Global and Domestic Strategies for Aerial Bushfire Suppression in Australia

Comparing Worldwide Innovations and Australian Practices to Strengthen Aerial Firefighting Capability

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Abstract

This comprehensive report evaluates two decades of aerial bushfire suppression in Australia, integrating global comparisons from leading firefighting nations. It analyses the effectiveness, roles, and costs of all major aircraft types used for bushfire suppression – including fixed-wing water bombers, large air tankers, helicopters, and drones – from 2000 to the present. Performance metrics such as response speed, area and property protected, lives saved, suppression effectiveness, and cost-efficiency are examined. The report details Australia's national aerial firefighting arrangements (60% focus) across all states and territories, and compares them with international best practices (40% focus) in the United States, Canada, Spain, and Chile.

It assesses operational factors like leasing, maintenance, training, logistics, insurance, and administrative overhead for aerial fleets, and evaluates command structures, fleet ownership models (public, private, hybrid), and emerging technologies (e.g. night operations, drones, improved retardants). Based on diverse vegetation, geography, climate trends, and budgets, the report provides state-by-state recommendations to optimize fleet composition, coordination, and cost-effectiveness.

The findings underscore that while aerial bushfire suppression in Australia is an indispensable and highly effective tool – credited with saving lives and thousands of properties – it is expensive and must be strategically integrated with ground efforts and climate adaptation strategies. The report's recommendations aim to enhance Australia's aerial firefighting capacity and efficiency under worsening fire conditions, through evidence-based investment, national coordination, and innovation.

1. Introduction

Aerial bushfire suppression in Australia has become an essential component of wildfire response over the past two decades. Australia is one of the most fire-prone countries in the world, with vast areas of flammable vegetation and increasingly extreme fire weather conditions. The period from 2000 to 2025 has seen a significant expansion in the use of aircraft to combat bushfires, driven by a series of catastrophic fire seasons and growing public expectation for rapid, effective firefighting interventions from the sky. Major bushfire disasters – from the 2003 Canberra fires to the 2009 "Black Saturday" fires in Victoria and the unprecedented 2019–2020 "Black Summer" fires – have underscored the importance of aerial resources in supporting ground crews, protecting communities, and attacking fires in remote or inaccessible terrain.

However, aerial firefighting is also an expensive and complex endeavour. Money spent on aircraft must be balanced against other firefighting investments like ground crews, fire trucks, and prevention programs. All Australian states and territories contribute the bulk of funding for aerial suppression operations, with additional support from the Australian federal government. Since 2003, the National Aerial Firefighting Centre (NAFC) has coordinated a cooperative national fleet on behalf of the states and territories, enabling cost-sharing and resource-sharing across jurisdictions.

This national approach was initiated after extreme fires demonstrated that no single state could alone afford or manage the large aircraft needed for modern wildfire threats. Through NAFC, Australia contracts approximately 130–170 specialized firefighting aircraft each year, supplemented by additional state-owned or call-when-needed aircraft, making over 500 aircraft available nationally during peak fire periods. In the 2015–16 season, for example, aircraft from the national fleet were activated 5,000 times and made nearly 30,000 water or retardant drops on fires – illustrating the scale of aerial operations.

Australia's Role in Global Aerial Firefighting: Both a Contributor and a Learner

Many large firefighting aircraft and crews now rotate between the northern and southern hemispheres, spending the North American summer in the United States or Canada and then the Australian summer down under. Australia has drawn on overseas expertise (for instance, California's and Canada's long experience with airtankers and "scooper" water-bombers) and has, in turn, provided knowledge to other countries. The focus of this report (60% on Australia, 40% international) allows a detailed examination of Australia's operations alongside comparisons with the United States, Canada, Spain, Chile, and other leaders in aerial firefighting. Key questions addressed include: How effective are different types of aircraft in controlling bushfires, and under what conditions? What are the costs (leasing, operating, maintenance, etc.) associated with these aerial assets? How do Australia's arrangements and outcomes compare to those overseas? And what strategies or technologies can improve cost-efficiency and firefighting outcomes in the face of growing fire threats due to climate change?

The remainder of this report is organized into clear sections covering the types of aircraft and their roles (Section 3), the costs and logistics of aerial suppression (Section 4), performance metrics and effectiveness (Section 5), a state-by-state overview of Australian aerial firefighting operations (Section 6), international comparisons (Section 7), a discussion of best practices and lessons learned globally (Section 8), emerging technologies (Section 9), future challenges including climate change (Section 10), and specific recommendations tailored to Australian states and territories (Section 11). Throughout, "aerial bushfire suppression in Australia" is analysed with supporting data, case studies, and citations to provide an evidence-based assessment suitable for policymakers, fire agencies, and stakeholders. By integrating two decades of domestic experience with global insights, this report aims to guide strategic improvements in Australia's aerial firefighting capability to meet the escalating bushfire challenge.

2. Background: Bushfire Threats and Aerial Suppression in Australia

Australia's climate and vegetation produce one of the most severe bushfire environments on the planet. Southern Australia (particularly Victoria, New South Wales, South Australia, and Tasmania) is commonly regarded as one of the three most fire-prone regions globally, alongside California and the Mediterranean Basin. The "bushfire season" in Australia is long and varied: northern tropical regions face fires in the dry season (mid-year), while the more populated southern regions face spring-summer-autumn fire seasons (late year into early next year). Droughts, heatwaves, and high winds can align to create extreme bushfire weather (such as Forest Fire Danger Index (FFDI) ratings of "Severe", "Extreme" or "Catastrophic"). In such conditions, fast-moving bushfires can overwhelm traditional ground suppression methods. This context has driven the increasing reliance on aircraft for rapid attack and support.

The history of aerial firefighting in Australia dates back to at least the 1930s for fire detection, and to the 1960s for operational water-bombing trials. By the late 20th century, Australian states were experimenting with agricultural aircraft fitted for water or retardant drops, and helicopters with belly tanks or buckets. Notably, Victoria's state forestry agency was a pioneer in using light aircraft for fire reconnaissance and bombing, often in collaboration with North American agencies. Despite early successes, significant expansion of aerial suppression capability did not occur nationally until the early 2000s, catalyzed by severe fire seasons and technological advances.

A critical turning point was the formation of the National Aerial Firefighting Centre (NAFC) in 2003. NAFC was established by the collective fire authorities of Australia's states and territories, with federal support, to coordinate the contracting and sharing of firefighting aircraft across the country. The impetus was the recognition that the cost of maintaining a robust aerial fleet year-round was beyond any single state's resources, and that a national approach could provide "surge capacity" when a state's own resources were overwhelmed. Under NAFC's model, a core fleet of aircraft is contracted each year (with costs co-funded by states and the Commonwealth) and positioned across the country based on expected risk. These assets can be re-deployed interstate as needed through the National Resource Sharing Centre. NAFC also standardizes contracts, training, and operating protocols nationwide, improving interoperability.

Since 2000, Australia's aerial firefighting fleet has grown dramatically in size and variety. In the early 2000s, operations relied mostly on light fixed-wing bombers and helicopters for initial attack, with only occasional use of heavy aircraft (for example, the first Erickson S-64 "Air-Crane" heavy helicopter nicknamed Elvis was leased in 2001–02, proving its worth by saving nearly 300 homes and 14 firefighters in NSW). By the mid-2010s, Australia began contracting Large Air Tankers (LATs) – converted airliners or military transports carrying 10,000–15,000 litres of retardant – from North America on a regular basis. The fleet composition in 2025 includes everything from single-engine agricultural planes dropping water on small grassfires, to giant multi-engine air tankers capable of laying long retardant lines ahead of massive fire fronts.

Major Categories of Aerial Firefighting Aircraft in Australia (2025)

Single-Engine Air Tankers (SEAT) are fixed-wing aircraft such as the Air Tractor AT-802 "Fire Boss" and the Thrush 710P. They carry approximately 2,000 to 3,000 litres and are used for quick initial attacks on new fires, especially in rural areas. In Australia, they are deployed across all states for rapid responses to grassfires and small bushfires. The Fire Boss, being amphibious, can scoop water from nearby lakes and rivers for fast turnarounds.
Large Air Tankers (LAT) include aircraft like the Boeing 737 Fire liner, Lockheed C-130 Hercules, Avro RJ85, and Bombardier Q400. With a capacity of around 10,000 to 15,000 litres, they are designed for direct and indirect attacks on large fires. Their role includes laying long retardant lines to slow the spread of fire or protect key assets. These tankers are typically based in New South Wales and Victoria but are flown nationally as needed. They often operate from major airports due to their size.

Very Large Air Tankers (VLAT) such as the McDonnell Douglas DC-10 "Air Tanker" and, briefly, the Boeing 747 Supertanker, carry approximately 35,000 to 45,000 litres of retardant. They are used for large-scale indirect attacks and structure protection during major fire events. Due to their size and operational cost, they are only brought in during extreme fire seasons and require long runways.

Type 1 Helicopters (Heavy) include rotary-wing aircraft like the Erickson S-64 Air-Crane "Helitanker" (famously known as "Elvis"), Boeing CH-47D Chinook, and modified Sikorsky UH-60 Black Hawks. These helicopters can carry up to 9,000 litres and are used for targeted water or foam drops on active fire fronts, structure protection, and operations in rugged terrain. They can refill from water sources using snorkel hoses and are often leased for the summer fire season, especially in Victoria and New South Wales.

Type 2 Helicopters (Medium) such as the Bell 412, Airbus AS332 Super Puma, and Kamov Ka-32 carry between 1,000 and 2,600 litres. These versatile aircraft support firefighting with tanks or buckets, transport firefighting crews, insert teams by hover, and carry out reconnaissance. They are widely used by Australian state agencies for a variety of tasks, particularly in moderately difficult terrain.

Type 3 Helicopters (Light) like the Eurocopter AS350 Écureuil ("Squirrel") and Bell 206 JetRanger typically carry around 500 litres in a bucket. They are used for rapid responses to spot fires, aerial intelligence gathering, and supervision of other aircraft. These helicopters are often first on scene and play a key role in guiding larger aircraft during suppression efforts.

Aerial Supervision and Reconnaissance Aircraft include fixed-wing and rotary types like the Cessna 182 and 210, Rockwell Commander, and Learjet 35A equipped with infrared scanners. These aircraft do not drop water or retardant but are essential for coordinating air attacks, mapping fire intensity, spotting new ignitions, and scanning fires with infrared technology. Every multi-aircraft fire operation includes some form of air supervision.

Unmanned Aerial Systems (Drones) are increasingly being used, ranging from small quadcopters with infrared cameras to prototype heavy-lift drones. Their suppression capacity is currently limited (up to 50 litres), but they are extremely useful for night reconnaissance, hotspot mapping, and igniting controlled burns. As the technology advances, drones are expected to take on more active roles in suppression.

The aerial fleet ranges from small single-engine aircraft able to operate from short strips or water sources, to large multiengine tankers that require airports and significant logistical support. Each category has unique strengths. For example, helicopters offer hover capability and precision – crucial for directly protecting specific houses or dropping into rugged terrain – whereas fixed-wing tankers typically carry larger volumes and are faster, enabling coverage of more area per sortie. Scooping amphibious aircraft (like the Fire Boss or the Canadair CL-415 used overseas) can refill from lakes or the ocean in seconds, giving them rapid turnaround on fires near water.

Australia has trialled and included some amphibious water bombers (the Air Tractor Fire Boss) in its fleet, though the availability of suitable water bodies limits their use in some inland regions. Unmanned Aerial Vehicles (UAVs) have lately become valuable for gathering real-time intelligence – for instance, detecting spot fires through smoke or at night – augmenting the effectiveness of manned aircraft by guiding them to targets.

It is important to note that aerial firefighting is a support tool, not a standalone solution. Aircraft can slow the spread of fires, drop suppressant to protect high-value areas, and provide time for ground crews to work, but by themselves they rarely extinguish large bushfires. This principle is emphasized by fire agencies worldwide. Aircraft are most effective when fire intensity is moderate, when used in direct coordination with ground personnel, and especially during initial attack – the early phase of a fire when it is still small enough to contain.

As fire intensity increases (for example, in extreme weather with tall flames and strong winds), the effectiveness of water or retardant drops diminishes greatly. Australian fire authorities often reiterate that "aerial firefighting is not effective in isolation" and that the "heavy lifting" of final extinguishment is done on the ground once aircraft have knocked down flames. Nonetheless, there are numerous instances where aerial suppression has proven decisive in saving lives and property.

One famous example is the Erickson Air-Crane "Elvis" heavy helicopter: during the 2001–02 fire season, Elvis was credited with helping save almost 300 homes in suburban Sydney and with rescuing 14 firefighters who were trapped by flames. In that incident, the helicopter's massive water drops literally beat back flames from the firefighters and halted the fire's advance on neighborhoods – a dramatic illustration of aerial support's value.

Australia's use of aircraft has continually expanded in the 2010s and 2020s. The Black Summer fires of 2019–20 saw an unprecedented deployment of aerial assets, including over a dozen large air tankers and heavy helicopters operating simultaneously across multiple states. International assistance was also critical: firefighting aircraft from North America, Europe, and New Zealand were brought in to assist.

This season highlighted both the capabilities and the limits of aerial suppression. On one hand, tanker drops and helicopter sorties undoubtedly saved many towns and lives; on the other, during the peak of the crisis (with extreme pyro convective firestorms), even continuous bombing by VLATs (Very Large Air Tankers like the DC-10) could not stop the biggest fire fronts. These events have spurred ongoing debates about the optimal aerial fleet size and composition for Australia, and how to ensure availability of aircraft when both northern and southern hemispheres experience overlapping fire seasons.

In summary, aerial suppression has evolved from a niche support role to a central pillar of bushfire response in Australia. The country now fields a sophisticated, multi-faceted aerial armada each summer, integrated under a national strategy. The following sections delve deeper into the costs of operating this armada (Section 4), how effectiveness is measured

(Section 5), differences across Australian jurisdictions (Section 6), and comparisons with global practices (Sections 7 and 8).

3. Roles and Types of Aerial Firefighting Aircraft

Modern aerial firefighting involves a diverse fleet of aircraft, each type fulfilling specific roles in a bushfire suppression campaign. This section describes the main types of aircraft currently used for aerial bushfire suppression in Australia, and analyses their roles, effectiveness, and typical operational context. The focus is on how these aircraft are employed in Australian conditions, with reference to international usage where relevant.

3.1 Fixed-Wing Airtankers: SEATs, Large Air Tankers, and Water Scoopers

Fixed-wing "airtankers" are airplanes configured to drop water or fire retardant onto fires. They range from small single-engine planes to jumbo jets:

Single-Engine Air Tankers (SEATs):

These are light agricultural-style aircraft (like the Air Tractor AT-802) fitted with tanks (approximately 3,000 litres capacity) to drop water, foam, or retardant. SEATs are prized for their nimbleness and low cost. They can operate from short airstrips or even farm fields, and some (like the AT-802 "Fire Boss") can scoop water from rivers or lakes. In Australia, SEATs are often the first suppression aircraft on scene in rural or remote areas, as they are usually locally based and can take off quickly after a lightning storm or fire report.

For example, Western Australia and the Northern Territory rely heavily on SEATs for fast initial attack on bushfires in pastoral lands and savannas. While a single SEAT drop is relatively small, multiple SEATs working in tandem can substantially slow a fire's spread. They are cost-effective for small fires, but less so against large, intense fires unless used in large numbers.

Large Air Tankers (LATs):

These are much larger planes, often converted from passenger or cargo aircraft, capable of delivering about 7,000 to 15,000 litres of retardant per drop. Common LATs in Australia include the Lockheed C-130 Hercules, the Avro RJ85 (a converted regional jet airliner), and more recently a Boeing 737 Fire liner operated by Coulson Aviation for the NSW Rural Fire Service. LATs fly at higher speeds and cover greater distances than SEATs, making them ideal for reinforcing containment lines on large fires or protecting assets ahead of a fire front.

They typically drop long lines of slurry (aerial fire retardant, which is a phosphate-based chemical mixed with water and dye) across vegetation. The retardant doesn't extinguish fire outright, but it coats fuels and slows or stops combustion if the fire reaches that line. An advantage of LATs is payload – a single C-130 or 737 drop (say ~ 12,000 L) equals 4 or more SEAT drops, allowing concentration of effort. A disadvantage is that they require suitable infrastructure: large tankers need sizable runways and tanker bases for refilling with retardant, and they incur high operating costs.

In Australian practice, LATs are often strategically positioned at major airports (e.g. Richmond RAAF Base in NSW or Avalon Airport in Victoria) and dispatched to emerging major fires statewide or even interstate. During the 2019–20 fires, a national deployment of up to 10 LATs occurred, something not seen before in Australia at that scale.

Very Large Air Tankers (VLATs):

These are a subset of LATs at the extreme heavy end – like the DC-10 Air Tanker (~35,000 L capacity) or the now-retired 747 Supertanker (~70,000 L, though typically 19,000 US gallons / ~72,000 L in practice). VLATs can drop massive quantities of retardant, creating fire breaks several kilometers long in one pass. Australia has used VLATs sparingly; a DC-10 (call sign "Thor") was leased to NSW and Victoria in recent years, and the 747 Supertanker was briefly deployed to help in 2019–20 (on a private philanthropic arrangement).

These giants can be effective for defensive operations, such as protecting towns by saturating the vegetation around them with retardant. However, VLATs are extremely costly to operate and come with logistical challenges – for example, only a few airports (with long runways) can host them, and specialized equipment is needed to reload their huge tanks. NAFC's strategy has generally been to rely on overseas VLAT contracts on an as-needed basis rather than maintain any permanently in-country. This "surge" approach is considered the most cost-effective way for Australia to access such aircraft, given that keeping them year-round would be prohibitively expensive and unnecessary in most seasons.

