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A safety analysis of aerial firefighting occurrences in Australia

July 2000 to March 2020

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Addendum

Page	Change	Date

Safety summary

Why the ATSB undertook this research

On 6 April 2020, the Royal Commission into National Natural Disaster Arrangements (RCNDA) issued a notice to give information to the ATSB. Within this notice, was the requirement to 'describe any key operational and safety challenges encountered in coordinating and responding to fires associated with the use of aircraft and aerial fire fighting techniques'. This statistical report forms part of the ATSB's response to the Royal Commission's notice to give information.

In addition, since 2018 the ATSB has commenced six investigations involving aerial firefighting aircraft, this includes the high profile investigation (AO-2020-007) into the collision with terrain involving a Lockheed C-130 near Cooma, New South Wales, on 23 January 2020.

What the ATSB found

Aviation activity relating to aerial firefighting has increased over recent bushfire seasons. However, official exposure data (hours flown and flights for Australian-registered aircraft) before 2014 and beyond 2018 were not available to the ATSB for this report. Estimates of aerial firefighting activity for the most recent bushfire season (2019–20) have been around four times higher than other recent bushfire seasons.

There were more reported occurrences[1] involving aerial firefighting aircraft in Australia in the financial year covering the last bushfire season (between July 2019 and March 2020) than any financial year since July 2000. In addition, there were two fatal accidents since August 2018, whereas the previous 17 years only had three fatal accidents. Further, the number of occurrences per financial year increased steadily since 2016–17. Given the increased activity, these results could be expected and probably do not indicate a significant increase in the risk per flight. (A more extensive analysis would incorporate exposure data for the full 20-year study period if the data was available.)

Over the full 20-year study period, all fatal accidents and around 40 per cent of other occurrences happened in New South Wales.

Around three quarters of aerial firefighting occurrences involved Australian VH-registered aircraft. Foreign-registered aircraft accounted for the bulk of the remaining occurrences. Probably reflective of increased activity, the proportion of occurrences involving foreign-registered aircraft increased significantly over the study period. Between July 2019 and March 2020, foreign-registered aircraft were involved in two thirds of more severe occurrences (serious incidents, accidents and fatal accidents).

The average maximum take-off weight (MTOW) of aerial firefighting aircraft involved in a reported occurrence increased significantly over the study period. Foreign-registered aircraft, which had an average MTOW around 10 times that of VH-registered aircraft, contributed most to this increase.

Between 2014 and 2018 (the period with available exposure data – departures and hours flown), the rate of reported occurrences involving VH-registered aircraft was consistent between aeroplanes and helicopters. VH-registered piston-powered helicopters had around double the rate of more severe occurrences than turboshaft helicopters.

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

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[1] Occurrences are incidents, serious incidents, accidents and fatal accidents that have been reported to the ATSB. This report includes all occurrences involving aerial firefighting aircraft. This is to highlight potential safety risks to aircraft conducting aerial firefighting, and includes events where actions of the aerial firefighting crew did not lead to the occurrence.

more severe occurrences associated with aircraft control. Further, around one quarter of more severe occurrences involved a technical issue, most commonly engine failure or malfunction.

Additional risks to those inherent to low-level flying can be seen in higher occurrence rates compared to other low-level flying activities. Between 2014 and 2018, VH-registered aerial firefighting aircraft had higher rates of communication-related occurrences, flight preparation/navigation operational occurrences, aircraft separation occurrences, operational non-compliance occurrences, airframe-related technical issues, and encounters with remotely piloted aircraft. Aerial firefighting had lower rates for terrain collision and aircraft control related occurrences.

Data sources and analysis limitations

Sources of information

The sources of information used included:

- the ATSB aviation occurrence database – July 2000 to March 2020
- aircraft activity data from the Bureau of Infrastructure, Transport and Regional Economics (BITRE) – 2014 to 2018, VH- registered aircraft only.

Limitations

This report presents both the *number* of occurrences and the *rate* of occurrences per hours flown and number of flights. While the number of occurrences gives an indication of the overall risk, the rate is a more appropriate measure for relative risks.

A more extensive analysis would require exposure data (hours flown or number of flights) over the full study period, including all aircraft conducting aerial firefighting in Australia. This data was not available to the ATSB for this report. Estimates from the National Aerial Firefighting Centre and the Australian Helicopter Industry Association for the 2019–20 season indicate that aerial firefighting activity was around four times that of other recent bushfire seasons. The only exposure data available (provided from BITRE) was for VH-registered aircraft conducting aerial firefighting from 2014 to 2018.

Aerial firefighting comprises of several separate sub-activities (including water-bombing, surveying and air attack). Each of these have different operational requirements resulting in different safety risks. Due to coding limitations, this report only considers all aerial firefighting activities collectively.

The ATSB database covers a broad range of aircraft types and activities. Aeroplane types have not been coded in ways specific to the aerial firefighting sector, which groups single-engine air tankers (SEATs), large air tankers (LATs) and very large air tankers (VLATs). Exposure data for these aerial firefighting aeroplane type categories was also not available to the ATSB for this report.

A further limitation is that the ATSB occurrence data relies on reported occurrences. Although these reports are mandatory under the Transport Safety Investigation Regulations (2003), the true number of occurrences would be expected to be greater than the set that is reported to the ATSB.

It should be noted that many of the statistics presented in this report rely on a low number of reported occurrences. Where possible the ATSB has used error bars or presented the range of values (95% confidence intervals) to display the level of uncertainty and had incorporated these uncertainties when making comparisons.

During the study period, there was one reported occurrence involving a remotely piloted aircraft conducting aerial firefighting. However, exposure data for remotely piloted aircraft was not available for this report.

Aerial firefighting occurrences in Australia

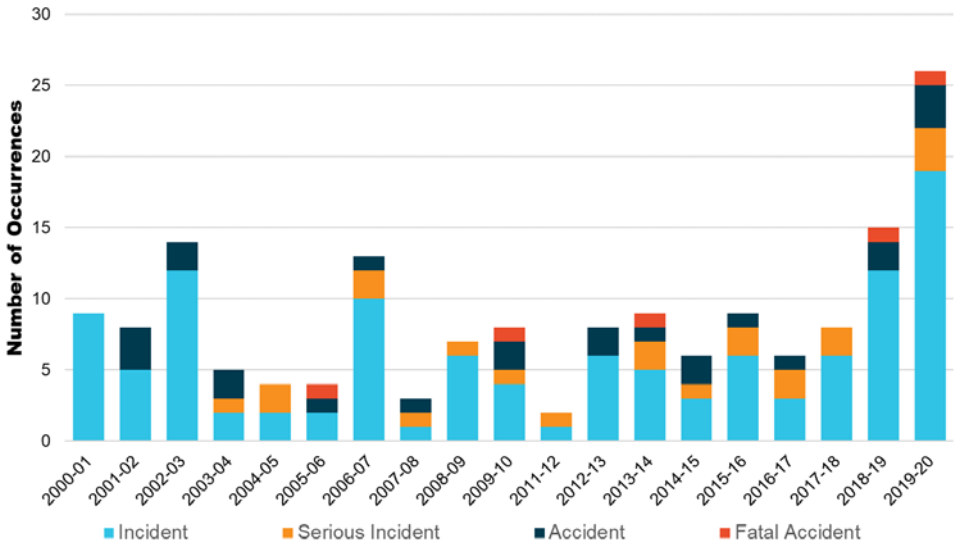
Why review aerial firefighting occurrences in Australia

On 6 April 2020, the Royal Commission into National Natural Disaster Arrangements (RCNDA) issued a notice to give information to the ATSB. Within this notice, was the requirement to 'describe any key operational and safety challenges encountered in coordinating and responding to fires associated with the use of aircraft and aerial fire fighting techniques'.

In addition, since 2018 the ATSB has commenced six investigations (two completed and four active) involving aerial firefighting aircraft. This included the high profile investigation (AO-2020-007) into the collision with terrain involving a Lockheed C-130 near Cooma NSW on 23 January 2020. This number is about one third of all investigations involving aircraft conducting aerial work commenced by the ATSB since 2018.

As a further basis for conducting this research, there were more occurrences involving aerial firefighting aircraft in Australia between July 2019 and March 2020 than any financial year in the study period (Figure 1). This was more than three times the period's average. In addition, there were two fatal accidents between August 2018 and March 2020, whereas the previous 17 years only had three fatal accidents. Further, the number of occurrences per financial year has increased steadily since 2016–17. Given the amount of recent bushfire activity in Australia (the 2019–20 season is estimated have around four times the aerial firefighting activity than other recent bushfire seasons), these results could be expected and probably do not indicate a significant increase in the risk per flight. However, it does indicate that the reported occurrences associated with aerial firefighting are probably[2] increasing. A more extensive analysis would require exposure data[3] (hours flown or number of flights) over the full study period.

Figure 1: Number of reported aerial firefighting occurrences per financial year[4]



Data sources: ATSB aviation occurrence database

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2 ATSB uses verbal probability expressions (for example 'very likely') as a standardised method to communicate probability information. More information regarding the ATSB's use of probability expressions can be found in the ATSB research report, *Analysis, Causality and Proof in Safety Investigations* (AR-2007-053), and Appendix B.

3 The ATSB had limited exposure data available as of March 2020.

4 Prior to 2003, the requirement for reporting occurrences in Australia were relatively general in nature. The reporting requirements changed with the introduction of the Transport Safety Investigation Act in 2003.

The Bureau of Infrastructure, Transport and Regional Economics (BITRE) publishes the Australian Aircraft Activity report annually which contains results of its survey of all Australian VH-registered commercial and general aviation aircraft. Since 2014, this report has contained exposure data for all aerial work activities, including firefighting. Since it only includes VH-registered aircraft, it is only a sample of the entire aerial firefighting activity, which also includes foreign-registered aircraft. During the study period, over 75 per cent of reported occurrences involved VH-registered aircraft. Therefore, the BITRE data probably includes a significant proportion of firefighting activity flown within Australia.

