefighting was dependent on a number of factors including the distance and time to travel to the fire-ground, the type of aircraft used, pilot skill, weather conditions, fire-fuel type, intensity and size of the fire, type of suppressant use, and the tactics employed to respond to the fire. Specifically, the report identified the following limitations:

> Aircraft alone are not a solution to fighting bushfires. Interaction between aircraft and fire crews is necessary to bring a fire fully under control…
>
> …poor weather conditions can limit and sometimes prevent the use of aircraft. For example, requirements for pilots to maintain visibility of terrain can limit the use of aircraft in severe conditions (eg low visibility in heavy smoke or cloud); and turbulence caused by strong winds and the terrain can make operating aircraft unsafe, especially at low altitude.
>
> Poor weather conditions can also restrict the effectiveness and use of aerial firefighting. For example, during the 2019 SA [South Australian] Cudlee Creek and Kangaroo Island fires, weather conditions

[81] The aural stall warnings generally occurred within 1-2 kt of the pre-stall buffet being felt by the QTPs.

> prevented all attempts by aircraft, including LATs, from containing the forward spread of the fires. Furthermore, extreme weather conditions experienced periodically throughout the 2019-2020 bushfire season meant there were a number of days when aerial firefighting could not be employed.

Activity

According to research conducted by the ATSB (2020), *A safety analysis of aerial firefighting occurrences in Australia,* the number of occurrences per financial year increased steadily between 2016–17 and the bushfire season 2019-20. However, data collected by the NAFC and presented in the Australian and New Zealand National Council for fire and emergency services' (AFAC) 2019-20 annual report, estimated that aerial firefighting activity for the 2019-20 season was around 4 times higher than previous seasons. Given the increased activity, the rising trend in the number of occurrences could be expected and probably did not indicate a significant increase in the risk per flight.

In addition, the ATSB research report identified that half of all reported aerial firefighting occurrences and four fifths of more severe aerial firefighting occurrences were operational in nature, typically terrain collisions, with around one quarter of the more severe occurrences associated with aircraft control. Further, there were 2 fatal accidents between August 2018 and the report publication in May 2020, whereas the previous 17 years only had 3 fatal accidents.

While there have been various deployments and trials of larger aircraft over many years, the current LAT program including the use of C-130 aircraft was evaluated during the 2014-2015 bushfire season. Since commencing operations in Australia in 2015, these LATs have been operating between North America and Australia over alternate bushfire seasons.

On 1 June 2022, in response to the draft report, the RFS reported that the 2019-2020 bush fire season was unprecedented, which meant that a large contingent of aerial resources was required for firefighting, personnel and resource movement, and for surveillance and reconnaissance missions. The RFS acknowledged that aircraft were particularly valuable for fires in difficult terrain or fast-moving fires that were too dangerous for ground personnel to confront.

Over the season, there were 317 aircraft engaged in firefighting activities including 2 very large air tankers (VLATs)[82] and 4 LATs. Together, the LATs and VLATs completed a total of 1,708 missions and dropped more than 24 million litres of fire suppressant. This represented the largest contingent of VLAT and LAT used in Australia to date.

The RFS further noted:

> The season also challenged assumptions about how agencies fight fires - techniques and strategies that worked in previous seasons often did not work as well in the 2019-20 season. The scale of the fires stretched the capacity of fire authorities with many ignitions started by lightning in remote and rugged terrain, quickly spreading to the point where suppression was extremely difficult.

For the 2019-2020 season, the RFS contracted one C-130 and one Boeing 737 from Coulson Aviation via a service agreement subject to the NAFC contract.

Coulson Aviation

General information

Coulson Aircrane Ltd. was a privately-owned company based in British Columbia, Canada. The company had been involved in aviation for over 36 years, operating both fixed-wing and rotary-wing aircraft. The company's operations included helicopter logging, forest fire suppression, power-line construction, airliner passenger, transport, and other industrial heavy lift operations. Coulson Aviation (USA) Inc. was a subsidiary of Coulson Aircrane Ltd., and contracted rotary and fixed-wing aircraft to the US and Australia.

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82 A very large air tanker refers to fixed-wing aircraft with at least 8,000 US gallons (30,283 L) tanks.

Coulson Aviation (Australia) PTY Ltd. was formed in 2010 to support Coulson Aircrane's long-term commitment in Australia. The company provided aircraft personnel for Coulson's rotary and fixed-wing aircraft operating under contract in Australia for the 2019-2020 bushfire season through the National Aerial Firefighting Centre (NAFC). At the time of the accident, they had a fixed-wing fleet in Australia consisting of two C-130 aircraft and one Boeing 737 aircraft. They also provided crews for the NSW Rural Fire Service (RFS) Boeing 737, which had previously been purchased from Coulson Aviation in 2019. Following the Australian bushfire season, the aircraft and crews returned to North America for heavy maintenance and recurrent training prior to the US season.

B134 was contracted on an absolute availability requirement. This included standing charges, paid on an hourly availability, with additional charges for flight time (to account for fuel and other costs). Flight time charges were paid regardless of the fire retardant or suppressant being used.

Operating documents

Coulson Aviation maintained a suite of documents, which provided the necessary information for conducting operations in Australia and for operating the C-130 aircraft including N134CG. These were:

- Company operations manual (COM): The COM contained the procedures, instructions and information required by CASA necessary to enable the operations personnel, including crews, to perform their duties safely and ensure the safe conduct of flight operations. The COM was for Australian operations only and applied to both fixed-wing and rotary-wing aircraft.
- Airplane flight manual (AFM): Coulson Aviation, as the type certificate holder, developed their own C-130 AFM for FAA acceptance and approval. The manual was derived from the 1989 US Naval Air System Command document for the EC-130Q. It detailed the recommended procedures for normal and emergency operations, operating limitations, aircraft systems and equipment, weight and balance, and the aircraft performance that should be achieved when operating in accordance with these procedures. The AFM was approved by the FAA in 2013 with a supplement for the RADS later approved in 2016, and a supplement for an avionics upgrade, which included the CVR installation, approved in 2018.

The FAA advised the ATSB that, for restricted category/military surplus aircraft, the original equipment manufacturer (in this case, Lockheed Martin) did not usually provide any support to the operator, or issue amendments or offer a subscription service, as would normally occur for transport category aircraft. Rather, the source for documents and manuals was normally the military service, although Lockheed Martin may have originally prepared the manuals for the military.

While the COM contained some procedures applicable to all aircraft operations, at least one of the operator's C-130 PICs did not consider this manual as the reference document for operating the aircraft. Instead, they considered the AFM and checklists were the appropriate source.

Retardant drop procedures

The operator's RADS AFM supplement outlined the operating limitations and configuration for the retardant drop procedure. This included 100% flap selection, the landing gear retracted, and airspeed lower and upper limits of 118 kt and 170 kt respectively.

At interview, the operator's pilots reported the targeted parameters for the C-130 drop were 200 ft above ground level (AGL) and an indicated airspeed target of 120 kt. On completion of the drop, the climb-out procedure was for the PIC to increase power and request the copilot retract the flaps to the 50% position, while the flight engineer monitored and called the engine parameters (temperature and torque). The operator's crews also reported that they typically targeted 150 kt during the climb-out, with an initial climb to at least 500 ft. The crews who had previously flown with the accident PIC, indicated there was about a 2-3 second period from the completion of the drop to the start of the flap retraction when flying with the PIC.

Where the retardant drop was conducted without a birddog or aerial supervision (refer to section title *Aerial supervision*), prior to conducting the drop, the LAT crew conduct a number of assessment circuits at various altitudes. These circuits were for drop planning purposes, and as outlined in the COM, would include identifying hazards, the retardant drop plan, entry and exit strategies, as well as a dry run at 500 ft AGL and 150 kt.

Safety management system

Coulson Aviation had introduced a safety management system (SMS) in 2013. At the time of the accident, it was not mandated under either the CASA[83] or FAA regulations, although it was required under the USFS contract. The International Civil Aviation Organization (ICAO, 2018) defined SMS as:

> A systematic approach to managing safety, including the necessary organizational structures, accountability, responsibilities, policies and procedures.
>
> It is designed to continuously improve safety performance through: the identification of hazards, the collection and analysis of safety data and safety information, and the continuous assessment of safety risks. The SMS seeks to proactively mitigate safety risks before they result in aviation accidents and incidents.

An SMS comprised 4 components: safety policy and objectives, safety risk management, safety assurance, and safety promotion. The component of most relevance to this investigation was safety risk management, which included hazard identification, and safety risk assessment and mitigation.

From an Australian perspective, the NAFC indicated that an operator with an SMS would be highly regarded, but it was not compulsory. If an operator had an SMS, a requirement was included in their contract, to ensure the operator maintained the same safety standard throughout the contract period. The NAFC also indicated that they would not review or evaluate the SMS, with the expectation, if required for safety regulation purposes, that this would be undertaken by CASA. A review of CASA records found that, while surveillance had been conducted on the operator, these did not include an audit of the SMS, nor was it required as the system was not mandated.

The operator’s SMS manual outlined the company’s safety policy, processes, and procedures for implementing the SMS and safety management plan. It also included information regarding safety oversight, which included their safety reporting processes.

Safety risk management process

ICAO (2018) described the safety risk management process as:

> … a key component of safety management and includes hazard identification, safety risk assessment, safety risk mitigation and risk acceptance. SRM [safety risk management] is a continuous activity because the aviation system is constantly changing, new hazards can be introduced and some hazards and associated safety risks may change over time. In addition, the effectiveness of implemented safety risk mitigation strategies must be monitored to determine if further action is required.

The process allows validation of decisions, evaluation of the results, and provides an opportunity to assess the need for further risk mitigation. Where risks cannot be reasonably eliminated, risk management enables the tasking to be accomplished by controlling risks to acceptable levels.

[83] Regulatory change that commenced on 2 December 2021 re-categorised this operation under Civil Aviation Safety Regulation Part 138, and aerial work operators in Australia with multi-engine aircraft over 5,700 kg will be required to have an SMS as part of these regulations.

The operator's safety and risk management processes were detailed in the COM and were described as:

> …safety management processes provide a structure for Coulson to exercise its appropriate duty of care to minimise the risks involved.
>
> …provide a formal mechanism that are designed to capture all aspects of safety performance, conformance with approved procedures, continued improvement of procedures, regulatory compliance and operational risks that have the potential to adversely affect the operation.
>
> Risk management is a structured approach to managing uncertainty related to a threat or hazard through a sequence of activities including risk assessments, strategies developed to manage the threat and mitigation of risk...

Hazard identification

According to ICAO (2018), a hazard can be considered as a dormant potential for harm, which is present in one form or another within the system or its environment. Therefore, hazard identification is the first step in the safety risk management process. The intention is to proactively identify hazards before they lead to accidents, incidents, or other safety-related occurrences. Hazard identification may also consider hazards that are generated outside of the organisation and outside their direct control, such as weather (ICAO, 2018).

The COM stated that 'Coulson acknowledges that a certain element of risk exists in all aspects of its business' and that 'the implementation of a comprehensive safety system can greatly assist in reducing risk'. As part of their fatigue risk management system, the COM outlined the potential hazards crews may encounter in all types of operations (Table 3).

Table 3: Some hazards identified in the *Company Operations Manual*

• Unfamiliarity or low experience with the type of operation	• Operations at low altitude
• Lack of experience in operating under specific operational conditions	• Operations in reduced visibility
• Lack of familiarity with, or low experience on, specific aircraft equipment	• Operations at high density altitude
• Operations in high wind or turbulent conditions, particularly if accompanied by high ambient temperatures	• Operations at high ambient temperatures
• Operations in areas of mountainous or hilly terrain	• Contact of flight crew with high-demand clients

In addition to the hazards identified above, the ATSB's review of the COM found numerous references to other hazards. The fire-bombing procedures made references to factors such as prevailing winds (particularly with mountain flying), turbulence and downdrafts associated with either mountain or fire generated conditions, and visibility. Further, the training and checking, and standard operating procedures sections for fixed-wing aircraft also referred to windshear.

Hazards are detectable through many sources including reporting systems, inspections, audits, brainstorming sessions, and expert judgement. These sources are categorised as being either formal or informal methods, and can be used to detect hazards at all levels of an organisation. The operator's SMS used both informal and formal methods for hazard identification. This included a safety reporting system where all employees were encouraged to report issues, hazards and incidents that affected flight or ground safety. Further, the operator had a daily SMS conference call at the start of the day, which discussed the previous days operations, and the operations to be conducted that day. Present on the call were senior management, the safety manager, and the crew. They would discuss the current status of the crew and aircraft, any reported issues, and would often end with a relevant safety message or topical discussion. On 10 July 2022, in response to the draft report, the operator reported that this process allowed the group to tactically manage the risks in a dynamic environment providing an opportunity to discuss actual or emerging hazards and risks in an open and supportive environment.

Safety reporting system and daily SMS calls

The operator's safety reports for the period 2019 and 2020[84] were provided to the ATSB. A review of these 32 reports found that around 60% were related to maintenance issues, while only 9% were operationally focused. These operational events included aircraft separation issues and retardant overload events. While previous years' data was unavailable, the operator had conducted yearly SMS reviews, and these summaries were provided for the earlier period. Although the individual reports were not available, based on these summaries, it was likely the previous years' safety reports followed a similar reporting pattern, with a majority being maintenance related.

During the investigation, several of the operator's crew provided the ATSB with accounts of previous windshear encounters they had experienced:

- In the previous firefighting season, while conducting structure protection, they encountered a windshear event, which resulted in an uncommanded bank angle of 80°. The crew recovered the situation by flying the planned exit into an area of lower terrain (valley).
- In the season of the accident, while climbing out after completing a drop, the airspeed fluctuated 'quite a bit' (10 kt) and the aircraft sank slightly, while being 'tossed around'. This was while working with the birddog. After this encounter, the decision was made not to return to the drop area.
- On the day of the accident, the crew of B137 received a windshear warning and uncommanded bank angles up to 45° in the Adaminaby area.[85]

These encounters were not recorded in the operator's safety reporting system, nor were any other weather-related incidents found in the reports provided to the ATSB. Neither the former[86] nor current safety manager recalled any such reports in the system. At interview, one pilot reported that the online SMS program was used for issues that were considered applicable across the company. Issues that could be resolved within the small group of fixed-wing pilots, or could be taken directly to the chief pilot, noting they spoke on a daily basis, would not necessarily be included in the system.

In addition, the ATSB reviewed the daily SMS call notes from 2018 to 2020. While limited in detail, the topics most frequently discussed were maintenance issues. In the days preceding the accident, the hot and severe weather conditions were noted. These were the only occasions where the weather conditions were noted in the calls. In response to the draft report, the operator advised that they considered the incident reporting numbers discussed above were mitigated by the daily SMS calls' impact on flight risk awareness.

Risk assessment

A risk assessment is a process where sources of potential harm (hazards) and the chances of an adverse event happening due to the hazard were identified, analysed, and evaluated (CASA, 2021). This evaluation was expressed in terms of likelihood and consequence, and should highlight the risks to be considered before and while carrying out an operation.