Water Scooping Amphibious Aircraft:

These are specialized fixed-wing planes like the Canadair CL-215/CL-415 (Bombardier "Superscooper") used extensively in North America and Europe. They can land on water and "scoop" up a full load (about 6,000 litres) in mere seconds, then fly back to drop on the fire, cycling repeatedly. The idea is a near-continuous shuttle of water from a nearby lake or ocean to the fire line. In Spain and Canada, fleets of these scoopers are core to their aerial firefighting model. In Australia, large dedicated scoopers like CL-415s have not been part of the regular fleet (none are owned locally), mainly because of differences in geography and approach (Australian agencies have instead favoured land-based tankers and helicopters). However, smaller scooping-capable planes like the AT-802 Fire Boss have been used in targeted areas – for instance, in Gippsland (Victoria) or northern Australia where suitable water bodies exist.

There is ongoing interest in whether amphibious water bombers could play a bigger role in Australia, especially as climate change increases fire frequency near coastal regions and large inland water reservoirs. Any introduction of bigger scoopers would require analysis of resource availability (water sources), basing, and cost-benefit versus adding more helicopters or LATs. The NAFC strategy document notes that while small scooping aircraft already form part of the fleet, decisions on adding new types (like larger scoopers) must be evidence-based. Trials and reassessments of capabilities are encouraged, but any fleet changes will consider whether water scoopers would truly offer an advantage in the Australian context.

Summary:

Fixed-wing airtankers in Australia provide the backbone for building containment lines and slowing fires. SEATs handle many daily initial attacks; LATs take on the big jobs. A mix of both is used – SEATs for agility and distributed response, LATs for concentrated large-scale drops. Their effectiveness depends greatly on timing and strategy: dropping retardant in advance of a fire (indirect attack) is most useful when done hours (or at least minutes) before the fire arrives, so that the retardant has maximum effect. Retardant lines can fail if they're laid too early (dry out or wash off) or too late (fire has already overtaken the target area). Hence, coordination with weather and ground crews is vital.

3.2 Rotary-Wing Aircraft: Helicopters (Type 1, 2, 3) and Their Uses

Helicopters are extremely versatile firefighting machines. They can access areas airplanes cannot, hover to drop water with pinpoint accuracy, and perform a variety of missions beyond just water bombing (such as transporting crews, equipment, or conducting evacuations). Australia classifies helicopters by lift capacity:

Type 1 (Heavy) Helicopters:

These are the largest, capable of carrying over 2,650 litres of water per drop (often via an attached belly tank or bucket). Within Type 1, NAFC further identifies "Type 1 High Volume" helicopter that can deliver 100,000 litres in 90 minutes (through multiple quick turnarounds). Erickson S-64 Air-Cranes (like Elvis) and Chinook CH-47s fall in this high-volume category. Standard Type 1 helicopter include ex-military Sikorsky S-61N Sea Kings and modified UH-60 Black Hawks, which have slightly lower capacity (~2,600–4,000 L) but often better cruising speed and fuel efficiency than the bigger Air-Cranes. Heavy helicopters are used primarily for direct attack on the fire front, often in support of ground crews.

They excel at structure protection – hovering over homes or critical infrastructure and dousing the flames – and at working in broken terrain (gullies, steep forests) where fixed-wing drops might not penetrate or might miss the target. They usually refill water by dipping buckets into open water (rivers, dams, swimming pools) or by using pumps to suck water into belly tanks. Some can also refill from portable tanks or hydrants set up by fire agencies. A major advantage is their turnaround time: if a water source is very close, a helicopter might make many drops per hour.

For example, an Air-Crane with a 9,500 L tank could potentially drop 9 loads (85,500 L total) in 90 minutes if the water source is adjacent – fulfilling that 100,000 L/90min "high volume" criteria with ease. The heavy helicopter are iconic in Australian firefighting since Elvis' introduction in 2001, and typically 2–4 are leased each summer (commonly based in Victoria, New South Wales, and sometimes other states). They are expensive but valued assets. Notably, these helitankers often get personalized names (e.g. Elvis, Gypsy Lady, Ichabod) and public attention for their dramatic efforts.

An Erickson S-64 "Air-Crane" heavy helicopter (Type 1) in Australia. This helitanker carries up to 9,500 litres of water or retardant in its belly tank and can refill via the dangling snorkel hose in rivers or dams. Australia has leased Air-Cranes like this every summer since 2001, as they are highly effective for structure protection and direct attack on intense fires.

Type 2 (Medium) Helicopters:

These have capacities roughly between 1,000 and 2,500 litres. Examples are Bell 212/412, Eurocopter AS332 Super Puma, Kamov Ka-32 (the Russian-built twin rotor, which has been used in NSW in some seasons), and some Eurocopter BK-117 variants. Medium helicopters often serve multiple roles: they can carry a firefighting bucket or tank for water drops, but they may also be configured for personnel transport (moving crews to remote fire lines, medevac of injured firefighters) or winching operations (e.g., inserting firefighters into fire zones or rescuing people). Their water-drop capability is intermediate – more than a small heli but much less than an Air-Crane.

However, medium helicopter tend to be faster and cheaper to operate than the heavies, and they can be based nearly anywhere (they don't require an airport). Australian states commonly contract numerous Type 2 helicopters each season. For instance, NSW and Queensland use Bell 412s both for waterbombing and for ferrying their "rapid aerial response teams" (fire crews with rappel gear or hover-exit training to attack remote ignitions). Medium helicopter are the workhorses that fill the gap when heavy helicopter are not available or needed. They ensure there is aerial water-drop capacity in regions that might not justify a heavy helicopter but still face significant fires. Some state emergency services (e.g., NSW

RFS) even own or long-term lease a few medium helicopters for year-round multipurpose use (search & rescue in floods, etc., in addition to firefighting).

Type 3 (Light) Helicopters:

These are the smallest class, typically carrying under 1,000 litres (often 500–800 L buckets). They include models like the Airbus AS350 Squirrel (also known as Écureuil/AStar) and Bell 206/Bell 407. Light helicopters have limited water payload, but they make up for it with agility, low cost, and flexibility. They are frequently the first aerial attackers on a newly reported fire in their area: many rural districts keep a light heli on standby during fire weather, because it can get off the ground within minutes and reach a fire very quickly (often before ground crews).

Even dropping just half a ton of water early on can extinguish a small fire or at least knock it down until ground units arrive. Additionally, light helicopter serve as "Air Attack Supervision" platforms (with an Air Attack Supervisor on board) to direct larger airtankers in the vicinity of an active fire.

They are also used for reconnaissance – mapping fire perimeters, checking for spot fires – and increasingly for infrared scanning at night to locate hotspots while the fire is less active (some are equipped with thermal cameras and data link). Another role is ignition for backburning: a light heli can carry an incendiary device dispenser (so-called "ping-pong ball" devices that chemically ignite after being dropped) to start controlled burns ahead of the main fire. This technique, aerial ignition, is common in large firefighting operations to remove fuel in a controlled way and help contain the fire on our terms. Light helicopters, therefore, are invaluable eyes in the sky and fill many support roles beyond their modest water drops.

Australia's Heavy Helicopters - Military Support and Future Plans:

Beyond these, Australia also uses specialized helicopters like the Ericsson Skycrane (Air-Crane) mentioned (heavy Type 1) and occasionally military helicopters in firefighting roles. For example, Australian Defence Force Chinooks (CH-47) have been outfitted with firefighting buckets in extreme seasons to add capacity, and navy helicopters have assisted with reconnaissance and evacuation (though military involvement in direct firefighting is somewhat limited due to training and safety constraints).

One point on heavy helicopters: up until now, Australia has met its heavy heli needs by leasing from overseas each summer (mostly from North America). There's ongoing consideration of acquiring ex-military heavy helicopters domestically (such as surplus CH-47 Chinooks or Black Hawks being retired from armed service) and converting them for firefighting. While using ex-military aircraft might seem cost-effective, NAFC cautions that conversion, crewing, and maintenance costs for those can be significant. Any such move would require careful cost-benefit analysis to ensure it's worthwhile. Still, as fire seasons lengthen (making back-to-back northern/southern hemisphere leasing trickier), having some sovereign heavy lift capability year-round could be strategic. NAFC's 2021–26 strategy indeed flagged the idea of ensuring at least one heavy helicopter is available in Australia year-round for early or late-season fires as climate change progresses.

In operation, helicopters are often used in combined assaults with fixed-wing aircraft. A typical scenario on a large bushfire might see large airtankers drop retardant to create a buffer, then helicopters move in closer to the fire edge to drop water directly on flames and cool down hotspots, allowing ground firefighters to approach safely. Helicopters can also bounce between the fire and water sources continuously, whereas fixed-wing must go back to an airfield to reload. This means on fires near water (rivers, dams), a handful of helicopters can provide an almost continuous shower on the fire, which can be extremely effective if properly coordinated.

3.3 Emerging: Unmanned Aerial Vehicles (UAVs or "Drones")

While not "aircraft" in the traditional sense of carrying large payloads, drones have rapidly emerged as a valuable aerial tool for wildfire management. In Australia, drones (ranging from small quadcopters to larger military-style UAVs) are increasingly used for intelligence, surveillance, and reconnaissance (ISR) during fires. They can fly at night or in heavy smoke where it may be too dangerous or ineffective for manned aircraft. For example, during the 2019–20 fires, emergency agencies used drones with infrared cameras to detect spot fires and monitor fire intensity through thick smoke, feeding live data to incident management teams. Drones have also been used to patrol containment lines at night to ensure no embers are escaping. This greatly enhances situational awareness for firefighters.

Another use is aerial ignition:

Specialized drones can drop incendiary "dragon eggs" (small chemical capsules) in a pattern to start backburns or hazard reduction burns. This was pioneered in North America but has been trialled in Australia too, as it reduces risk to human pilots and can accurately ignite areas in difficult terrain.

At present, drones are not dropping water or retardant in meaningful volumes on active fires – their payload capacity is generally too low. However, technological innovation is underway. Companies and defense agencies are exploring heavy-lift drones or drone swarms that could carry water/retardant or fire-suppressant gel for very targeted attacks (for instance, to extinguish small spot fires or embers in remote areas).

We may see in the coming decade some prototype firefighting UAVs that operate semi-autonomously to douse small ignitions before they grow. For now, their main contribution is making aerial operations safer and smarter by providing real-time information and performing tasks (like night monitoring) that manned aircraft either can't do or would do at high risk.

The integration of drones has to be managed carefully to avoid airspace conflicts. During daytime operations, having many drones in the same airspace as helicopters and planes could be dangerous, so typically drones are grounded whenever water-bombing aircraft are working nearby. Airspace coordination is thus an evolving practice, with pilots and drone operators working under the same Air Operations supervision to deconflict.

3.4 Multifaceted Roles: Beyond Firebombing

It's worth noting that aerial assets perform other critical roles in bushfire scenarios besides dropping water or retardant:

Aerial Supervision (Air Attack):

As mentioned, fixed-wing aircraft (typically small twin-engine planes) often fly above a fire as the "eye in the sky" to manage all the suppression aircraft. In Australia these are often called "Birddog", "Firebird" or simply "Air Attack" aircraft. They carry an Air Attack Supervisor who directs tankers where to drop, ensures separation between aircraft, and communicates with Incident Control on the ground. This role is crucial for safety and effective use of aerial resources. Without it, coordinating multiple drops can become chaotic.

Mapping and Intelligence:

Australia uses both manned aircraft (like the Line scan aircraft operated by Air Affairs Australia – a Learjet with infrared line-scanning equipment) and drones for mapping fires. They produce fire perimeter maps and detect hot spots through smoke. This information guides where aircraft and crews should focus efforts. During large campaign fires, the Line scan aircraft might fly every night, as cooler conditions and darkness improve infrared imaging of residual heat.

Logistics and Transport:

Helicopters (and occasionally fixed-wing transports) move personnel, supplies, and even heavy equipment during fire operations. In remote fires, helicopters might be the only way to insert crews or deliver food and water to firefighters on the fire line. They also extract crews if fire behaviour changes dangerously. Post-fire, helicopters can help in damage assessment and in ferrying officials or scientists over the burned area for evaluation.

Evacuation and Rescue:

In extreme situations, helicopters have been used to evacuate people trapped by fires. A notable recent example was the military helicopters that rescued hundreds of civilians from the beach at Mallacoota, Victoria, during the 2019–20 fires (the roads were cut off by fire). While military, not firefighting, aircraft did that evacuation, it highlights how aerial assets are indispensable in multi-faceted emergency response. Firefighting helicopters with winches could similarly rescue individuals or firefighters in distress (indeed, Elvis the Air-Crane helped save those 14 firefighters in 2001 by dousing the flames around them).

In conclusion, Australia’s aerial firefighting fleet encompasses a wide range of aircraft, each chosen for specific strengths. The combination of fast fixed-wing bombers and flexible helicopters provides a powerful one-two punch against bushfires. By 2025, the fleet is more advanced and larger than ever, reflecting the high priority placed on aerial suppression as fires become more intense. The next sections will examine how effective these aerial assets are (with data on success rates and limitations) and what they cost to operate and maintain at such scale.

4. Costs and Operational Logistics of Aerial Firefighting

Deploying a large aerial firefighting fleet is not only a tactical endeavour but also a significant financial and logistical commitment. This section breaks down the various cost components of aerial bushfire suppression in Australia – including procurement (leasing or ownership), operational costs (fuel, maintenance, personnel), training, support infrastructure, insurance, and administrative overhead – and discusses how these costs are managed. It also covers logistical aspects like fleet positioning, maintenance schedules, and resource sharing that influence cost-efficiency.

4.1 Leasing vs Ownership: Procurement Costs

Australia primarily uses a leasing model for its aerial firefighting fleet. Rather than owning most firefighting aircraft outright (which would incur capital costs and year-round maintenance/storage expenses), Australian fire agencies contract aircraft for the fire season. NAFC facilitates national contracts for roughly 130–170 aircraft each year. These contracts typically cover a defined availability period (e.g. three months over summer) during which the aircraft is on standby in Australia, plus an hourly operating rate for actual flight hours used. The leasing approach has advantages:

Cost Sharing and Flexibility:

Because many of these aircraft come from the Northern Hemisphere (especially the larger LATs and Type 1 helicopter), Australia often shares their use with North America or Europe on opposite seasons. For instance, a Canadian company might lease an airtanker to NAFC for December–March and then use it in Canada/US for June–September. Each side pays for the period they use it. This greatly reduces costs per jurisdiction. NAFC notes this is "the most cost-effective way for Australia to obtain access to such aircraft" – if they were based in Australia year-round, we could afford far fewer of them on current budgets.

Essentially, leasing back-to-back with northern partners spreads the cost. However, NAFC also acknowledges a risk: as fire seasons lengthen and overlap between hemispheres, future availability of these shared aircraft could be strained. A longer-term strategy might require adding some domestically retained capacity if overlaps become severe.

Avoiding Idle Asset Costs:

In quieter fire seasons, if Australia owned a large fleet, many aircraft might sit idle (but still require maintenance and pilot proficiency training). Leasing allows scaling the fleet each year to the anticipated season severity (with additional contingency via "call when needed" contracts).

It prevents a scenario of expensive aircraft being unused (which is hard to justify financially). The flip side is, in an unexpectedly bad season, one might need to scramble to bring in extra aircraft on short notice (possibly at premium cost or if they're even available internationally).

That said, there are some aerial assets owned by or long-term dedicated to Australian agencies. For example, the NSW Rural Fire Service owns the Boeing 737 Fire Bomber (named Marie Bashir) in partnership with Coulson Aviation – effectively giving NSW a year-round large airtanker capability. Some states also own small fixed-wing aircraft for reconnaissance and air attack supervision. But by and large, the frontline tankers and helitankers are leased.

Cost figures:

Contract costs are not always public, but some indicative figures can be gleaned from budgets and international data. The Australian federal government's contribution via NAFC grants has grown from about AUD $5 million in 2003 to around $20 million or more in recent years, helping states lease high-end aircraft. States collectively spend much more on top of that (for example, NSW and Victoria each invest tens of millions annually in aerial assets). In the United States, the U.S. Forest Service spent over USD $500 million in 2018 on firefighting aircraft (contracts, support, and operations). This equates to thousands of dollars per flight hour for large tankers and helicopters.

A large airtanker can cost roughly $10,000–$20,000 per hour to operate when factoring in fuel, retardant, and maintenance. Helicopters have a wide range: a light helicopter might cost $1,000–$2,000 per hour, a heavy like the Air-Crane perhaps $5,000–$10,000+ per hour. Additionally, availability fees (the standby cost to have the aircraft on contract for the season) can be substantial – often several million dollars per aircraft for a 90-day contract for a heavy air tanker, for instance.

During the Black Summer, emergency extra leases (like the 747 Supertanker and additional LATs) were contracted at short notice; media reports indicated costs in the order of AUD $16,000 per hour of operation for the 737 and higher for the VLAT. While exact numbers vary, it's clear that aerial firefighting is a resource-intensive and expensive capability. As one U.S. official wryly noted, "we spend a lot of money to drop water and mud out of the sky" – highlighting the importance of ensuring that money translates into actual fire control benefit.

One financial positive is that because NAFC is a central buyer representing all states, it can negotiate better deals and avoid inter-state competition driving up prices. Also, bulk tenders for multi-year contracts give operators the confidence to invest in aircraft modifications and training, knowing they have steady work.

4.2 Operating Costs: Fuel, Maintenance, and Personnel

Once aircraft are contracted and in place, day-to-day operational costs kick in whenever they fly (and even when they don't, some costs accrue for readiness).

Fuel: Aviation fuel is a major cost component. Large turboprop or jet airtankers burn hundreds to thousands of litres of fuel per hour. Helicopters likewise can be very thirsty; for example, an S-64F Air-Crane burns roughly 1,000 litres of jet fuel per hour of firefighting. Fuel costs are typically built into the hourly rate charged by contractors, but in some arrangements the agency might supply fuel at the operating base. During intense firefighting campaigns, setting up fuel supply lines (tankers/trucks delivering Jet-A fuel to temporary airbases) is a critical logistics task. Any spike in global fuel prices can significantly increase aerial firefighting costs.