Table 1 displays occurrence rates (per 100,000 hours flown or 100,000 flights) for VH-registered aerial work activities between 2014 and 2018 (years with available BITRE data). Generally, the rates for incidents, serious incidents and accidents are relatively low for aerial firefighting compared to other aerial work activities.

Aerial firefighting had the second highest average fatal accident rate calculated using hours flown (second to agricultural spreading/spraying) and flights (second to agricultural mustering). However, during this period, there was only one fatal accident involving a VH-registered aerial firefighting aircraft, therefore there is a high level of statistical uncertainty associated with the aerial firefighting fatal accident rates.

Table 1: Occurrence rates for VH-registered aircraft conducting aerial work (2014–2018)[5]

Activity	Occurrence rate (per 100,000 hours flown)				Occurrence rate (per 100,000 flights)			
	Incident	Serious Incident	Accident	Fatal Accident	Incident	Serious Incident	Accident	Fatal Accident
Advertising	74 - 342	0.7 - 96.6	0	0	142 - 659	1 - 187	0	0
Agricultural mustering	0.1 - 0.9	0 - 1	3 - 5.9	0.1 - 1.1	0.1 - 1.3	0.3 - 1.8	4 - 7.9	0.2 - 1.5
Agricultural spreading / spraying	4.8 - 9.9	17.6 - 26.5	11 - 19	0.4 - 2.4	1.8 - 3.8	6.7 - 10.1	4.3 - 7.1	0.1 - 0.9
Construction	0.2 - 27.9	1.8 - 42.2	2 - 43	0	0.1 - 17.6	1.2 - 26.6	1.2 - 26.6	0
Firefighting	8 - 21	1.6 - 8.5	1.6 - 8.5	0 - 2.7	7 - 18	1.4 - 7.4	1.4 - 7.4	0 - 2.3
Observation and patrol	13 - 29	0 - 3.1	0 - 3.1	0	30 - 67	0 - 7.2	0 - 7.2	0
Policing	30 - 61	0 - 5.1	2.3 - 14.2	0	27 - 55	0 - 4.6	2 - 12.9	0
Search and rescue	85 - 144	2.2 - 18	0.5 - 11.4	0	60 - 102	1.6 - 12.7	0.3 - 8	0
Survey / Photographic	16 - 27	0.9 - 4.4	0.4 - 2.9	0 - 1.2	22 - 36	1.3 - 5.9	0.5 - 3.9	0 - 1.7

Data sources: Bureau of Infrastructure, Transport and Regional Economics (BITRE) and ATSB aviation occurrence database. Bars display the average (expected value) of the rates, value ranges (95% confidence interval) calculated using gamma-Poisson (hours flown) and beta-binomial distributions (flights)

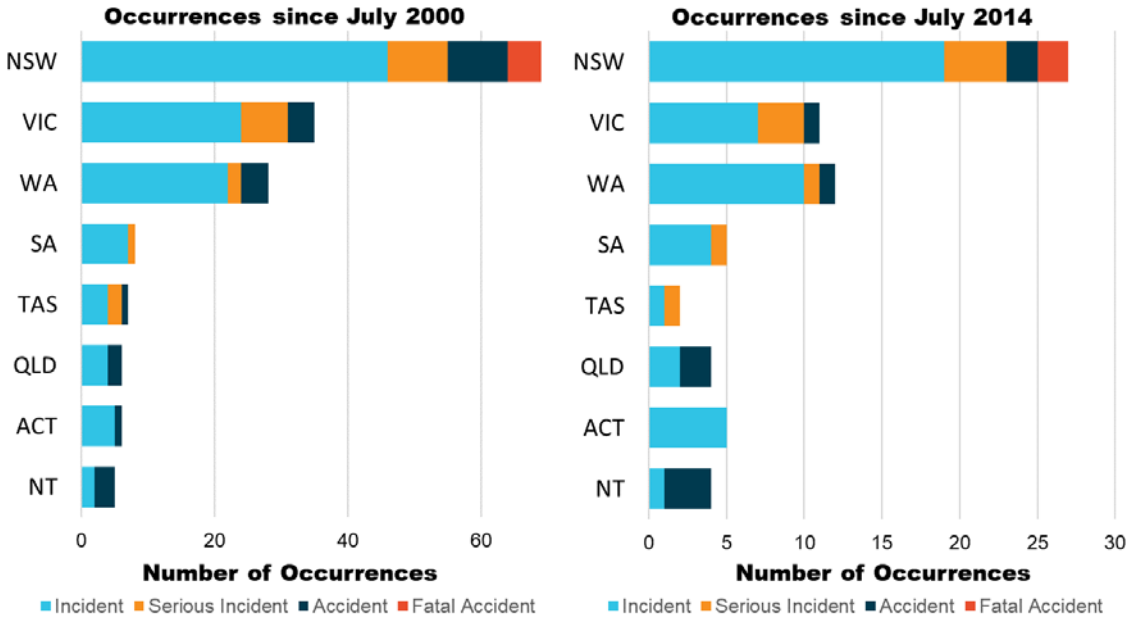
Where are they happening

Since July 2000, all fatal accidents and around 40 per cent of accidents, serious incidents and incidents occurred in New South Wales (Figure 2). The majority of the remaining occurrences were in Victoria and Western Australia. Additionally, almost half of the occurrences (incidents, serious incidents, accident and fatal accidents) since July 2000 occurred in the last five financial years (2014–15 onwards).

These statistics are probably correlated with the amount of aerial firefighting activity in these states and may not indicate an increased risk to aircrews. Exposure data for aerial firefighting activity within each state was not available to the ATSB for this report.

[5] Within this report, accidents are split into 'accidents' and 'fatal accidents'. These are classified by the highest injury sustained resulting from the occurrence. It is possible that fatal accident also resulted in additional serious or minor injuries. An accident should be read as 'non-fatal accident'.

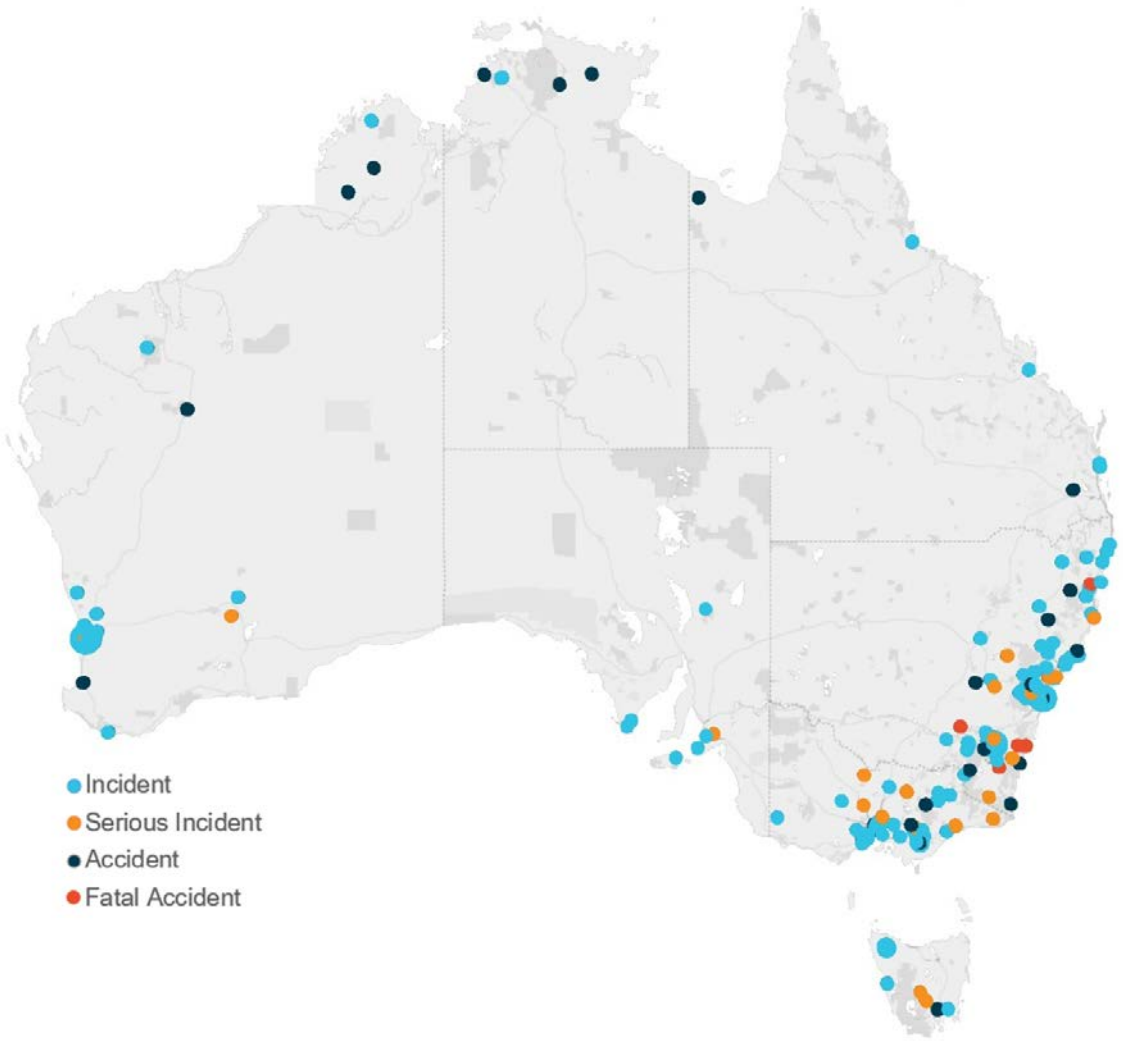
Figure 2: Number reported aerial firefighting occurrences by State



Data source: ATSB aviation occurrence database

Figure 3 displays the location of reported occurrences involving aerial firefighting aircraft around Australia (July 2000 to March 2020). Indicative of where most bushfire activity is expected to occur, this shows that the majority of aerial firefighting occurrences happened along the eastern coast, stretching from southern Queensland to central Victoria, with additional clusters in Tasmania, and around Perth and Adelaide.