Organisations should have multiple layers of controls or defences in place (CASA, 2014) to manage their identified hazards. Risk assessments should be carried out across all levels of an organisation and at different stages in the operation. These could consist of a formal, documented process or a continuous ongoing mental assessment carried out by a pilot, or a combination of both. Examples of a formal risk assessment may include an operational risk assessment conducted by the operator to consider and evaluate the risks associated with the type of work

[84] Due to a change in the operator's SMS program, only 2 years of data was able to be provided.
[85] It was noted that the accident occurred shortly after this incident.
[86] In 2020, after the accident, the safety manager at the time of the accident retired and was replaced.

being undertaken, and pre-flight risk assessments, conducted by the PIC and associated with a specific tasking. An example of continuous processes could include in-flight tactical[87] risk assessments.[88]

The operator's SMS manual stated that, if a risk assessment was required, the SMS manager would conduct and document the process by completing the risk management worksheet. The associated risk matrix categorised the risk as either acceptable, mitigable or unacceptable, although there was no guidance on how to categorise the risk. These risk assessments only applied to the safety reports and change management processes that were captured in the operator's online SMS program. At interview, both the former and current safety managers indicated there was no formal risk assessments conducted on the identified operational hazards, such as those listed in the COM.

Prior to the accident, the operator had voluntarily initiated the International Standard for Business Aircraft Operations audit phase II,[89] which was conducted between December 2019 and March 2020. This audit identified significant growth since the stage 1 audit completed in 2017, and that the SMS had not fully matured to be as effective as it could be. Of note, it identified that the operator could not provide a process for assessing risk potential in terms of likelihood and severity.

After the safety risks have been assessed, the appropriate risk controls can be implemented. ICAO (2018) noted that:

> It is important to involve the "end users" and subject matter experts in determining appropriate safety risk controls. Ensuring the right people are involved will maximize the practicality of safety risk chosen mitigations. A determination of any unintended consequences, particularly the introduction of new hazards, should be made prior to the implementation of any safety risk controls.

In response to the draft report, Coulson Aviation stated that aerial firefighting was conducted within an 'unforgiving, dynamic, and complex operational and meteorological environment'. Consequently, they considered aerial firefighting lends itself to a more tactical approach to risk identification and mitigation.

Risk register

Safety risk management activities should be documented, including any assumptions underlying the probability and severity assessment, decisions made, and risk controls implemented (ICAO, 2018). A tool such as a risk register could be used to ensure identified hazards were tracked and mitigated as part of a formal risk management process of prioritisation, documentation, and assessment. The register could include the hazard, potential consequences, assessment of the associated risks, and any controls put in place to manage the risk. This not only allowed for ongoing tracking and monitoring of the identified hazards, but also (ICAO, 2018):

> …becomes a historical source of organizational safety knowledge which can be used as reference when making safety decisions and for safety information exchange. This safety knowledge provides material for safety trend analyses and safety training and communication. It is also useful for internal audits to assess whether safety risk controls and actions have been implemented and are effective.

At the time of the accident, the operator did not maintain a risk register, or any alternate means to track the identified hazards and associated controls, as part of their SMS.

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87 In this context, the ATSB understands tactical risk management is the continual assessment of risk in the changing circumstances of a tasking in real-time. This allows crews to perform a contemporaneous assessment of the risks and implement control measures to ensure an appropriate level of safety is maintained throughout the tasking.

88 With the introduction of new CASA regulations in December 2021 for aerial work operations, operators such as Coulson Aviation would be required to conduct a risk assessment. This would involve a pre-operational risk assessment, the development of a flight risk management plan, and pre-flight and post-flight risk reviews.

89 International standard for business aircraft operations was a recommended code of best practices designed to help operators achieve high levels of safety and professionalism. A phase II audit reviewed the established SMS, with the focus on ensuring the safety risks were being effectively managed.

Assessing pre-flight risk

Flight risk assessment tool

Aerial firefighting activities, like other aerial work operations, are subject to elevated risks. A 2014 National Transportation Safety Board study of agricultural (aerial work) accidents in the US found the following:

> …the mission priorities…present pilots with unique hazards, challenges and constraints, some of which cannot be completely eliminated. For example pilots must manoeuvre their aircraft at very low altitude over terrain and must therefore accept an elevated risk of terrain and obstacle collisions, as well as having limited time to safely respond to an aircraft mechanical anomaly or recover from an inadvertent aerodynamic stall.
>
> Risk management is a decision-making process by which pilots can systematically identify hazards, assess the degree of risk, and determine the best course of action. Effective risk management involves good decision-making that allows a pilot to identify personal attitudes that are hazardous to safe flying, apply behavioral modification techniques, recognize and cope with stress, and effectively use all resources. Risk management strategies can help pilots apply a systematic process that can help them resist pressures that can adversely affect their decision-making and performance and can help them mitigate other hazards that could adversely affect the safety of flight.

The study also concluded that risk management guidelines and best practices specific to agricultural aircraft operations were necessary tools to help operators and pilots mitigate the unique risks associated with their operations. In addition to the safety risk management processes discussed above, another such tool was a flight risk assessment tool (FRAT). In 2016, the FAA Safety Team released their FRAT with the introduction:

> When implementing a Safety Management System (SMS), one of the most critical components to develop is a Flight Risk Assessment Tool (FRAT). Because every flight has some level of risk, it is critical that pilots are able to differentiate, in advance, between a low risk flight and a high risk flight, and then establish a review process and develop risk mitigation strategies. A FRAT enables proactive hazard identification, is easy to use, and can visually depict risk. It is an invaluable tool in helping pilots make better go/no-go decisions and should be a part of every flight.

This was consistent with the USFS 2016 *National Aviation Safety Management System Guide*, which stated that:

> Every flight has hazards and some level of risk associated with it. It is critical that management and pilots are able to differentiate, in advance, between a low risk flight and a high risk flight using a risk assessment tool that allows pilots, managers and dispatchers to see the risk profile of a flight in its planning stages. When the risk for a flight exceeds the defined acceptable level, the flight will be further evaluated and risk decisions made by appropriate leadership.

The USFS (*Forest Service Manual: Aviation Management Handbook*) also recognised that risk management was a critical component of their SMS, and the identification of new hazards, determination of risk levels and effectiveness of mitigations 'must be collaborated' from the local level to aviation staff in their headquarters. Noting this, they discussed the different types of risk assessments, which included a 'time critical risk assessment':

> Time critical risk assessment is the tool that pilots and managers use to assess actual risks specific to the day of flight. The product representing a time critical risk assessment is a Flight Risk Assessment Tool (FRAT)… While completing a FRAT, if an emerging hazard or higher than expected risk level is identified, the Aviation Manager (for example a helicopter manager, flight manager, project aviation manager, pilot in command), must follow up with the appropriate management level before a mission commences.

A FRAT was an efficient and structured process that allowed for a consistent and objective evaluation of flight risks, and could be adapted to manage the unique risks present for a specific operation or tasking. The tool established the risk profile for an individual flight and prompted the pilot or operator to take appropriate mitigation actions. It also allowed for better visibility by the operator, as to crew decisions made in accepting or rejecting tasks. However, it should be noted that a FRAT cannot anticipate all the hazards and corresponding risks that may emerge during a flight.

The FRAT could incorporate factors relating to the crew, such as operational experience and fatigue; environmental conditions, both at the airport and en route; aircraft factors, such as equipment serviceability; and any external pressures or factors, such as task rejection by another pilot or operator. Each of these factors was then assigned a numerical risk value and a total risk score was calculated. Based on this score, the risk profile was determined using predefined criteria for acceptable levels of risk, elevated levels of risk that required mitigation such as escalation to a more senior pilot, or task rejection.

The operator's COM acknowledged the risks associated with their operations, stating 'the combination of terrain, weather, fire occurrence patterns, and visibility can make firebombing extremely challenging'. The COM also required their rotary-wing pilots conducting firefighting activities using night vision goggles to complete a pre-flight risk assessment. However, the operator relied on the LAT crews to conduct their normal pre-flight planning and make their own assessment of the suitability of a tasking, without the need for a formal pre-flight risk assessment. The former safety manager also confirmed that, while the LAT operation was considered high risk, there was no FRAT available for the crews.

Accident flight estimated risk profile

Following the change in safety managers in 2020, the operator introduced a FRAT into their LAT operations, with the criteria for an acceptable level of risk (score <30), a level of risk that required mitigation or escalation (30–39), and a 'no-go' level of risk (40+). Using this tool, the ATSB calculated a score within the range that required mitigation or escalation for the accident flight. However, the ATSB noted that the FRAT did not consider factors such as a weather-related task rejection by another pilot, in this case, by the birddog pilot. Task rejection was a potential risk indicator for a FRAT, as explained in the US FAA advisory circular 135-14B for helicopter air ambulance operators:

> Declined HAA [helicopter air ambulance] Flight Requests. The operator must establish a procedure for determining whether another HAA operator has declined the flight request under consideration and if so, for what reason (weather, maintenance, etc.). If applicable, the reason for the declined flight must be factored into the required risk assessment process, i.e., do not include a declined flight due to a maintenance issue or pilot not available. This could be as simple as asking the requestor whether or not this specific flight request has previously been made and declined and why.

Similarly, the Helicopter Association International's FRAT tool included the risk factor of 'Flight Turned Down By Other Operators Due to Weather', which had the highest risk score of all the example factors.

Civil Aviation Safety Authority

When operating in Australia, Coulson Aviation aircraft were operated under a short-term air operator certificate authorisation issued by CASA, involving the use of foreign aircraft under relevant legislation and national aviation authorities. The certificate permitted aerial work including aerial spotting (fire and flood), dropping (water and fire retardant), and other activities such as search and rescue and surveillance.

As part of this process, CASA required Coulson to have a Company Operations Manual (COM) for Australian operations. CASA required Coulson Aviation to comply with their COM, which included reference to the FAA approved AFM. In these circumstances, CASA relies on the FAA approval process, and has no role in reviewing the AFM.

CASA had conducted 5 surveillance events in the past 5 years across 3 different short-term AOCs for this operator. All events were level 2[90] operational checks and no safety findings were raised. No CASA surveillance events were performed on Coulson during the 2019-2020 firefighting season. The short-term AOCs were not included in CASA's national surveillance selection process, and therefore no level 1[91] surveillance activities were conducted.

New South Wales Rural Fire Service

General

The NSW Rural Fire Service (RFS) was the lead combat agency for bushfires in NSW. They worked closely with other agencies to respond to a range of emergencies including bush and grass fires, bushfire mitigation, structure fires, search and rescue, motor vehicle accidents, and storms that occurred within rural fire districts. The RFS was primarily made up of volunteers, with paid staff members managing day-to-day operations, Fire Control Centres (FCCs), and operational support, among other roles. There were many roles involved in the RFS emergency management response; for simplicity, only those roles applicable on the day of the accident are discussed below.

The multiagency state-wide response to large bushfire emergencies were overseen and coordinated by the State Operations Centre, located at NSW RFS Headquarters in Sydney Olympic Park (Sydney). The State Operations Centre provided a variety of specialised resources to the FCCs, including but not limited to, aviation resources. The state operations controller (SOC), located in the State Operations Centre, maintained an overall awareness of the firefighting effort across the state, and ensured resources were allocated as needed. The State Operations Centre also contained the state air desk (SAD), which was the state level multiagency team responsible for coordination of aircraft operations.

FCCs were the administrative and operational base of each rural fire district or zone. The coordination and management of local brigade responses to fires and other incidents was undertaken through the incident management team, led by the incident controller. For each emergency response, an incident controller was responsible for that response, including the objectives, operations, and application of resources. Where necessary, an aviation unit was established to manage and support deployment of aviation resources within the rural district, including an aviation radio operator (ARO).

The LATs were based at an airbase overseen by an airbase manager (ABM). The ABM was responsible for the supervision and coordination of airbase personnel and the layout and operation of the airbase. They operated as a liaison for the RFS SAD, and could be from another organisation.

Aircraft management procedures

The RFS maintained a suite of documents, which detailed the procedures for managing aerial firefighting. The 2 primary documents for air tanker operations were the *NSW and ACT Aviation Standard Operating Procedures* (operating procedures), which outlined the basic procedure of all air tanker operations, and the *Operating guidelines for air tanker operations* (operating guidelines), which provided further details specifically for the LAT program.[92] The preface to the operating procedures stated it was 'produced to assist all members…in the safe, efficient, and effective management and use of aircraft for operational purposes'. This should be read in conjunction with

90 A level 2 surveillance event relates to less formal interactions with authorisation holders and may be in the form of checklist-based compliance and product check of a specific section of its systems.

91 A level 1 surveillance event is a structured, forward-planned, larger-type surveillance event and covers systems audits, health checks and post-authorisation reviews.

92 The NSW Large Air Tanker program is managed by NSW RFS of behalf of NSW agencies in consultation with NAFC, and included the LAT and very large air tanker (VLAT) aircraft.

other relevant documents, 'which may contain more comprehensive information, specification and overarching operational and incident management procedures'. Additional procedures and forms were contained in the *Operational management procedures* and *Incident management procedures*.

While the RFS were responsible for coordinating aircraft and conducted training on various aviation aspects, they did not claim to be aviation experts. Therefore, it was possible that the frontline staff may have had a limited understanding of the operational capabilities and constraints for the varied aircraft used. The ATSB noted that there was limited information contained in any documentation provided to the frontline staff regarding the capabilities and constraints of each aircraft type within the LAT category. Where a LAT was requested by an incident management team, the asset was selected based on availability, location, and response time, rather than aircraft type. There was no distinction of capability between LAT aircraft types aside from information related to tank capacity, delivery system, and cruise capability. It did not contain any performance capability information related to operating conditions. However, the documents acknowledged that, 'it is essential that all personnel seek specialist advice when planning or conducting air operations'. It also stated that 'any agency members, contractors or air crew may decline to carry out tasks for which they are unfamiliar, unprepared or consider unsafe'.

On 1 June 2022, in response to the draft report, the RFS acknowledged that aerial 'operations are risky, made more so as weather conditions deteriorated. However, when assessing tasking decisions, the RFS must balance this against the risk posed by fire to civilians and [ground] fire fighters… with the ability of aerial operations to achieve far greater gain' than ground-based firefighting. Further, they considered that the tasking of large air tankers 'may be sufficiently safe in circumstances that were not necessarily safe for other aircraft.' They also indicated that 'B134 had greater flight capability than other aircraft' used by the RFS and was able to make a different assessment of risk. 'Therefore, conditions that may have been unsafe for other aircraft, including B137, may not have been so for B134.'

Aerial supervision

The air attack supervisor (AAS) was a tactical command position, which ensured that aerial operations were consistent with the procedures and incident controller's intent. This included maintaining communications with relevant incident management team personnel, and coordinating ground and air communications to achieve these objectives.

An incident AAS would be in an independent local aircraft overseeing the fire-ground, responsible for coordinating the aviation assets over an incident. They were responsible for coordinating the smaller aircraft and overall strategy, and in place when there were 3 or more aircraft operating on an incident. When LATs were involved, the incident AAS would normally communicate to another AAS onboard the birddog aircraft (LAT AAS).

A LAT AAS was located in the birddog aircraft, and coordinated the LAT movement with the incident AAS. Their role included briefing the LAT crew on the specific assignment, identify hazards, tactics and manage communications with the incident AAS. In practice, the LAT AAS established contact with the assigned LAT crews as they approached the relevant fire-ground to provide this information.

Requirements

When discussing aerial supervision for air tanker firefighting operations, the RFS operating procedures stated the following requirements:

> Generally, Air Tanker Suppression operations, training flights and evaluation flights should not be undertaken without the supervision of an authorised AAS [air attack supervisor]. The AAS provides tactical aircraft coordination with the Incident AAS and/or IMT [incident management team] and directs the firebombing aircraft to critical areas of a fire for suppressant or retardant drops.