Retardant and Water Supply:

For fixed-wing airtankers that drop chemical retardant, the retardant itself costs money. Long-term fire retardant is purchased as a concentrate and mixed with water at tanker bases. It contains ammonium phosphate salts, thickeners, and iron oxide dye (to mark drops). Agencies must stockpile retardant powder or liquid concentrate each season. In high usage seasons, retardant resupply can become a logistical issue; for example, in 2019–20 some Australian bases almost ran out of retardant and had to rush-order more from overseas.

Retardant is not cheap (cost can be on the order of $2–$3 per gallon of mix, which translates to a few thousand dollars per full load of a LAT). For water drops (from helicopters or scooping aircraft), the water itself is usually sourced for free (from rivers or hydrants), but sometimes this involves setting up water points, portable dams, or pumps (a logistical cost).

Maintenance:

Aviation is a maintenance-intensive industry, especially when operating in the harsh conditions of firefighting (smoky, hot, often low-altitude flying which is hard on engines and airframes). Contractors typically handle maintenance of their aircraft, but those costs are factored into contract prices. Heavy usage in a season can drive up maintenance needs (e.g., more frequent engine overhauls). Additionally, firefighting aircraft sometimes sustain damage – for instance, from ingesting ash/debris, bird strikes, or even minor collisions with trees or ground during operations. Repairing and maintaining safety standards is paramount, as the lives of flight crews depend on airworthiness.

Notably, Australia (like other countries) has seen tragic accidents in aerial firefighting – such as the crash of a C-130 airtanker in NSW in January 2020, which killed three American crew. Such incidents often lead to reviews and may incur costs related to fleet stand-downs or modifications for safety. Maintenance also includes daily and periodic checks: mechanics must inspect aircraft frequently due to the stresses of low-level firefighting flight (which can cause more wear than normal flight hours). If Australia eventually owns more aircraft, maintenance and parts inventory would become a direct state expense; currently, by leasing, much of that responsibility is on the operators.

Personnel (Pilots and Crew):

Skilled pilots, maintenance engineers, and support crew are essential and form a significant operating cost. Many firefighting pilots are contracted seasonally, coming from a global pool that moves between continents. Operators must pay pilot salaries (often with hazard pay given the risky flying), and agencies may cover costs for embedded roles like Air Attack Supervisors or contract managers. In addition to pilots, each aircraft might have an aircrew (co-pilot, flight engineer, drop system operator, depending on type) and a ground crew (mechanics, refuelling personnel).

For helicopters, typically a pilot plus sometimes a co-pilot or crew chief will be onboard; for complex operations like helitack (inserting crews), additional crew may fly. The cost of training these personnel specifically for local conditions is also a factor – e.g., incoming pilots from North America need orientation to Australian terrain and procedures. NAFC and state agencies often run training or certification programs every season before high-risk periods (which is an overhead cost to ensure everyone is on the same safety page).

Insurance:

Operating low-flying aircraft in wildfire conditions is high risk, and insurance premiums for aerial firefighting operations are accordingly high. Contract costs implicitly include insurance coverage for the aircraft hull and liability. After accidents or near-misses, insurance rates can climb.

In some cases, governments self-insure or limit liability via contract terms, but generally operators must carry robust insurance. For example, the unique 747 Supertanker had difficulty securing contracts partly due to insurance and operating cost issues, and it was eventually decommissioned because it wasn’t financially sustainable. The limited pool of operators also means insurance markets are tight. If costs become too high, that can reduce the number of available aircraft in the market (a supply issue that could drive prices up further – a vicious cycle).

Wear and Tear/Airframe Age:

Some firefighting aircraft are older models (e.g., converted 1980s airliners or ex-military cargo planes from the 1960s–70s). Aging airframes require more frequent checks and part replacements. NAFC has identified fleet age as an area of concern, noting that some contracted aircraft are aged and that "fleet modernisation and renewal" must be considered to keep reliability high. Older aircraft can also face parts obsolescence issues (finding or fabricating spare parts for a 50-year-old plane can be costly). Thus, part of the operating cost includes long-term sustainability – eventually upgrading to newer models (like replacing older Convair or DC-10 tankers with newer Boeing 737s or Dash-8 Q400 multirole airtankers, as has been happening gradually).

4.3 Training and Readiness

For aerial firefighting to be effective, not just pilots but also ground crews and support personnel require specialized training. This includes:

Pilot Training and Certification:

Firebombing pilots undergo rigorous training in drop techniques, low-level flying, and coordination with fire agencies. In Australia, NAFC and AFAC ensure there are standard training programs and accreditation. Some training is done in simulators (for example, there are flight simulators for water-bombing scenarios being developed – NAFC's "Aviation Simulation Project" is one initiative). Training time and cost is significant: pilots often need to fly with experienced leads before being cleared to lead drops themselves, and they need to learn local conditions (winds, fuel types, weather patterns).

Air Crew (Observers, Winch Operators, etc.):

Many helicopter missions involve crew like winch operators (for rescue or insertion) or navigators. These crew members train for firefighting scenarios, including safety protocols like what to do if a water drop causes a sudden updraft or if visibility is lost in smoke. Some crew are from firefighting agencies (e.g., an Air Attack Supervisor often is a fire service officer trained to fly and communicate with pilots).

Support Personnel:

This includes Air Base Operators, who manage the bases where aircraft reload. They are responsible for mixing retardant, refuelling planes, loading them efficiently, and maintaining safety on the ground. NAFC notes roles such as Air Base Manager, Aircraft Loader, and Aviation Radio Operator as part of the aerial firefighting ecosystem. These personnel often undergo annual training refreshers in things like handling retardant safely, communicating with pilots via radio, and emergency response (e.g., how to respond to an aircraft incident on base).

Training incurs costs in instructors, fuel for training flights, simulation facilities, etc. However, it's a crucial investment as it improves mission success and reduces the risk of accidents (which can be far costlier). Some costs are shared internationally: Australian and North American pilots sometimes participate in exchange programs or joint training, given they often work together.

4.4 Logistics and Infrastructure

The success of aerial suppression hinges on having the right logistics and infrastructure in place. Key elements are:

Airbases and Airstrips:

Each state maintains a network of designated tanker bases and helicopter staging areas. Major bases (often at airports) have retardant mixing tanks, fuel, and equipment to service large airtankers. Smaller regional airstrips might be upgraded with portable retardant batch plants and fuel trailers during fire season to host SEATs or helicopters. Building and maintaining this infrastructure is a cost. For instance, after a big fire season, a state might invest in expanding an existing airstrip or installing permanent retardant storage tanks to improve turnaround times. Some bases are jointly used by multiple states – e.g., Dubbo in NSW can serve northern Victoria or southern Queensland if needed. Efficient base location and preparation is part of what NAFC's "Resource-to-Risk" planning addresses, optimizing coverage so that aircraft have reasonably short ferry distances to likely fire hotspots.

Maintenance Facilities:

While day-to-day maintenance is often done at the bases or by mobile crews, heavy maintenance or repairs might need hangar facilities. Australia's general aviation industry (85% of the national fleet is Australian-owned and maintained) has benefitted from the steady work of maintaining firefighting aircraft. Companies like Coulson (in NSW) or Field Air (which operates AT-802s) have local facilities. In emergency cases (like if an airtanker suffers a mechanical issue), getting parts flown in or temporarily substituting an aircraft is part of logistic planning.

Relocation and Ferrying:

At times, moving aircraft around the country is necessary – e.g., if a severe fire outbreak occurs in WA, NAFC might redeploy some eastern states aircraft over there. These ferry flights cost fuel and crew time (and risk exposure). Likewise, at the start and end of the season, aircraft have to be ferried across the ocean to/from the Northern Hemisphere. The logistics of these long ferry flights (including arranging in-flight refuelling stops or shipping by cargo plane in case of helicopters that can't fly that far) are complex and costly. For example, in 2001, two Air-Cranes were flown from the US to Australia aboard an Antonov An-124 cargo jet (paid for by the Australian government). Nowadays, most firefighting aircraft can self-deploy (with extra fuel tanks or via island-hopping), but it still takes coordination.

Communications and Command Systems:

Effective aerial ops require robust communication networks – radios, satellite links, tracking systems. Australia utilizes systems like Aircraft Tracking (so incident command knows where each aircraft is in real time) and digital mapping tools that can be updated from the air. These systems have associated costs for equipment, software, and personnel (like radio operators). The ARENA system (developed by NAFC) is a software platform housing nearly 10 years of aerial incident data, now being leveraged to analyse effectiveness. There's also investment in common terminology and protocols so that if, say, a Canadian pilot and an Australian fire controller are working the same incident, they communicate clearly (Australia has adopted many of the standard Incident Command System air operations terminologies).

Resource Sharing Logistics:

When an aircraft moves interstate or internationally to assist, cost-sharing arrangements kick in. For interstate within Australia, there are agreements on who pays for what (usually the requesting state pays the operational hourly costs while the providing state or NAFC covers the relocation). Internationally, arrangements exist (like between NAFC and CAL FIRE or the USFS) to facilitate loans of aircraft. Negotiating these arrangements and handling the administrative side (billing, legal permissions, customs for equipment, etc.) are part of NAFC's administrative overhead.

4.5 Administrative and Overhead Costs

Behind the scenes, organizations like NAFC and the state fire agencies incur overhead costs to manage aerial firefighting. This includes:

Planning and Coordination Staff:

NAFC is a small company under AFAC, but it employs staff who plan the national fleet mix, negotiate contracts, and coordinate during operations. Similarly, each state may have an Aviation Operations unit within its fire service or emergency service department. These staff do work like season planning, contract management, compliance audits (ensuring contracted aircraft meet safety standards), and post-season reviews. Their salaries and office costs are part of the overhead.

Safety and Standards Development:

Ensuring safe operations has a cost – regular safety audits, developing guidelines, running workshops for pilots and firefighters to learn about each other's capabilities and limitations, etc. Given the inherently dangerous nature of low-level flying, a strong safety management system is essential. NAFC convenes national groups of aviation experts to share information and improve processes. The time and resources to hold these meetings, produce manuals, and implement recommendations are part of overhead.

Research and Development:

Some budget is allocated to research, such as the **"Why Fly?" project that NAFC mentions , aimed at statistically analysing aerial firefighting effectiveness. Investing in R&D (like fire simulators, new drop technologies, or better decision support tools) should eventually pay off in improved efficiency, but it requires upfront funding.

Insurance (Liability) and Legal:

NAFC likely carries liability insurance and legal coverage for its role in coordinating contracts. Contracting dozens of aircraft from around the world involves complex legal agreements – ensuring responsibility for accidents, damage, or other liabilities is clearly delineated. There are legal fees and risk management strategies at play.

Public Information and Alerts:

Some overhead is also in public-facing aspects. For example, issuing warnings to other aircraft (closing airspace around fires to keep hobby drones or private planes out), or informing the community about planned water-bombing operations (especially if using chemical retardant near waterways, there are environmental precautions and notifications required). Agencies often have to engage with communities – e.g., explaining why a particular water-bomber is or isn't being used in a local fire (since public perception can be that more aircraft should always be thrown at a fire, when sometimes they're not effective under certain conditions). Managing these expectations is partly a communications cost.

In financial summary

While the cost of aerial firefighting in Australia runs into hundreds of millions of dollars over a decade, stakeholders generally consider it money well spent when weighed against the potential damages of uncontrolled fires. Studies and inquiries frequently emphasize cost-effectiveness in terms of value – for instance, it's pointed out that aerial firefighting, though expensive, provides valuable support that can save lives and significant property and environmental values. The 2020 Bushfire Royal Commission recognized that aircraft are a critical part of firefighting capability, and recommended sustained investment and better national coordination of this resource (including exploring a larger Commonwealth role in funding) – indicating that the cost is justified by the benefits when managed correctly.

However, it's important that this expenditure be optimized. Cost-effectiveness can be improved by data-driven deployment (using aircraft where they make the most difference), by maintaining a balanced fleet mix (not overspending on one very expensive asset if the same money could fund several less expensive ones that collectively have greater impact), and by sharing resources (both between states and internationally). We will now look at how effectiveness is measured – tying together cost and outcome – to understand if and when these aerial investments pay off in terms of fire suppression success.

5. Effectiveness and Performance Metrics

A central question for policymakers and fire managers is: how effective is aerial bushfire suppression in Australia in achieving desired outcomes, such as faster fire containment, reduced fire size, lives and properties saved, and improved cost-efficiency of firefighting efforts? This section examines the performance of aerial firefighting using various metrics and data, while also discussing the challenges in measuring effectiveness. Key metrics include response time, containment success rates, area and property protected, lives saved, and cost per outcome.

5.1 Speed of Response and Initial Attack Success

One of the clearest advantages of aerial suppression is speed of response. Aircraft can often reach a new ignition in a fraction of the time it would take ground crews, especially in remote or roadless areas. This rapid response is crucial because bushfires can grow exponentially in their early stages. If a fire is attacked quickly while still small (initial attack), the chances of containing it before it becomes a large, damaging blaze are much higher.

Research in Australia has quantified this. A landmark study by the Bushfire CRC (Plucinski et al. 2007) analysed initial attack outcomes for bushfires with and without aerial support. The findings can be summarized as follows:

Under moderate fire weather conditions (Forest Fire Danger Index below 24) and when response (detection to first attack) was fast (within 2 hours), the probability of containing the fire on first attack was 80% with aerial support, compared to 30% without aircraft. In other words, adding an aircraft turned a fairly unlikely containment into a very likely one in these conditions – a huge boost in success rate.

Under high fire danger (FFDI 24–49) with a very quick response (first attack launched within 30 minutes of detection), containment success was about 50% with aircraft vs only 10% without. This demonstrates that at higher fire danger, fires are harder to control, but aerial support still multiplied the chance of success by five-fold in those early, critical moments (from very unlikely to about even odds).

In contrast, under extreme fire weather (FFDI 50+), even a quick initial attack had low success probabilities – around 40% with aircraft vs 30% without. In extreme conditions (very high temperatures, strong winds, very low humidity), fires often spread so fast and intensely that initial efforts frequently fail, whether aerial or ground. The data indicates aircraft provided only a marginal improvement in these scenarios – in other words, when nature is at its worst, our tools have limited effect.

Speed is Critical: The First Hour Matters

These statistics highlight two key points. First, timeliness is everything – getting water or retardant onto a fire quickly (within the first hour) dramatically improves odds of containment, especially under moderate to high conditions. Aircraft, by virtue of speed, are often the only way to achieve that quick response in rural Australia. A motto in fire aviation is: "Hit it hard, hit it fast." The faster you hit a new fire, the smaller and cooler it is, and the easier to put out.

Conditions Matter: Weather and Timing Influence Success

Second, effectiveness is strongly weather-dependent. Aerial suppression works best in mild to moderate conditions or on the less intense flanks of a fire. In the worst weather, drops may evaporate before reaching the ground, or winds may carry firebrands well ahead of any area you treated, causing new spot fires beyond the retardant lines. Pilots also may be grounded if winds are above safe limits or if visibility is too poor (e.g., dense smoke columns or nighttime, though night operations are now cautiously expanding with helicopter).

The above is supported by anecdotal evidence from numerous fires: e.g., during Black Saturday 2009, aircraft were largely ineffective in the peak afternoon fire runs due to extreme conditions, whereas the following day when conditions eased, aircraft played a big role in stopping residual fire spread near communities.

Fast Response, Small Fires: The Power of Early Aerial Action:

In terms of response speed, Australia's arrangement of pre-positioning aircraft on high fire danger days yields average dispatch times often just minutes after a fire call. For example, in high risk areas in Victoria, a network of small lightning-spotting aircraft and helicopters are on standby; if a strike is detected or smoke reported, an aircraft can be overhead in 15-30 minutes. In NSW, they implemented the "Rapid Aerial Response Teams" (RART) where a helicopter with firefighters and water capability is dispatched immediately to any fire in designated zones, often arriving well before ground crews.

The metric often cited is the proportion of fires contained at under 5 hectares or similar threshold. While exact national figures vary year to year, many states report that upward of 90-95% of bushfire ignitions are contained in initial attack (meaning they never become large fires), thanks to a combination of quick ground and aerial response. For instance, CAL FIRE in the U.S. has a similar stat: ~95% of fires are contained at less than 10 acres (4 ha), reflecting aggressive initial attack with both engines and aircraft. Australia's numbers are likely similar in many regions, although the very remote areas (where even aircraft might take longer to reach) can pull that percentage down.

The value of this initial attack success is enormous – every fire stopped when small is potentially a major disaster averted. It is hard to quantify lives saved or property saved from these "invisible victories" because we rarely hear about fires that didn't happen. But one can point to historical contrasts: the 1980s and earlier had many fires that grew large simply because it took many hours for ground crews to reach them, whereas now an aircraft might squash the same kind of fire in its infancy.

5.2 Lives and Property Saved

Quantifying lives and property saved by aerial firefighting is challenging because it involves hypotheticals (what would have happened without the aircraft?). However, there are documented cases where officials credit aircraft with preventing greater losses:

The earlier example of Elvis the Air-Crane in 2001–02: the helicopter was lauded for helping save nearly 300 homes in Sydney's suburban fringe and protecting 14 firefighters from entrapment. These numbers came from New South Wales officials who assessed that without the heavy helicopters intervention, the fire would have likely destroyed hundreds more structures in those severe fires.

In the 2019–20 Black Summer, numerous townships were defended by combined ground and air efforts. For instance, in early January 2020, a DC-10 VLAT made critical drops around the town of Eden, NSW when a massive fire approached. Local RFS commanders noted that those retardant lines helped the largely volunteer crews save the town, limiting losses to the town's periphery. Similar stories emerged from places like Humevale (VIC), where sustained water-bombing by helicopters protected houses nestled in forest.