Figure 3: Locations of reported aerial firefighting occurrences



Data source: ATSB aviation occurrence database. Map source: Bing

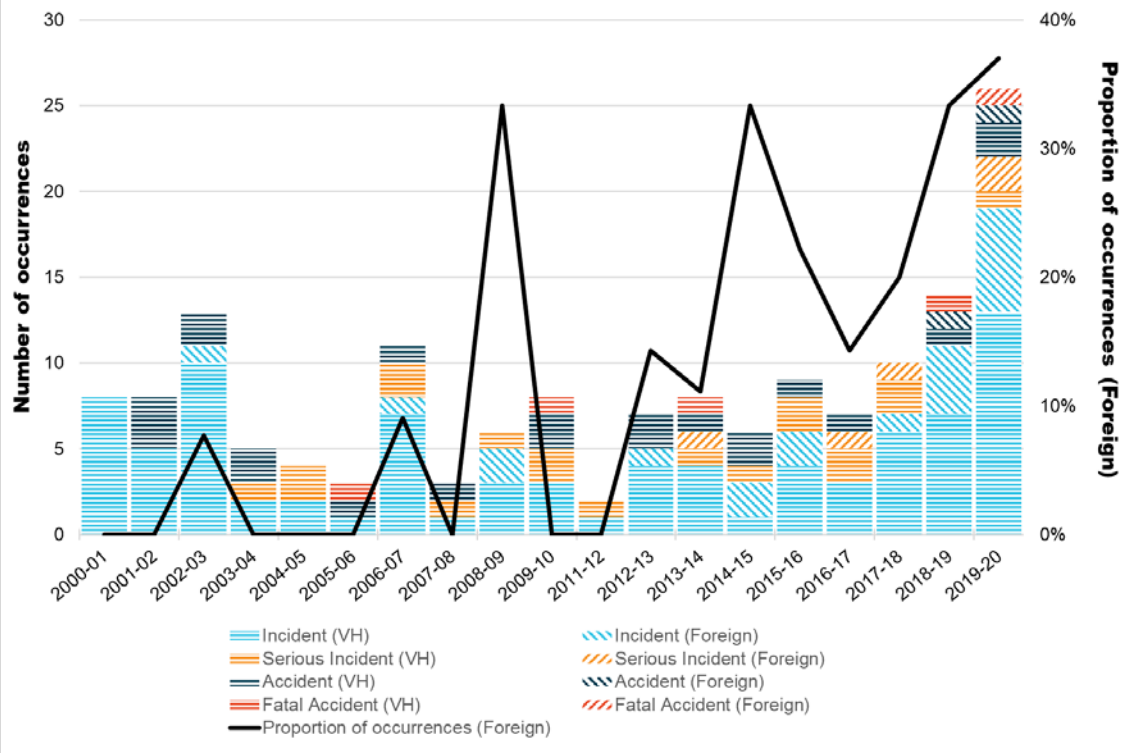
Registration type

Over the study period, around three quarters of aerial firefighting occurrences involved an Australian VH-registered aircraft. Foreign-registered aircraft made up the bulk of the remaining occurrences (16%); followed by aircraft where the registration details were unknown (7.5%) and a significantly smaller proportion (0.6%) involved remotely piloted aircraft systems (RPAS).

Figure 4 shows that the proportion of occurrences involving foreign-registered aircraft increased significantly ($p<0.01$)[6] from July 2000. In the financial year 2019–20, foreign-registered aircraft were involved in two thirds of more severe occurrences (serious incidents, accidents and fatal accidents). This is probably correlated with an increased use of foreign-registered aircraft conducting aerial firefighting within Australia.

[6] Within this report, the ATSB uses the non-parametric Mann-Kendall trend test to identify significant increases or decreases in the yearly number of occurrences or rates.

Figure 4: Proportion of aerial firefighting occurrences involving Australian VH-registered and foreign-registered aircraft



Data source: ATSB aviation occurrence database

Aircraft age

As of March 2020, specific details for every aircraft conducting aerial firefighting within Australia were unknown. Therefore, as a proxy, the average age[7] was calculated from aircraft that were involved in a reported occurrence with a known year of manufacture (around 73% of occurrence aircraft).

At the time of the occurrence, the average age of an aircraft conducting aerial firefighting involved in a reported occurrence was 23 ± 1 years. The average age of an Australian VH-registered aerial firefighting aircraft was 23 ± 1 (131 aircraft, 90% with known aircraft age) years and the average age of a foreign-registered aircraft was 35 ± 3 years (28 aircraft, 32% with known aircraft age).

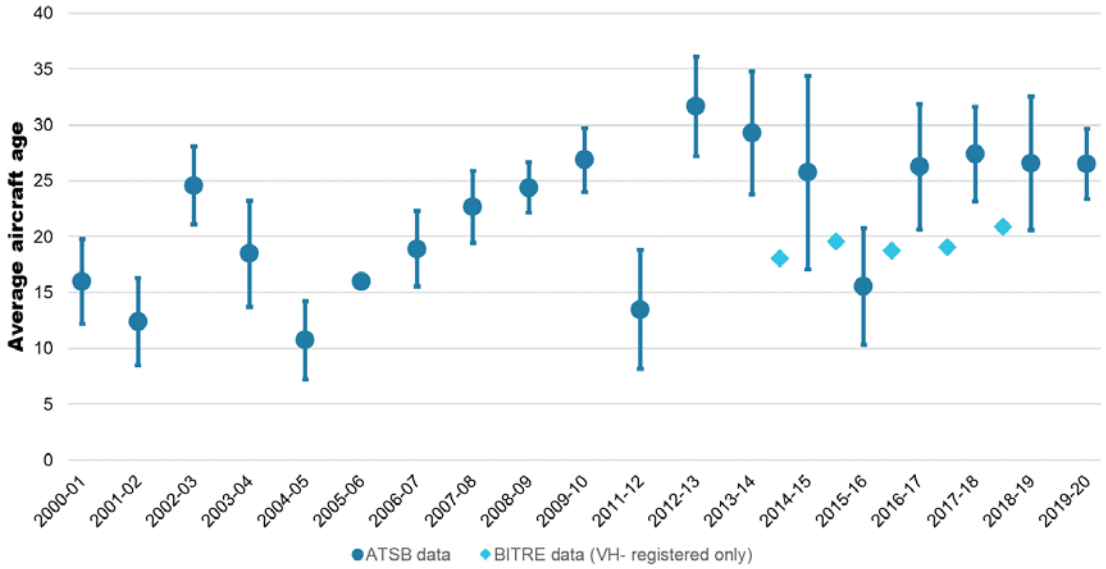
Considering aircraft type, the average age of an aeroplane conducting aerial firefighting involved in a reported occurrence was 22 ± 2 years (72 aircraft, 82% with a known aircraft age). For helicopters, the average age was 25 ± 2 years (98 aircraft, 70% with known aircraft age).

Figure 5 appears to indicate that the average age of an aerial firefighting aircraft involved in a reported occurrence is greater than the average for *all* VH-registered aerial firefighting aircraft. However, the high level of statistical uncertainty (p=0.35) associated with this comparison makes this level of inference about the data imprecise.

Further, the occurrence data indicates that it is highly likely (p=0.01) the average age of an aircraft conducting aerial firefighting involved in a reported occurrence increased over the study period. However, the BITRE data does not indicate a significant increase (p=0.22) in the average age of VH-registered firefighting aircraft between 2014 and 2018.

[7] The data set used for this calculation contained the year of manufacture of the aircraft not the specific date the aircraft was completed. The age was calculated by subtracting this value from the year the occurrence happened. As a result, aircraft that were manufactured later in the year will have an age up to one year greater.

Figure 5: Average age of aerial firefighting aircraft involved in a reported occurrence compared (Jul 2000–Mar 2020) with VH-registered aerial firefighting aircraft (2014–2018)



Data sources: Bureau of Infrastructure, Transport and Regional Economics (BITRE) and ATSB aviation occurrence database. Error bars display the standard error

Aircraft size

Another potential indicator of a change in the safety risk associated with aerial firefighting is the average aircraft size (presented by the aircraft's maximum take-off weight – MTOW). As discussed above relating to the average aircraft age, at the time of writing there was limited data available to the ATSB concerning the entire fleet of aerial firefighting aircraft operating in Australia. Instead, the MTOW of aircraft involved in a reported occurrence was used.