> The only exception to the above may be in the event that an Air Tanker has an 'initial' attack' certified crew on board who understand the mission requirements, Agency Air Tanker Procedures and there are operational advantages to the LAT commencing operations prior to an AAS arriving.

Operational advantages, while not defined or outlined in any documentation, were described at interview as including aspects such as the faster LAT transit times,[93] when a birddog was not available due to resourcing constraints, or a crew specific concern such as fatigue or exceeded duty times. There were no further requirements or considerations in either the operating procedures or guidelines regarding aerial supervision for LATs, or its use when an AAS was not available due to an operational safety concern. It was also noted that there was no policy, procedure or guidance identified in the provided documentation for tasking air tankers with initial attack certified crew in the case where a birddog pilot, and therefore the associated AAS, had rejected the tasking.

On 1 June 2022, in response to the draft report, the RFS advised that it was always their intention to send a birddog when possible. However, due to the constantly changing circumstances on the day, this was not possible to do. The decision to deploy the LATs without the birddog was based on an evaluation of the available information at the time and the unavailability of the birddog. In addition, the RFS stated that prohibiting LATs from operating if a birddog had not assessed the conditions, or if it was considered unsafe for smaller aircraft to operate would have severe impacts on firefighting operations across the state, and the resultant safety of people and property on the ground.

Initial attack certification recognition

The ATSB was unable to find a definition for the term 'initial attack certified' within the RFS documentation and sought clarification from the RFS. The RFS advised that it was their intention to recognise the initial attack certification endorsed by the US Forest Service (USFS). Broadly, this certification required a minimum flight time as a PIC in the specified aircraft type; a minimum flight time conducting low-level retardant drops; ground school training on relevant aspects such as hazard identification, ingress and egress strategies, and communications; and the satisfactory completion of 25 supervised drops.

In addition, the RFS advised that they did not maintain a register of initial attack certified pilots, and did not confirm the crew were initial attack certified when issuing the tasking. Rather, they relied on the individual aircraft operators for ensuring pilots held and maintained the necessary licences and certification. When the ATSB discussed the initial attack certification with Coulson Aviation, they also noted that this had not been defined by the RFS. Therefore, they utilised their own internal training framework to determine when a PIC was capable of operating without aerial supervision. One such example cited was the PIC of the Boeing 737 (B137) who had received the requisite internal training, but had not yet completed the required number of supervised drops to gain the USFS certification.

Tasking large air tankers

The operating procedures, and more so the operating guidelines, detailed the process for the tasking and mission management of air tankers. This included what aspects were to be considered when tasking an air tanker, the request and approval process, and dispatch. The ATSB noted that some functions during this process could be completed by multiple RFS positions. However, for simplicity, only those roles applicable on the day of the accident are discussed below.

[93] It was noted that the C-130 was recorded as having a loaded cruise speed of 300 kt in the operating guidelines, however, due to the limitations imposed through the aircraft manufacturer published service bulletin 382-57-97, they generally operated at about 190 kt. The birddog aircraft was listed as having a cruise speed of 285 kt.

Considerations and request

The operating procedures noted that air tankers could provide large volumes of suppressant, and careful planning and supervision was needed to ensure this was used effectively. The first step involved the incident controller (incident management team in the FCC) advising the intent to consider a tanker to the SAD, and outlining a strategy in conjunction with the SAD who could provide ‘guidance on availability and suitability’.

When considering tasking air tankers, the operating procedures stated the incident controller was to consider the following:

- incident objectives
- threats (life/property, assets, forests)
- a proposed strategy
- prevailing and/or forecast weather conditions
- the likely period of deployment or loads [suppressant/retardant] required
- the terrain and fuel (grass, urban, forest) type
- possible risks and safety issues
- time of day (last light considerations)
- the mission alternatives.

A similar list of considerations was also included in the operating guidelines (for both air tanker and birddog taskings), with the addition of the elapsed time for the aircraft to arrive onsite. The operating guidelines stated that these considerations were a ‘risk assessment’. However, there was no further guidance on assessing each of these considerations.

Approval

The SAD would then brief the SOC. The SAD would provide advice on the availability, competing priorities, strategies, and load requirements for the LAT. The SOC then decided on the mission approval. Following that approval, the SAD would advise the LAT airbase manager (ABM) of the approval and mission objectives.

In this case, the Cooma incident controller did not request the tasking of the LATs. Rather, the decision to task a LAT was determined during the 1100 conference call discussing the fire situation at Adaminaby with senior personnel from the State Operations Centre (which included the RFS Commissioner and Deputy Commissioner). On that 3.5-minute conference call, while aware that the smaller fire-control aircraft were not flying due to the weather conditions, it was decided to send the LATs. They were unsure if a birddog had been launched to assess the conditions due to the known visibility and weather conditions, but determined that rather than wait for the birddog assessment, they could send a LAT ‘as it can bomb by itself if need be, if the opportunity presents’. The tasking decision was then communicated to the SAD, who then communicated the tasking for B137, B134, and the birddog from Richmond airbase to the Richmond ABM.

While the tasking on the day did not follow the RFS procedure outlined above, it was very likely that the LATs and birddog would have still been tasked if the above procedures had been followed.

Dispatch

The LAT ABM then conducted a pre-mission briefing with the crew, providing the required tasking details. The RFS operating guidelines indicated that these details would include, at a minimum, the latitude and longitude, a geographic location (referencing a map or chart), the incident air attack supervisor’s contact details, communication details for the incident controller radio channel and fire location’s common traffic advisory frequency, information on any aircraft working in the same location, and the type of load product.

Generally, the birddog with an aerial attack supervisor would arrive at the fire-ground ahead of the LATs. Given that the smaller birddog aircraft would generally fly slower than a LAT, it was common for the birddog to depart before the LATs. However, where there was an urgency to dispatch aircraft due to the rapid spread or the impending impact of the fire, and the crew were appropriately certified, it was standard practice to launch the LATs at the same time, or ahead of, tasking the associated birddog.

Re-tasking

Generally, re-tasking would be managed through the SAD in consultation with the incident management team and the LAT AAS, noting that the LAT crew would take on the AAS role when flying initial attack operations. On the day of the accident, the re-tasking from the Adaminaby fire-ground to the Good Good fire-ground was managed by the Cooma incident management team, who were in direct contact with the crew via the Cooma aviation radio operator (ARO). This re-tasking was considered within scope, as both fires were being managed by the Cooma team, and therefore, they could direct the crew as necessary at the local level.

Task rejections

The ATSB were provided with an example of a previous occasion where a task was stopped in-flight, while operating in Australia. In that case, an aircraft had a number of warnings activated, and the crew elected not to continue. This decision was communicated among the other crews involved in the tasking, who were in continual contact with each other, and the task was subsequently stopped by the AAS.

For the tasking related to the accident, a task rejection had been made on the ground by the birddog pilot (due to weather-related safety concerns) and no communication had been established with other crews. The birddog pilot reported that they had not conveyed the decision to the crew of B134, but expected the RFS personnel would relay this information in their continued coordination of the tasking, or cancel the tasking.

A review of the available radio recordings provided by the RFS found no evidence to indicate that the birddog pilot’s rejection of the tasking had been communicated to the LAT crews (B134 and B137) by either the Richmond ABM or the SAD. In addition, the Cooma ARO, who could reasonably be expected to be in contact with the crews, reported that they were not aware of the birddog rejection. However, it was noted that not all radio communications were recorded.

At interview, mixed responses were received from pilots regarding their expectations on task rejections. All were consistent in that, there was a need to be informed of, and the reason for, the rejection decision, so this could be factored into their decision-making, in line with their company policies and procedures. Others stated that a weather-related rejection should result in cancellation of the tasking. The operator indicated that while a birddog can provide valuable risk mitigations, when the PIC is initial attack trained, they do not consider it to be a requirement. However, for a tasking without the birddog, the reason for this would need to be factored into the PIC’s pre-flight planning.

In addition, the birddog pilot had also reported that, after making the decision to reject the tasking based on the weather conditions, an air attack supervisor had advised them that the smaller fire-control aircraft had earlier ceased operations due the wind conditions. The birddog pilot further stated that this information was generally not passed on to the pilots by the RFS.

The ATSB reviewed the available RFS documentation and procedures. No policy or procedure was in place to support the ABM or SAD’s management and communication of a task rejection by any of the crews operating in the tasking area that day or involved in the task.

In response to the draft report, the RFS stated they were of the view that ultimate responsibility for assessing risk, and accepting or rejecting a task, was the responsibility of the PIC. For the RFS to make such assessments on behalf of the PIC would constitute a shift in RFS responsibility.

United States firefighting practices

For comparison, the ATSB reviewed the aerial firefighting practices currently in place in the US. This was particularly relevant as many of the LAT operators worked in both the US and Australia, and the NSW RFS reviewed the practices from the US Department of Agriculture, Forest Service (USFS) when implementing their current LAT program.

Task rejections

The USFS placed a significant focus on managing risk exposure. They outlined their safety expectations in a statement of intent, placing emphasis on implementing:

> …strategies and tactics that commit responders only to operations where and when they can be successful…[and that] understanding and acceptance that intense fire behaviour may mean we can't protect values at risk under all circumstances…this direction also requires greater focus on identification of unnecessary exposure.

These expectations were then supported in the USFS *Forest Service Manual – Aviation Management Handbook*, which included the following statement:

> Pilots and aviation users are expected to make sound decisions, including cancelling a flight, when conditions or circumstances may cause undue risk…
>
> Forest Service employees perform challenging work in very high-risk and dynamic environments that are not always predictable. This responsibility can only be realized through participation of every employee. Safety is the first priority, and leadership at all levels must foster a culture that encourages employees to communicate unsafe conditions, policies, or acts that could lead to accidents without fear of reprisal...

The USFS 2019 *Standards for Airtanker Operations* detailed the processes and procedures to be followed by staff, supervisors, specialists, and managers when planning, administering and conducting airtanker operations. When discussing aviation safety, one aspect considered was task rejections or a 'turn down'. Notably, the document stated:

> Every individual (government and contracted employees) has the right and obligation to report safety problems affecting his or her safety and has the right to contribute ideas to correct the hazard. In return, supervisors are expected to give these concerns and ideas serious consideration. When an individual feels an assignment is unsafe, he or she also has the obligation to identify, to the degree possible, safe alternatives for completing that assignment. Turning down an assignment is one possible outcome of managing risk.
>
> A "turn down" is a situation where an individual has determined he or she cannot undertake an assignment as given, and is unable to negotiate an alternative solution. The turn down of an assignment must be based on assessment of risks and the ability of the individual or organization to control or mitigate those risks. Individuals may turn down an assignment because of safety reasons…

The standards further indicated that those individuals who turned down a task were to directly advise their supervisor. That supervisor would then communicate this information to others associated with the management of fire control activities. In addition, when a tasking had been turned down and the supervisor then asked another individual (resource) to perform the task:

> …he or she [the supervisor] is responsible to inform the new resource that the assignment had been turned down and the reasons why. Furthermore, personnel need to realize that a "turn down" does not stop the completion of the assigned operation. The "turn down" protocol is an integral element that improves the effective management of risk, for it provides timely identification of hazards within the chain of command, raises risk awareness for both leaders and subordinates, and promotes accountability.
>
> Proper handling of turn downs provides accountability for decisions and initiates communication of safety concerns within the incident organization.

Task rejections, including those related to weather, was also recognised within the Alaskan USFS *Forest Service Handbook – Flight Operations Handbook: 33.1 - Forest Service Flight Operations*, as follows:

> If a flight is cancelled or refused by one operator or pilot because of weather or other operating conditions, the flight will be postponed until the weather improves. Forest Service employees shall not "shop" for an operator that will make the trip when another operator has refused.

Aerial supervision

The USFS *Standards for Airtanker Operations* outlined the circumstances and minimum supervision required based on the following situations:

- number of aircraft assigned to an incident
- drops conducted in high traffic areas
- low light conditions
- use of the modular airborne firefighting system or very large air tankers
- airtanker flight crews not initial attack carded
- combination of different types of aircraft operating simultaneously
- use of foreign aircraft
- periods of marginal weather, poor visibility or turbulence
- night operations
- if requested by the airtanker, birddog or others involved.

It also noted that initial attack certified pilots were authorised to drop retardant without the supervision of a birddog and/or AAS. However, the standard stated that:

> Aerial supervision resources must be launched together with the airtanker on the initial order to maximize safety, effectiveness, and efficiency of incident operations. Incidents with 3 or more aircraft over/assigned will have aerial supervision over/assigned the incident.

Likewise, The US National Wildfire Coordinating Group[94] document, *Standards for Aerial Supervision*, stated that 'a safe aviation operation depends on accurate risk assessment and informed decision making'. It further indicated that, often, incident response flights were conducted under adverse flight conditions, and this complexity dictated the level of supervision required to conduct aerial operations safely and effectively. While noting factors similar to those listed above, it outlined:

> There is no way to define an exact trigger point for adjusting, downsizing, or completely suspending aviation operations. The factors listed below [similar to those listed above] should be evaluated to determine whether additional Aerial Supervision resources are needed or tactical/logistical missions need to be modified/suspended.

The standard further stated that, in some cases, the aerial supervisor would be required to shut down or suspend operations. In this case, 'air operations must not proceed until risk mitigations are in place'.

Flight risk assessment tool

When considering aviation safety, the USFS 2019 *Standards for Airtanker Operations*, stated that a FRAT was required for every flight conducted for the USFS. They also recommended that a FRAT sheet be used when planning a mission and that this should be updated as necessary. The tool, provided as an appendix to the standards, contained the following note:

> Because the overall cumulative score is a composite of individual flight, environmental, and operational values, it may not fully emphasize a heightened level of risk that may be associated with an individual category. For example, extremely adverse weather in itself, exclusive of the other categories, may alone merit the suspension of operations. Conditions also change over time and

94 The group provides national leadership to enable interoperable wildland fire operations among coordinated operations among federal, state, local, tribal, and territorial partners in the US. The USFS was a member agency of the group.

distance, therefore, this tool should be used periodically throughout a mission as conditions change to assure that individual or overall risks have not measurably increased.

Lessons learnt from aerial campaign management

In response to 3 accidents involving helicopters undertaking locust control operations in 2004, the ATSB commenced a research investigation (B2004/0337) into the practices used by Government organisations to contract aerial operators. While focused on locust control, the report findings were also applicable to fire control, other pest management, and emergency service operations. Collectively referred to as ‘aerial campaigns’, these types of operations were generally conducted in relatively hazardous environments that also had the potential to be high-risk environments characterised by:

- a significant community need for the operation, possibly urgent
- requiring the coordination of significant numbers of resources and organisations
- a degree of irregularity or unpredictability as to when the operation will be required and the size the operation
- requiring aerial operations with a relatively high hazard level
- a regularly changing operational environment throughout the course of the campaign.

The report identified that organisations that contracted aerial operators were directly involved in the management of significant parts of the aerial campaign, such as assigning tasks and briefing pilots. Therefore, decisions made in the management process had the capacity to influence the level of risk of the operations. If safety was to be maintained, that capacity had to be monitored and managed: leaving responsibility for safety to another party that was not managing the overall campaign would not be effective.

In addition, the organisational complexity of aerial campaigns and the subsequent coordination effort required may lead to a diffusion of responsibility among the parties involved. This complexity was further increased when staff from different organisations were working together towards a joint outcome.

The report concluded that, while the aerial component of the operation was provided by an aerial contractor, the campaign control organisation was in a central position to understand the big picture. The adoption of good systems for managing risk by the contracting organisation could provide an effective additional layer of defences over and above that provided by each operator to protect against an incident or accident. An effective overall management system could ensure that no one aspect of the operation compromised another aspect.