When Aerial Support Saves Homes—and When It Falls Short

A tragic counterpoint underscores the potential: In the 2003 Canberra fires, aerial resources were overwhelmed and unable to stop firestorms that entered the suburbs, resulting in 4 fatalities and 500 homes lost. In subsequent inquiries, it was surmised that more aerial support earlier might have reduced the damage (though it's speculative given the intensity). As a result, investments in aerial capacity were ramped up post-2003. By contrast, in the 2020 Canberra fires (in Namadgi National Park), a strong aerial response (including LATs) helped prevent fires from reaching suburban Canberra – essentially a replay of 2003 was averted.

Fire agencies often use "properties saved" as a metric in post-incident analysis. This is usually done by counting houses that were in the fire's path or very close to it that did not burn down, and attributing that to suppression efforts. Aircraft contribute significantly, especially in asset protection drops (e.g., helicopters continually wetting down a rural subdivision as fire fronts pass, or airtankers laying retardant around a town). For example, after the 2015 Sampson Flat fire in South Australia, analysis showed hundreds of homes were saved by firefighting efforts; water-bombing helicopters working with ground crews were credited for many of those in the peri-urban fringe of Adelaide.

As for lives saved, direct attribution is rare (because saving lives is often a combined effort of warnings, evacuations, and suppression). However, one can infer life safety improvements by the fact that aggressive aerial attack can slow fires and give people more time to escape. Also, aircraft themselves sometimes perform rescues (like heli winching people out). In 2020, military Chinooks pulled dozens from raging fire areas – though not firefighting per se, it's aerial assistance saving lives.

One clear measure is firefighter lives: by cooling fire behaviour, aircraft reduce the likelihood of firefighters being overrun. There are documented near-misses where a timely water drop shielded firefighters. Tragically, when aircraft are absent or cannot fly, firefighters face higher personal risk. So while intangible, aerial support undoubtedly has saved firefighter lives by reducing the intensity of flames they face on the ground (as in the Elvis example with 14 RFS firefighters saved in 2001).

5.3 Suppression Effectiveness and Fire Containment

Effectiveness can be viewed through the lens of "drop effectiveness" – i.e., did a given water or retardant drop accomplish its intended tactical goal? The U.S. Forest Service undertook an extensive study called AFUE (Aerial Firefighting Use and Effectiveness) to measure this, which concluded in 2020. Some relevant metrics from AFUE:

The study introduced "Interaction Percentage (IP)" – the proportion of drops that actually interacted with fire (as opposed to being preventative drops where fire never reached, or missing the target). It found that water drops (mostly from helicopters or scoopers) have nearly 100% interaction because they are usually aimed directly at flames, while retardant drops from large airtankers have lower interaction, 74–80% on average. This is expected: many retardant drops are placed ahead of the fire intentionally, so some never see fire if conditions change or if it was for contingency. This doesn't mean they were wasted – having fire not reach a retardant line might mean the line helped steer the fire or the fire was suppressed before reaching it – but it complicates raw "success" measures.

Drop Accuracy and Tactical Success Rates:

For drops that did interact with fire, AFUE used "Probability of Success (POS)" – essentially, if a drop hits the fire, how often does it achieve the desired effect (slow/stop that part of the fire). They found helicopters and fixed-wing tankers had roughly similar success rates (~72-

73%) in large fires, when considering drops that engaged the fire. If excluding very small helicopter (since on big fires small Type 3 helicopter are less used), the helicopter success average rose to ~84%. So effectively, when used appropriately, both airtankers and helitankers succeed in meeting their drop objectives about 3 out of 4 times or better. That indicates a high level of effectiveness tactically.

What constitutes success in a drop? For water, success might mean knocking down flames to low intensity on that sector of fire. For retardant, success typically means the fire was stopped at that retardant line or was significantly slowed. There are qualitative aspects too: e.g., even if a drop doesn't fully stop fire spread, if it buys 30 minutes of slowed fire, that can be a success if ground crews exploit that to strengthen a firebreak.

Measuring Aerial Firefighting Efficiency and Value

Australia has not published an equivalent detailed statistical study yet (though NAFC's "Why Fly?" project aims to analyse its ARENA database for such insights). However, field experience echoes the above: well-placed drops under suitable conditions are very effective, whereas drops under extreme conditions or misapplied yield little benefit.

One measure used by incident controllers is "litres per hectare" – how much water or retardant was applied relative to fire area or perimeter contained. If an extraordinary amount was used for little gain, that implies inefficiency. If relatively modest drops stopped a big fire spread, that's high efficiency. NAFC's strategy document suggests future metrics might include "litres delivered per hour, per dollar" and "response time against target time" as key performance measures to better quantify efficiency. In other words, they want to measure not just that aircraft flew X hours, but what was achieved in those hours in terms of output and outcome.

Another angle is cost-effectiveness: e.g., cost per hectare of fire suppressed. If one fire was stopped at 100 ha with $100k of aircraft, that's $1k/ha. Another might have $1M of drops and still burn 10,000 ha ($100/ha). But context matters: maybe the expensive one saved a town (priceless in terms of values protected) whereas the cheap one just burned grassland.

5.4 Limitations and Factors Affecting Effectiveness

Important to temper the above successes are the limitations and conditions in which aerial suppression is less effective:

Extreme Fire Behaviour:

As noted, in high winds (say >50 km/h) and extreme temperatures, fires can spread via embers far ahead of drops. Aircraft struggle because the fire is essentially outrunning or bypassing suppression efforts. Also, strong winds can disperse water/retardant so it doesn't land where intended. Pilots sometimes describe drops in strong winds as the liquid "blowing off course" or "atomizing" before it hits the target.

Smoke and Visibility:

Aircraft generally need sufficient visibility to operate safely and effectively. In mega-fires generating huge smoke plumes, visibility can drop to near-zero around the fire, grounding aircraft or making drops blind. During Black Summer, there were days when the smoke was so thick that almost no flying could be done until it cleared. This obviously reduces effectiveness at critical times.

Nighttime:

Historically, aerial firefighting ceased at dusk for safety. This allowed fires to rage unimpeded all night. This is changing – both California and Australia have begun night aerial firefighting with helicopters equipped with night-vision goggles and proper training. In early 2019, Victoria conducted its first night firebombing operations successfully, and NSW followed. Night operations can be a game-changer for effectiveness: fires typically lay down (calm) at night, so hitting them then can be very effective in containment. However, the rollout of night ops is still limited and careful due to safety; it will improve overall effectiveness in coming years as it becomes routine. For now, it's a factor that most aerial suppression still only occurs about 10-12 hours a day.

Terrain:

In very rugged or forested terrain (thick canopy), drops may be intercepted by the canopy and not reach ground fuel, especially for water which doesn't stick around like retardant. This can reduce drop effectiveness. Steep terrain can also create updrafts or downdrafts that complicate flying and drop trajectories.

Distance/Reload Time:

If an aircraft has to travel a long way to reload (fuel or retardant), there's a lot of dead time not dropping on the fire. Effectiveness per hour declines if an airtanker is spending 40 minutes of each hour just commuting. That's why having mobile retardant bases or strategically locating reload points (even for helicopters, placing portable water tanks close to the fire) is crucial. An inefficient setup can waste the potential of the aircraft.

Coordination and Ground Follow-up:

Aircraft don't put fires "out" – they suppress them. If ground crews do not follow up to dig fire line or extinguish what's left, the fire can recover. There have been instances where a fire was believed to be controlled by drops, but without ground verification, it later flared up. So effectiveness is tied to an integrated approach. Poor coordination can negate aerial efforts (like if ground crews aren't ready to capitalize on an airtanker's drop, the fire might rekindle). Conversely, when well coordinated, even a moderate drop can lead to a fully extinguished section of line because ground teams move in immediately to mop-up.

Despite these caveats, aerial firefighting is widely regarded by fire authorities as having high operational value in reducing losses, even if quantifying that value precisely is difficult. Public perception also equates planes and helicopters with "strong action" – people take comfort seeing them overhead (though this can also lead to unrealistic expectations if people assume aircraft alone will save them regardless of conditions).

5.5 Cost-Efficiency Considerations

Linking effectiveness to cost, one can consider cost per avoided damage. For example, if $5 million of aerial firefighting prevented a fire from destroying an area with $100 million in property (very plausible in a suburban fringe fire), then the cost-benefit is clear. On the other hand, if a huge expenditure is made on a remote fire that ultimately burns mostly uninhabited forest, one might question if those resources could have been better allocated (perhaps to mitigation or other fires).

Australian agencies employ a form of "value-driven suppression" where more resources (including aircraft) are concentrated where values are highest (human life, then property/infrastructure, then environmental/cultural assets). So effectiveness is partly measured in outcomes like "no lives lost, X properties saved" in a given fire, rather than area burned. A fire might burn large area but if most was remote forest and no one died and minimal homes lost, that is seen as a success of suppression effort (especially if conditions were extreme).

From a productivity standpoint, one can measure outputs:

e.g., litres dropped per hour flown. If a helicopter can do 8 drops of 2,000 L in an hour (16,000 L/hour) and a large airtanker can drop 12,000 L in one sortie taking one hour (12,000 L/hour), superficially the heli delivered more water that hour. But if the fire was 20 km from water, the heli might only do 4 drops (8,000 L/hour). So productivity depends on context. Multi-rotor drone swarms in future might do many tiny drops – high frequency but low volume each. We may need new metrics to compare such tactics.

NAFC has acknowledged that “currently we measure activity, not effectiveness” and that needs to change. They propose metrics like:

Response time vs target time: Did the aircraft arrive within, say, 30 minutes as planned?

Litres delivered per dollar: A crude efficiency measure to compare across types.

Outcome-based metrics: e.g., was the fire kept to a certain size or was a specific asset successfully defended?

In practice, after each major fire, internal reviews often qualitatively assess the aerial contribution: Did the aircraft help achieve the incident objectives? If not, why (was it weather, availability, communications)? Those lessons feed into future improvements.

Finally, one must note community and firefighter morale – while not as tangible, having aircraft on a fire often boosts morale of ground crews (“air support is on the way!”) and shows the community that everything possible is being done. This can have indirect effectiveness in galvanizing effort and maintaining public trust. Conversely, visible failure of aircraft (like drops that seem to do nothing on a raging crown fire) can be disheartening, but also educative that there are limits.

Summary:

The effectiveness of aerial bushfire suppression in Australia is high when used in the right way: it significantly increases initial containment success rates in moderate to high conditions, has saved many lives and properties when integrated into the suppression strategy, and provides capabilities that ground efforts alone cannot (speed, reach, volume). It is not a panacea – extreme fires will overwhelm it, and it must be cost-effective. The next sections compare how Australia’s approach and success with aerial firefighting stack up against other countries (Section 7), and what best practices exist to maximize effectiveness (Section 8).

6. Aerial Firefighting Across Australian States and Territories

Australia's states and territories each face unique bushfire challenges, and while they collaborate nationally through NAFC, there are differences in how each jurisdiction configures and utilizes its aerial firefighting resources. This section provides an overview of each state/territory's approach, notable operations, and any specialized practices or fleet compositions. Emphasis is on how aerial bushfire suppression in Australia is tailored to diverse regional conditions, from tropical savannas to temperate forests.

6.1 New South Wales (NSW)

New South Wales experiences a wide range of fire environments – from the grasslands and farmlands of the west, to the dense eucalyptus forests of the Great Dividing Range, to the populous coastal and Blue Mountains areas. The NSW Rural Fire Service (RFS) is the lead combat agency for bushfires, and it operates one of the largest aerial firefighting setups in the country.

NSW RFS, in partnership with NAFC, typically secures a significant portion of the national fleet. For the 2024/25 season, assets based in NSW include at least one Boeing 737 Fire liner (LAT) stationed at RAAF Richmond, a C-130 Hercules LAT (also at Richmond), and a BAe RJ85 LAT based in Dubbo, among others. NSW also fields numerous SEATs (Air Tractor AT-802s distributed in high-risk rural zones) and a robust helicopter fleet: heavy Type 1 helicopter like the Sikorsky S-64 Air-Crane and UH-60 Black Hawks (in recent years private operators have imported ex-US Army Black Hawks and fitted them for firefighting), and plenty of medium Type 2 and light Type 3 helicopters (Bell 412s, AS350s, BK117s) which are often pre-positioned around Sydney, the Hunter, North Coast and the Snowy region.

NSW is notable for being the first Australian state to obtain a large fixed-wing tanker for exclusive use: the 737 "Marie Bashir" (Tanker 138) delivered in 2019 is effectively owned by NSW (though operated by Coulson) as part of a government strategy to have a resident year-round LAT capability. This came after a series of bad fire seasons and public pressure post-2013 fires in the Blue Mountains. That aircraft can also be loaned to other states via NAFC when available (it's considered a "national" asset but NSW-funded).

NSW's Tactical Aerial Teams and Firefighting Hubs

New South Wales also leverages tactical aerial firefighting teams. It has the Remote Area Firefighting Team (RAFT) and RART (Rapid Aerial Response Team) concepts: essentially pairing helicopters and highly trained firefighters who can be quickly inserted into remote fire starts that aircraft bomb, to finish the job on foot. For example, a Bell 412 might fly a team of RAFT crew to a remote lightning strike fire, drop them off, then use its bucket to support them as they cut fire line. This integration maximizes the effect.

The state has major aerial hubs at Richmond (near Sydney), Bankstown Airport, Tamworth, Dubbo, and Cooma, among others, where large aircraft can operate. In the southern part of NSW, aerial resources are often shared with the ACT and Victoria (fires in the Snowy Mountains or South Coast might get Victorian aircraft help and vice versa).

During the 2019–20 Black Summer, NSW had perhaps the most intensive aerial campaign in its history. At peak, over 100 aircraft (various types including international assistance like Canadian Convairs and Singaporean Chinooks) were working fires in NSW. While the season still saw catastrophic losses, RFS leadership credited aircraft with saving many towns. One RFS report noted that in the coastal fires, towns such as Bermagui and Nowra were shielded by retardant lines laid by LATs in advance, significantly reducing the damage when the fire hit.

NSW RFS also invests in technology:

they have a fixed-wing “Firebird 100” infrared mapping plane (Cessna Citation) for line-scanning and several surveillance helicopters with infrared and real-time video downlink (these feed into their State Operations Centre to coordinate strategy).

Overall, NSW’s approach is to maintain a large and varied fleet, positioning heavy hitters near Sydney and regional centers, and ensuring a layered response (small local aircraft for initial attack, big planes for major fires, and plenty of helicopters for versatility). They operate under an incident management system where an “Air Operations Manager” in the Incident Management Team will draw upon these resources as needed, coordinating through an Air Desk at RFS HQ which interfaces with NAFC for additional requests.

6.2 Victoria

Victoria is another state with very high bushfire risk, historically suffering some of Australia’s worst fires (1939 Black Friday, 1983 Ash Wednesday, 2009 Black Saturday). Victoria’s aerial firefighting is managed by Forest Fire Management Victoria (FFMVic) in partnership with the Country Fire Authority (CFA) and Emergency Management Victoria (EMV). There is a dedicated State Aircraft Unit (SAU) that coordinates aircraft procurement and operations – this was one of the earliest such units, established in the 1980s.

Victoria usually contracts a mix of aircraft similar to NSW in number (often around 50–60 contracted plus many on-call). For example, common Victorian assets include: Air-Cranes (e.g. Elvis was famously first brought to Victoria), Sikorsky S-61 heavy helicopter, a couple of Type 1 helicopter (often a Chinook or large Erickson machine) based around Melbourne or strategically moved; plenty of Type 2 helicopters (Bell 212/412, etc.) spread across regional centres like Ballarat, Benalla, Latrobe Valley; and Type 3 helicopter in high lightning areas (e.g. around the Alpine National Park).

Victoria's Aerial Strategy: SEATs, LATs, and Remote Crew Deployment

On the fixed-wing side, Victoria shares LATs with NAFC – in recent years they have hosted aircraft like a C-130 LAT in the north-east (Wangaratta or Albury) which could cover alpine fires, and an RJ85 or Q400 at Avalon Airport to cover western/central Victoria and deploy quickly to South Australia or Tasmania if needed.

Victoria heavily uses fixed-wing SEATs and water bombers particularly in its grassland and farmland areas. The state has some dedicated agricultural-strip networks where Air Tractor AT-802s are on contract – e.g., places like Hamilton in the western districts, or Mildura in the north-west. In mallee country and grassfire prone areas, these small bombers often stop fast-moving grassfires before they hit towns.

A unique aspect in Victoria is the concept of "Hover exit" operations – winching crews from helicopters – which they have refined for initial attack in remote forest. They also have specialized " rappel crews" (firefighters trained to rappel from a hovering helicopter into remote spots) – one of the few Australian jurisdictions to do so (drawing from Canadian/American "helitack" practices).

Victoria's Adaptive Aerial Strategy and Night Operations

Victoria's climate means some years they face significant fires in the alpine High Country and forests, while other years the threat is grassfires racing across the flat western districts or in the peri-urban scrub of places like the Dandenong Ranges.

The state adapts by moving aircraft as needed. For instance, in a dry summer with drought in Gippsland, they will stage more aircraft at bases like Bairnsdale and Albury to cover the eastern forests. If western grasslands are cured and at risk, they'll ensure SEATs and helicopters are positioned at places like Hamilton and Bendigo. Victoria also pioneered the use of night-time aerial firefighting in Australia: in early 2019, trials were conducted where a Sikorsky S-61 and a smaller Bell 412, equipped with night-vision goggles and lighting, successfully water-bombed fires after dark. This capability has since been modestly expanded, giving Victoria an edge in attacking fires 24/7.

A notable aspect in Victoria is cross-border cooperation:

the state frequently shares aerial resources with South Australia (for fires near the SA/Vic border or if one state has spare capacity to assist the other) and with New South Wales and Tasmania. For example, during Tasmania's 2019 fires, several Victorian aircraft (including an Air-Crane and fixed-wing bombers) were deployed south across Bass Strait to help. This is facilitated by NAFC but also longstanding MOUs between state agencies.

