CONTEMPORARY ISSUES IN AIR AND SPACE POWER

BUILDING FIGHTING DEPTH

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AIR AND SPACE POWER CENTRE

Contemporary Issues in Air and Space Power

Special Issue:

Building Fighting Depth

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Both the Air and Space domains play important roles in facing current geopolitical challenges. Together, they have not only shaped modern warfare but their contributions are pivotal in shaping and deterrence. To remain relevant into the future, however, requires a constant examination of their employment and future opportunities.

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A catalogue record for this journal is available from the National Library of Australia

E-ISSN: 2653-7745

P-ISSN: 2981-8311

DOI: 10.58930

Published by: Air and Space Power Centre

14 Pt Cook Ave, Canberra Airport

ACT, 2609, Australia

Foreword

I take great pleasure in presenting this special issue of the *Contemporary Issues in Air and Space Power Journal* in the lead up to the *2026 Air and Space Power Conference*. This issue explores the Conference theme of Building Fighting Depth—a call to think beyond immediate readiness toward the endurance required to prevail in protracted competition and conflict. Fighting depth is how we will continue to offer more options in more places more often in what the Chief of Air Force calls strategic autumn.

Several contributions examine the demands of protracted, high-intensity conflict. Peter Layton argues "long, big wars" expose the fragility of homogeneous crewed-centric air forces and proposes a heterogeneous model integrating crewed aircraft, missiles, rockets and drones. Kurt Simmill's study of Ukraine's integrated air and missile defence shows how preparedness in depth—mobility, integration and domestic sustainment—can deny air superiority under pressure. Such depth must be designed before conflict and adapted under attrition.

Strategic depth is also institutional. David Hood warns of the risk that tactical excellence eclipses strategy, while Michael Dorman draws historical lessons on the symbiosis between economic power, industry and military capability. Yvette Ross argues for a shift from episodic planning to a whole-of-nation posture integrating STEM pipelines, sovereign space capability and reserve networks. Neil Stott, Jarrod Pendlebury and Paul Tracey extend this discussion by examining how military innovation is organised across a "military-innovation complex" of government, industry, academia and the armed forces. They argue innovation emerges through the interaction of ideas, organisational structures and inter-organisational relationships that collectively shape military capability. Together, these contributions reinforce that fighting depth is a national endeavour, emerging not only from force structure but from the broader system that generates, mobilises and sustains military power.

Operational depth depends equally on resilience and integration. Charles Tomlinson & Shane Ivimey highlight the importance of resilient airbases built on hardening, dispersal and rapid recovery. Andrew Rees argues combined Command Post Exercises must evolve to generate genuine interoperability and multinational resolve before crisis. From a soldier's perspective, Thomas McDermott challenges sailors, soldiers and aviators alike to move beyond integration toward true all-domain orchestration.

The cyber and information domain receives equal attention. Theresa Sobb & Benjamin Turnbull propose a Unified Mission Assurance framework centred on mission resilience, while Laurens Visser explores the implications of autonomy and artificial intelligence for air power, arguing machines may accelerate decision cycles but human control remains decisive.

Technological change and combat mass are further explored through autonomy and industry. Michael Gan situates collaborative combat aircraft within Australia's geography and demography, arguing that affordable, sovereign uncrewed systems are essential to generating combat mass at range. Maurits Grimberg examines the strategic balancing required to manage dual-use semiconductor technology in an era of great power competition.

Finally, Alexander Robinson, Luis Silva & Johan Linder turn to the human dimension of air power, proposing modernising advanced aircrew training by shifting cognitively rich tasks to lower-cost platforms while preserving high-performance aircraft for tasks only they can perform. In an era of limited fighter numbers and finite flying hours, scalable training is itself fighting depth.

This issue's articles demonstrate Building Fighting Depth is multi-domain, Whole of Government and Whole of Nation. In this sense, Building Fighting Depth embodies National Defence. It underpins Australia's Strategy of Denial by boosting the nation's ability to sustain credible combat power, absorb shocks, and regenerate and adapt capability faster than an adversary. This strengthens deterrence and reduces the likelihood of conflict.

This journal exists to strengthen the contest of ideas in Australian air and space power—because intellectual depth is inseparable from fighting depth. I encourage readers to engage most seriously with the arguments that challenge their assumptions. As we approach the 2026 Air and Space Power Conference, may this issue sharpen our thinking. Building Fighting Depth begins with ideas and the deepest ideas are those most thoroughly tested.

GPCAPT Jesse Laroche
Director, Air and Space Power Centre

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Air Power

Building an Air Force for a Long, Big War

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Keywords: airpower, air forces, Fundamental Inputs to Capability

https://doi.org/10.58930/bp52184561

Vol. 3, Issue 1, 2025

Australia's 2024 National Defence Strategy warns of protracted major regional conflicts. Fighting such long, big wars requires modern air forces to have three important attributes that they do not currently possess. There are some alternatives to addressing the identified shortfalls but the preferred approach is adopting the heterogeneous air power model. This uses crewed aircraft, rockets, missiles and drones in coordinated, synchronised and collaborative ways to efficiently achieve operational objectives. To build such a new model air force will require changes in the Fundamental Inputs to Capability.