Similar occurrences

This accident was the first occurrence of a collision with terrain involving a LAT in Australia. However, the ATSB identified another C-130H firefighting weather-related accident, and a windshear encounter during firefighting operations in the US where the retardant was not jettisoned. A summary of these reports is provided below.

US Air Force Aircraft Accident Investigation Board investigation

On 1 July 2012, the crew of a US Air Force Lockheed Martin C-130H aircraft was conducting wildland firefighting operations near Edgemont, South Dakota, US. While following a lead aircraft (birddog) and positioning for a fire-retardant drop, both aircraft encountered a microburst.

The pilot of the lead aircraft conducted a ‘show me’ run,[95] and shortly after, the crew of the C-130 established a 0.5 NM (1 km) trail formation for the first drop. About 7 minutes later, while setting up for the second drop, the C-130 was in about a 1 NM (1.9 km) trail formation when the lead

[95] ‘Show me’ run referred to a simulated bombing run made by the birddog to demonstrate the run and identify the target for the air tanker.

aircraft hit a 'bad sinker', resulting in a loss of altitude and airspeed. The lead aircraft came within 10 ft of the ground, and the pilot called 'I got to go around'. One second later, the C-130 crew also elected to go-around, and 16 seconds after, they called 'E-dump, E-dump'. Despite completing an emergency dump of the remaining retardant, the C-130 collided with terrain shortly after, fatally injuring 4 crew and seriously injuring 2 crew.

The investigation found that an inadequate assessment of the operational conditions resulted in the aircraft impacting the ground after flying into a microburst. In addition, it was established that there was a failure to communicate critical operational information from the lead aircraft and air attack crew to the C-130 crew, and there was conflicting guidance concerning thunderstorm avoidance.

SAFECOM report

The USFS and Department of the Interior maintained an aviation safety reporting system as part of its safety program, and published a yearly safety summary. On average, it was noted there were about 8 weather-related events reported in the database yearly, with an incident of significance to this investigation described below.

On 17 June 2017, the flight crew of a British Aerospace BAe-146 aircraft were conducting firefighting operations in northern New Mexico, US. The pilot reported that, during a fire-retardant drop, they experienced significant 'down air', which resulted in them coming close to terrain. While slowing the aircraft through 130 kt when about 500 ft above the planned drop height, 'the bottom fell out' resulting in a loss of about 10 kt airspeed and 300 ft altitude. The pilot applied engine power and manoeuvred the aircraft toward lower terrain, but they did not achieve the expected climb performance and passed just above the tree line. The pilot indicated that the event took less than 10 seconds, and while they should have jettisoned the load in hindsight, they did not consider this at the time as they were focused on flying the escape manoeuvre.

Safety analysis

Introduction

About midday on 23 January 2020, a Lockheed Martin C-130 aircraft, call sign ‘Bomber 134’ (B134), departed the Richmond Royal Australian Air Force Base, New South Wales (NSW) on a firefighting tasking to Adaminaby. On arrival at Adaminaby, the crew determined that the conditions were unsuitable for a fire-retardant drop and were subsequently re-tasked to the Good Good fire near Peak View. Shortly after conducting a partial drop, and while in a left turn, the aircraft stopped climbing. The pitch attitude reduced, followed by a slight right wing down attitude. Shortly after, the aircraft was observed left wing down at low-level before colliding with terrain. The 3 crew were fatally injured and the aircraft was destroyed.

The extent of the impact damage and post-impact fire meant the ATSB was unable to verify the operation of every aircraft system. However, there were no known defects that would have affected the aircraft’s serviceability, with the only item noted relating to the propeller anti-icing system on engine number 2, with rectification deferred in accordance with the minimum equipment list. There was no evidence of pre-impact structural damage, and detailed examination showed all engines were operational and producing power at the time of impact.

The ATSB established that the crew were appropriately qualified to perform the flight and there was no evidence of fatigue. While the post-mortem examination identified abnormalities with the copilot’s heart, there was no pathological evidence of scarring or a blockage suggesting a pre-existing heart condition. Although elevated blood cholesterol levels increase the risk of coronary heart disease, the copilot had been appropriately treated for several years prior to the accident, and their blood pressure readings and last electrocardiogram were all within normal limits. In addition, ATSB research into pilot incapacitation occurrences (AR-2015-096) emphasised that multi-pilot operations provide a safety net if one crew member becomes incapacitated and that such events had a minimal effect on flight. Therefore, noting the medical information above and that the copilot was not the pilot flying, it was considered very unlikely that they had experienced a heart-related condition that contributed to the accident.

This analysis will examine the environmental conditions and how this influenced the aircraft’s degraded performance and subsequent stall. The tasking process, management of task rejections, and the crew’s awareness of such on the day will also be discussed. It will also consider the risk management of large air tankers, the use of a flight risk assessment tool, and the aerial supervision and initial attack certification requirements in place. Further, the impact of limited recorded flight data and cockpit voice recordings, along with the benefits of on-board windshear systems will also be discussed.

Hazardous weather conditions

The Bureau of Meteorology graphical area forecasts for the area of operation contained strong winds, mountain wave activity and severe turbulence, which extended from Richmond to the Adaminaby and Good Good (at Peak View) fire-grounds. The Cooma-Snowy Mountains Airport (50 km from the accident site) aerodrome forecast also indicated gusting winds nearing 50 kt and reduced visibility from blowing dust. These forecasts were consistent with the Peak View weather station recordings, witness reports, and video of the actual conditions. The ATSB’s analysis of the aircraft’s ground speed from the automatic dependent surveillance broadcast (ADS-B) data also showed that the wind speed was likely of a magnitude of 20-40 kt from a north-westerly direction during their drop planning circuits at Peak View.

Overall, the Bureau of Meteorology concluded that the actual conditions in the accident area were consistent with the forecasts. This was reinforced by the pilot reports in the morning, which resulted in the smaller fire-control aircraft ceasing operations due to winds of about 50 kt. In addition, the pilot in command (PIC) of the Boeing 737 (B137) reported similar winds and experiencing a windshear warning and uncommanded roll when at Adaminaby. Of note, the birddog pilot had rejected the tasking to Adaminaby as the forecast conditions were worse than what they had experienced 2 weeks prior, where they were subjected to moderate to severe turbulence and downdrafts.

At Peak View, the crew had followed their procedures and conducted a number of circuits over the drop location, which was on the eastern side of a ridgeline. As the crew had elected to conduct the drop, this would indicate that they had assessed the meteorological conditions during these circuits as suitable to continue. However, the lowest circuit height of 500 ft may not have been low enough for the crew accurately assess the conditions at the drop height and identify any localised terrain or fire effects.

The low-pressure spike recorded in the ADS-B data potentially indicated the aircraft had been subjected to localised weather effects, but due to limited information the reason for this could not be conclusively determined. The drop was located on the lee side of a ridgeline, an area prone to turbulence and potential development of mountain waves. However, while mountain waves were confirmed by the Bureau of Meteorology analysis to be present across the Snowy Mountains region at the time of the accident, the severity of this could not be ascertained from the available information. In addition, the drop was in an area noted by local glider pilots to be subject to turbulence and rotor conditions.

Strong winds and mountain waves are considered hazardous conditions due to their ability to generate strong downdrafts that may adversely affect an aircraft's climb performance. They may also create windshear, which is of particular significance when it results in an increased tailwind component, with a subsequent reduction in airspeed. At the same time, moderate to severe turbulence would increase the stall speed.

In addition, the presence of a large fire will produce smoke and heat plumes, and potentially fire-driven winds, that is likely to exacerbate the forecast conditions. The Blue Mountains fire case study suggested the possibility of fires drawing strong winds down closer to the surface than might otherwise be forecast.

Therefore, the environmental conditions in the accident area were conducive to windshear and downdraft development at a time when the aircraft was most vulnerable, with low airspeed and low height.

Tasking continuation by the Rural Fire Service

In the 1100 conference call between the Cooma incident controller and several senior personnel from the State Operations Centre, they discussed the severe fire weather conditions and escalating fire threat at Adaminaby. They also acknowledged that the smaller fire-control aircraft (which included the incident air attack supervisor), had stopped operations due to strong winds, with pilots reports of winds up to 52 kt and limited visibility. In that same conference call, a senior NSW Rural Fire Service (RFS) officer indicated that they should send B137 rather than wait for a birddog assessment. That is, they elected to send the LATs as initial attack to determine if they could work the fire-ground, rather than wait for an assessment prior to re-starting aerial operations. Following this, the State Operations Centre tasked 2 large air tankers (LATs), and subsequently the birddog, from Richmond to Adaminaby knowing the conditions were marginal, and that the LATs would arrive prior to the birddog.

During the initial crew tasking, the Richmond airbase manager (ABM) had mentioned the wind conditions to the crew of B137 and advised them to 'take care'. Similarly, subsequent calls made between the ABM and the state air desk (SAD) at 1137 and 1209 discussed the adverse environmental conditions and that the birddog pilot was questioning the suitability of the weather. When the birddog pilot rejected the tasking, based on operational safety concerns, there was an expectation from them and the operator's pilots that the tasking for the LATs would be cancelled, or at least reconsidered. This was consistent with the normal practice for a 'turn down' in the United States (US), and the need for aerial supervision in marginal weather conditions as outlined in the US Department of Agriculture, Forest Service (USFS) *Standards for Airtanker Operations* and *Forest Service Handbook*. However, despite an awareness of the hazardous environmental conditions, the earlier withdrawal of the smaller fire-control aircraft and the birddog pilot rejection, the tasking was continued, and this information was not relayed to either B137 or B134 crews.

Subsequently, following the drop at Adaminaby, the PIC of B137 reportedly advised the RFS Cooma aviation radio operator to cancel all aircraft operating in the area and indicated to the ABM (at about 1232) that they would not be returning due to the weather. While the crew of B134 had already been tasked and were en route to Adaminaby, this was another opportunity for the RFS to reassess the suitability of the tasking. In addition, the RFS, having received information that further operations in the Adaminaby area were unsuitable for LAT operations, did not communicate this information to the Cooma aviation radio operator or B134. In response to the ATSB draft report, the RFS noted that, while the State Operations Controller was aware of these rejections, they elected to allow B134 to continue, for further intelligence gathering purposes.

It was recognised that RFS personnel may have a limited understanding of aviation operations and therefore, there was a reliance on aircraft operators and crew to manage safety. However, in this case, the crew were not provided with a full awareness of the situation, with no knowledge of the birddog pilot rejection or that the smaller fire-control aircraft were no longer flying. In addition, while B134 had been in contact with B137 and received advice on the conditions, this was unknown to the RFS at the time.

While some RFS personnel considered it unlikely that the LATs would be able to achieve the planned objectives due to the weather conditions, they continued with the tasking, relying on the crews to independently assess the conditions and cancel the tasking while airborne. As highlighted in the ATSB's research into aerial campaign management, leaving the responsibility of safety to another party (the operator and crew in this instance) who are not managing the overall campaign is not effective. When there is a high-level decision to proceed with a tasking despite known elevated risk factors, providing information on those risks would allow crews and operators to make more informed decisions.

Crew awareness of task rejection

As discussed above, the smaller fire-control aircraft had ceased operations in the area earlier that day, which had been acknowledged by the RFS personnel from the State Operations Centre in the 1100 conference call. Also, the birddog pilot had rejected the tasking to Adaminaby, unaware that the smaller aircraft had stopped flying at that time. The birddog pilot indicated that it was not routine to talk to the other pilots about taskings. Therefore, they did not communicate with the crew of B134 that they had declined the tasking, but expected the RFS personnel would relay this information.

In addition, there was no indication in the available radio calls or at interview that the cessation of operations earlier that day or the birddog pilot task rejection was communicated to the crew of B134 by any RFS personnel. It was noted that this information was not required to be passed on in any of the tasking or dispatch procedures. While not directly communicated to the crew, there was the potential that they may have been monitoring the radio call between the SAD and the Richmond ABM at 1209, shortly after they had departed. However, there was no clear statement of the rejection in that call, rather, they only discussed the birddog pilot's uncertainty about the weather conditions.

Therefore, while known to RFS personnel, it was very unlikely that the crew of B134 were aware that the birddog pilot had rejected the tasking, or that the smaller fire-control aircraft were no longer operating in the area, due to the hazardous environmental conditions. While this was only one risk factor among others that would be considered by the crew, having this information would have allowed them to make a more informed decision about the weather conditions and task acceptance.

Nevertheless, as the tasking to Adaminaby for B134 had been provided prior to the assignment of the birddog, it was likely the crew expected to be departing as initial attack. In which case, even if they were aware of this information, it was possible that they may have still departed to self-assess the conditions, particularly given the fire-ground was at least 45 minutes away. However, as this was an individual judgement, it could not be established how this information alone would have influenced their decision on the day.

Task acceptance by the crew

The weather forecasts applicable at the time of the flight contained mountain wave activity and severe turbulence, which extended from Richmond to both the Adaminaby and Good Good fire-grounds. While the crew's access to weather information on the day could not be determined, the usual practice of filing a flight plan through the operator's electronic flight bag provided access to the required forecasts. They had also attended the morning RFS briefing with the Richmond ABM in which the weather conditions across the state were discussed. In addition, the PIC was one of the recipients of the ABM's text message for the weather alert for Richmond in the morning prior to the tasking.

Although the PIC of B137 was made aware by the ABM at the time of the initial tasking that there no other aircraft operating at Adaminaby, they were not aware of the reason for this. Therefore, it was plausible that the crew of B134 were also not aware of this information and were not able to factor in the actual conditions to their decision when accepting the initial tasking to Adaminaby. Further, as discussed above, they were very likely unaware of the birddog pilot's rejection of the task. Irrespective, it was reasonable to conclude that the crew of B134 were at least aware of the forecast conditions for the area of operation before departing Richmond.

While both the operator's and manufacturer's documents stated that flight was prohibited in known severe turbulence, this did not prevent crews from departing when severe turbulence was forecast. The only weather-related operational limitations were associated with thunderstorm activity. Therefore, it was considered normal practice to accept a tasking in these forecast conditions. Most of the operator's LAT pilots interviewed indicated a preference to depart and assess the actual conditions to determine if they could find a workable solution rather than rely solely on a forecast, which could cover a large area and time frame, and may not necessarily reflect the actual conditions at the fire-ground.

When B134 was en route to Adaminaby, the PIC of B137 (returning to Richmond) discussed the actual conditions with the PIC of B134, and advised they were not returning. Although B134 continued to Adaminaby, the crew discontinued the task once there as they had experienced similar conditions. Despite this, knowing the decision made by the PIC of B137 and the forecast conditions for the area, the crew of B134 accepted the alternate tasking to the nearby Good Good fire-ground, consistent with company practice. Circuits were conducted at Good Good, as per the standard retardant drop planning, to identify the asset for protection and the suitability for a drop. While the details of the assessment were unknown, the crew elected to continue with the retardant drop. Ultimately, the decisions to accept the initial and alternate tasking, and proceed with the retardant drop by the crew exposed the aircraft to a situation where it experienced degraded performance following the drop.

Degraded aircraft climb performance

Witness video, ADS-B and SkyTrac data showed that, following the completion of the drop, the aircraft climbed about 170 ft over a period of about 10 seconds, which was comparable to previous climb rates from the operational load management system. It was reported by the operator's pilots that, at this stage of the flight, they would be targeting an airspeed increase from the drop at 120 kt indicated airspeed (IAS) to 150 kt IAS, while climbing from the drop height of 200 ft to at least 500 ft above ground level. However, during this period, the ATSB calculated a calibrated airspeed (CAS) range of between 100 and 123 kt (comparable to the IAS), which indicated the airspeed likely stagnated or reduced over this period.