In summary, Victoria's aerial firefighting strategy emphasizes quick initial attack (with pre-positioned small aircraft and rappel crews) and heavy reinforcement on bad days (with large aircraft near key risk areas). The investment has paid dividends; for instance, in the 2019–20 season, despite horrific conditions, aerial support helped save the towns of Corryong and Omeo when massive fires approached – those towns experienced ember attacks and some losses, but were not wholly consumed, in part due to extensive water and retardant drops around them.

6.3 Queensland

Queensland has a hot tropical to subtropical climate with a winter/spring fire season in the south-east and more year-round grassfire risks in the interior. Historically, Queensland had fewer catastrophic fire events compared to the southern states, but this has been changing. Notably, in 2018, Queensland had an unusually severe late-spring fire outbreak (with fires in tropical rainforests – unprecedented conditions fueled by climate anomalies).

Queensland's aerial firefighting is coordinated by Queensland Fire and Emergency Services (QFES). The state uses a mix of contracted aircraft, though generally fewer large fixed-wing assets than NSW/Vic. Emphasis is on helicopters and smaller fixed-wing bombers that can serve dual roles (bushfires and other emergencies like floods). For example, QFES contracts multiple Type 2 and 3 helicopters each season – commonly Bell 412s, Bell 214Bs, AS350s – positioned around high-risk regions such as the populous SEQ (South East Queensland) corner (Brisbane, Gold Coast, Sunshine Coast hinterlands), as well as near regional centers like Rockhampton and Townsville when needed.

Queensland's Use of LATs, SEATs, and Local Partnerships

The state has in recent years also made use of LATs on loan from NAFC when conditions warrant. During the 2018 fire crisis, NAFC deployed a C-130 and a 737 to Queensland to assist local efforts in containing big forest fires in central QLD. Impressed by this, QFES in subsequent years arranged to have at least one large air tanker on standby in the spring period (typically an NAFC-contracted LAT moved up from southern states as their season hasn't started yet in September/October).

Queensland's landscape includes vast areas where traditional ground access is tough, so SEATs (Air Tractors) are useful in western QLD for grassfires. QFES often partners with local governments and private operators in rural areas to call up cropduster planes for fire drops under its "call when needed" arrangements.

A peculiarity for QLD is the fire management on large state-owned plantations and national parks in the coastal strip. Agencies like HQPlantations (for pine plantations) sometimes retain their own small water-bomber planes or contract helicopters to protect valuable timber assets. These often integrate with QFES during major incidents.

Queensland's Evolving Aerial Strategy and Military Support

The aerial strategy in QLD is still growing; the state has recognized that with climate change, their bushfire risk is increasing. After 2018, QFES has enhanced training and pre-planning for aerial firefighting. The state now has an Air Operations Unit ensuring that on severe fire days, aircraft are pre-deployed (for instance, on forecast extreme days in spring, they might station a water-bombing helicopter at scenic rim towns or near high-risk parks).

Queensland also benefits from military assistance at times – being home to many Australian Defence Force bases. In big fire situations, RAAF helicopters or Army Black Hawks have occasionally pitched in for water dropping. A notable example is the 2019 fire on World Heritage K'gari (Fraser Island) where a Navy MRH-90 helicopter helped with bucket drops alongside civilian contracted aircraft.

In terms of infrastructure, QLD has fewer established tanker bases (since they rarely host large airtankers long-term), but during operations they set up temporary bases. For instance, in 2018 the LATs operated out of Bundaberg Airport with portable retardant mixing facilities brought in.

In summary, Queensland's aerial firefighting capability is on an upward trajectory, moving from a historically modest fleet to a more robust one as recent fire seasons have demanded it. The focus remains on quick response to stop fires before they grow, using a lot of helicopters for direct attack near communities, and calling in larger bombers from the national pool when conflagrations exceed local capacity.

6.4 South Australia (SA)

South Australia has a more centralized population, with high bushfire risk particularly in the Mount Lofty Ranges (Adelaide Hills) and lower Eyre and Yorke Peninsulas, as well as in the Lower South East (around Mount Gambier) which has large pine plantations and forests contiguous with western Victoria. The South Australian Country Fire Service (CFS), with support from the Department of Environment, coordinates aerial firefighting for the state.

SA's aerial fleet typically includes a number of fixed-wing water bombers (often AT-802 Air Tractors) and medium helicopters contracted each summer. A key installation is the Clare Valley / Adelaide Hills aerial firefighting setup: they maintain a dedicated airbase at Brukunga (near Mount Barker) which houses multiple AT-802s and helicopters ready to respond in the Adelaide Hills. This area sees frequent summer fires that threaten suburbs and vineyards, such as the significant 2019 Cudlee Creek fire (where several bombers and helicopters played a major role in saving hundreds of homes, though sadly some were lost).

South Australia usually has at least one Type 1 heavy helicopter (often an Erickson Air-Crane or a large Kamov Ka-32) on lease during summer, shared in usage with Victoria if needed. Given SA's smaller budget, they maximize resource sharing – for example, if a major fire exceeds SA's aerial capacity, NAFC brings in additional aircraft from Victoria or NSW. This occurred during the catastrophic Kangaroo Island fires in January 2020, where LATs from interstate were deployed to assist CFS – including the DC-10 VLAT and multiple water-bombing helitankers – to combat the huge blaze on the island.

South Australia's SEAT Strategy and Cross-Border Coordination

One interesting facet: SA's CFS has a strong network of farm firefighting units and often relatively easier terrain in parts (like broadacre fields), so SEATs are quite effective for them in quickly knocking down field fires. They place SEATs at strategic ag airstrips in places like Port Lincoln (Eyre Peninsula) and Cleve when fire risk is high.

SA also covers some of the arid interior and the Nullarbor – largely low fuel load areas, but they have had big bushfires in mallee scrub. For remote fires, they may rely on water drops by planes since ground access is sparse (the 2021 Blackout complex fires in the Far West were fought in part with aerial ignition for backburning by aircraft to contain them).

Operationally, the South Australian CFS has embraced the national protocols; they integrate with the Victorian system readily. In fact, South Australian aircraft often cross into western Victoria to help and vice versa. It's common that the same contracted company provides aircraft to both SA and Victoria, allowing easy sharing.

Given South Australia's smaller scale, their performance metric is often quick knockdown – and indeed, many SA fires are contained small by aggressive use of bombers and a well-drilled volunteer ground force. When fire intensity overwhelms (like the 2015 Sampson Flat fire or 2020 Kangaroo Island fires), they've learned and improved; after 2015, they upgraded Brukunga base and increased the number of contracted aircraft.

6.5 Western Australia (WA)

Western Australia faces bushfire conditions in its south-west corner (Mediterranean climate similar to California), as well as frequent large fires in the tropical north and arid interior (often started by lightning in savanna or spinifex). The Department of Fire and Emergency Services (DFES) and the Parks and Wildlife Service (within Dept of Biodiversity, Conservation and Attractions) share responsibility, with Parks and Wildlife managing many forested lands.

WA's aerial firefighting approach has some unique elements:

In the Perth region and SW forests, they rely heavily on a fleet of water bombing fixed-wing planes – specifically Air Tractor AT-802s (often with wheel/skid gear, not floats, as there aren't large lakes to scoop from in summer) and smaller piston-engine bombers. These are strategically based at airfields like Jandakot (near Perth), Murray Field, Busselton, and Manjimup during summer. WA was actually one of the first to use Air Tractors extensively in Australia. These aircraft have proven very effective in the jarrah and karri forests – they can navigate the terrain and quickly reload at local airstrips.

WA's helitack capability historically was smaller – a few Type 2 helicopters (e.g. Bell 214 "Boeing" helitankers) are contracted around Perth for the high population areas. In recent years, WA has increased contracts for Type 1 heavy helicopter after experiencing extreme fire seasons (for example, the 2016 Waroona–Yarloop fire disaster). Now, in severe conditions, NAFC may allocate a heavy heli like an Air-Crane to WA for part of the season. WA has also trialled large LATs: a LAT was brought to WA for the first time in the 2015–16 season as a demonstration, operating out of Pearce RAAF Base.

WA's remote area fires (the Kimberley and Goldfields) are often managed with minimal suppression (due to low risk to life/property), but when needed – e.g., if a fire threatens an indigenous community or infrastructure – they might deploy a small plane or heli to quell it. The state's large size means positioning aircraft is challenging – they can't cover everything. Instead, they concentrate aerial resources where people live (SW corner).

Western Australia's Aerial Burning Program and Self-Reliant Strategy

One hallmark is the aerial prescribed burning program in WA's forests. The Parks and Wildlife Service extensively uses aerial ignition (dropping incendiaries from fixed-wing aircraft) to conduct controlled burns over large areas annually. This indirectly contributes to suppression effectiveness by reducing fuel loads. During wildfire operations, those same skills are used to light backburns from the air to contain fires.

WA's effectiveness with aircraft is well-regarded in their domain: they often contain potentially disastrous fires near Perth with a combination of aggressive aerial bombing and a strong volunteer Bush Fire Service. A performance metric: since boosting aerial resources after mid-2010s fires, they've reduced the number of homes lost in subsequent fires. For example, in the 2021 Perth Hills fire, despite extreme conditions, fewer than 90 homes were lost; many more were saved, with firefighters crediting constant water-bombing by several AT-802s and helitankers for keeping the fire out of more densely populated neighborhoods.

One challenge WA faces is distance for backup – unlike east coast states that can borrow neighbors' aircraft, WA is far. NAFC will still send help (e.g., in 2015 NAFC sent aircraft from Victoria to WA by flying across the Nullarbor), but there's a time lag. This puts a premium on WA investing in its own capacity. As climate change is leading to more severe fire seasons (with 2019-20 igniting fires even in normally wet karri forests), we may see WA acquiring or stationing more large assets on its own.

6.6 Tasmania

Tasmania has significant forested wilderness and rural areas at risk of bushfires, with a milder summer but occasionally very dry conditions. The Tasmania Fire Service (TFS) and Parks & Wildlife Service cooperate on firefighting. Due to the island's size and limited resources, Tasmania relies heavily on assistance from mainland Australia for large fires.

Tasmania typically contracts a handful of Type 2 helicopters (often AS350s and BK117s for initial attack and mapping) and a couple of water-bomber airplanes (such as AT-802s or smaller GA8 Airvans with belly tanks) that are locally based. They use these for quick response to local fires. However, for any significant campaign fire – such as the extensive fires in 2013 or the major World Heritage Area fires in 2016 and 2019 – NAFC-arranged aircraft from the mainland are deployed.

For example, in the 2019 fires in Tasmania's southwest, several aircraft including two large helicopters and multiple fixed-wing bombers were ferried across by ship or air to Hobart and operated from there for a week. The logistical hurdle of crossing Bass Strait means Tasmania ideally requests resources early, before the mainland's own season peaks, otherwise availability can be an issue.

Tasmania's Wilderness Fire Strategy and Aerial Asset Protection

Tasmania's use of aircraft is a bit different because much of its fire activity is in remote wilderness (Tasmanian Wilderness World Heritage Area) where suppression is very difficult. In those cases, aircraft are used primarily for protection of specific assets (like heritage-listed infrastructure or towns at the edge of wilderness) and for limiting spread rather than outright control (some fires in peat or rainforest areas can't be put out by bombing). The effectiveness is seen, for example, in saving the town of Geeveston in 2019 by massive water drops on the approaching fire edge.

The state has invested in a modern Air Operations management system and training, recognizing that as climate warms, the formerly rain-soaked Tasmania is experiencing more frequent severe fire weather. One can see improvement: the 1967 Hobart fires (before aerial suppression was available) devastated suburbs; now, with aerial assets, a similar ignition scenario might be mitigated significantly.

6.7 Northern Territory (NT)

The Northern Territory has vast savanna landscapes that burn every dry season. Bushfires NT (the rural fire service) and Parks Australia handle these fires, which are often managed fire for ecological reasons. The NT does use aerial suppression, but usually on a small scale due to the low population density. They contract a few SEATs (Air Tractors) and occasionally light helicopters, mainly to protect remote communities, pastoral infrastructure, or national parks when needed.

A typical scenario: a fire raging across Top End savanna might be left to burn unless it threatens a community or culturally significant site, at which point Bushfires NT will deploy an Air Tractor from Batchelor airstrip (south of Darwin, where they maintain a couple of plane) to knock down flames around the assets. They might also use aerial incendiaries to steer the fire away by backburning, which is a common practice.

Northern Territory's Remote Fire Strategy and Aerial Innovation

In central Australia (Alice Springs region), bushfires are sporadic (following rare heavy rain years that produce abundant grass). When they occur, small planes or choppers may be hired to help control lines in conjunction with graders and ground crews. Given the NT's limited local aviation resources, they too can request NAFC reinforcements, but this is infrequent (for instance, NAFC sent a large helicopter to Alice Springs in 2018 for a period of heightened fire activity after a big rain year).

The NT's metric of success is largely area protected vs area that can be let go. They adopt a strategic suppression approach, and aerial tools enable them to execute that in remote settings relatively cheaply (cheaper to send a plane than mobilize dozens of 4WD units across hundreds of kilometers).

One innovation: The NT has tested drones for ignition extensively, to assist their widespread controlled burning program. That indirectly reduces the need for suppression by preventing late dry-season fires.

6.8 Australian Capital Territory (ACT)

The ACT, being a small territory, relies on NSW RFS and its own ACT Rural Fire Service resources. The ACT has a couple of helicopters on contract (usually shared arrangements with NSW for the Canberra area) and access to NAFC aircraft staged in nearby NSW. The 2003 Canberra fires led the ACT to greatly enhance cooperation with NSW for aerial assets. By agreement, whenever the ACT has a serious fire, NSW will divert substantial aerial resources there (since Canberra's bushfire in 2003 started in NSW anyway). In return, the ACT helps fund some of those assets. For example, a helicopter might be jointly funded to ensure it's based at Canberra during the peak summer. The ACT also maintains a small fixed-wing reconnaissance aircraft for initial attack and mapping.

Given the ACT's tiny size, we won't elaborate more; suffice to say it integrates into the NSW system seamlessly.

Across all these jurisdictions, a common thread is that aerial firefighting has become indispensable for initial attack and for assisting in major fires. The degree of usage varies by local risk and budget, but every state and territory now has plans that involve getting eyes in the sky and water or retardant on the fire very quickly. As NAFC noted, all Australian states and territories participate in national resource sharing and recognize the importance of aerial capability to protect communities and support ground crew】. This national cohesion allows even the smaller jurisdictions to punch above their weight by drawing on the collective fleet.

Having examined Australia's internal operations, we now compare with international models to glean insights and best practices that could further improve aerial bushfire suppression in Australia.

7. International Comparisons: Aerial Firefighting Globally

Australia's approach to aerial firefighting can be better understood in context by comparing it with other countries that have significant wildfire challenges. This section focuses on four key international cases: the United States, Canada, Spain, and Chile. Each provides lessons in fleet composition, effectiveness, command structure, and cost management. We will see parallels – for example, all these countries use a mix of fixed-wing and rotary aircraft – but also differences, such as Spain's reliance on government-owned water scoopers or Chile's evolving strategy after catastrophic fires.

7.1 United States

The United States probably operates the largest and most varied aerial firefighting fleet in the world. Wildfires (especially in the western states like California) are a massive problem, and U.S. agencies have been using aircraft since the 1950s to combat them.

Key features of the U.S. model include:

Mix of Federal and State Programs: The U.S. Forest Service (USFS) and Department of the Interior agencies (like BLM, National Park Service) manage a national fleet primarily for wildfires on federal lands, but also supporting states. Simultaneously, some states have their own fleets; the most notable is CAL FIRE (California's fire department) which operates a large state-owned fleet of 23 Grumman S-2T Tracker airtankers (~4,000 L each), 12 UH-1H Super Huey helicopters (~1,000 L), and 14 OV-10 Bronco spotter planes. Other states like Oregon, Colorado, and Texas have smaller fleets or contract their own suppression aircraft to supplement federal ones.

Large Air Tankers (LATs) and Very Large Air Tankers (VLATs): The U.S. was the first to employ heavy air tankers, converting surplus military bombers and transports after WWII. Today, the USFS contracts a mix of around 20–30 LATs annually (the number varies year to year) from private companies. These include aircraft types such as the Lockheed C-130 Hercules, Boeing 737 Fire liner, BAe-146/Avro RJ85 regional jets, Douglas DC-7 and MD-87, and Dash-8 Q400. They also had at times VLATs like the DC-10 (three are in regular service with 11,350 US gallons capacity each) and previously the 747 Supertanker (no longer active after 2021 due to funding issues). The USFS does not own most of these (except a few HC-130H's being converted for its use); they are contracted much like NAFC does, but on multi-year Exclusive Use contracts. In 2018 the USFS spent over $500 million on firefighting aircraft, highlighting the scale.

A Boeing 747 "Supertanker" (VLAT) dropping a massive load of retardant. The U.S. and several other countries have utilized VLATs on huge wildfires. In 2017, this very 747 helped fight Chile's worst fire. Such aircraft can lay retardant lines up to 3 miles long in one drop, but at very high operating cost. Australia has occasionally used VLAT assistance (e.g., a 747 in 2019–20), but primarily relies on smaller LATs and helicopters due to cost and logistical considerations.

Helicopters: The U.S. uses hundreds of helicopters for wildfire fighting, ranging from Type 1 heavies (like CH-47 Chinook, Sikorsky S-61, Boeing Vertol 107) down to Type 3 light (like Bell 206). Many are contracted per fire season across the West. The USFS also maintains a few specialized helicopter crews such as "helitack" and rappellers similar to Australia's. Additionally, federal agencies can call upon National Guard helicopters equipped with collapsible buckets under a program for military support in large fires (similar to how Australian states can ask for military aid).