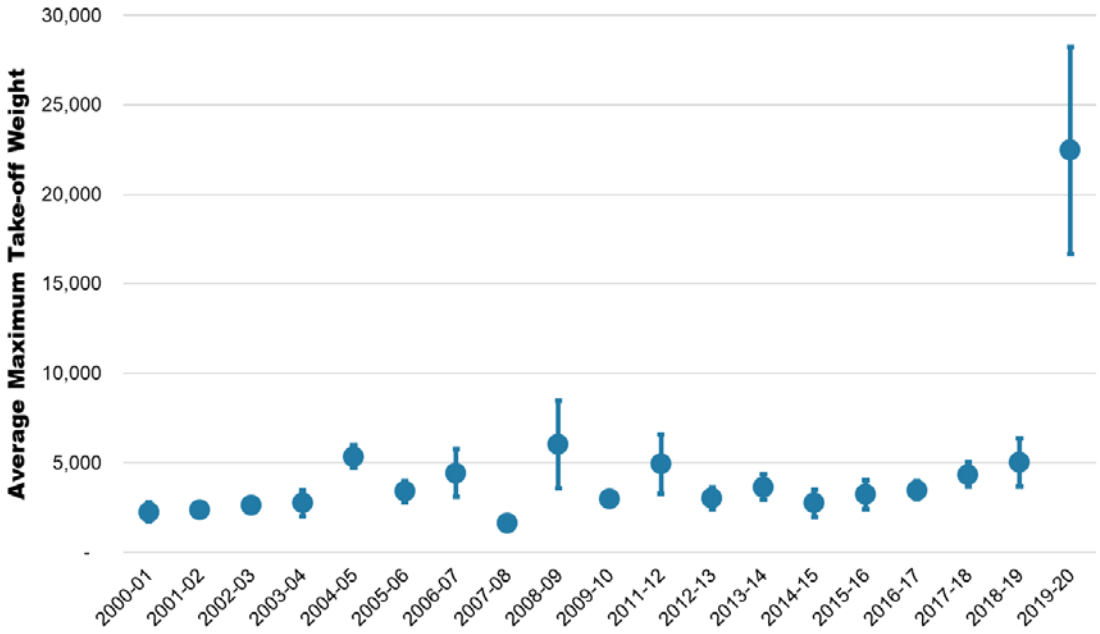
Over the period, the average MTOW of an aerial firefighting aircraft involved in a reported occurrence, where the MTOW was known, was 6,600 ± 1,100 kg. The average for VH-registered aircraft was 3,400 ± 200 kg (131 aircraft, all with known MTOWs) and the average for a foreign-registered aircraft was 32,000 ± 7,000 kg (28 aircraft, 61% with known MTOWs). This indicates that average MTOW of a foreign-registered aircraft conducting aerial firefighting involved in an occurrence is probably around 10 times greater than VH-registered aircraft.

Considering aircraft type, the average MTOW of a helicopter involved in a reported occurrence was 4,000 ± 400 kg (98 aircraft, 86% with known MTOWs) whereas the average aeroplane MTOW was 10,000 ± 2,400 kg (72 aircraft, 92 % with known MTOWs).

Figure 6 indicates that it is highly likely (p=0.01) that the average MTOW of a firefighting aircraft involved in an occurrence increased over the study period. Excluding 2019–20 as an outlier,[8] it is still highly probable (p=0.049) that the average MTOW increased.

[8] Three of the largest aircraft by MTOW (Boeing 737, Lockheed C-130 and BAE Avro RJ85), involved in a reported occurrence (one fatal accident and five incidents), had their only reported occurrences in 2019–20.

Figure 6: Average maximum take-off weight of aerial firefight aircraft involved in a reported occurrence



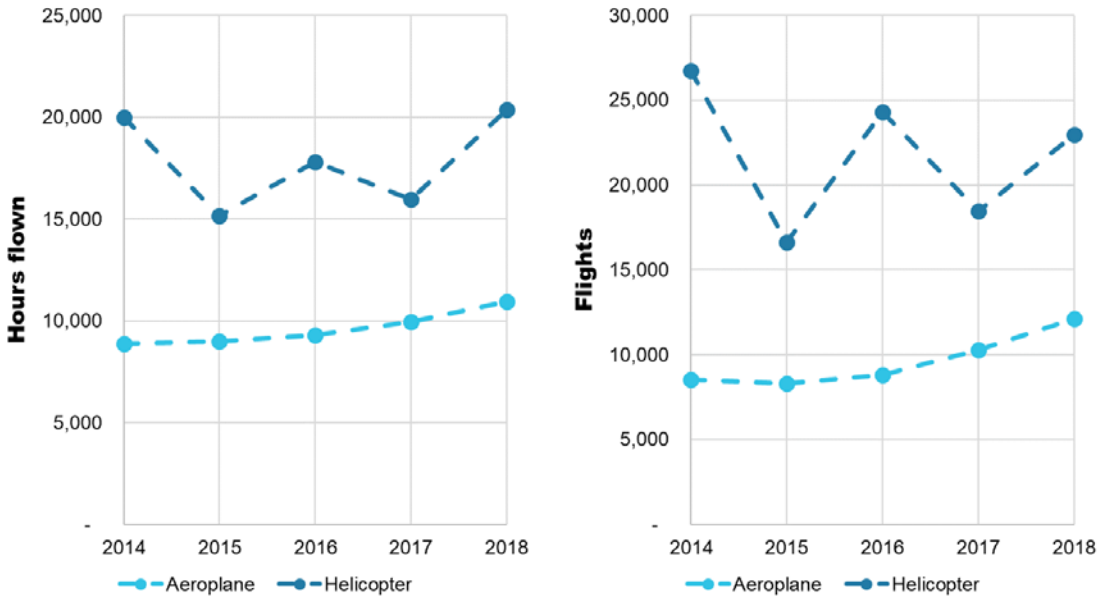
Data source: ATSB aviation occurrence database. Error bars display the standard error

Aircraft type

BITRE publishes exposure data (hours flown and flights) for commercial and general aviation activities involving Australian-registered aircraft within its annual Australian Aircraft Activity report. As of March 2020, exposure data was available for (VH-registered) aeroplanes and helicopters conducting aerial firefighting (Figure 7).

From this data, between 2014 and 2018, around two thirds of firefighting activity was conducted using helicopters. However, while helicopter activity remained relatively constant, it is very likely that the hours flown (p=0.03) and number of flights (p=0.09) conducted by firefighting aeroplanes increased between 2014 and 2018.

Figure 7: Hours flown and number of flights for VH-registered aerial firefighting aeroplanes and helicopters (2014–2018)

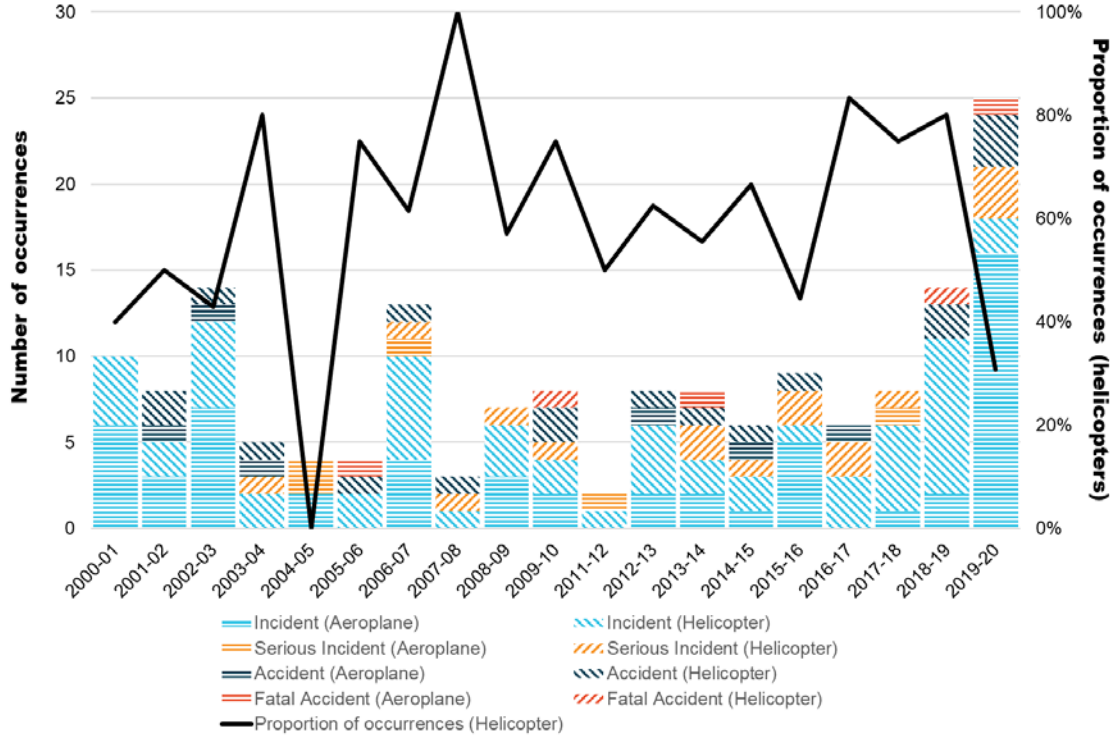


Data source: Bureau of Infrastructure, Transport and Regional Economics (BITRE)

Figure 8 displays the proportion and number of aerial firefighting occurrences involving aeroplanes and helicopters per financial year. It is likely (p=0.06) that the number of occurrences involving firefighting helicopters increased over the study period, in contrast there was no significant trend detected from the number of occurrences involving aeroplanes.