Following this initial 10 seconds, the climb ceased, and altitude appeared to be maintained for about 3 seconds before the aircraft began to sink with an estimated descent rate increasing to 2,000 ft/min. The CAS also continued to stagnate after the initial 10 seconds. The reduction in vertical speed and estimated airspeed stagnation occurred at the time it would be expected that the engine power would be increasing. This increase in power would either translate to an increased height (while maintaining IAS) or maintained altitude (with an increase in IAS). Of note, the ATSB had established that there were no indications of mechanical or technical failures with the aircraft.

After the drop, the aircraft was turned from a predominant crosswind to a predominant tailwind, based on the recorded mean wind direction. This would have resulted in an initial slight decrease in the IAS. At the same time, as previously established, there were strong gusting winds, turbulence, and mountain wave activity present at the time of the accident, and these conditions were conducive to windshear.

If there was an additional increase in this tailwind component from windshear, this would have resulted in a further reduction of the airspeed. There would also be a corresponding decrease in pitch attitude and rate of climb, with a subsequent loss in altitude, as highlighted in the Lockheed Martin C-130 Airplane Flight Manual (AFM), and by the Bureau of Meteorology (2014) and Bowles (1990). These descriptions were consistent with the ATSB's analysis of the recorded information. The witness video showed that the maximum pitch-up angle occurred 4 seconds after the completion of the drop and from this point it decreased. Likewise, the aircraft initially had a rate of climb up to 1,000 ft/min, but this also decreased, and the aircraft descended.

For comparison, the simulator testing showed that a strong constant mean wind during the climb-out resulted in a small loss of IAS, but a significantly higher ground speed than was seen in the accident sequence. However, scenarios that used a moderate (15 kt) mean wind with gusts and windshear between 15 kt and 35 kt (similar to the total wind speeds recorded on the day), produced similar ground speeds to the recorded accident data. They also consistently resulted in the IAS decaying into the stall speed region, with minimum speeds between 84 kt and 98 kt.

In addition, observations made on the reconstruction flight noted an airspeed decay when they turned and were flying toward the accident site, even though the engine power was increasing. This was consistent with the glider pilot comments that there could be localised effects in this area due to the terrain. On the day of the accident, while the reason could not be determined, the ADS-B data recorded a low-pressure spike, which also had the potential to result in decreased aircraft performance.

The intensity of the environmental conditions (including mountain wave activity, strong gusting winds and turbulence) and therefore the windshear, could not be determined. However, the ATSB's analysis of the available recorded data showed that the aircraft's performance had degraded during the climb-out, consistent with encountering windshear, while concurrently turning into an increased tailwind, based on the mean wind direction. This was supported by the C-130 simulator testing. With the limitations of the available recordings, and the absence of a cockpit voice recorder, it could not be determined if the crew had identified the conditions or initiated a recovery procedure. As cautioned in the Lockheed Martin AFM, severe windshear could exceed aircraft performance capability.

Stall at low altitude

About 10 seconds after the completion of the drop, the aircraft had climbed to about 330 ft above ground level but then ceased climbing, and the altitude was maintained for a few seconds. Although the aircraft was in a nose-up attitude, the aircraft was sinking and developed a high sink rate up to 2,000 ft/min. This was followed by a significant left roll just prior to impact. This was consistent with the stall characteristics as outlined in the C-130 discussion paper (Mizell 2009), where the approach to the stall in this configuration exhibited high descent rates, before the left wing stalled resulting in a large angle of bank excursion.

The ATSB calculated the power-on stall speed, with 50% flap and at the post-drop weight, as 83 kt. Consideration was also given to the potential effect of turbulence, which increased the stall speed to between 101-117 kt for moderate turbulence and 117-143 kt for severe turbulence. Noting that the ATSB derived CAS for the accident flight was between 100 and 123 kt in the last 10 seconds of the available data, this presented a significant overlap with the calculated stall speeds. It was also noted that, in the simulator test scenario that was most consistent with the accident flight, the IAS consistently decayed into the stall speed region with repeated stall warnings activated.

In the absence of the cockpit audio recording, it was unknown if the PIC, as the pilot flying, had initiated a response to the stall. Despite this, in consideration of the observed high sink rate followed by a significant left-wing roll, and the overlap in the stall speed and CAS, it was likely that the aircraft aerodynamically stalled at a height that was insufficient to recover before colliding with terrain.

Coulson Aviation risk management of large air tankers

While there was no regulatory requirement at the time of the accident, Coulson Aviation had implemented a safety management system (SMS), it was a contract requirement in the US, and which was viewed favourably by the National Aerial Firefighting Centre. However, as the system was not mandated, it was not assessed by the Civil Aviation Safety Authority or the Federal Aviation Administration. The ATSB acknowledges that any operator's SMS will evolve and mature with time. However, significant events like accidents need to be used to explore whether their SMS is operating in a way that can assure the highest level of safety given the nature of their operations.

Acknowledging the element of risk associated with firefighting operations, the ATSB reviewed the safety risk management component of the SMS. Although the operator's SMS manual outlined that the online SMS program would record the identified hazards, this was limited to submitted incident reports, and did not contain previously identified hazards. Although, the *Company Operations Manual* had detailed several operational hazards, the current and previous safety managers indicated that no risk assessments for the identified hazards associated with the LAT operations had been conducted. However, it was noted that risk assessments were included in the SMS manual, but these only applied to safety reports and change management contained within the online SMS program. While some of these hazards may have been discussed during the daily SMS conference call, this process was not formalised.

Without formal operational risk assessments of the recognised hazards applicable to the LAT operation, there was no identified risk mitigation strategies nor was there any assurance that the risks were at an acceptable level. For example, windshear and downdrafts had been recognised as a potential hazard in the *Company Operations Manual*. However, as no formal assessment for the C-130 aircraft had been conducted, there was no opportunity to formally identify and assess potential risk mitigators, such as those discussed by Hallowell and Cho (2010).

As noted by ICAO (2018), safety risk management activities such as operational risk assessments should be documented. Both the current and previous safety managers indicated that the operator did not have a risk register as part of their SMS, or an alternative process, at the time of the accident. This limited their ability to track, monitor, and mitigate the identified hazards, and assess the effectiveness of any risk controls.

Another important element of safety risk management was the use of reporting systems for hazard identification. The ATSB's review of the operator's safety reporting system found that there were few reports related to flight operations, and there were no reports of weather-related incidents. This was despite several of the crews interviewed having recalled encountering windshear during firefighting operations, which affected the aircraft. Given the operator's draft report response comments that they considered the incident reporting numbers were mitigated by the daily SMS calls, it was likely they relied on this informal process for flight risk awareness, rather than incident reporting. Although the weather conditions were mentioned in the days prior to the accident, there was minimal detail of the discussions recorded in the daily SMS conference calls. Therefore, as there was limited information on operational issues recorded in the SMS, there was limited ability to conduct risk assessments of any identified hazards, to gain an understanding of their potential impacts on operations and mitigate the associated risks, or to perform any safety trend analysis.

As established above, aerial firefighting operations were subjected to elevated risks. Therefore, the supporting risk management practices should consider risk assessments at all levels of the organisation and all stages of the operation. Acknowledging that the risks cannot be entirely eliminated, an operational risk assessment would have provided an opportunity to identify the need to establish acceptable risk levels associated with firefighting taskings. While elevated risks were individually identified, there was no clear process for pilots to review or assess all the factors collectively and consistently. Instead, the operator's risk management process relied predominately on crews conducting their individual, undocumented risk assessments for each task as part of their normal pre-flight planning and tactical assessment during flight. In particular, there was no identification of the need for a risk-based decision-making framework to support pilot decision-making when accepting potentially high-risk taskings.

The operator's voluntary audit had identified significant growth in the company since the initial audit 2 years earlier, but it also noted that the SMS had not yet fully matured. While it was recognised there was no requirement for Coulson Aviation to have an SMS in Australia, the ATSB identified that there was very limited oversight of the identified hazards. Without operational risk assessments for the LAT operations or a method to monitor identified hazards, associated risk assessments, or risk mitigation, this limited Coulson Aviation's ability to manage the risks related to their LAT operation.

Pre-flight risk assessment tool

As noted by the US National Transportation Safety Board, effective risk management involves good decision-making. These skills are important in most work domains, but are especially critical in high-risk settings when individuals may be functioning under time pressure and stress, such as firefighting operations.

The LAT operation was a 15-minute notice standby tasking arrangement, which could send the aircraft to any location within the bounds of the tasking authority. The retardant drop task was a response to a possibly urgent threat that involved low-level, low-speed operations in a potentially hazardous and challenging environment. This made it a comparatively high-risk activity, in addition to which pilots were also responding to an external tasking agency, a potential source of external pressure.

At the start of each day, the RFS conducted a briefing for the LAT and birddog crews, which provided an overview of the weather, likely areas of operation, and fire conditions. However, on receiving a tasking, crews were still required to conduct their own flight planning specific to the area of operation, in a timely manner, to determine what was an acceptable level of risk.

The only consideration provided at interview as no-go criteria by the Coulson Aviation crews was a thunderstorm. Consequently, there could be several flight planning factors, which individually were not a no-go criterion, but collectively elevated the risk to higher-than-normal for the LAT operation. There could also be additional external factors, such as task rejections or cancellations by other pilots, which could elevate the risk if they were known to the LAT crew.

While acknowledging that LAT operations had inherent risks, Coulson Aviation had not introduced a pre-flight risk assessment tool for their LATs. Instead, there was a reliance on the PIC to assess the acceptability of the task based on their assessment of the conditions. However, this process may not have necessarily detected the cumulative effect of several indicators of elevated risk.

On the day of the accident, there were multiple pre-flight risk indicators, which included:

- forecast strong winds, severe turbulence, and mountain waves in the area of operation
- operating in mountainous terrain
- the Richmond Airport weather warning sent to the LAT crews by the ABM prior to the Adaminaby tasking
- the cessation of the smaller fire-control aircraft due to the actual weather conditions in the Snowy Mountains
- the birddog pilot's rejection of the task following assessment of the forecast weather conditions for the area compared with a previous experience
- the copilot and flight engineer were in their first firefighting season
- potential pressure to respond to the bush-fire risk to the town of Adaminaby.

While it could not be determined if all factors were known to the crew of B134, or their assessment of each factor, none of the above risk indicators were likely to be individually sufficient for the PIC to reject the task. However, when assessed collectively against pre-defined criteria, they would have produced an elevated score, as identified in the ATSB's estimate of the accident flight risk profile using the operators recently introduced pre-flight risk assessment tool. However, it was noted that this tool did not include weather-related task rejections, considered one of the highest risk indicators for helicopter operations by the Helicopter Association International.

While there was no regulatory requirement at the time, the use of a pre-flight risk assessment tool was a contract requirement with the USFS. A 2014 NTSB study of aerial work accidents outlined that risk management guidelines and best practices specific to aerial work aircraft operations included a pre-flight risk assessment tool. These help operators and pilots mitigate the unique risks associated with their operations, in particular, when the operation is often conducted in high-risk circumstances. As emphasised by both the US Federal Aviation Administration (FAA) and USFS, every flight has some level of risk. Therefore, it is critical that crews can differentiate between a low-risk and high-risk flight during the planning stage to establish the overall risk profile. Risk management strategies, such as a pre-flight risk assessment tool, can assist pilots with applying a systematic process that helps them resist pressures that can adversely affect their decision-making and identify risks that could affect the safety of the flight.

In this case, the availability of such a tool would have assisted the PIC with making a more informed go/no-go decision for the initial tasking to Adaminaby. This almost certainly would have resulted in the PIC identifying the elevated risk associated with the tasking, and having to consider implementing risk mitigations, or escalation of the decision-making, if not rejection of the task. In addition, the PIC was reported to be conservative, therefore, the knowledge of the cessation of aerial operations due to strong winds and limited visibility, and followed by subsequent weather-related rejections due to safety concerns, would have likely increased the risk above an acceptable level,.

Rural Fire Service aerial supervision requirements

Although it was acknowledged that the RFS was not an aviation operator, they were responsible for tasking a variety of aerial assets, with substantially different operating capabilities, often in high pressure situations in challenging environmental conditions. It could be foreseen that there will be community expectations that the RFS respond to fire threats, and use all available aerial assets to achieve the planned objectives. Accordingly, the tasking agency needs to define the acceptable level of risk for the overall operation, to provide an effective additional layer of defence above that provided by the aircraft operator. Such systems and policies have been implemented in firefighting operations in the US.

Operationally, the tasking-related risk assessment noted in the RFS *Aviation Standard Operating Procedures* (operating procedures), predominantly focused on the use of the aircraft to manage the fire threat rather than ensuring the safe use of those aircraft. The RFS had identified considerations to ensure the effective use of LATs, and acknowledged that certain task environments had higher risks. However, there was no guidance provided to frontline RFS personnel on how to assess these risks as part of the tasking process, such as those noted by the USFS and the US National Wildfire Coordinating Group.

For example, the RFS tasking considerations included weather as a potential threat, but there was no further guidance around how to assess the environmental conditions, or under what circumstances taskings should be considered acceptable or not acceptable. For the tasking to Adaminaby, it was noted in the 1100 conference call and various logs that the weather conditions were hazardous and that no aircraft were flying in the area due to the wind and visibility conditions. Despite this, there was an expectation that the LATs had greater flight capabilities and the pilots could make their own assessment of the conditions. Therefore, the decision was to send the LATs, and see if an opportunity presented itself that allowed for their assistance.

However, if the RFS had implemented policies and supporting procedures applicable to minimum aerial supervision requirements, similar to those in place in the US, this would have provided guidance to the front-line staff to assist with tasking decision making. For example, the USFS documents outlined the requirement for aerial supervision in marginal weather, including limited visibility and turbulence, and further, where the aerial supervisor suspended operations, they must not proceed with further taskings until risk mitigations are in place. If such policies were in place, it was likely that RFS personnel would have identified the higher risk environment, and therefore the need for aerial supervision on this tasking. In turn, this would have likely identified that an initial attack deployment was not suitable in the elevated risk environment.

The operating procedures indicated that aerial supervision was generally required for LAT firefighting operations unless the crew were initial attack certified and there were operational advantages to commencing operations prior to aerial supervision arriving. Those advantages included considering the speed differential between a birddog and LAT, or when a birddog was not available due to resourcing constraints, such as diversion to another tasking. However, there was no differentiation between the use of an initial attack deployment where aerial supervision was not available, in comparison to the rejection or cessation of a tasking due to safety concerns.

While the initial deployment of B137 ahead of the birddog could reasonably be accepted as meeting an operational advantage, the departure of the smaller fire-control aircraft and subsequent rejection of the birddog should have resulted in reconsidering the use of ‘initial attack’. However, there was no supporting procedure or guidance on the use of ‘initial attack’ deployment in these elevated risk circumstances, such as when the task was rejected by the birddog due to safety concerns. In the case of the accident, this rejection occurred shortly prior to B134 departing Richmond, and there would have been sufficient opportunity to reassess the task, and potentially redirect the LAT elsewhere, prior to their arrival overhead Adaminaby.