Aerial Supervision & Smokejumpers:

The U.S. has a strong system of Air Tactical Group Supervisors (ATGS) who fly in small planes (call-sign "Air Attack") over incidents to coordinate tanker and heli drops – very analogous to Australia's Air Attack Supervisors. They also uniquely employ smokejumpers – firefighters parachuted from planes into remote wildfires to attack them early. Smokejumper aircraft (like the Twin Otter or Sherpa) are part of the aerial fleet in a way, though they deliver crew, not retardant.

Dispatch and Command Structure:

The U.S. uses the Incident Command System (ICS) nationwide, with defined roles such as Air Operations Branch Director in large incidents. One notable practice is National Coordination: all federal aircraft are allocated through a National Interagency Coordination Center (NICC) in Boise, Idaho when fires exceed local capacity. This is similar to how NAFC's NRSC moves Australian aircraft interstate.

The US has Geographic Area Coordination Centers (GACCs) too, which is like each Australian state's system, and NICC for interstate akin to NAFC. In big fire sieges (like California's 2020 fires), prioritization becomes key, as there aren't enough aircraft for every fire at once. The US has developed decision support tools to allocate aircraft where life and property threat is highest, much as Australia does informally through AFAC/NAFC agreements.

Scale of Operations:

It's not uncommon in the U.S. to see 20 or more aircraft on a single large fire – multiple LATs cycling in and out, a couple of VLATs, numerous helicopters, plus air attack and lead planes. For example, during the massive 2020 August Complex in California (the largest fire in CA history), the operation deployed 10+ large tankers and over a dozen helicopters at times.

This dwarfs typical Australian single-fire operations (except Black Summer mega-fires where similar numbers were approached). The U.S. has the advantage of a larger nearby fleet, but even then they reach limits, and sometimes they request international help (they've borrowed Canadian and Australian aircraft in extreme seasons, like Australia sent LATs to California in late 2020).

Effectiveness and Innovations:

The U.S. has scrutinized cost-effectiveness heavily (Congress and watchdogs demand justification for the big budgets. This led to the AFUE study we discussed, which helped affirm that aircraft do have tactical value, albeit with caveats. One innovation from the U.S. is night-flying helicopters in Southern California (LA County Fire has had night-capable water-dropping helicopter for years, owing to urban interface needs).

They also experiment with new retardants and gels, improving environmental safety and drop efficacy, and use tools like the Next Generation Incident Command System (NICS) and other software to integrate aerial operations data in real-time maps.

A challenge the U.S. faces is aging aircraft and accidents – similar to Australia's concerns. They had two fatal airtanker crashes in 2002 that led to grounding of old fleets and a long modernization effort (including bringing in jet-powered tankers). They still work through that, and it parallels Australia's trial-and-error of different aircraft.

Another interesting point is public-private synergy:

Many of the U.S. airtanker operators are private companies (e.g., Coulson Aviation from Canada, 10 Tanker Air Carrier for DC-10s, etc.), and they also service other countries, including Australia. Coulson, for instance, operates in the U.S., Australia, and Chile. This means developments in the U.S. market often flow to Australia through those companies (like the 737 Fire liner and C-130 were first used in U.S./Canada before coming to NSW).

Overall, the U.S. model shows the value of a tiered approach: federally managed big resources, plus state-owned smaller rapid response fleets (the CAL FIRE model). Australia has effectively mirrored some of that by NAFC (federal support) plus state investments (like NSW's own 737 and VIC's SAU). The U.S. also underscores how critical national coordination is, and how budget oversight drives continuous evaluation of effectiveness.

7.2 Canada

Canada also has extensive wildfires, primarily in its vast boreal forests and remote areas, as well as populated areas like British Columbia's interior and Alberta's foothills that see severe fires (e.g., the 2016 Fort McMurray fire).

Canada's aerial firefighting approach is somewhat different:

Provincial Responsibility: Wildfire management in Canada is largely provincial. Each province has its own firefighting agency and typically its own air fleet. For example, Ontario and Quebec for decades have operated large fleets of water-scooping amphibious aircraft (Canadair CL-215/CL-415). Ontario's Ministry of Natural Resources (OMNR) has had over a dozen of these "CL" planes, using the thousands of lakes in the province as natural water sources. Quebec similarly.

Alberta and British Columbia historically relied more on airtankers that operate from land bases – BC uses contracted Convair 580s and now Q400s and RJ85s, plus plenty of helicopters, while Alberta had a mix including CL-215Ts and land-based tankers.

Aircraft Types:

Canada is famous for the CL-215/415 "Superscooper" (now successor CL-515 in development). These carry ~6,000 L and can scoop in about 12 seconds from a lake. This tactic is ideal in lake-rich areas – the plane can do continuous circuits, achieving high litres/hour delivered. Provinces like Manitoba, Ontario, Quebec, and Newfoundland rely almost entirely on scoopers instead of retardant tankers. In western Canada (BC, Alberta) where fewer lakes or different tactics, they also use land-based tankers (like Air Tractor FireBoss floatplanes, Electra L-188 tankers, or contracted jets).

Helicopters: Across Canada, helicopters are heavily used, often to support initial attack crews inserted by helicopter into lightning fires (the "Rapattack" crews in BC rappel like smokejumpers but from helicopters). Heavy helicopters (like the Coulson-Unical CH-47s or local operators' S-61s) are used in big campaigns, but the mix skews slightly more to fixed-wing in some provinces because of the strong scooper program. Nonetheless, BC in 2017 had up to 100 helicopters fighting fires – so similar or more than Australia in peak effort.

National Sharing – CIFFC:

Canada has the Canadian Interagency Forest Fire Centre (CIFFC), akin to NAFC, which coordinates resource sharing between provinces and with other countries. Provinces send aircraft to each other during surges. For instance, during Ontario's bad 2018 fire season, water bombers from Quebec, Newfoundland, and even as far as Minnesota (USA) came to assist. CIFFC also facilitates sending Canadian aircraft abroad (they often send CL-415s to the US when needed, as happened in numerous California seasons).

Fleet Ownership Model: Many Canadian provinces own their airtanker fleets (especially water scoopers, often government-owned and operated). For example, Quebec's fleet of CL-415s is government operated. In contrast, BC moved to contracting private companies for retardant tankers (Conair is a big Canadian company providing services to BC and others). This public ownership model means high upfront costs but perceived long-term payoff in guaranteed capacity. It's an interesting contrast to Australia's mostly contract model.

Technology and Practices:

Because water is the primary agent used by scoopers (instead of chemical retardant), Canada's philosophy historically was to attack fires very aggressively when small with multiple water-drops (water is less retardant but quick to reload). In heavy timber fires, they sometimes add foam to water for better stickiness.

Retardant is still used, but typically via ground or by chartered large tankers in special cases. Canadian agencies also extensively employ infrared scanning aircraft (especially at night to map fires – similar to Australia's Line scan). They train Air Attack Officers who fly in the front right seat of birddog (lead) planes to direct tanker runs – again, very akin to Australia's system.

One outcome:

Canada often boasts high initial attack success rates (like Ontario often keeps >90% of ignitions under 4 hectares). However, climate change has thrown curveballs; in 2023, Canada had its worst fire season in history, overwhelming even its significant aerial resources. That led to unprecedented global sharing (with aircraft from the U.S., EU, Australia, etc., all helping Canada). It underscores that no country can have enough aircraft for truly extreme scenarios and international cooperation is vital – a lesson not lost on Australia either.

Australia can learn from Canada's scooper usage – some suggest in northern Australia or areas with many dams, more use of FireBoss or CL-415 could help. Conversely, Canada has learned from Australia/US in adopting more large air tankers for specific scenarios (British Columbia now contracts a 737 tanker like NSW's, through Coulson).

7.3 Spain

Spain is a leader in aerial firefighting in Europe, with a model somewhat like a nationalized version of NAFC combined with regional resources.

Key points:

National Fleet (Ministry-Owned): Spain's central government (Ministry for Ecological Transition, previously Ministry of Agriculture, etc.) maintains a robust national fleet of firefighting aircraft that can be deployed anywhere in the country. This includes around 18 Canadair CL-215T/415 water scooping amphibious planes and a number of helicopters (mostly heavy Kamov Ka-32 and medium Bell 412). These are operated by the Air Force (the Canadairs belong to the Spanish Air Force's 43 Grupo) and contracted companies for helos, respectively. They are stationed at various air bases across Spain and moved as needed. Essentially, Spain decided to invest in owning the Canadairs because the Mediterranean climate, with many reservoirs and coastline, is ideal for their use.

Regional Resources:

In addition to the national fleet, each autonomous region (like Catalonia, Andalusia, Castilla-La Mancha, etc.) has its own wildfire agency and often some aircraft. For example, Catalonia's Bombers have a few Air Tractor FireBoss amphibious planes and several helicopters (and famously pioneered helitack crews). Andalusia has a mix of their own small planes and lots of helicopter contracts. But when fires exceed their capacity, they call on the national fleet.

Military Emergency Unit (UME):

Spain has a dedicated military unit for emergencies (UME) which also has some aerial assets or works closely with the Air Force. The UME can deploy large helicopters (Cougars or Chinooks) for fire, primarily transporting troops who help on ground, but they can bucket too. The integration of military in civilian firefighting is relatively seamless in Spain due to the UME's mandate.

Technique:

With many water scoopers, Spain's approach on forest fires often is to mass water drops from multiple CL-415s if water bodies are nearby. These planes can be very effective on coastal fires (e.g., in Galicia or along the Mediterranean) by continuous scooping from the sea. For interior fires, helicopters and land-based Air Tractors with retardant might be used if fewer water points exist.

Command:

Spain uses an Incident Command-like system but terminology may differ; however, they have air coordinators (COA – Coordinador Aéreo) similar to Air Attack. They also adhere to EU wildfire aviation standards so that they can share assets with other European countries. Spanish planes often go abroad (they assist Portugal, Greece, etc., under the EU Civil Protection Mechanism).

Outcomes:

Spain has had some very severe fires, but its investment in aerial means every significant fire gets a strong airborne attack. For example, in a 2012 wildfire near Valencia, up to 35 aircraft (planes and helicopter combined from across Spain) attacked the fire. This massive surge capability (way beyond any single region's own) kept losses lower than they could have been.

One difference:

Spain's heavy use of water (vs retardant) is viable partly because of shorter distances (European fires are in relatively smaller areas than, say, Australian outback fires). Quick turnaround with water is effective if you can dump enough of it. In Australia, where remote fires might have no accessible water, retardant from LATs is more valuable. So context matters.

From Spain, Australia can observe the success of a nationally owned backbone fleet (the CL-415s) and consider whether owning some critical assets (like a few LATs or heavy helicopter) might ensure guaranteed access. Spain also shows excellent integrated multi-region response, analogous to Australia's interstate mutual aid.

7.4 Chile

Chile provides a case study of a country that had relatively limited aerial firefighting resources but dramatically ramped up after catastrophic fires. Chile's big wake-up call was the 2017 wildfires, which were the worst in its history – including a megafire in the Maule and Biobío regions that burned entire towns. At that time, Chile's National Forestry Corporation (CONAF) had some aircraft: mainly light planes and helicopters (e.g., some Air

Tractor AT-802s, a few medium helicopters) mostly for initial attack in commercial forestry plantations. But 2017 overwhelmed them, and Chile had to seek international help.

Notably they hired the Global Supertanker 747 from the U.S. to come and make huge drops (privately funded by a philanthropist, and also Russia sent an Ilyushin IL-76 water bomber. These very large aircraft made headlines and helped somewhat (for example, the 747 made multiple drops protecting town). However, post-2017, Chile realized it needed a more robust, systematic approach.

Changes since then:

Chile, with government and private sector collaboration (timber companies also protect their assets), increased the number of contracted helicopters (especially heavy helicopter like Chinooks, which can carry 10,000+ L) and water scooping aircraft. By 2020, Chile had obtained at least three Chinook helicopters for CONAF, and numerous Air Tractor Fireboss amphibious planes through private companies.

Fleet ownership vs contract:

I believe Chile opted to contract from international companies (Global Supertanker was put on a call contract for 2017/2018 but then that company ceased operations in 2021; instead they use Russian Beriev Be-200 scoopers or Coulson's LATs when needed). In recent fires (2023), Chile had a Boeing 737 Fire liner on lease (coincidentally the same model as NSW's) and multiple Air Tractors and helicopters from overseas.

Coordination and Command:

Chile's CONAF created a more organized wildfire management system after 2017, including better training and integration of aerial assets into their tactics. They often fight fires in plantation forests which are high value – planes and helicopter are crucial to save those.

Chile also has varied terrain:

from coastal ranges to Andean foothills. They sometimes use the Pacific Ocean for scooper planes to reload (similar to how CL-415s scoop off Spain's coast).

An interesting initiative:

a Chilean company built a local airtanker called "Ten Tanker" (not to be confused with the DC-10 company) by converting a BAe-146 jet to drop water. This shows the impetus for local innovation due to need.

For Australia, Chile is a reminder of how a single disastrous season can prompt major changes. Australia's 2020 season similarly accelerated discussions of national capacity. Also, it underscores the value of public-private partnership: in Chile, corporate funding (from large forestry companies and individuals) supplemented government efforts to get assets like the 747 and others. In Australia, we've seen some philanthropic contributions but mostly it's government funded. Still, engaging industry (e.g., water bombing services from private crop-sprayers, or mining companies' aircraft adapted for fires) is another tool.

7.5 Other Notable Global Practices (Briefly)

Europe & EU Sharing: Beyond Spain, countries like France, Italy, Greece heavily use Canadair water bombers too (France's "Sécurité Civile" has a famous Canadair fleet). The EU has a program called rescEU that funds a pool of aircraft available to member states. This is analogous to NAFC's concept but multi-national. It has funded additional CL-415s and helicopters in Europe. Australia and New Zealand have talked about an Australasian pool possibly, but NZ's need is smaller – however, maybe a broader Asia-Pacific pool could be a future idea.

Russia and Asia:

Russia has a fleet of water bombers like the Beriev Be-200 amphibious jet and the Mil Mi-26 heavy helicopter (the world's largest helicopter) used in huge Siberian fires. Some of these Russian aircraft have been exported or leased abroad (the Be-200 went to fight fires in Greece and Israel; a Mi-26 was leased to Indonesia). They demonstrate capability but also come with high operating cost and logistics (Mi-26 can dump 15,000 L but is expensive and needs a lot of fuel).

South Africa and others:

South Africa uses a lot of cropduster aircraft (like Air Tractor AT-802) for wildfires, with private contractors (Working on Fire program). Israel, like Spain, has a squadron of Air Tractors for initial attack and can call on foreign help for big fires (they famously used a Supertanker in 2010 Carmel fire).

These international cases provide a spectrum of solutions.

Some key takeaways for Australia might be:

The value of a permanently available core fleet (like Canada's provincial scoopers or CAL FIRE's own airtankers) to ensure rapid response without relying solely on seasonal contracts.

The effectiveness of amphibious water bombers in areas with water sources (perhaps worth expanding Fireboss use in Australia's north or along Murray/Darling basins).

The need for strong national coordination – which Australia does well through NAFC, comparable to US NICC or CIFFC.

The importance of innovation and research (every country is looking at better retardants, use of drones, night ops – collaborating internationally can accelerate development).

Cost-sharing models:

Europe's rescEU is an interesting approach of pooling funds to own assets that individual countries alone wouldn't. Similarly, could Australia, NZ, and maybe SE Asian neighbors co-fund some heavy aircraft that can rotate through their fire seasons? Something to ponder for long-term resilience.

Having compared these global models, the next section will distill best practices and emerging trends that Australia could adopt or is already adopting, and Section 9 will focus on emerging technologies shaping the future of aerial firefighting.

8. Best Practices and Lessons Learned

Drawing from both Australian experience and international comparisons, this section outlines best practices in aerial firefighting operations, command structures, fleet management, and policy. Implementing these can enhance the effectiveness and cost-efficiency of aerial bushfire suppression in Australia. Many of these practices are already in place in some form, but consistent application and refinement will further optimize outcomes.

8.1 Integrated Incident Management and Air-Ground Coordination

One of the clearest best practices is integrating aerial resources into the incident command system so that air and ground efforts are complementary. Australia has been a leader in adopting the Australasian Inter-service Incident Management System (AIIMS), akin to ICS, which clearly defines an Air Operations branch in the incident management team. Ensuring that every significant bushfire incident has:

An Air Operations Manager (AOM) or Air Attack Supervisor in the command post.One or more Air Attack Supervisors/“Birddogs” overhead coordinating drops, and strong communication links (dedicated radio channels for air-ground comms, joint briefings of pilots and ground sector leaders) is crucial.

Coordination, Training, and Safety in Aerial Firefighting:

This has proven vital in avoiding mishaps and maximizing effect. For example, in CAL FIRE (USA) they have a rule that no retardant drop is made without ground personnel either on site or soon to arrive – because otherwise it might waste retardant. Likewise, Australia’s practice is to have ground controllers indicate targets for water drops whenever possible (via radio or signalling), aligning with the principle that “the success of an aerial drop is measured by what the ground crews do after.”

A best practice is conducting regular joint training exercises between pilots and firefighters. Some states run annual simulation exercises where an incident is mimicked, and pilots, air attack officers, and ground commanders practice working together. This builds trust and understanding of each other’s needs. NAFC has national training curricula for Air Attack Supervisors to standardize skill.

Additionally, safety protocols like having clear dip sites for helicopters, designated approach/departure paths, and temporary flight restrictions over fire areas (to keep unrelated aircraft out) are essential and now routine. Australia has an excellent safety record in firefighting aviation relative to flight hours – maintaining this requires adherence to these coordination best practices.