Over the 20-year study period, helicopters and aeroplanes were each involved in 49 per cent of incidents. The remaining consisted of occurrences where the aircraft type was unknown (1.2%) and RPAS (0.6%). Concerning more severe occurrences (serious incident, accidents and fatal accidents), around 72 per cent involved helicopters with aeroplanes making up the remaining 28 per cent. However, this largely reflects the higher activity levels of helicopters and the rates of reported occurrences per 100,000 hours flown and flights (for 2014–18) were consistent between VH-registered aeroplanes and helicopters (Figure 9).[9]

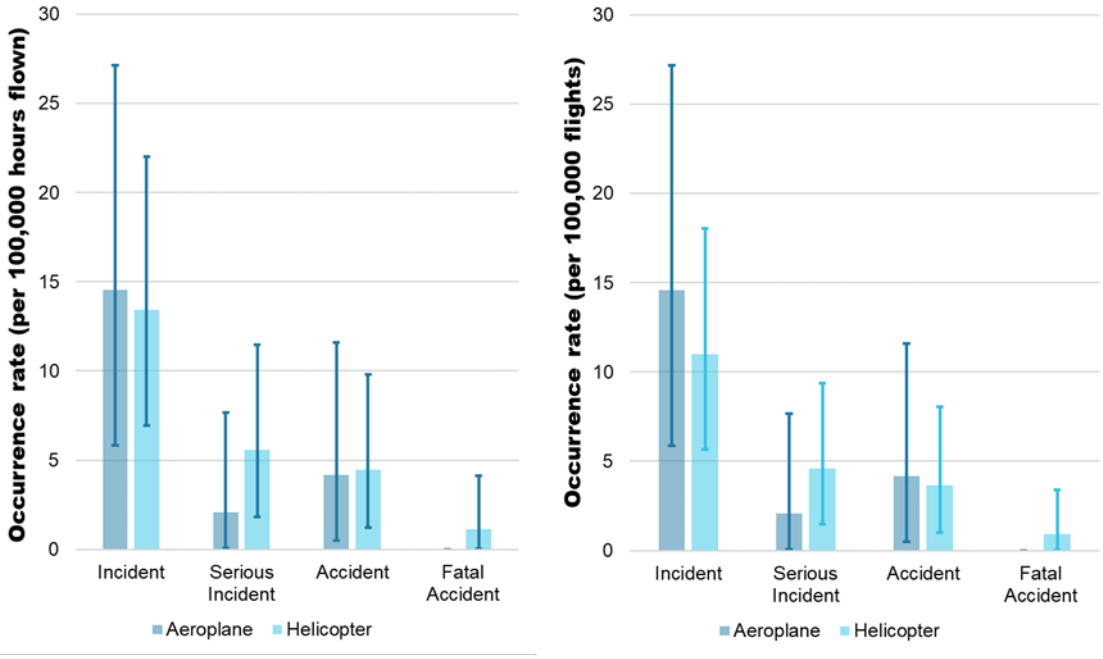
Figure 8: Proportion of aerial fighting occurrences involving aeroplanes and helicopters



Data source: ATSB aviation occurrence database

[9] Calculated using Bayesian models for binomial proportion and Poisson rate estimation

Figure 9: Rate of reported occurrence for VH-registered aeroplanes and helicopters conducting aerial firefighting (2014–2018)



Data sources: Bureau of Infrastructure, Transport and Regional Economics (BITRE) and ATSB aviation occurrence database. Bars display the average (expected value) of the rates, error bars (95% confidence interval) calculated using gamma-Poisson (hours flown) and beta-binomial distributions (flights)

Aircraft model

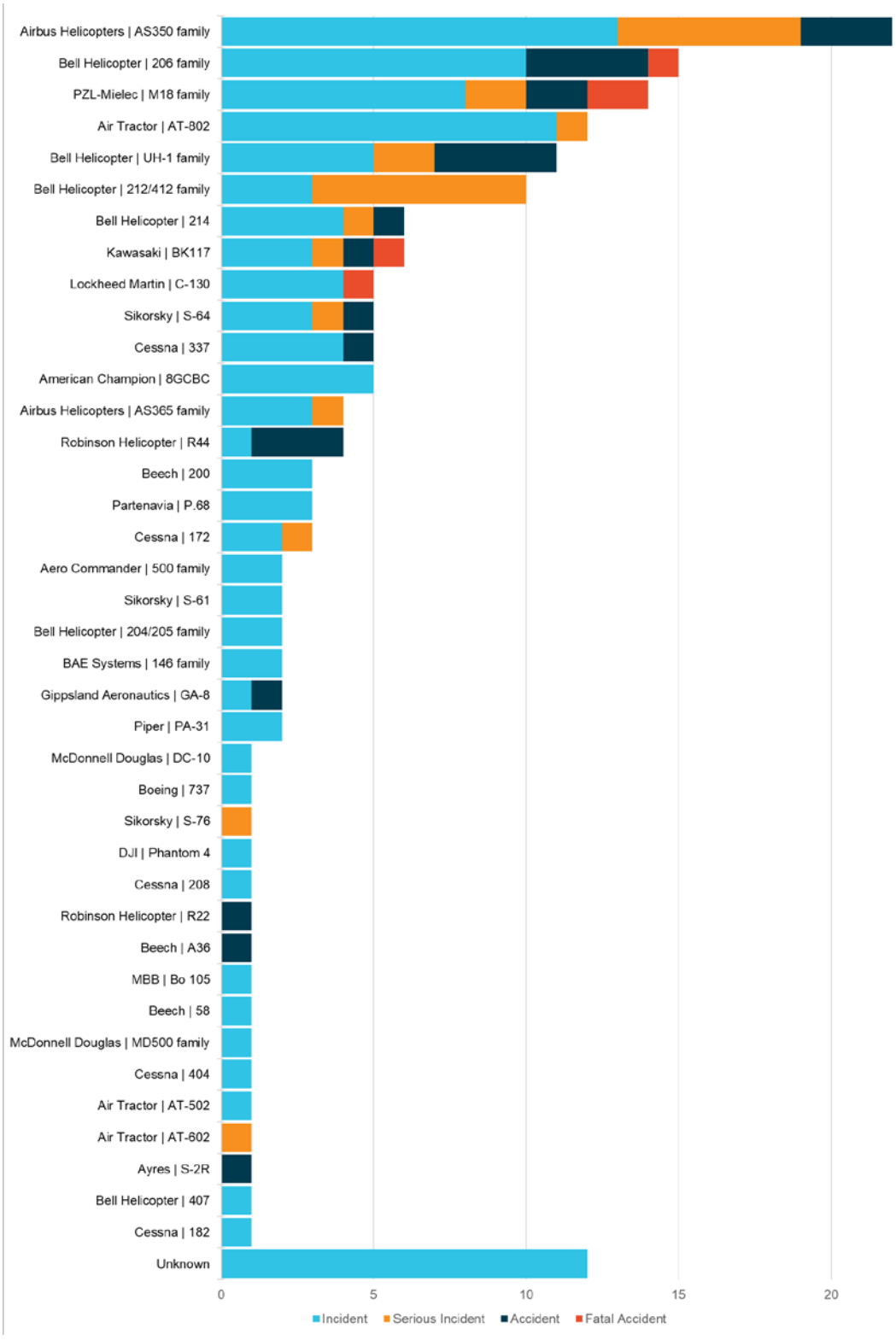
In Figure 10, for brevity and ease of comparison, aircraft models that were variants within the same family were grouped. Bell 212/412, UH-1 and 204/205 aircraft were separated due to their different operational characteristics. Appendix C contains a list of the groupings of each specific aircraft model.

Figure 10 should not be used to compare the relative safety risk between aircraft models. A more extensive analysis would incorporate exposure data (hours flown or number of flights) for each aircraft model to utilise occurrence rates for the comparison.

Over the study period, the Airbus AS350 family of helicopters were involved in more reported occurrences (13%) than any other aircraft model (Figure 10). This was followed by the Bell 206 family helicopters (9%) and the PZL-Mielec M18 Dromader family of aeroplanes (8.5%).

Airbus AS350 family helicopters were involved in 18 per cent of more severe occurrences (serious incidents, accidents and fatal accidents); this was followed by Bell 212/412 family helicopters (14%) then the M18 family aeroplanes and Bell UH-1 family helicopters, both accounting for 12 per cent of more severe occurrences.

Figure 10: Number of reported aerial firefighting occurrences per aircraft model



Data source: ATSB aviation occurrence database

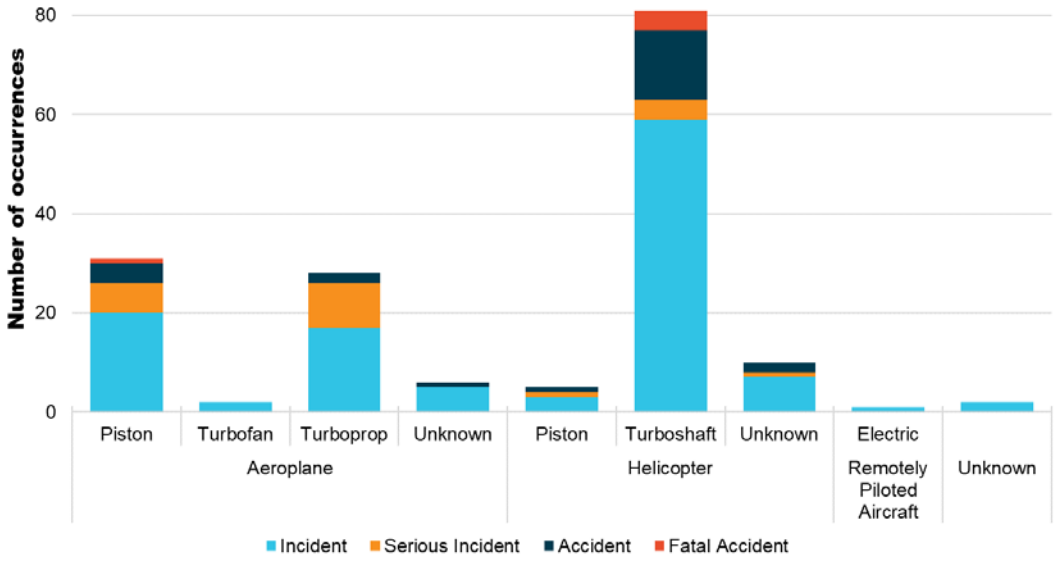
Engine type

Over the study period, almost half of more severe occurrences involved a helicopter with a turboshaft engine (Figure 11). However, when incorporating exposure data (hours flown and flights) for VH-registered aircraft between 2014 and 2018 (Figure 12), the occurences rates are

consistent with the other aircraft/engine types. Helicopters with piston engines had almost double the rate of more severe occurrences than turboshaft helicopters.