Policies and procedures on aerial supervision should include consideration of the known factors that elevate risk associated with aerial firefighting tasks, and would ensure the RFS have minimum aerial supervision requirements in place for each tasking circumstance. It would also include policies and procedures for the deployment of LATs without aerial supervision (initial attack), and in what circumstances this would be acceptable. In order to make acceptable risk-based tasking decisions, these considerations need to be enshrined in policies and procedures, to assist with time-critical decisions during the fire season by frontline staff. The RFS personnel would have to assess that the tasking meets the minimum aerial supervision requirements prior to approaching operators with taskings, to ensure the taskings can be conducted within their defined, accepted risk levels.

Rural Fire Service management of task rejections

The ATSB’s 2004 research into aerial campaign management stated that organisations that contracted aerial operations (such as the RFS) were directly involved in the management of significant parts of the aerial campaign and were in a central position to understand the big picture. Decisions made during this process had the capacity to influence the level of risk of the operations.

It could be reasonably expected that there will be situations in which tasks are declined for safety reasons. While the RFS *Aviation Standard Operating Procedures* and the *Operating Guidelines for Air Tanker Operations* outlined some initial considerations regarding the tasking of LATs, there was no further policies or procedures following the initial tasking process to support the ongoing task. Consequently, there was no process in place to support RFS frontline personnel on managing a task rejection by crews or operators.

These policies and procedures would detail when task rejections should be considered as a risk indicator, such as when flights were declined due to weather-related safety concerns. For comparison with the USFS *Standards for Airtanker Operations*, this may also include communication of this information to other crews, reassessment of the tasking, incorporation of appropriate mitigations, or cancellation of the task. They should also encourage pilots and operators to communicate unsafe conditions without fear of reprisal.

On the day of the accident, neither the Richmond ABM nor the SAD communicated to either of the LAT crews or the birddog pilot tasked to Adaminaby, information regarding the smaller fire-control aircraft ceasing operations due to unsuitable weather. Nor did they communicate the task rejection by the birddog pilot to the crew of B134 shortly prior to take-off from Richmond (noting this occurred about the time B137 was overhead Adaminaby). The LAT AAS (who would have been on board the birddog) also did not communicate this to the LAT crews, as their communication role did not commence due to the birddog aircraft not departing. In addition, this rejection was not communicated by RFS personnel to the Cooma Fire Control Centre aviation radio operator, who could reasonably be expected to be in contact with the LAT crew as they were operating as initial attack, and they were the appropriate local ground contact to coordinate the task. While acknowledging the LAT's, birddogs, and the smaller fire-control aircraft have different capabilities and performance limitations, this was relevant information (specifically, reported strong winds and limited visibility, and the rejection based on safety concerns) that could reasonably have been communicated to the crews. As previously discussed, there was an expectation from the birddog pilot and the operator's pilots that the RFS would either relay this information to them so it could be included in their decision-making processes, or the task would be cancelled by the RFS.

The subsequent rejection of further tasking by B137 as the conditions were worsening and reportedly unsuitable for LAT operations, was also not communicated by either the ABM or SAD to the crew of B134 nor to the Cooma incident management team. In addition, shortly after this rejection, the ABM and SAD discussed sending an alternative LAT to Adaminaby. None of these rejections resulted in a reassessment or cancellation of the tasking for B134 to Adaminaby. Rather, the RFS allowed B134 to proceed with the intention of gathering additional intelligence to assist in determining whether further aerial operations would proceed. Subsequently, the Cooma aviation radio operator was also unaware of this rejection of further tasking by B137, or their assessment of the conditions when providing the secondary tasking to the B134 crew.

As outlined above, while some crews were initial attack certified and could operate without aerial supervision, the RFS operating procedures indicated that this was only to occur when there were operational advantages prior to an air attack supervisor (AAS) arriving. However, the operating procedures did not reference any circumstances, such as in the case of the accident flight, where a tasking had been rejected due to safety concerns, such as unsuitable weather. While initial attack crews were trained to conduct operations without the AAS, continuing a tasking where the local AAS had departed or grounded due to weather concerns, and/or the birddog pilot (and therefore LAT AAS) rejected the tasking, appeared outside of the intended scope of 'initial attack' deployments.

As the task rejections were on the basis of weather or fire-ground safety concerns, which equally applied to B134, appropriate policies and procedures regarding task rejection should have resulted in the initial tasking to Adaminaby being cancelled following the rejections. There were

2 opportunities for this. The first was at the time of the birddog rejection when B134 was departing Richmond, which, at the very least (noting the RFS understanding of differing capabilities between the birddog and the LATs) should have resulted in communication of that information to allow the LAT pilots to make their own more informed risk assessment. The second was when B134 was transiting over the Canberra region and the RFS received advice from B137 which indicated that it was not suitable for LAT operations. Task cancellation would have also been consistent with the RFS intended use of initial attack and the general operating principles in the US.

While the RFS was not an aviation organisation or directly responsible for flight safety, they were closely involved in the aerial operation, being responsible for determining the task objectives and selecting the aircraft category for the task. Policies and associated procedures for task rejections would provide RFS personnel with the required steps to effectively and safely manage taskings, and provide guidance for decision-making. It would allow for consideration of a rejection by other crews, resulting in clear communication from RFS personnel of crew rejection decisions both internally, and to all aircraft on the tasking, and additional risk treatments being implemented up to task cancellation. A policy would also provide all RFS personnel with an objective mechanism to cancel taskings on the basis of safety.

Retardant load not jettisoned

Although the aircraft was obscured by smoke at various points, the witness video showed no further retardant dispersal after the initial drop, nor was any found between the drop area and the accident location. At the site, the operational state of the retardant aerial delivery system could not be determined due to the damage sustained, but a large amount of retardant was found in the wreckage near the tank.

However, as there was only about 10 seconds between the climb performance degrading and the likely stall, there was limited time available for the crew to identify and respond to the situation. Past research shows pilot recognition time of windshear can be expected to be about 5 seconds, and the emergency dump function would take a further 2 seconds. However, in the absence of the cockpit audio recording, it could not be determined if the crew had considered or called for an emergency dump of the remaining load. Therefore, for reasons undetermined, the remaining 11,340 kg of retardant was not jettisoned during the accident sequence.

The ATSB established that jettisoning the remaining load would have lowered the stall speed and optimised the aircraft’s climb performance. This was also confirmed from the simulator testing. Nonetheless, it was not possible to determine if jettisoning the remaining load, taking into account the time available, and typical recognition and response times, would have prevented the collision with terrain. The outcome of the US Air Force C-130 accident, where the crew did jettison the load, is an example of when this action may not be sufficient to avoid a collision with terrain.

Windshear recovery procedure and training

It is acknowledged throughout the aerial firefighting industry that they operate in a challenging environment with elevated risk conditions. Windshear was a known phenomenon, which could be exacerbated by fire-associated winds that may be difficult to forecast and could be influenced by local terrain effects. Most of the operator’s crews interviewed reported encountering a windshear event during firefighting operations. The FAA study published in 2010 identified 3 categories of windshear mitigators: ground-based alerting systems, pilot training, and airborne detection systems.

Large air tanker firefighting operations were generally conducted away from airports often over inhospitable terrain. Therefore, it would be unlikely the ground-based systems, or weather-based monitoring from airports would be available for windshear alerting during a retardant drop.

The Lockheed Martin C-130 AFM had been updated prior to 2010 to include a section on adverse environmental conditions, which included a windshear recovery procedure. Although the FAA had approved the Coulson Aviation C-130 AFM in 2013, the operator had used an earlier version

(1989) of a military document to develop the manual. This was consistent with comments provided by the FAA to the ATSB, where the documents and manuals for military surplus aircraft would normally be sourced from the military rather than the manufacturer. Therefore, the windshear recovery procedure was not included in the Coulson Aviation C-130 AFM.

While both the departures and standard operating procedures sections of the *Company Operations Manual* provided basic windshear recovery guidance for the C-130, it was not presented as an emergency procedure, nor did it consider any specific requirements for firefighting activities, such as the potential jettison capability offered by the retardant aerial delivery system. In addition, while this manual was applicable to all aircraft types, it was specifically developed for Australian operations only, although the company operated internationally. At least one of the operator's C-130 pilots stated that they did not consider this manual to be the reference document for operating the aircraft, rather, the AFM and checklists were the appropriate source. This was consistent with the purpose of an AFM, which was to provide the procedures for operating the aircraft.

Although the PIC of B134 had completed an in-flight training scenario in 2019 that incorporated a simulated downdraft, the training generally focussed on responding to an emergency on the drop run, rather than specific to windshear. While a windshear encounter could be simulated airborne in the aircraft, it was not possible to replicate the effect on aircraft performance. Therefore, this would not provide pilots with the performance instrument indications that would be typically experienced. However, the operator provided their C-130 pilots with annual simulator training. While it was noted that a briefing on windshear recovery was incorporated into the training syllabus, there was no requirement to conduct a simulator-based low-level windshear recovery scenario as part of initial or recurrent training. This could provide crews with the experience needed to recognise the symptoms of windshear and practice a recovery procedure.

The operator also noted that most of their crews were former or current military pilots and would have received windshear training on a bi-annual basis when serving members. However, for those pilots no longer in the military, no recurrent training was provided by the operator to maintain proficiency in windshear recovery. Further, it was also recognised that the air drop scenario conducted in the military differed somewhat from a retardant drop. Most notably was the inclusion of the retardant aerial delivery system and capability to conduct an emergency dump to improve aircraft performance.

Research conducted on behalf of the FAA found that there was only about 5-15 seconds available for pilots to recognise and respond to a windshear encounter. Japanese research into pilot reactions to windshear on landing approach found that about 5.5 seconds was the average time to recognise a windshear event. As such, when in a low airspeed and low height scenario associated with a retardant drop, recognition and reaction to a significant windshear event must be prompt to avoid a collision. However, as no cockpit audio recording was available for the accident flight, it could not be determined if the crew had recognised that they very likely experienced a windshear event and/or had initiated a recovery. Despite this, an effective training program, using a combination of theory and practice, could provide pilots with the necessary skills and experience to recognise and respond to a low-level windshear encounter with minimal delay.

In multi-pilot operations, effective crew coordination and performance depends on the crew having a shared mental model of the task. This mental model is founded on operating procedures (ICAO, 2015). Such procedures are designed to help reduce variation within a given process and ensure operations are performed correctly. Without formal procedures, pilots are required to exercise judgement to the best of their abilities, based on their experience, skills and knowledge. Together, a recovery procedure specific to the nature of the operation supported by training, should provide pilots with a shared mental model of the symptoms and recovery actions for a windshear encounter.

Windshear system not fitted

Where it has been recognised that pilot awareness and training are not 100% effective for windshear avoidance, advanced warning systems are designed to detect and confirm the hazardous condition prior to the encounter. This provides additional time for the crew to increase the aircraft's energy state and climb, so that any windshear encountered is at a higher, safer altitude. Alternatively, reactive systems alert the crew that they are experiencing windshear so that they can respond immediately, thereby minimising the time required for the crew to identify the situation before responding. These systems are particularly relevant to aerial firefighting aircraft, where there is an increased risk of encountering windshear, which is most hazardous in the low-level low-speed environment where they regularly conduct operations. As noted by some pilots interviewed, the fitment of such a system was reported to have had a positive effect on their management of a windshear encounter.

While a birddog pilot could provide advanced warning of a windshear condition, there may not be enough time for the LAT crew to respond and avoid the encounter. In the 2012 US Air Force C-130H accident, the birddog aircraft was about 1 NM (about 2 km) ahead when a warning was provided. This was insufficient for the C-130 crew to prevent a collision with terrain after experiencing low-level windshear, despite conducting an emergency retardant jettison. It was also noted that LATs deployed as initial attack, such as in the case of the accident, will not have aerial supervision, or an aircraft providing a 'show me' run.

Airborne forward-looking, or predictive, windshear detection systems have been developed in response to commercial aviation accidents and have been shown to be around 95% effective (in simulator studies). It is acknowledged that the bushfire environment will be dry (low relative humidity) and the effectiveness of a forward-looking system may be reduced. However, the Lockheed Martin FireHerc aircraft, a civilian-certified aerial firefighting tanker is fitted with a windshear warning system. This would suggest these systems offer an enhanced level of safety for firefighting operations, in particular where operations are at low level in windshear prone environments, which would assist pilots in the early identification and/or potential avoidance of windshear, minimising any loss of aircraft performance. In addition, reactive systems are considered capable of confirming potentially hazardous windshear conditions in advance of human pilot recognition time. The activation of the warning on B137 at Adaminaby, and the crew's subsequent response and adjustment of the drop location indicated a standard response to a windshear warning in aerial firefighting operations.

B134 and the operator's other C-130 aircraft were not fitted with any windshear warning systems as these were not available at the time of manufacture and there was no regulatory or contract requirement to have them. The operator also indicated that they had not considered installing windshear detection systems into their C-130 fleet when they were re-purposed for firefighting activities.

Given the local weather conditions, the fact that B134 was very likely subjected to windshear, and the activation of the warning on B137 in similar environmental circumstances, it was possible that the crew of B134 would have also received a warning. If a warning had triggered, it was reasonable to expect that the crew would have responded. In addition, if this had occurred during the drop planning phase, it would have also assisted the crew in their hazard assessment and identification that the location was possibly unsuitable before committing to the drop run. If it had occurred during, or following the drop at Peak View, it would have provided immediate identification to all crew of the situation, assisting with timely recognition and response.

However, in the absence of an airborne system, windshear detection is reliant on the pilot's assessment of the conditions based on the information available and their interpretation of that information. Without any known weather phenomena or reports from that location, detection is likely to be reactive, and dependent on the crew identifying a loss of aircraft performance. The recovery is subject to timely recognition and response, which could take 5 to 15 seconds and potentially result in further altitude loss. In this case, there was only 10-15 seconds and 330 ft between the degradation in climb performance and the impact.

Either a reactive or a predictive windshear detection system may have warned the crew of B134 of the actual or impending windshear and allowed for an earlier response. However, given the limited time and height available, it could not be determined if this would have been sufficient to have reduced the performance loss and prevent the accident. Despite this, research conducted on behalf of the FAA indicated that the risks associated with a windshear encounter would be reduced through a combination of pilot training and the use of on-board systems.

Initial attack certification

The *NSW and ACT Aviation Standard Operating Procedures* stated that aerial supervision was generally required for air tanker firefighting operations, except for those crew who were 'initial attack certified'. While the RFS documentation did not define the requirements for this, their intention was to recognise the US Department of Agriculture, Forest Service (USFS) certification and for operators to ensure crews held this certification. However, without a definition, or any reference to the USFS certification in the procedures, this allowed individual operators to determine when pilots were initial attack capable, without necessarily having the official USFS certification. This was consistent with Coulson Aviation's understanding, where they determined if a pilot was initial attack capable based on their internal training framework, rather than relying on the USFS certification. Despite this, this did not influence the development of the accident as the PIC of B134 held the initial attack certification from the USFS.

Standard operating procedures, among other risks controls, are fundamental for safe operations. They provide a common ground for users by ensuring consistency and predictability across all aspects of an operation. However, if procedures are not clearly defined, this results in a risk control not being applied as intended, lessening their effectiveness in managing safety. In this case, an individual operator may assess the capability of their pilots as satisfactory based on their own training, but it may not necessarily reflect the same requirements as that achieved through the USFS certification process.

Lack of recorded data

While the aircraft was not required to be fitted with a cockpit voice recorder (CVR) under the Australian or US regulations, it was a contract requirement in the US.