8.2 Prioritization and Resource Sharing

When fires are numerous, prioritizing allocation of aerial resources to where they will have the greatest benefit is a best practice. Australia achieves this through the NAFC/National Resource Sharing Centre mechanisms and state ops centers that triage fires. The guiding principle is to send aircraft to fires threatening lives and significant property or environmental values first, smaller or less damaging fires get resources after. This is similar to the U.S. "Preparedness Level" system and prioritization process when national resources are stretched.

A key best practice related to this is dynamic reallocation: moving aircraft between incidents as priorities change. In practice, this means if Fire A is now contained but Fire B is blowing up, the incident controller at Fire A should release the aircraft to head to Fire B. This requires a non-myopic view by each incident controller – facilitated by higher-level coordination centers that can override if necessary. In Australia, this is usually done cooperatively (all agencies recognize the greater good). It's common during a campaign that an airtanker might work multiple fires in one day, hitting the most critical phases of each.

Resource sharing between states is also critical. NAFC's ability to shift the national fleet has been proven. For instance, in late 2019 when NSW was in crisis early, some VIC-contracted aircraft came up to help. Later, when VIC's worst days came, NSW (though still battling fires) sent a couple of their aircraft south. This reciprocal sharing is a best practice that maximizes national coverage and justifies the co-funding model.

Internationally, having agreements in place (like Australia does with the US and Canada) to share aircraft during opposite seasons is a best practice for global efficiency. It's how Australia gets extra LATs each summer, and conversely Australia has sent crews/aircraft north when needed. Keeping those partnerships strong (perhaps expanding to Europe, South America) ensures help can be called upon if a Black-Summer-scale event happens again.

8.3 Fleet Mix and Flexibility

A best practice in fleet management is maintaining a diverse mix of aircraft types to handle different tasks. As discussed, helicopters, SEATs, LATs each have niches. No single type can do it all. The NAFC fleet strategy of fielding everything from small scouts to large air tanker is sound. Within that, flexibility is key: contracts that allow moving aircraft where needed, multi-role aircraft that can pivot to other emergencies (like heavy helicopters used for flood relief in off-season), and not over-specializing such that an asset sits idle if its specific mission isn't needed.

One emerging best practice is investing in multi-role capability. For example, some firefighting helicopters are now equipped to also do night medical evacuations or rescue winching when not firefighting, increasing their utility (and justification for year-round employment). NAFC mentions exploring uses of aerial assets for "other emergencies like flood and storm" to spread fixed cost. In practice, an Air-Crane could lift heavy relief supplies post-cyclone, or a waterbomber plane could be used for locust spraying if needed. This concept is analogous to Spain's approach where fire aircraft are occasionally used for other civil protection roles in winter.

Interoperability and Surge Capacity: Lessons from International Best Practice

Another best practice gleaned from Canada and the U.S. is standardization and interoperability: using common systems (like standard retardant types and mixing systems, compatible bucket hookups, common radio frequencies) so that different agencies' aircraft can operate interchangeably on an incident. Australia does well here through AFAC standards (e.g., all contracted helicopters must have certain belly-hook types, all fixed-wing use retardant approved to U.S. standards to ensure effectiveness).

Also, maintaining a portion of fleet as "Call When Needed" (CWN) is wise – this is a best practice to handle surge without paying full season for assets that might not be used in a mild year. NAFC does this by having about 100-150 contracted full-time and then a roster of additional planes on CWN. The key is to have CWN contracts in place ahead of time so that those resources can be activated quickly. After 2020, NAFC and states did sign more CWN arrangements (for example, securing potential access to additional LATs if the season ramps up).

8.4 Continuous Improvement and Research

Leading programs invest in data analysis and R&D to keep improving. A best practice is to systematically gather data from each fire season (drop locations, outcomes, costs, weather) and analyse what worked and what didn't. NAFC's ARENA database and the "Why Fly?" effectiveness research are example. The U.S. AFUE study is another. These help answer questions like: Are there aircraft that are underutilized? Did certain drops always fail under certain conditions (implying we shouldn't attempt them)? Could new tactics (like gel drops near houses, or UAS surveillance) improve results?

Adaptation of new technology is also best practice:

for instance, night operations – agencies should methodically test, evaluate, and implement when safe. Victoria's night flying trial in 2018–19 is a model; they used experienced pilots, tight safety controls, gradually expanded scope, and by 2020 were using it on real fire. Now NSW and others are following. This incremental approach mitigates risk and builds confidence.

Another tech is fire prediction and simulation tools integrated with air ops. If we can predict where a fire will be by tomorrow, we can pre-position aircraft in that area or conduct pre-emptive drops. Systems like Phoenix RapidFire (developed in Australia) are being used to inform such strategie】. The best practice is to link these predictions with decision-support that triggers appropriate aerial response – essentially, being proactive rather than reactive.

Environmental best practices also matter:

Using retardants responsibly (keeping them out of waterways to protect fish), using the most eco-friendly formulations, and cleaning aircraft to prevent spread of weeds or pathogens between drop zones (some parks require tankers to flush out if they scoop water from a lake with invasive algae before going to another). Australia has protocols for this (e.g., using only USDA-approved retardant which has known ecological profil】, and rinse requirements). As aerial use increases, these become more important for sustainable operation.

8.5 Fleet Ownership and Contracting Strategy

From a management perspective, striking the right balance between owning vs leasing assets is a strategic choice.

Best practice seems to be:

Own or long-term lease a core, reliable group of aircraft that you know you will use heavily every year (ensures availability and potentially lower long-run cost). Contract additional aircraft seasonally for surge.

CAL FIRE's example of owning a fleet means they are self-sufficient for initial attack, then they call in U.S. federal contract tankers for huge fires. Similarly, Ontario's ownership of CL-415s guarantees initial attack capability even in busy continental years.

Australia has mostly leased historically, but recently, NSW essentially "owns" the 737 and Victoria/NSW did a long lease of an RJ85 in mid-2010s with federal help. A recommendation might be that Australia consider acquiring a small national fleet (perhaps via NAFC or RAAF) of a few aircraft for critical needs (like 2-3 LATs and some heavy helicopter) while continuing to lease the majority. This hybrid model is emerging best practice to mitigate reliance on foreign availability. The 2020 Bushfire Royal Commission indeed recommended examining a "national sovereign fleet" for the future.

Best practice in contracting is also moving toward multi-year contracts with vendors, to secure availability and potentially lower costs. NAFC does this (3-4 year contract packages), as it gives operators stability to invest in better aircraft. The U.S. moved to "Next-Gen" contracts of 5-year blocks for air tankers, which brought newer jets online.

8.6 Training and Capacity Building

Ensuring a pipeline of skilled personnel is a less discussed but vital best practice. Pilots with firefighting experience are in high demand globally. Australia should continue supporting training programs for new pilots (maybe in partnership with Canada/US off-season training exchanges). Similarly, training ground firefighters in how to work with aircraft (e.g., marking targets with panels, directing drops via radio) improves effectiveness.

A culture of after-action reviews for aerial ops (what in military terms is called debriefing) is also best practice. Many fire agencies do it: after a campaign, gather pilots, air attack supervisors, ground commanders, discuss what went well or any close calls. These lessons feed into revised protocols. NAFC's national aviation safety group fosters this sharin】.

8.7 Public Communication and Expectations Management

Best practice extends to how agencies communicate the role of aerial firefighting to the public. Unrealistic expectations (like the idea that waterbombers will save every house no matter what) need to be managed by transparent communication. Agencies in Australia have improved at this – during Black Summer, fire chiefs often explained that aircraft were invaluable but "cannot alone stop these fires in extreme conditions" (a direct message to make sure communities still heed evacuation orders, etc.). Continual public education that aerial suppression is one tool, not a silver bullet, is important so that other crucial work (like mitigation and home preparation) isn't neglected under a false sense of security.

In summary, best practices revolve around integration, coordination, appropriate resource allocation, maintaining a capable and flexible fleet, and learning/improving continuously. Australia is aligned with most global best practices and in some areas (like national coordination) is a model itself. The recommendations in the next section (Section 11) will build on these best practices to suggest how to further strengthen aerial firefighting across Australia's states and territories in a tailored way.

9. Emerging Technologies and Innovations

The field of aerial firefighting is evolving, with new technologies and methods on the horizon that promise to enhance effectiveness, safety, and efficiency. This section explores some key emerging technologies and how they might be applied to aerial bushfire suppression in Australia in coming years.

9.1 Unmanned Aerial Vehicles (UAVs) and Drones

As mentioned earlier, drones are already making an impact in wildfire management, primarily for reconnaissance and intelligence. The next steps in UAV integration include:

Large Firefighting Drones:

Companies are developing heavy-lift drones capable of carrying water or retardant payloads. For example, Boeing tested an unmanned Little Bird helicopter for firefighting, and other prototypes like drone swarms carrying incendiary spheres for burnout. While no drone today can carry anywhere near what a helicopter or plane can, the idea is that many small drones working in concert might saturate an area or tackle multiple spot fires simultaneously. In Australia, CSIRO and other innovators are likely investigating this space, as drones could operate when manned aircraft cannot (e.g., high risk at night in mountainous terrain). We might see drone swarm trials in Australia's northern savannas to control remote lightning fires without risking pilots.

AI and Automated Flight:

UAVs can potentially be guided by artificial intelligence to drop precisely on heat signatures detected by their sensors. A future scenario: a fire starts, and a drone auto-launches, finds the fire via thermal camera, and drops a suppressant – all before human teams mobilize. Some elements of this are being tested (automated detection is advanced; automated drop is nascent). If realized, this could drastically reduce response times in remote areas.

Persistent Surveillance:

High-altitude drones or even stratospheric balloons could loiter over fire-prone regions during fire season, providing continuous real-time imagery and mapping of any fire that starts. This technology exists (e.g., the World View balloon or solar-powered Airbus Zephyr drone) and could be a game-changer for early fire intelligence. NAFC's strategy hints at interest in "better use of satellite and potential high-altitude platforms to identify fires and guide aircraft – so this is on the radar.

Challenges:

The main challenges for drones are regulatory (airspace deconfliction with manned aircraft) and payload limitations. Likely near-term, drones will augment rather than replace manned aircraft. A coordinated system might see drones scouting ahead of manned tankers to pinpoint targets or performing mop-up drops on small hotspots that would be inefficient for a big tanker to handle.

9.2 Advanced Materials: Gel and Enhanced Retardants

Traditionally, fire retardant is a liquid slurry that works by coating and chemically inhibiting combustion. Firefighting gels are a newer alternative/addition: these are super-absorbent polymer gels that can stick to vertical surfaces (like walls of a house) and hold water for hours. Some firefighting helicopters in the U.S. began using gel drops for structure protection – it's more effective than water alone at clinging and insulating.

In Australia, use of gels from aircraft hasn't been widespread yet, but trials have occurred. As environmental concerns about standard retardant (phosphate can cause algae blooms in waterways) grow, gels might offer a more benign option for certain applications.

A possible innovation would be pre-treating areas with gel by aircraft before a fire arrives (e.g., if a fire is 1-2 hours away from a town, helicopter could spray gel on the town's perimeter vegetation or structures). This could significantly improve the chance of saving them. Already ground crews do some gel application; extending it via air is plausible.

Another angle is encapsulated water – dropping water with a chemical that prevents evaporation so it's more effective. There are products that create a gel from water on the fly as it's dropped. Research into these could yield something that replaces standard retardant at least in some situations.

9.3 Night Operations and All-Weather Capabilities

Operating at night has been a frontier now being crossed.

By 2025, we can expect:

Widespread Night Helicopter Operations: Building on the Australian trials, it's likely that heavy helicopters with night-vision and infrared capability will routinely attack fires throughout the night, at least in areas without too many aerial hazards. This effectively doubles the useful work time of aerial assets on a given fire, potentially containing fires faster. The technology (NVG goggles, infrared cameras, powerful directional lights) exists;

the main developments will be training more pilot crews for night ops and ensuring communications and ground safety.

Night Fixed-Wing Ops:

This is more challenging due to speed and hazards, but perhaps smaller fixed-wing like SEATs might eventually do dawn/dusk or even night drops guided by GPS and infrared. The U.S. is experimenting with a military C-130 outfitted with tech to do retardant drops after dark using advanced avionics.

All-Weather Flying:

Currently, strong winds or extreme turbulence (like pyrocumulus clouds) ground aircraft. Looking ahead, there's exploration of using military-style drones or hardened aircraft that could fly in conditions unsafe for humans. Additionally, better real-time wind mapping and flight control could allow planes to drop accurately even in somewhat smoky, windy conditions, by computing ballistic trajectories of drops – essentially using software to adjust drop timing for wind so it still lands on target. These are incremental improvements, but in a decade we might see tankers with computerized drop systems that adjust for wind automatically (some systems already adjust for speed/height, adding wind would be next).

9.4 Data Analytics and AI in Decision Support

With large amounts of fire data available, Artificial Intelligence and machine learning can assist decision-makers in where to send aerial resources for maximum impact. For example:

AI models might predict which new ignitions are likely to become major fires (based on weather, fuel, topography) and thus warrant dispatching aircraft versus those likely to self-extinguish or stay small.

Optimizing aircraft dispatch:

algorithms could consider all active fires, the locations of all available aircraft, travel times, fire growth rates, and automatically propose an optimal assignment of aircraft to fires to minimize overall damage. Humans would oversee, but this could aid complex multi-fire situations. Real-time fire line mapping by AI analysing infrared drone feeds to direct helicopters exactly to the hottest parts.

Australia, with its innovative tech sector and organizations like CSIRO and Geoscience Australia, is well placed to implement such advanced decision support. NAFC's Resource-to-Risk project is one such initiative using software to model coverage and risk; future iterations likely will include AI-driven recommendations.

9.5 New Aircraft and Engineering Innovations

Manufacturers are introducing new aircraft tailored for firefighting:

CL-515 "next-gen scooper": An updated Canadair scooper with modern avionics and higher performance is in development. Countries like Indonesia have ordered some. Australia could consider if these might be suitable especially for the northern or eastern coastal areas with lots of water bodies.

Converted Commercial Jets:

The success of converting Boeing 737s and BAe-146s shows many mid-sized retired airliners can be airtankers. In future, perhaps Airbus A400M military transports or even newer regional jets could be converted. If more airlines retire jets (post-COVID surplus planes), companies might scoop them up for tankers – possibly lowering acquisition costs for more LATs globally (supply increase). Australia could benefit from more availability of modern second-hand tankers at cheaper cost.

Electric or Hybrid Aircraft:

It's early days, but the push for electric aviation might one day yield electric drones or even waterbombers (likely smaller ones) which have simpler mechanics and potentially lower operating cost/carbon footprint. Given fires themselves are worsened by climate change, having greener firefighting methods is an interesting full-circle consideration. Already, there are electric drones used for ignition (quiet, no emissions locally). Perhaps initial attack could be done by a fleet of solar-charged drones in the future.

Higher Capacity Helitankers:

The heavy-lift helicopter world might see expansions – e.g., adaptations of new heavy-lift helicopters (like the modern CH-53K or the hypothetical civilian tilt-rotor aircraft) for firefighting could increase speed or volume delivered. A tilt-rotor (like a V-22 Osprey) could theoretically hover to fill like a heli but fly fast like a plane – not used yet due to complexity and cost, but conceptually interesting for reaching distant fires faster than a chopper and accessing water sources unlike a plane.

9.6 Satellite and Geospatial Tech

Satellites have long been used for detecting hotspots (NASA's MODIS/VIIRS).

The future will bring:

Dedicated Fire Satellites:

Companies are launching cubesat constellations specifically to monitor wildfires (e.g., OroraTech from Germany launched fire detection satellites in 2022). These can provide detection within minutes of a flare-up and track fire spread continuously. Integrating this feed with aerial dispatch is an emerging practice – basically, the moment a satellite sees a fire, it could alert the nearest aircraft to get there.

Downlinked satellite comms to aircraft:

So pilots can see a real-time heat map of the fire on a tablet in the cockpit, even through smoke. This tech is feasible now with satellite internet (Starlink, etc.) – giving pilots unprecedented situational awareness.

GIS-Based Risk Mapping:

Long before fire season, AI and satellite imagery could map fuel loads and pinpoint where aerial suppression would be most needed. Then prepositioning of bases or dipping sites can be done accordingly. Essentially, intelligence-led placement of resources.

In conclusion:

The next decade is likely to transform aerial firefighting with these innovations. They align with Australia’s needs: faster response, safer operations (fewer people in harm’s way), and doing more with finite resources. Embracing these emerging tech solutions, testing them in Australian conditions, and scaling up the successful ones will be critical for staying ahead of the escalating bushfire threat under climate change.

10. Future Challenges: Climate Change and Escalating Bushfire Risk

As climate change drives hotter temperatures, longer droughts, and more extreme weather, bushfire regimes in Australia are becoming more intense and less predictable. This poses several challenges for aerial firefighting:

Longer Fire Seasons and Overlapping Seasons:

Historically, Australia could count on the Northern Hemisphere winter (our summer) to borrow aircraft. But fire seasons globally are extending and overlapping. For example, the U.S. fire season now often goes well into October; Canada had fires burning into what used to be their snow season. Simultaneously, Australia's season is starting earlier (spring) and ending later (autumn). NAFC noted this risk: if the northern and southern fire seasons "get longer in the future", the back-to-back leasing strategy is at risk.

Indeed, in 2019, some contracted aircraft arrived late because they were still fighting fires in California. This trend may worsen, meaning Australia might face shortages of available aircraft exactly when domestic need is highest. The challenge is to secure a sustainable fleet despite global demand. This likely requires either owning more assets or entering into guaranteed-sharing agreements well in advance. One Royal Commission recommendation was for the Australian Government to boost sovereign aerial firefighting capacity to mitigate this dependency.

More Extreme Fire Behaviour:

Climate change is leading to more days of "Catastrophic" (Code Red) fire weather, where fires burn at intensities aerial suppression can barely touch. We saw in Black Summer fire-generated thunderstorms (pyrocumulonimbus) that grounded aircraft due to severe turbulence and lightning risk. If such mega-fires become more common, aerial tactics must adapt: focusing on flanks and asset protection rather than direct frontal assault, for instance.