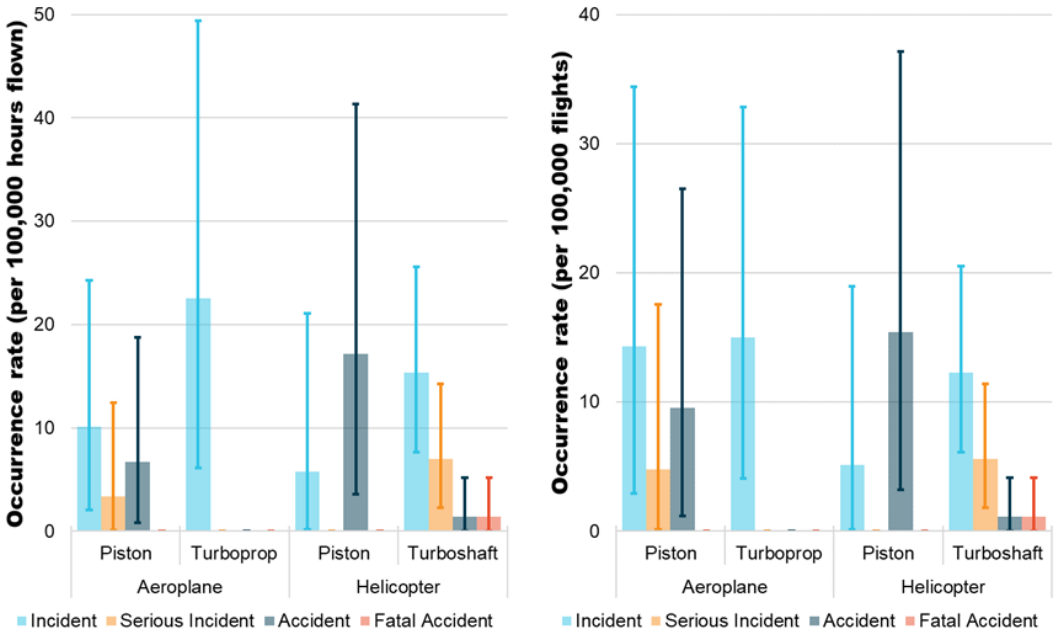
A more extensive analysis would incorporate exposure data of all aircraft conducting aerial firefighting aircraft in Australia.

Figure 11: Number of reported aerial firefighting occurrences per engine type



Data source: ATSB aviation occurrence database

Figure 12: Rate of reported occurrences for VH-registered aeroplanes and helicopters conducting aerial firefighting per engine type (2014–2018)



Data sources: Bureau of Infrastructure, Transport and Regional Economics (BITRE) and ATSB aviation occurrence database. Bars display the average (expected value) of the rates, error bars (95% confidence interval) calculated using gamma-Poisson (hours flown) and beta-binomial distributions (flights)

Occurrence types

Occurrences are often the result of a complex set of circumstances, involving multiple events and conditions. The ATSB categorises each reported occurrence into one or more occurrence types to

identify what happened, and how the sequence of events developed to lead to an occurrence. Classifying occurrences in this way helps to understand what types of occurrences have taken place, and to identify potential areas for safety improvement and communication.

Occurrence types do not explain why an occurrence happened; they are generally a description of what occurred. The ATSB uses a three-level hierarchical structure to classify occurrence types. There are broad occurrence type categories (level 1). These are:

- airspace-related
- infrastructure-related
- environment-related
- operational-related
- technical-related.

Consequential events that happen as the result of an occurrence, for example forced and precautionary landings, emergency descents, rejected take-offs, evacuations and fuel dumps to reduce landing weight, are also recorded.

The five level 1 occurrence types are broken down further into different level 2 occurrence types, which are further broken down into level 3 occurrence types. These are detailed in the ATSB's *SIIMS Occurrence Type Coding Manual*. The ATSB records one or more occurrence types for all aircraft involved in each occurrence. More severe occurrences (serious incidents, accidents and fatal accidents) generally have more occurrence types coded than incidents, as they are more likely to be investigated, and their severity usually means that there is a greater amount of information to draw upon for analysis and coding.

The frequency of a particular occurrence type does not necessarily reflect its importance or safety risk. For example, fuel-related events may be relatively rare, when compared with fumes events, but fuel starvation is more likely to lead to an accident. Many fuel starvation events result in an attempt at an emergency landing, and potential aircraft damage and injury to people on board or outside the aircraft. In comparison, most fumes-related events are minor in nature, and do not affect the safety of flight, or result in any injuries.

Figure 13 displays the number of reported occurrences per level 1 and level 2 occurrence type; Table 2 also includes level 3 occurrences types.

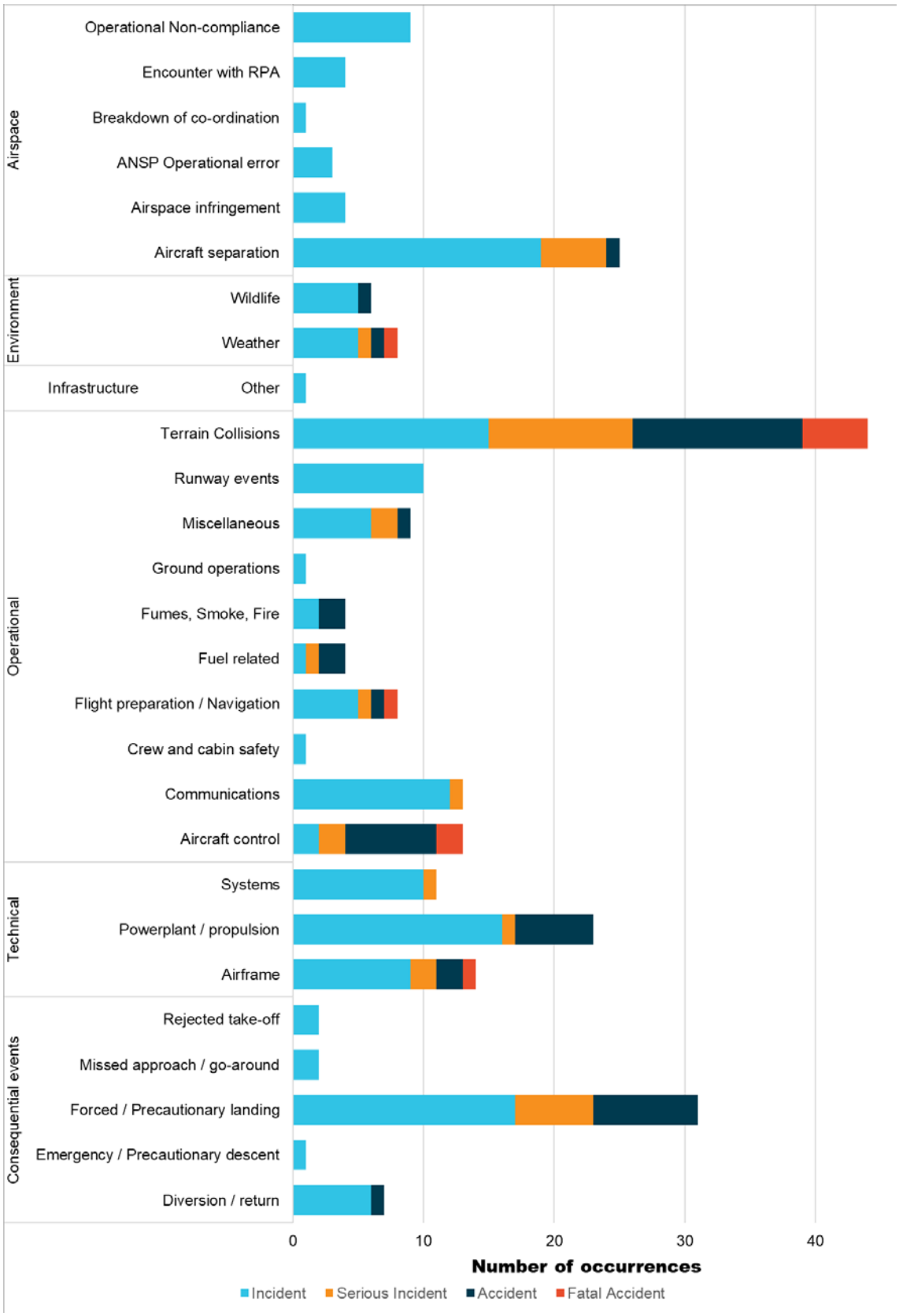
Note: Occurrences can have more than one associated occurrence type. Figure 13 and Table 2 display the number of occurrences and not the number of aircraft involved in an occurrence, if there were more than one firefighting aircraft involved in an occurrence (for example aircraft separation), it would count as one occurrence. In addition, only occurrence types involving one or more aerial firefighting aircraft are included.

Over the study period, over half of reported occurrences, all fatal accidents and four fifths of more severe occurrences were operational in nature. Terrain collisions (level 2) accounted for around half of the operational occurrences and 71 per cent of the more severe occurrences. Additionally, around one quarter of operational more severe occurrences involved aircraft control (level 2).

Around one quarter of more severe occurrences involved technical issues (level 1). Over half of these were powerplant/propulsion related (level 2) typically engine failure or malfunction (level 3). A further 23 per cent of occurrences were airspace-related; the majority of these were aircraft separation (level 2), of which 28 per cent were near collisions (level 3).

Around one quarter of occurrences and 30 per cent of more severe occurrences resulted in a consequential event, generally forced/precautionary landings (level 2).