As detailed in the AFM supplement, when power was applied to the CVR, the system conducted a self-test and the status of that test was presented to the crew. However, the CVR did not record the accident flight as a result of the inertia switch activating on a previous flight about 8 months prior. Subsequently, the aircraft was operated on multiple flights by several crews in the intervening period with the CVR in an unserviceable condition. It was very likely that the inertia switch had not been reset during that time as the checklist being used in B134 did not include the requirement for the crew to check the status of the CVR. None of the operator's C-130 crew interviewed were aware of this requirement.

While this had no influence on the accident, the CVR being inoperable resulted in a valuable source of information not being available to the investigation. This increased the time taken to determine the contributing safety factors, and restricted the extent to which important safety issues could be identified and analysed. The benefits of flight recorders were further outlined in the ATSB publication *Black box flight recorders,* which highlighted recorders, such as the CVR, could be an invaluable tool to assist in identifying the factors behind an accident. The CVR captured more than crew communications, it also captured the audio environment in the cockpit, which could include radio transmissions, aural alarms, switch activations and engine noise.

Findings

ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition, 'other findings' may be included to provide important information about topics other than safety factors.

Safety issues are highlighted in bold to emphasise their importance. A safety issue is a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

From the evidence available, the following findings are made with respect to the collision with terrain involving Lockheed EC-130Q, registered N134CG (call sign B134), that occurred near Peak View, New South Wales, on 23 January 2020.

Contributing factors

- Hazardous weather conditions were forecast and present at the drop site near Peak View, which included strong gusting winds and mountain wave activity, producing turbulence. These conditions were likely exacerbated by the fire and local terrain.
- The Rural Fire Service continued the B134 tasking to Adaminaby when they learned that no other aircraft would continue to operate due to the environmental conditions. In addition, they relied on the pilot in command to assess the appropriateness of the tasking to Adaminaby without providing them all the available information to make an informed decision on flight safety.
- The pilot in command of B134 accepted the Adaminaby fire-ground tasking, which was in an area of forecast mountain wave activity and severe turbulence. After assessing the conditions as unsuitable, the crew accepted an alternate tasking to continue to the Good Good (Peak View) fire-ground, which was subject to the same weather conditions. The acceptance of these taskings were consistent with company practices.
- Following the partial retardant drop and left turn, the aircraft was very likely subjected to hazardous environmental conditions including low-level windshear and an increased tailwind component, which degraded the aircraft's climb performance.
- While at a low height and airspeed, it was likely the aircraft aerodynamically stalled, leading to a collision with terrain.
- **Coulson Aviation's safety risk management processes did not adequately manage the risks associated with large air tanker operations. There were no operational risk assessments conducted or a risk register maintained. Further, as safety incident reports submitted were mainly related to maintenance issues, operational risks were less likely to be considered or monitored. Overall, this limited their ability to identify and implement mitigations to manage the risks associated with their aerial firefighting operations. (Safety issue)**
- **Coulson Aviation did not provide a pre-flight risk assessment for their firefighting large air tanker crews. This would provide predefined criteria to ensure consistent and objective decision-making with accepting or rejecting tasks, including factors relating to crew, environment, aircraft and external pressures. (Safety issue)**

- **The New South Wales Rural Fire Service had limited large air tanker policies and procedures for aerial supervision requirements and no procedures for deployment without aerial supervision. (Safety issue)**
- **The New South Wales Rural Fire Service did not have a policy or procedures in place to manage task rejections, nor to communicate this information internally or to other pilots working in the same area of operation. (Safety issue)**

Other factors that increased risk

- The B134 crew were very likely not aware that the 'birddog' pilot had declined the tasking to Adaminaby fire-ground, and the smaller fire-control aircraft had ceased operations in the area, due to the hazardous environmental conditions
- In the limited time available, the remainder of the fire-retardant load was not jettisoned prior to the aircraft stalling.
- **Coulson Aviation did not include a windshear recovery procedure or scenario in their C-130 Airplane Flight Manual and annual simulator training respectively, to ensure that crews consistently and correctly responded to a windshear encounter with minimal delay. (Safety issue)**
- **Coulson Aviation fleet of C-130 aircraft were not fitted with a windshear detection system, which increased the risk of a windshear encounter and/or delayed response to a windshear encounter during low level operations. (Safety issue)**
- **The New South Wales Rural Fire Service procedures allowed operators to determine when pilots were initial attack capable. However, they intended for the pilot in command to be certified by the United States Department of Agriculture Forest Service certification process. (Safety issue)**

Other findings

- The aircraft's cockpit voice recorder did not record the accident flight, which resulted in a valuable source of safety information not being available. This limited the extent to which potential factors contributing to the accident could be identified.

Safety issues and actions

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues. The ATSB expects relevant organisations will address all safety issues an investigation identifies.

Depending on the level of risk of a safety issue, the extent of corrective action taken by the relevant organisation(s), or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue a formal safety recommendation or safety advisory notice as part of the final report.

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

The initial public version of these safety issues and actions are provided separately on the ATSB website, to facilitate monitoring by interested parties. Where relevant, the safety issues and actions will be updated on the ATSB website as further information about safety action comes to hand.

Rural Fire Service task rejection management

Safety issue description

The New South Wales Rural Fire Service did not have a policy or procedures in place to manage task rejections, nor to communicate this information internally or to other pilots working in the same area of operation.

Issue number:	AO-2020-007-SI-01
Issue owner:	New South Wales Rural Fire Service
Transport function:	Aviation: General aviation
Current issue status:	Open - Safety action pending
Issue status justification:	To be advised

Response by New South Wales Rural Fire Service:

On 1 June 2022, in response to the draft report and the identified safety issue, the New South Wales Rural Fire Service advised the ATSB that:

> …The NSW RFS considers the ultimate responsibility for assessing risk and accepting or rejecting taskings must sit with each aircraft and pilot in command. To require the NSW RFS to make these assessments on behalf of individual aircraft would constitute a shift in responsibility which would have significant implications for the NSW RFS operating picture and other jurisdictions operating in the fire-fighting environment….
>
> …The NSW RFS denies that the existence of task rejection policies and procedures would have resulted in the tasking/s of Bomber 134 being cancelled or rejected or that it would have changed the outcome on the day. This is because it is reasonable to assume that the pilot's decision to proceed with the drop at Peak View was made appropriately, after an adequate safety assessment. Any further information reasonably available to the NSW RFS on the day, if relayed to the pilot, was not likely to have impacted this decision….
>
> …As acknowledged in the draft report, the pilot in command was reportedly methodical, conservative, always undertook due diligence and avoided unnecessary risks. It is reasonable to assume that the pilot's decision to proceed with the drop at Peak View was made appropriately, after an adequate safety assessment including a determination that [they were] in possession of sufficient information.

> Any further information the NSW RFS was reasonably able to provide is not likely to have impacted on this decision

The New South Wales Rural Fire Service also advised the ATSB that they were taking the following actions with a planned final completion date of 30 September 2022:

- Undertake detailed research to identify best practice (nationally and internationally) relating to task rejection policies and procedures, considering how this may be applied across all aviation operations.
- Undertake a comprehensive review of NSW RFS aviation doctrine to incorporate outcomes of above-mentioned research into existing policies and procedures.
- Promulgate the revised NSW RFS doctrine detailing the task rejection policies and procedures to all operational personnel, pilots/aircrew and the other key stakeholders. This is to be reinforced at the Aviation Operators briefing held annually prior to the bush fire season.
- Provide the National Aerial Firefighting Centre (NAFC) and national fire fighting agencies with copies of the updated doctrine.

ATSB comment

While the ATSB acknowledges the commitment to undertake reviews and research, at the time of publication, the New South Wales Rural Fire Service had not yet committed to any safety action that would reduce the risk associated with the identified safety issue to an acceptable level. The RFS outlined to the ATSB during the course of the investigation that they had access to the US policies and procedures relating to the use of large air tankers and had referred to these in developing and managing the large air tanker program. Noting that the RFS are closely involved in aerial operations, the ATSB considers that the inclusion of policies and procedures for task rejections would provide RFS personnel with the necessary information to effectively manage and communicate taskings on the basis of safety. As such, the ATSB issues the following safety recommendation to the New South Wales Rural Fire Service to take further action to address this safety issue.

Safety recommendation to the New South Wales Rural Fire Service

> The ATSB makes a formal safety recommendation, either during or at the end of an investigation, based on the level of risk associated with a safety issue and the extent of corrective action already undertaken. Rather than being prescriptive about the form of corrective action to be taken, the recommendation focuses on the safety issue of concern. It is a matter for the responsible organisation to assess the costs and benefits of any particular method of addressing a safety issue.

Recommendation number:	AO-2020-007-SR-09
Responsible organisation:	NSW Rural Fire Service
Recommendation status:	Released

The Australian Transport Safety Bureau recommends that the New South Wales Rural Fire Service take further action to address the absence of policies and procedures for personnel to effectively manage and communicate task rejections on the basis of operational safety concerns.

Rural Fire Service aerial supervision requirements

Safety issue description

The New South Wales Rural Fire Service had limited large air tanker policies and procedures for aerial supervision requirements and no procedures for deployment without aerial supervision.

Issue number:	AO-2020-007-SI-02
Issue owner:	New South Wales Rural Fire Service

Transport function:	Aviation: General aviation
Current issue status:	Open - Safety action pending
Issue status justification:	To be advised

Response by New South Wales Rural Fire Service:

As a result of this investigation, on 1 June 2022 and 1 July 2022, the New South Wales Rural Fire Service advised the ATSB that they were taking the following actions with a planned final completion date of 31 December 2022:

- Construction of the Aviation Centre of Excellence at the NSW RFS Training Academy in Dubbo, incorporating simulation technology to assist in skill maintenance and policy adherence relating to aerial supervision requirements (eg. Air attack supervisors). it is noted an aviation simulator has already been commissioned and in use for this purpose.
- Finalise the independent report commissioned by NSW RFS into the management of airspace in which aircraft are operating in support of fire fighting activities. The draft report was finalised on 20 June 2022 and is currently under active consideration by the NSW RFS. The report contains several options that are provided for consideration by the NSW RFS and are drawn from a review of the NSW RFS and other agency procedures, discussion with industry participants, and the Australian aviation regulatory environment.
- Undertake detailed research to identify best practice (nationally and internationally) relating to aerial supervision policies and procedures, including aircraft taskings without aerial supervision.
- Undertake a comprehensive review of NSW RFS aviation doctrine to incorporate outcomes of above-mentioned research into existing policies and procedures.
- Formalise and establish a ‘Large Air Tanker Co-ordinator' role description to be positioned on the State Air Desk during heightened fire activity.
- Promulgate the revised NSW RFS doctrine detailing the aerial supervision requirements to all operational personnel, pilots/aircrew and other key stakeholders. This is to be reinforced at the Aviation Operators briefing held annually prior to the bush fire season.
- Provide the National Aerial Firefighting Centre (NAFC) and national fire fighting agencies with copies of the updated doctrine.

ATSB comment

While the ATSB acknowledges the commitment to undertake various reviews and research, at time of publication, the New South Wales Rural Fire Service had not yet committed to any safety action that would reduce the risk associated with the identified safety issue to an acceptable level. The RFS outlined to the ATSB during the course of the investigation that they had access to the US policies and procedures relating to the use of large air tankers and had referred to these in developing and managing the large air tanker program. Policies and procedures regarding aerial supervision and the use of initial attack would ensure taskings can be conducted within their defined, accepted risk levels considering the elevated risks associated with such taskings. As such, the ATSB issues the following safety recommendation to the New South Wales Rural Fire Service to take further action to address this safety issue.

Safety recommendation to the New South Wales Rural Fire Service

The ATSB makes a formal safety recommendation, either during or at the end of an investigation, based on the level of risk associated with a safety issue and the extent of corrective action already undertaken. Rather than being prescriptive about the form of corrective action to be taken, the recommendation focuses on the safety issue of concern. It is a matter for the responsible organisation to assess the costs and benefits of any particular method of addressing a safety issue.

Recommendation number:	AO-2020-007-SR-10
Responsible organisation:	NSW Rural Fire Service
Recommendation status:	Released

The Australian Transport Safety Bureau recommends that the New South Wales Rural Fire Service take further action to address the absence of policies and procedures regarding minimum aerial supervision requirements and the use of initial attack to assist frontline staff with making acceptable risk-based tasking decisions.

Initial attack certification

Safety issue description

The New South Wales Rural Fire Service procedures allowed operators to determine when pilots were initial attack capable. However, they intended for the pilot in command to be certified by the United States Department of Agriculture Forest Service certification process.

Issue number:	AO-2020-007-SI-07
Issue owner:	New South Wales Rural Fire Service
Transport function:	Aviation: General aviation
Current issue status:	Open - Safety action pending
Issue status justification:	To be advised

Response by New South Wales Rural Fire Service

As a result of this investigation, on 1 June 2022, the New South Wales Rural Fire Service advised the ATSB that they were taking the following actions with a planned final completion date of 30 September 2022:

- Undertake an immediate audit, in conjunction with operators, of pilots qualified as initial attack capable and ensure appropriate records are accessible by NSW RFS (including ARENA system).
- Undertake detailed research to identify best practice (nationally and internationally) relating to initial attack training and certification process.
- Undertake a comprehensive review of NSW RFS and interagency aviation doctrine to incorporate outcomes of above mentioned research into existing policies and procedures.

ATSB comment

While the ATSB notes the intention to conduct an audit, undertake a review and conduct further research, it is uncertain how these proposed safety actions will remove the ambiguity between the procedure and intention for pilots to have the United States Department of Agriculture Forest Service (USFS) initial attack certification, first notified to the NSW RFS in July 2020. As such, there is no assurance that crews operating as initial attack will be consistently certified to the same requirements as that achieved through the USFS certification process. Therefore, the ATSB issues the following safety recommendation to the New South Wales Rural Fire Service to take further action to address this safety issue.

Safety recommendation to the New South Wales Rural Fire Service

The ATSB makes a formal safety recommendation, either during or at the end of an investigation, based on the level of risk associated with a safety issue and the extent of corrective action already undertaken. Rather than being prescriptive about the form of corrective action to be taken, the recommendation focuses on the safety issue of concern. It is a matter for the responsible organisation to assess the costs and benefits of any particular method of addressing a safety issue.

Recommendation number:	AO-2020-007-SR-08
Responsible organisation:	NSW Rural Fire Service
Recommendation status:	Released

The Australian Transport Safety Bureau recommends that the New South Wales Rural Fire Service address the ambiguity with the interpretation of 'initial attack' in the *NSW and ACT Aviation Standard Operating Procedures* with the intent of this requirement.

Coulson Aviation's risk management processes

Safety issue description

Coulson Aviation's safety risk management processes did not adequately manage the risks associated with large air tanker operations. There were no operational risk assessments conducted or a risk register maintained. Further, as safety incident reports submitted were mainly related to maintenance issues, operational risks were less likely to be considered or monitored. Overall, this limited their ability to identify and implement mitigations to manage the risks associated with their aerial firefighting operations.

Issue number:	AO-2020-007-SI-05
Issue owner:	Coulson Aviation
Transport function:	Aviation: General aviation
Current issue status:	Open - Safety action pending
Issue status justification:	To be advised

Proactive safety action taken by Coulson Aviation

Action number:	AO-2020-007-PSA-60
Action organisation:	Coulson Aviation
Action status:	Monitor

As a result of this investigation, on 3 August 2022, Coulson Aviation advised the ATSB that:

> Numerous enhancements have been made to the Coulson Group SMS, and these continue to be developed and improved. The three-tier risk management approach of organisational risk, operational risk and tactical/mission risk will be utilised during the upcoming fire season in Australia.