It also means on those days where aircraft can't fly, reliance on them is moot – so fuel reduction and other mitigations become even more critical to reduce intensity. Fire agencies will have to communicate that even doubling the aerial fleet won't stop every fire in 50°C heat and gale-force winds. The strategy will likely shift to heavy aerial response on days when it can make a difference, and knowing when to pull back for safety.

Higher Operational Tempo and Wear:

Longer seasons and frequent large fires mean aircraft will be flying more hours per year. This accelerates wear and tear, requiring faster replacement cycles or more robust maintenance regimes. Costs will go up accordingly – something governments must budget for. It might make sense to invest in newer, more durable aircraft if usage is to be high, as older ones may break down more often under relentless tempo. Ensuring enough pilots and maintenance crews are available is also a concern; burnout and fatigue management for aircrews will be vital as seasons lengthen.

Geographic Spread of Fire Risk:

Areas that traditionally didn't see frequent big fires might start to – such as rainforest areas (e.g., the 2018 fires in Queensland rainforest, or potentially wet tropics in NT if drying trend continues). This requires rethinking placement of aerial resources. For instance, historically there was minimal aerial capacity in far north Queensland, but maybe in future a scooper or heli should be staged there as their climate becomes drier seasonally. Similarly, tropical savanna fires might grow larger with climate variability, threatening communities that have little firefighting infrastructure – aerial could be the primary tool there.

Concurrent Disasters:

Climate change may bring simultaneous or sequential disasters (fire season followed by flood season). Emergency services resources, including aircraft, might be stretched year-round (dropping water on fires one month, dropping hay to stranded cattle in floods the next, and then assisting in cyclone relief). This challenge underscores the value of multi-use aircraft and flexible planning, but also may necessitate greater total numbers of aircraft (one set can't do everything everywhere at once).

Economic Constraints:

While fire risk grows, governments face economic pressures. Aerial firefighting is expensive and that expense might increase (insurance premiums rising due to more accidents risk under extreme conditions, fuel costs potentially rising, etc.). Ensuring cost-effectiveness will be even more scrutinized. It's a challenge to justify large expenditures if they only occasionally deliver results (like VLATs on the worst days might often be grounded by weather – do we still invest in them for the few windows they can operate?).

Tough decisions loom on where money is best spent: on more aircraft, or on prevention (hazard reduction, community hardening) which might reduce the need for those aircraft. The likely answer is "both," but budgets are finite. For example, an economist might argue $20 million on prevention could save more than $20m on a tanker – fire agencies need to gather data to support a balanced approach.

Environmental and Safety Regulations:

As fire suppression intensifies, we must watch for unintended consequences – e.g., overuse of retardant affecting waterways, noise impact of low-flying aircraft on wildlife and communities, safety of people on the ground when huge aircraft are operating overhead. There may be increasing regulation (for environmental protection) that restricts certain suppression methods (some U.S. forests limit retardant in critical watersheds).

Climate change can also make flying more hazardous – hotter air means less lift for aircraft, so on extreme heat days, heavily loaded airtankers might have reduced performance or need longer runways. Pilots will have to adjust tactics for those conditions (taking smaller loads when it's 45°C, for example, which means more trips).

In facing these challenges, a few strategic shifts might be needed:

Building surge capacity that is domestic (so it's not reliant on international when global demand peaks). Investing in early detection and rapid attack (to catch fires on milder days so they don't become unstoppable on extreme days).

Coordinated research into firefighting under extreme conditions – e.g., how to suppress flank spread of a firestorm, or protect evacuation routes via aerial actions. Enhancing international partnerships for mutual aid because no country can have all resources required for the worst case. Possibly formalizing arrangements with countries in opposite seasons (like a standing agreement that, say, Canada will send X planes if Australia has Y level of emergency, and vice versa).

Climate change essentially demands a scaling up of all efforts and a nimbleness to respond to more frequent high-severity events. Aerial firefighting, as a highly visible and dynamic tool, will certainly see more demand. Australia will likely have to increase spending on aerial suppression (and associated mitigation to maximize its effectiveness) as part of adapting to climate change.

With these future challenges in mind, we now move to final recommendations that combine all the insights – focusing on what specifically should be done in the Australian context to optimize aerial firefighting for the future.

11. Recommendations for Australia’s Aerial Firefighting Strategy

In light of the analysis of effectiveness, costs, state-by-state operations, international comparisons, and future outlook, this section presents targeted recommendations to strengthen aerial bushfire suppression in Australia. The focus is on actionable strategies for Australian states and territories (and the Commonwealth) to ensure the aerial capability is robust, cost-effective, and suited to the evolving bushfire threat. These recommendations take into account each region’s needs, while emphasizing national coordination and shared resources.

11.1 Develop a National Sovereign Core Fleet

Recommendation: Establish a modest nationally-owned or long-term leased core fleet of key aerial assets to guarantee availability and rapid deployment, even during global competition for resources. This could include:

Two to three Large Air Tankers (e.g., C-130 or Q400 class) stationed strategically (e.g., one in eastern states, one in southern/western).

Two heavy Type 1 helicopters (e.g., Erickson Air-Crane or Chinook with firefighting kit) that can be kept in Australia year-round.

This core would be jointly funded by states and the Commonwealth (building on the existing NAFC grant model) and managed by NAFC as a national asset. They would supplement – not replace – the contracted fleet. The idea is to have some guaranteed “big guns” on hand at all times. This addresses the climate-driven risk of overlapping seasons with the Northern Hemisphere, ensuring Australia is not left short if overseas contracts are delayed or unavailable.

The business case:

owning/long-leasing might cost more upfront but provide stability and potentially save money long-run (leasing costs rising with demand). It also allows year-round training and multi-use (these aircraft could be used for floods/cyclones off-season as heavy lift transports or water movers, improving cost efficiency).

Lead: Commonwealth funding via NAFC; NAFC and AFAC to coordinate acquisition and management. Possibly involve RAAF for hangars/maintenance (a civil-military partnership, similar to how some countries' militaries operate firefighting planes).

11.2 Expand and Modernize the Fleet Mix Based on Regional Needs

Recommendation:
Each state and territory, in collaboration with NAFC, should review their fleet mix annually against emerging risk patterns and adjust contracts accordingly. Specifically:

New South Wales & Victoria:

Given their high population and heavy fuels, continue robust contracting of LATs and heavy helicopters. Consider adding amphibious scooping capacity (like contracting a CL-415 or FireBoss team) for areas like the Snowy Mountains or Murray system, where water sources exist, to test efficacy.

Queensland:

Increase contracts for waterbombing aircraft in the north and inland as fire activity rises there. A couple of extra SEATs in central/north QLD could prevent major outbreaks in remote areas.

South Australia:

Maintain current SEAT and heli fleet for Adelaide Hills, but consider access to a LAT earlier in season (perhaps co-fund a permanent LAT presence in SA/Vic border region in summer).

Western Australia:

Given its isolation, WA should invest in at least one LAT or large scooper dedicated for its use (perhaps co-funded by Commonwealth due to climate risk). Also, more rotary wing for Perth's expanding peri-urban fringes.

Tasmania:

Pre-position contracts such that a LAT and a heavy heli can be quickly ferried to the island during high-risk periods (the MOU with Vic/NAFC to send help exists, but formalize it with dedicated standby arrangements each summer).

Northern Territory:

Continue reliance on SEATs and contract them each dry season (perhaps 2 AT-802s in Darwin and Alice Springs each). Trial higher-tech solutions like drones for remote fires, given the low population density – NT can be a testbed for those emerging tech because risk to life is low but area is huge.

In general, modernize the fleet by phasing out any aging aircraft and encouraging vendors with newer models via multi-year contracts. Push for vendors to equip aircraft with latest avionics (for night ops compatibility, etc.). Invest in high-capacity quick-refill bases in new hotspots (e.g., build a retardant reload base in Townsville or Cairns if northern QLD risk is rising).

Lead: State fire agencies with NAFC to coordinate contracts. Commonwealth could provide grants for infrastructure (e.g., building new airbases, purchasing portable retardant mixers, etc., in underserviced regions).

11.3 Strengthen National Coordination and Surge Protocols

Recommendation: Enhance NAFC's coordination role by developing an explicit national surge plan for aerial resources.

This plan would:

Define trigger points (fire danger indexes, number of concurrent fires) at which interstate sharing automatically kicks in.

Establish a national "pool" of call-when-needed aircraft that can be activated by NAFC and moved around (with cost-sharing formulas pre-agreed so no haggling during crises).

Conduct national-level training exercises or simulations annually to practice moving multiple aircraft interstate and managing a multi-state air operation under one unified command (virtually simulate a Black Summer scenario but with improved coordination).

While NAFC already does much of this informally, formalizing it ensures speed and clarity in extreme events. Also, link NAFC's resource sharing with international agreements: e.g., if Australia is in extreme need, have a plan for requesting specific help (like 5 CL-415s from EU or US Air National Guard C-130s via defense channels).

Lead: NAFC in consultation with AFAC council. Commonwealth to assist in negotiating any international MOUs for aircraft sharing (perhaps add to existing emergency management treaties).

11.4 Invest in Technology and Innovation Locally

Recommendation: Dedicate funding to research and pilot programs for the emerging technologies discussed.

Concretely:

Fund a multi-agency trial of night-time waterbombing operations in at least two more jurisdictions (NSW and WA, for instance) and expand Victoria's program. Aim to have an initial night-capable contingent in each major region by 2025.

Launch a drone integration pilot project – e.g., in the NT or QLD, deploy a fleet of drones for fire detection and maybe limited suppression (ignition or small water payload) to evaluate effectiveness and develop protocols for using drones alongside manned aircraft.

Work with Australian defence and aerospace industry to test unmanned or remote-operated firefighting aircraft. Perhaps convert a redundant small aircraft to remote operation and attempt a firefighting mission (this could also have safety applications for very dangerous missions).

Develop a real-time aerial firefighting management system that uses AI to suggest optimal drops and assignments. This could be a software that all Air Attack Supervisors have access to on a tablet, which, for example, shows live fire spread predictions and recommends where next drop should go for best effect (as a decision support, not replacing human judgment).

Continue to improve retardants/gels:

Sponsor trials of environmentally friendly retardant alternatives in Australian fuels, to ensure any new product still works on our eucalypt forests and doesn't harm native flora/fauna. Also test use of gel via helicopters around structures in a controlled experiment to see how much it improves structural survival.

Lead: This needs collaboration – CSIRO, Bushfire CRC (or its successor, Natural Hazards Research Australia), NAFC, and industry. Commonwealth could allocate a special innovation grant for bushfire aviation (perhaps through a climate adaptation fund). Each state can contribute by offering terrain and fire scenarios for trials.

11.5 Enhance Training, Recruitment, and Retention of Specialist Personnel

Recommendation:

Given increasing reliance on aerial firefighting, ensure we have enough trained pilots, air attack supervisors, and support staff.

Actions:

Expand training programs for aerial firefighting pilots. Work with aviation colleges to create a stream for ag pilots to transition into firebombing, perhaps offering subsidized training hours or simulator training. Encourage experienced overseas pilots (from North America or Europe off-season) to come to Australia to mentor and fly (making sure visa processes are smooth for seasonal pilot imports).

Build a national credentialing system for Air Attack Supervisors and related roles so qualifications are recognized across all states and even internationally. This allows sharing of personnel (e.g., if one state has few fires, their air attack officers could be deployed to another state's fires).

Focus on retaining veteran knowledge:

Many current fire pilots and air ops managers are very experienced; capturing their knowledge in training materials and involving them in coaching new recruits will ensure skills are passed on. Perhaps establish a "Center of Excellence for Fire Aviation" under AFAC where best practices, case studies, and simulation training is concentrated.

Address fatigue: implement protocols for rest rotations for pilots and support crews during long campaigns (e.g., after X hours of flying in a week, mandatory rest – this might require having more pilots per aircraft to alternate).

Encourage diversity in recruitment, tapping into e.g., military pilot pools (retiring RAAF pilots could be great tanker pilots), agricultural pilots, even overseas pilots who might migrate. Aim to grow the community of fire aviation specialists, as demand will grow.

Lead: AFAC and NAFC with state agency training divisions, potentially with Civil Aviation Safety Authority (CASA) input for certification aspects.

11.6 Boost Preventative Use of Aerial Resources

Recommendation:

Use aerial assets not just reactively but proactively for mitigation when possible:

Increase aerial controlled burning operations in mild conditions (using helitorch or incendiary drones/planes) to reduce fuels in remote or inaccessible areas. This prevents mega-fires and also keeps pilots/procedures practiced.

Pre-position retardant lines or gel drops ahead of fire on extreme danger days in specific high-risk spots (experimental). For example, if forecasts show an explosive day, consider laying a retardant line along a ridge between a likely ignition area and a town before any fire starts (a tactic tried in the US in limited cases). Study whether this helps contain potential fires. Essentially, treat retardant drops as temporary firebreaks in advance.

Encourage land managers (like forestry companies or large landowners) to coordinate with fire agencies so that their contracted assets for private land (like plantation owner's helicopters) can be shared in public firefighting when free, and vice versa. This increases the pool of available aircraft during big events (some arrangements like this already exist, but formalizing public-private cooperation and co-funding fuel reduction burns using those aircraft can pay off).

Lead: State fire agencies in concert with land management agencies (National Parks, forestry corporations). NAFC could potentially coordinate a program of national significance (like an "Aerial Prescribed Fire Initiative" funded federally, using aircraft to burn large remote areas safely).

11.7 Community Education and Engagement

Recommendation:

Alongside operational improvements, engage communities about the capabilities and limits of aerial firefighting:
Develop public information campaigns on what water bombers can/can't do (for instance, RFS NSW did videos explaining that aircraft assist ground crews, not replace them). Continue this so people prepare their properties and heed evacuations rather than assuming the "fire planes" will save them at last minute.

Solicit local knowledge for dip sites or airstrip locations – community members in rural areas often know the best farm dams or flat paddocks. Fire agencies can work with them preseason to arrange access for aircraft (and in return perhaps help augment those water sources). This fosters goodwill and readiness.

Encourage citizen reporting of fires via apps that can directly cue aerial dispatch (crowd-sourcing ignition detection effectively, feeding into systems like AFDRS – Australian Fire Danger Rating System – combined with lightning tracker data to launch a "find and attack" mission even before confirmation by ground crew).

Lead: Fire agencies' community engagement units, with NAFC providing overarching facts about aerial firefighting to ensure consistency in messaging nationwide.

These recommendations collectively aim to ensure Australia's aerial firefighting is faster, smarter, safer, and more resilient in the face of growing challenges. They balance investment in capability (more and better aircraft where needed) with investment in innovation (to amplify what each aircraft can do and to find new solutions). Importantly, they emphasize that aerial firefighting must remain integrated in the broader bushfire strategy – as part of a continuum with ground efforts and prevention.

By adopting these recommendations, Australia can bolster what is already a world-class aerial firefighting system, and be better prepared for the escalating bushfire risks in the coming decades.

12. Conclusion

Aerial firefighting has indisputably become an essential pillar of Australia's bushfire response, proving its worth in saving lives, protecting property, and assisting ground crews in countless fires over the past two decades. This report has examined the effectiveness and costs of aerial bushfire suppression in Australia from 2000 to the present, with a detailed 60% focus on Australian operations and a 40% lens on international comparisons.

We have analysed the roles of every major aircraft type – from agile single-engine water bombers to giant air tankers and helicopters – and assessed their performance metrics such as response speed, fire containment success, and cost-efficiency. Across all states and territories, we found that while there are regional differences in fleet composition and practice, a common thread is the reliance on rapid aerial attack to keep fires small and the value of sharing resources to combat the biggest blazes.

Internationally, comparisons with the United States, Canada, Spain, Chile, and others highlighted that Australia's collaborative model (through NAFC) is a strength, and that a balanced fleet mix is universally seen as best practice. We also gleaned ideas – like Spain's use of water scoopers or CAL FIRE's dedicated fleet – that could inform Australian enhancements.

The report discussed emerging global best practices such as integrated air-ground command, data-driven deployment, and continuous training, many of which Australia is already embracing or can improve upon.

Adapting Aerial Firefighting for a Changing Climate:

Looking ahead, climate change stands as the greatest challenge to aerial firefighting. Longer, more intense fire seasons will stretch resources and expose the limits of what aircraft can do in ultra-extreme conditions. However However, by proactively adapting – investing in key capabilities, integrating emerging technologies, and strengthening national coordination – Australia can ensure that its aerial firefighting armada continues to rise to the challenge.

The recommendations provided in this report chart a path forward: from developing a sovereign core fleet and leveraging drones and night operations, to tailoring resources to each region's needs and bolstering training and research.

Summary:

Aerial bushfire suppression in Australia has proven highly effective when used appropriately, and it will only grow in importance under escalating fire regimes. It is expensive, but the evidence shows it is often money well spent in terms of disaster losses avert. By learning from two decades of experience and global best practices, Australia can optimize its aerial fleet for maximum impact and cost-efficiency.

A coordinated national strategy – one that marries the strengths of each state and territory with a robust federal support framework – will provide the agility and strength needed to combat future mega-fires. Coupled with continued ground efforts and community preparedness, a well-equipped and well-managed aerial firefighting capability will remain a cornerstone of protecting Australian lives, property, and environments in the face of climate-driven fire challenges.

Research Collaboration – AI and the Author

This report was produced through a collaborative research and drafting process between the author, Ken Ashford, and advanced AI tools provided by OpenAI. The AI was used to assist in information synthesis, structural drafting, grammar refinement, and formatting. The insights, interpretations, and final editorial decisions remain the work of the author. This human-AI collaboration aimed to enhance accuracy, depth, and efficiency in the development of this evidence-based report for public benefit.

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