Figure 13: Number of reported aerial firefighting occurrences per occurrence type (level 1 and 2)



Data source: ATSB aviation occurrence database

Table 2: Number of reported aerial firefighting occurrences per occurrence type (all levels)

Occurrence Types			Incident	Serious Incident	Accident	Fatal Accident
Level 1	Level 2	Level 3				
Airspace	Aircraft separation	*Airborne collision alert system warning*	0	0	1	0
		Collision	0	1	0	0
		Issues	10	0	0	0
		Loss of separation	6	0	0	0
		Near collision	3	4	0	0
	Airspace infringement		4	0	0	0
	ANSP Operational error	*Information / procedural error*	3	0	0	0
	Breakdown of co-ordination		1	0	0	0
	Encounter with RPA	*Near encounter with RPA*	4	0	0	0
	Operational Non-compliance		9	0	0	0
Environment	Weather	*Other*	0	0	1	0
		Turbulence / Windshear / Microburst	4	1	0	0
		Unforecast weather	2	0	0	1
	Wildlife	*Birdstrike*	5	0	1	0
Infrastructure	Other		1	0	0	0
Operational	Aircraft control	*Control issues*	0	1	0	0
		Hard landing	1	0	1	0
		In-flight break-up	0	0	0	1
		Loss of control	0	0	3	1
		Other	1	1	1	0
		Wheels up landing	0	0	2	0
	Communications	*Air-ground-air*	12	1	0	0
	Crew and cabin safety	*Flight crewincapacitation*	1	0	0	0
		Passenger related	1	0	0	0
	Flight preparation / Navigation	*Aircraft preparation*	2	1	0	0
		Flight belowminimum altitude	1	0	0	0
		Other	0	0	1	0
		VFR into IMC	2	0	0	1
	Fuel related	*Contamination*	1	0	0	0
		Exhaustion	0	1	0	0
		Starvation	0	0	2	0
	Fumes, Smoke, Fire	*Fire*	1	0	2	0
		Smoke	1	0	0	0
	Ground operations	*Taxiing collision / Near collision*	1	0	0	0
	Miscellaneous	*Other*	4	2	1	0
		Warning Devices	2	0	0	0
	Runway events	*Runway Excursion*	1	0	0	0
	Runway events	*Runway Incursion*	9	0	0	0
	Terrain Collisions	*Collision with terrain*	4	3	13	5
		Controlled flight into terrain	1	0	0	0
		Ground strike	8	0	0	0
		Wirestrike	2	8	0	0
Technical	Airframe	*Furnishings and fittings*	1	0	1	0
		Fuselage / Wings / Empennage	0	0	1	0
		Objects falling from aircraft	5	2	0	1
		Other	2	0	0	0
		Windows	1	0	0	0
	Powerplant / propulsion	*Abnormal engine indications*	4	0	0	0
		Engine failure or malfunction	12	1	4	0
		Propellers / Rotor malfunction	1	0	2	0
	Systems	*Datalink (UAS)*	1	0	0	0
		Electrical	1	0	0	0
		Fire protection	1	0	0	0
		Flight controls	2	0	0	0
		Fuel	1	0	0	0
		Hydraulic	4	0	0	0
		Other	0	1	0	0
Consequential events	Diversion / return		6	0	1	0
	Emergency / Precautionary descent		1	0	0	0
	Forced / Precautionary landing		17	6	8	0
	Missed approach / go-around		2	0	0	0
	Rejected take-off		2	0	0	0

Data source: ATSB aviation occurrence database

Comparison with other low-level aerial work activities

To examine the risks associated with aerial firefighting in addition to those inherent with low-level flying,[10] the occurrence rates for each associated occurrence type[11] between VH-registered aerial firefighting aeroplanes and helicopters[12] and the combined results for other VH-registered low-level flying aerial work (agricultural mustering, agricultural spreading/spraying and survey/photographic) aeroplanes and helicopters were compared between 2014 and 2018.

[10] Includes activities were a significant proportion of their flying was conducted at low-level.

[11] Due to low counts and the resulting high uncertainties, the data excluded level three occurrence types. Further, the rates are the combined results for all occurrences (incidents, serious incidents, accidents and fatal accidents).

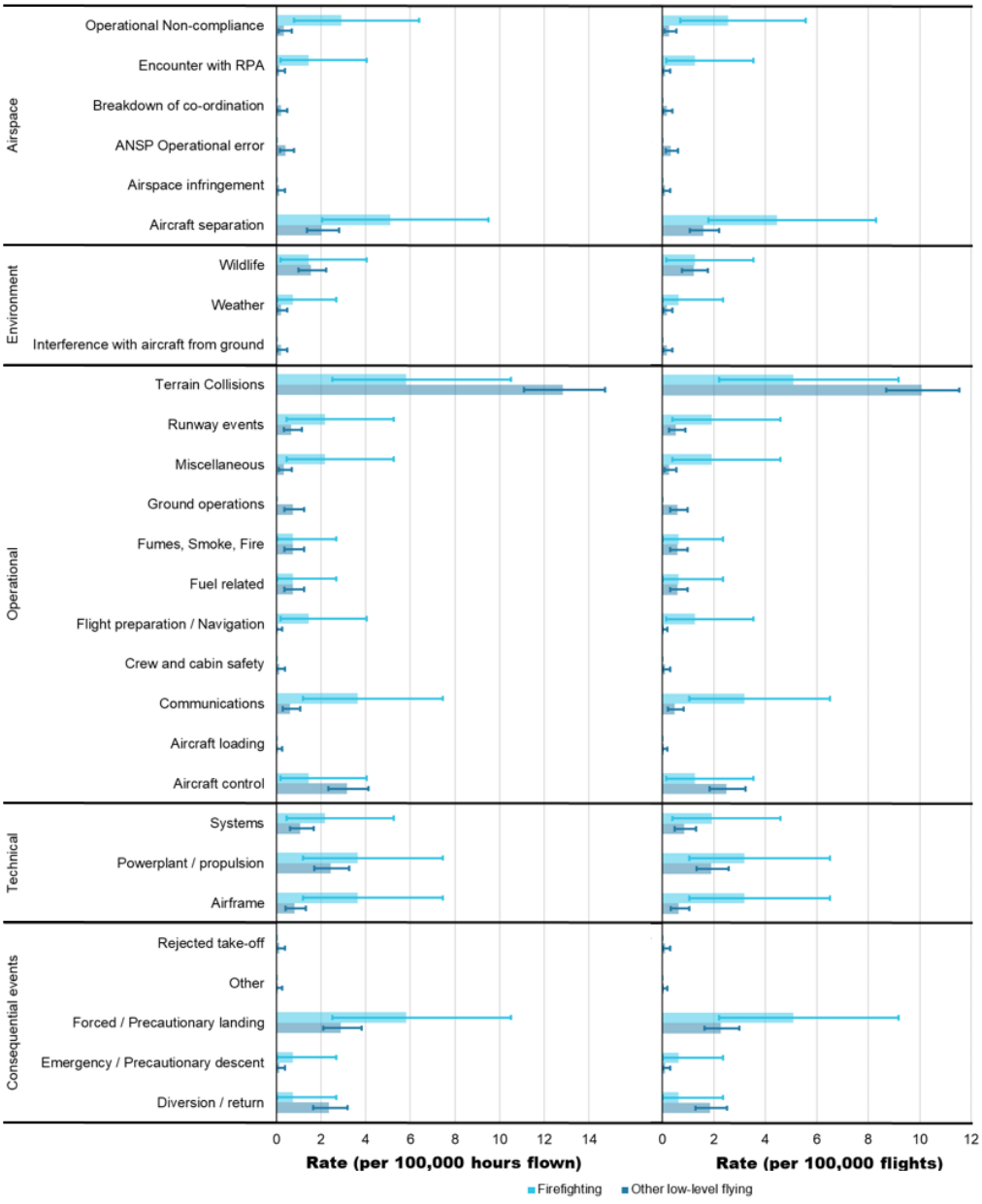
[12] RPAS conducting aerial firefighting were excluded due to a no available exposure data.

It is highly likely (greater than 95%) that the rate of reported occurrences involving a VH-registered aerial firefighting aircraft, compared to other low-level flying aerial work activities, was greater for:

- communications-related occurrences
- encounters with remotely piloted aircraft (RPA)
- airframe-related technical issues
- flight preparation/navigation operational occurrences
- aircraft separation occurrences
- operational non-compliance occurrences.

It is highly likely that the rate of reported terrain collisions was lower for VH-registered aerial firefighting aircraft than other low-level flying aerial work activities. Further, it is also likely that aerial firefighting aircraft had a lower rate of reported occurrences associated with aircraft control.

Figure 14: Rate of reported aerial firefighting occurrences per occurrence type for VH-registered low-level aerial work activities (2014–2018)



Data sources: Bureau of Infrastructure, Transport and Regional Economics (BITRE) and ATSB aviation occurrence database. Bars display the average (expected value) of the rates, error bars (95% confidence interval) calculated using gamma-Poisson (hours flown) and beta-binomial distributions (flights)

Appendices

Appendix A – Aerial work activity subtypes

Aerial work is an activity type falling within general aviation and is further divided into 16 activity subtypes. Specifically this includes:

- Agricultural spreading/spraying (*Activity Subtype*) – Flying involving the spreading/spraying of chemicals, seeds, and fertilisers (includes flights from the spreading/spraying area).
- Agricultural mustering (*Activity Subtype*) – Aerial stock mustering involving the direct use of aircraft for the movement of livestock.
- Other agricultural (*Activity Subtype*) – Other agricultural activity not classified elsewhere (includes aerial culling and baiting, bore and property inspections).
- Unknown agricultural (*Activity Subtype*) – Agricultural activity where the activity subtype is unknown.
- Construction – sling loads[13] (*Activity Subtype*) – Flying using sling loads for construction purposes.
- Other construction[13] (*Activity Subtype*) – Flying for construction purposes (excludes sling loads).
- Photography[14] (*Activity Subtype*) – All aerial photographic work (includes media filming operations).
- Pipeline / powerline surveying[14] (*Activity Subtype*) – Aerial inspection patrols along pipelines or powerlines (includes insulator washing).
- Other surveying[14] (*Activity Subtype*) – Flying involving the use of aircraft for surveying not classified elsewhere (including geophysical surveys).
- Observation and patrol (*Activity Subtype*) – Flying involving the use of aircraft for aerial observations and patrol (includes coastal surveillance, customs/border force patrols, traffic monitoring).
- Search and rescue (*Activity Subtype*) – Any search missions (includes evacuations or rescue work).
- Policing (*Activity Subtype*) – Flying involving the use of aircraft in police operations (includes traffic control, ground support, high-speed car pursuits, observation, air patrol).
- Firefighting (*Activity Subtype*) – Flying involving the use of aircraft to combat fires (e.g. fire spotting, water bombing) (includes flight to and from the fire area).
- Advertising (*Activity Subtype*) – Flying for of advertising purposes (includes skywriting and banner towing advertising).
- Other aerial work (*Activity Subtype*) – Aerial work flying not classified elsewhere (includes stock or fish spotting, cloud seeding, Military target towing by non-military aircraft, aerial refuelling, military support, medical clinics, radar/nav-aid calibration flights).
- Unknown aerial work (*Activity Subtype*) – Aerial work flying where the activity subtype is unknown.