ATSB comment

The ATSB welcomes Coulson Aviation's safety action, and recognises that it takes time to develop and implement these aspects within a safety management system. The ATSB will monitor the progress of these developments.

Windshear procedures and training

Safety issue description

Coulson Aviation did not include a windshear recovery procedure or scenario in their C-130 Airplane Flight Manual and annual simulator training respectively, to ensure that crews consistently and correctly responded to a windshear encounter with minimal delay.

Issue number:	AO-2020-007-SI-06
Issue owner:	Coulson Aviation
Transport function:	Aviation: General aviation
Current issue status:	Closed – Adequately addressed

Issue status justification:	The ATSB notes the incorporation of the windshear recovery procedure, including consideration of load jettison, into the C-130H Airplane Flight Manual, and the commitment to undertake recurrent simulator-based windshear training. The ATSB is satisfied that the dedicated windshear procedure and training combined will ensure crews have a shared mental model of the symptoms and recovery actions for a windshear encounter.

Proactive safety action taken by Coulson Aviation

Action number:	AO-2020-007-PSA-58
Action organisation:	Coulson Aviation
Action status:	Closed

On 10 July 2022, Coulson Aviation advised the ATSB that they had 'published revised [airplane flight] manuals for both variants of the C-130H it operates based on a US Air Force Flight Manual…to bring the two manuals as much into alignment with each other as possible'. As such, the C-130H manuals now include the Lockheed Martin recommended windshear recovery procedure, while also incorporating consideration of jettisoning the load (emergency dump).

On 3 August 2022, Coulson Aviation further advised that:

> Simulator-based windshear recurrent training will take place over the coming 12 months. The C-130 crews attend the simulator as a group in the weeks leading up to the in-aircraft Spring Training in California. The specifics of the exercise conducted will be informed by the performance modelling of the simulator, however it will include identification of windshear and recovery in accordance with flight crew operating manual procedures. Boeing 737 flight crew will complete a windshear training package as part of their annual simulator training which occurs at various times during the year.

Windshear warning systems

Safety issue description

Coulson Aviation fleet of C-130 aircraft were not fitted with a windshear detection system, which increased the risk of a windshear encounter and/or delayed response to a windshear encounter during low level operations.

Issue number:	AO-2020-007-SI-04
Issue owner:	Coulson Aviation
Transport function:	Aviation: General aviation
Current issue status:	Open - Safety action pending
Issue status justification:	To be advised

Response by Coulson Aviation

On 10 July 2022, in response to the draft report and identified safety issue, Coulson Aviation advised the ATSB that:

> The reactive based system relies on aircraft performance instruments, combined with altitude, angle of attack, and accelerometer inputs. The reactive based systems alert the pilots of a windshear event once the airplane has entered the windshear event. The report quotes the FAA saying, "even reactive systems provide a valuable service in the detection, timely annunciation and confirmation of a potentially hazardous windshear condition generally in advance of human pilot recognition time." This type of system is of marginal value as it is of most utility when alerting a crew who are unaware of actual or impending windshear conditions. LAT crews knowingly operate within areas in which the precursor indications of windshear are expected and trained for.

> We would make the point that given Coulson pilots' experience in the firefighting environment that is often flown in unstable air, the aircrew are highly experienced in recognizing windshear type events and that their reaction time would be as timely, if not quicker, than a reactive based system.
>
> The commentary on the use of a Predictive Windshear Detection equipment is flawed in a fundamental way. The Draft Report discusses the advent and development of this equipment that can give a flight crew a 5-10 second advance warning of a windshear event. These systems "used doppler weather radar and the moisture in the atmosphere to collect wind velocity data. Therefore, drier air would reduce the reflectivity and windshear warning time." Coulson is not aware of any system that could predict windshear in such a dry environment.
>
> Aerial firefighting takes place in a very dry environment that is conducive to active fires. With minimal or no moisture present in the atmosphere it can be concluded that the forward-looking Predictive Windshear Detection equipment would provide little or no advance warning of a windshear event.
>
> Unless evidence that Predictive Windshear Detection equipment would provide detection in an extremely dry atmosphere (found around fires) can be provided, any discussion regarding Predictive Windshear Detection equipment for these types of operations, is irrelevant. As per various points made above, aerial firefighting operations knowingly fly into areas where windshear is prevalent. The procedures, practices and training for the crews reduce the resultant risk to as low as reasonably practicable.

ATSB comment

The ATSB acknowledges that forward-looking (predictive) windshear warning systems may have reduced effectiveness in drier environments. However, on the day of the accident, the windshear system on the Boeing 737 (whether predictive or reactive) activated when operating in similar environmental conditions to that very likely experienced by N134CG. Further, the fitment of a windshear system in the Lockheed Martin 'FireHerc', and acknowledgement by some of the pilots interviewed that they have had a positive effect on managing a windshear encounter, would suggest that these systems have a degree of effectiveness.

In the absence of an airborne detection system, a successful recovery from a windshear encounter is reliant on the pilot's timely recognition and response, which research has shown could take 5 to 15 seconds. When conducting firefighting operations in the low-level environment, there is often limited time and height available for such recognition and response. Therefore, the ATSB believes that the fitment of windshear detection systems to the C-130 aircraft would be an important safety enhancement for aerial firefighting operations. As such, the ATSB issues the following safety recommendation to Coulson Aviation to take further action to address this safety issue.

Safety recommendation to Coulson Aviation

> The ATSB makes a formal safety recommendation, either during or at the end of an investigation, based on the level of risk associated with a safety issue and the extent of corrective action already undertaken. Rather than being prescriptive about the form of corrective action to be taken, the recommendation focuses on the safety issue of concern. It is a matter for the responsible organisation to assess the costs and benefits of any particular method of addressing a safety issue.

Recommendation number:	AO-2020-007-SR-11
Responsible organisation:	Coulson Aviation
Recommendation status:	Released

The Australian Transport Safety Bureau recommends that Coulson Aviation further consider the fitment of a windshear detection system to their C-130 aircraft to minimise the time taken for crews to recognise and respond to an encounter particularly when operating at low-level and low speed.

Pre-flight risk assessment tool

Safety issue description

Coulson Aviation did not provide a pre-flight risk assessment for their fire-fighting large air tanker crews. This would provide predefined criteria to ensure consistent and objective decision-making with accepting or rejecting tasks, including factors relating to crew, environment, aircraft and external pressures.

Issue number:	AO-2020-007-SI-03
Issue owner:	Coulson Aviation
Transport function:	Aviation: General aviation
Current issue status:	Open - Safety action pending
Issue status justification:	To be advised

Proactive safety action taken by Coulson Aviation

Action number:	AO-2020-007-PSA-63
Action organisation:	Coulson Aviation
Action status:	Monitor

In September 2021, Coulson Aviation advised the ATSB that they had introduced a flight risk assessment tool into their fixed-wing aerial firefighting operations to be completed, at a minimum, prior to the first tasking of the day.

ATSB comment

The ATSB acknowledges that Coulson Aviation introduced a pre-flight risk assessment tool into their fixed-wing operations. However, this tool did not consider all foreseeable external factors that could elevate the risk of a flight, such as weather-related task rejections or cancellations by others, which was considered the highest risk factor by the Helicopter Association International. Without this factor, the overall risk profile for a tasking, or essentially the safety of the flight, could be underestimated by crews. Therefore, as it is critical that crews can differentiate between a low-risk and high-risk flight in the already elevated risk environment of aerial firefighting, the ATSB issues the following safety recommendation to Coulson Aviation to take further action to reduce the risk of this safety issue to low as reasonably practicable.

Safety recommendation to Coulson Aviation

The ATSB makes a formal safety recommendation, either during or at the end of an investigation, based on the level of risk associated with a safety issue and the extent of corrective action already undertaken. Rather than being prescriptive about the form of corrective action to be taken, the recommendation focuses on the safety issue of concern. It is a matter for the responsible organisation to assess the costs and benefits of any particular method of addressing a safety issue.

Recommendation number:	AO-2020-007-SR-12
Responsible organisation:	Coulson Aviation
Recommendation status:	Released

The Australian Transport Safety Bureau recommends that Coulson Aviation take further action to incorporate foreseeable external factors into their pre-flight assessment tool to ensure the overall risk profile of a tasking can be consistently assessed by crews.

Safety action not associated with an identified safety issue

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Additional safety action by Coulson Aviation

The ATSB has been advised of the following proactive safety action taken by Coulson Aviation in response to this accident:

- The Retardant Aerial Delivery system (RADS) software was reprogrammed so that the system would not require re-arming between partial load drops where less than 100% volume was selected.
- Updated their pre-flight procedures to incorporate a cockpit voice recorder system check in their abbreviated checklist before each flight.

General details

Occurrence details

Date and time:	23 January 2020 - 1315 EST	
Occurrence category:	Accident	
Primary occurrence type:	Collision with terrain	
Location:	Cooma Airport, New South Wales, 46.77° M 50Km	
	Latitude: 36º 0.012' S	Longitude: 149º 23.058' E

Aircraft details

Manufacturer and model:	Lockheed Corporation EC-130Q	
Registration:	N134CG	
Operator:	Coulson Aviation (Australia) PTY LTD	
Serial number:	382-4904	
Type of operation:	Aerial work-fire control - aerial work	
Activity:	General aviation/recreational - aerial work - firefighting	
Departure:	Richmond Royal Australian Air Force Base, New South Wales	
Destination:	Richmond Royal Australian Air Force Base, New South Wales	
Persons on board:	Crew – 3	Passengers – 0
Injuries:	Crew – 3 (fatal)	
Aircraft damage:	Destroyed	

Glossary

ABM	Airbase manager, responsible for the supervision and coordination of airbase personnel and the layout and operation of an airbase.
ADS-B	Automatic dependent surveillance broadcast
AFM	Airplane Flight Manual. The aircraft manufacturer, Lockheed Martin, produced a C-130 AFM for military operations. When introducing the aircraft to the civilian register, the FAA required the operator to produce an AFM, meeting the FAA requirements. The operator’s AFM was based on the US Navy flight manual, but incorporated procedures and limitations for the intended use of the aircraft.
AGL	Above ground level
AMSL	Above mean sea level
ARO	Aviation radio operator
ATC	Air traffic control
B134	A Lockheed Martin C-130H aircraft, registered N134CG, a large air tanker with the callsign ‘Bomber 134’.
B137	A Boeing 737 aircraft, registered N137CG, large air tanker with the callsign ‘Bomber 137’.
Birddog	Birddog aircraft were used to lead large air tanker aircraft across the fire-ground and provide guidance on the release of the water or fire suppressant (retardant or gel). The birddog crew consisted of a birddog pilot and a large air tanker air attack supervisor (LAT AAS).
CAS	Calibrated airspeed
CASA	Civil Aviation Safety Authority
COM	Company Operations Manual (Coulson Aviation). The COM was developed to contain the procedures, instructions and information required by CASA for the conduct of operations in Australia.
CVR	Cockpit voice recorder
ECG	Electrocardiogram
FAA	Federal Aviation Administration (US)
FCC	A Fire Control Centre forms the administrative and operational base of the rural fire district or zone. The coordination and management of local brigade responses to fire and other incidents was undertaken through the Fire Control Centre.
FRAT	Flight risk assessment tool
GPS	Global positioning system
IAS	Indicated airspeed
ICAO	International Civil Aviation Organization

Incident controller	The incident controller was responsible for all aspects of an emergency response, and managed the response, including the objectives, operations, and application of resources of the FCC.
Incident management team	The coordination and management of local brigade responses to fire and other incidents was undertaken through the incident management team, led by the incident controller.
Incident AAS	Incident air attack supervisor
LAT	Large air tanker. An aircraft with a minimum suppressant/retardant capacity of 3,000 US gallons (11,356 L).
LAT AAS	Large air tanker air attack supervisor (onboard the birddog aircraft)
MAFFS	Modular airborne firefighting system
NAFC	National Aerial Firefighting Centre. Formed by the Australian States and Territories in 2003, NAFC provided a cooperative national arrangement for combating bushfires by facilitating the coordination and procurement of specialised firefighting aircraft.
NSW	New South Wales
OLMS	Operational load monitoring system
PIC	Pilot in command
RAAF	Royal Australian Air Force
RADS	Retardant aerial delivery system XXL
RFS	Rural Fire Service (NSW)
SAD	State air desk. The state level multi agency team located in the State Operations Centre responsible for coordination of aircraft operations.
SMS	Safety management system. A systematic approach to organisational safety encompassing safety policy and objectives, risk management, safety assurance, safety promotion, third party interfaces, internal investigation and SMS implementation.
SOC	State operations controller roles was to maintain overall awareness of the firefighting effort across the state ensuring information and warnings are being distributed and resources are being allocated where needed. The SOC was located within the State Operations Centre.
State Operations Centre	State Operations Centre was located at NSW RFS Headquarters in Lidcombe and allows the RFS and its partners to effectively oversee and coordinate incidents. The staff within the Centre monitor developments, analyse their potential and provide a variety of specialised resources to the incident management teams and firefighters on the ground.
TAS	True airspeed
US	United States
USFS	US Department of Agriculture, Forest Service

Sources and submissions

Sources of information

The sources of information during the investigation included:

- Coulson Aviation
- Coulson Aviation current and former personnel
- other C-130 crews and maintenance staff
- New South Wales Rural Fire Service
- Lockheed Martin
- a number of witnesses
- Royal Australian Air Force
- Defence Flight Safety Bureau
- the Bureau of Meteorology
- ATSB aviation medical specialist
- Rolls Royce
- Hamilton Sundstrand
- National Aerial Firefighting Centre
- CAL FIRE
- Airservices Australia
- United States Federal Aviation Administration
- United States Department of Agriculture, Forest Service
- Canadian Transportation Safety Board
- next-of-kin
- video footage of the accident flight
- recorded data from automatic dependent surveillance broadcast (ADS-B), SkyTrac and historic data for the operational load monitoring system.

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Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the following directly involved parties:

- Coulson Aviation
- New South Wales Rural Fire Service
- Coulson Aviation personnel
- Lockheed Martin
- Royal Australian Air Force Aircraft Research and Development Unit
- the Bureau of Meteorology
- ATSB aviation medical specialist
- National Aerial Firefighting Centre
- Civil Aviation Safety Authority
- United States National Transportation Safety Board
- the birddog pilot.

In addition, the draft report was sent to the NSW State Coroner for information.

Submissions were received from:

- Coulson Aviation
- New South Wales Rural Fire Service
- Royal Australian Air Force Aircraft Research and Development Unit
- the Bureau of Meteorology
- Civil Aviation Safety Authority
- the birddog pilot.

The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. It is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB's purpose is to improve the safety of, and public confidence in, aviation, rail and marine transport through:

- independent investigation of transport accidents and other safety occurrences
- safety data recording, analysis and research
- fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia, as well as participating in overseas investigations involving Australian-registered aircraft and ships. It prioritises investigations that have the potential to deliver the greatest public benefit through improvements to transport safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, international agreements.

Purpose of safety investigations

The objective of a safety investigation is to enhance transport safety. This is done through:

- identifying safety issues and facilitating safety action to address those issues
- providing information about occurrences and their associated 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. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner. The ATSB does not investigate for the purpose of taking administrative, regulatory or criminal action.

Terminology

An explanation of terminology used in ATSB investigation reports is available on the ATSB website. This includes terms such as occurrence, contributing factor, other factor that increased risk, and safety issue.