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13 Construction – sling loads and Other Construction are merged within this report as Construction.

14 Photography, Other Surveying and Pipeline/Powerline Surveying are merged within this report as Survey/Photographic.

Appendix B – Estimative language

Throughout this report, estimative language is used. This defines a probability range of an occurrence or outcome given in a statement (Table 3).

Table 3: Estimative language expressions with associated probability of occurrence/outcome

Terminology	Likelihood of the occurrence/outcome	Equivalent terms
Virtually certain	> 99% probability	*Extremely likely, almost certain*
Highly likely	> 95% probability	*Highly probable*
Very likely	> 90% probability	*Very probably*
Likely	> 66% probability	*Probable*
About as likely as not	33 to 66% probability	*More or less likely*
Unlikely	< 33% probability	*Improbable*
Very unlikely	< 10% probability	
Exceptionally unlikely	< 1% probability	*Extremely unlikely*

Appendix C – Aircraft model classification table

Manufacturer	Model	New Model Name
Aero Commander	690-A	Aero Commander | 500 family
Rockw ell International	690-B	Aero Commander | 500 family
Air Tractor Inc	AT-602	Air Tractor | AT-602
Air Tractor Inc	AT-802	Air Tractor | AT-802
Air Tractor Inc	AT-802A	Air Tractor | AT-802
Air Tractor Inc	AT-502B	Air Tractor |AT- 502
AIRBUS HELICOPTERS	AS 350 B3	Airbus Helicopters | AS350 family
Aerospatiale Industries	AS.350B	Airbus Helicopters | AS350 family
Aerospatiale Industries	AS.350B2	Airbus Helicopters | AS350 family
Eurocopter	AS.350B2	Airbus Helicopters | AS350 family
Eurocopter	AS.350B3	Airbus Helicopters | AS350 family
Aerospatiale Industries	AS.350BA	Airbus Helicopters | AS350 family
Aerospatiale Industries	AS.365N2	Airbus Helicopters | AS365 family
Eurocopter	AS.365N2	Airbus Helicopters | AS365 family
Eurocopter	AS365N3 Dauphin	Airbus Helicopters | AS365 family
AEROSPATIALE	AS65	Airbus Helicopters | AS365 family
American Champion Aircraft Corp	8GCBC	American Champion | 8GCBC
Ayres Corporation	S2R-G10	Ayres | S-2R
British Aerospace PLC	AVRO 146-RJ85A	BAE Systems | 146 family
BAE Systems	Avro RJ85	BAE Systems | 146 family
Beech Aircraft Corp	200	Beech | 200
Beech Aircraft Corp	B200T	Beech | 200
Beech Aircraft Corp	58	Beech | 58
Beech Aircraft Corp	A36	Beech | A36
Bell Helicopter Co	204B	Bell Helicopter | 204/205 family
BELL HELICOPTER TEXTRON INC.	205A-1	Bell Helicopter | 204/205 family
Bell Helicopter Co	206A	Bell Helicopter | 206 family
Bell Helicopter Co	206B	Bell Helicopter | 206 family
Bell Helicopter Co	206B (III)	Bell Helicopter | 206 family
Bell Helicopter Co	206L-1	Bell Helicopter | 206 family
Bell Helicopter Co	206L-4	Bell Helicopter | 206 family
Cessna Aircraft Company	U206G	Bell Helicopter | 206 family
Bell Helicopter Co	212	Bell Helicopter | 212/412 family
Bell Helicopter Co	412	Bell Helicopter | 212/412 family
Bell Helicopter Co	412 SP	Bell Helicopter | 212/412 family
Bell Helicopter Co	412EP	Bell Helicopter | 212/412 family
Bell Helicopter Co	214B-1	Bell Helicopter | 214
Bell Helicopter Co	B214	Bell Helicopter | 214
Bell Helicopter Co	BELL 214B-1	Bell Helicopter | 214
Bell Helicopter Co	407	Bell Helicopter | 407
Bell Helicopter Co	AMT UH-1H	Bell Helicopter | UH-1 family
Bell Helicopter Co	TH-1F	Bell Helicopter | UH-1 family
Garlick Helicopters Inc	TH-1F	Bell Helicopter | UH-1 family
Garlick Helicopters Inc	UH-1H	Bell Helicopter | UH-1 family
OAS Parts LLC	UH-1H	Bell Helicopter | UH-1 family
Williams Helicopter Corporation	UH-1H	Bell Helicopter | UH-1 family
The Boeing Company	737-3H4	Boeing | 737
Cessna Aircraft Company	172M	Cessna | 172
Cessna Aircraft Company	182P	Cessna | 182
Cessna Aircraft Company	208B	Cessna | 208
Cessna Aircraft Company	337A	Cessna | 337
Cessna Aircraft Company	337E	Cessna | 337
Cessna Aircraft Company	337G	Cessna | 337
Cessna Aircraft Company	404	Cessna | 404
DJI	Phantom 4	DJI | Phantom 4
Gippsland Aeronautics Pty Ltd	GA-8	Gippsland Aeronautics | GA-8
Kaw asaki Heavy Industries	BK117 B-2	Kaw asaki | BK117
KAWASAKI HEAVY INDUSTRIES, LTD.	BK117 B-2	Kaw asaki | BK117
Lockheed Martin Corp	C-130H	Lockheed Martin | C130
Lockheed Aircraft Corp	EC130Q	Lockheed Martin | C130
Lockheed Martin Corp	EC-130Q	Lockheed Martin | C130
MBB Helicopter Canada Limited	BO 105LS A-3	MBB | Bo 105
Mcdonnell Douglas Corp.	DC10	McDonnell Douglas | DC-10
Mcdonnell Douglas Corp.	369HS	McDonnell Douglas | MD500 family
Partenavia Costruzioni Aeronautiche S.p.A	P.68 OBSERVER	Partenavia | P.68
Partenavia Costruzioni Aeronautiche S.p.A	P.68B	Partenavia | P.68
Partenavia Costruzioni Aeronautiche S.p.A	P.68C	Partenavia | P.68
Piper Aircraft Corp	PA-31	Piper | PA-31
Piper Aircraft Corp	PA-31-350	Piper | PA-31
PZL Mielec	Dromader M18A	PZL-Mielec | M18 family
PZL Mielec	M-18	PZL-Mielec | M18 family
PZL Warszaw a-Okecie	M-18	PZL-Mielec | M18 family
PZL "WARSZAWA-OKECIE"	M-18A	PZL-Mielec | M18 family
PZL Mielec	M-18A	PZL-Mielec | M18 family
PZL Warszaw a-Okecie	M-18A	PZL-Mielec | M18 family
PZL Mielec	M-18B	PZL-Mielec | M18 family
PZL Warszaw a-Okecie	M-18B	PZL-Mielec | M18 family
Robinson Helicopter Co	R22 BETA	Robinson Helicopter | R22
Robinson Helicopter Co	R44	Robinson Helicopter | R44
Robinson Helicopter Co	R44 II	Robinson Helicopter | R44
Sikorsky Aircraft	S64	Sikorsky | S-64
Erickson Air-Crane Inc	S64E	Sikorsky | S-64
Erickson Air-Crane Inc	S64F	Sikorsky | S-64
Sikorsky Aircraft	Sikorsky S-64E/F Skyrcrane	Sikorsky | S-64
Sikorsky Aircraft	S76	Sikorsky | S-76
Sikorsky Aircraft	SK61	Sikorsky | SK61

Glossary

Occurrence - an accident, incident or serious incident. Includes occurrences where an aerial firefighting aircraft may not have caused the occurrence. For example, a near encounter with a remotely piloted aircraft (RPAS) where the RPAS infringed into airspace where aerial firefighting was being conducted. The intention of this report is to highlight potential safety risks to aircraft conducting aerial firefighting not detail events where actions by the crew of an aerial firefighting aircraft led to an occurrence.

Accident - an occurrence involving an aircraft where:

- a person dies or suffers serious injury
- the aircraft is destroyed, or is seriously damaged
- any property is destroyed or seriously damaged (Transport Safety Investigation Act 2003).

Within this report, accidents are split into “accidents” and “fatal accidents”. These are classified by the highest injury sustained resulting from the occurrence. It is possible that fatal accident also resulted in additional serious or minor injuries. An “accident” should be read as “non-fatal accident”.

Incident - an occurrence, other than an accident or serious incident, associated with the operation of an aircraft that affects or could affect the safety of operation (International Civil Aviation Organisation Annex 13).

Serious incident - an incident involving circumstances indicating that an accident nearly occurred (International Civil Aviation Organisation Annex 13).

Serious injury - an injury that requires, or would usually require, admission to hospital within seven days after the day when the injury was suffered (Transport Safety Investigation Regulations 2003).

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: 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 that fall within the ATSB's jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to operations involving the travelling public.