1. Introduction

Australia's 2024 National Defence Strategy (NDS) warns of the dangers of a protracted major regional conflict (Department of Defence, 2024). In such a conflict, the NDS envisages air warfare would be important. The Royal Australian Air Force's (RAAF) air elements could have a significant role but combat attrition could mean only for a disturbingly short time.

Modern air forces like the RAAF are designed and built around highly sophisticated, technically impressive, crewed combat aircraft. It is this homogeneity, where most of the important constituent parts are of a similar kind, that is these air forces' Achilles heel. Such aircraft take years to build and if lost cannot quickly be replaced. In a major war, crewed aircraft losses are more likely than not. The result is a peacetime air force that enters a major conflict would probably progressively decline in size and effectiveness. This well-known shortcoming now has a solution albeit with major implications for the building of air forces.

The aim of this article is to set out a new model for middle power air forces like the RAAF that is appropriate to fighting a protracted, major conflict. First, I outline the characteristics of long, big wars and three important attributes air forces need to have to fight them but which they do not presently possess. Second, I consider alternatives to addressing these shortfalls before settling on a plausible new model. Third, I explain how this new model addresses the shortcomings initially noted. Finally, I briefly sketch out how to build such an air force using the Australian Defence Force's (ADF) Fundamental Inputs to Capability framework.

Drawing on recent international law statements, the article defines air warfare as: military operations in armed conflict involving the use of aircraft or missiles of all types; whether in offence or defence; and whether or not over the territory of one of the belligerent parties. (HPCR, 2013, pp. 8–11, 34).[1] Importantly, the article does not address possible concepts of operations for the new model air force. While some insights may be gleaned in the discussion following, this sizeable topic remains for another article to explore.

2. Fighting a long, big war

Peter Wallensteen, a leading researcher in peace and conflict studies, considers major wars have five distinct attributes. Major wars are waged by: (1) authoritarian governments that use highly disciplined, centralised armies to secure their survival; (2) they are fought by major powers; (3) involve developed countries; (4) are regional; and (5) have a global impact (Wallensteen, 2006, pp. 82–87). Such wars are accordingly large scale, intense and in arousing national passions involve, as Clausewitz noted, violence, hatred and enmity (Cole, 2020, p. 43). Implicit is that the militaries fighting such wars will use the more advanced technology of their era, and the states involved will be able to fully mobilise their populations and be able to extract substantial resources from their societies.

On the other hand, in preparing their armed forces, states can choose the length of a war they would prefer to fight depending on their resources relative to an adversary. While the desired length is a major pre-war strategic decision, it may be invalidated as the war progresses. In both World Wars, Germany sought to fight short, sharp wars believing the country lacked the depth and breadth of resources to fight a long war. Britain, considering its global empire gave it great mobilisation potential, based its strategies on the reverse.

1 In the commentary referenced, 'Air or missile operations' is used as a generic phrase referring to any military airborne activities, whether by crewed or uncrewed aircraft (fixed or rotary wing), missiles, balloons, blimps or dirigibles.

Today, researchers in China's People's Liberation Army have noticed shortcomings in the United States (US) defence industrial base's ability to meet the demands of Ukraine in the Russia-Ukraine War. Consequently, they consider a protracted war with the US would favour China, the manufacturing powerhouse of the world. Moreover, it is argued that the margin of US technological superiority over China at the start of the war would steadily diminish as the war continued, as American combat losses would be unable to be readily replaced (Wang & Zakheim, 2025).

The last protracted major war that Australia and most nations fought was World War II (1939–1945). A future major war in the Indo-Pacific might again feature highly industrialised warfare similar to the European theatre of World War II while being fought mainly in a maritime environment as in the Pacific theatre during 1941–1945.

World War II's war in the air was mainly won through a process of attrition (Murray, 1983). The large, highly competent German air force and Japanese air arms at the start of the war were steadily worn down in combat and continued to be worn down even as their nation's aircraft production rates sharply escalated. It did not initially appear that way as the aircraft losses that Germany and Japan suffered in the first part of each of their air wars looked 'acceptable' given the results. However, aircraft losses also meant aircrew losses and their national training systems were unable to quickly replace them. Aircrew training was fast-tracked producing inexperienced personnel that meant ever increasing losses in both aircraft accidents and combat. For the German air force and the Japanese air arms, World War II was a long war of steadily accelerating decline (Overy, 1987, pp. 78–84). Attrition bit harshly, even when their forces were seemingly winning.

On the Allied side, air power proved central to victory across the many operational theatres, recognised at the time by their air forces generally receiving the largest share of their armed forces' funding (O'Brien, 2015, pp. 17–66). These were air forces built on a grand scale. Many tens of thousands of aircraft were built and lost, air forces expanded hugely in size and air battles often involved thousands of aircraft. Such large numbers of aircraft being built, used in combat and even lost are today not just unimaginable, but also arguably unattainable.

Modern crewed combat aircraft have remarkably long production times and low production rates. The highest production rate is America's F-35 production line that completes 13 new aircraft a month, almost 160 each year; however, a single F-35 takes 18 months to build (Waldron, 2024). Elsewhere, Europe's highest production rate is the Dassault Rafale with about three aircraft a month; building a single Rafale takes about 24 months (France 24, 2025; Meddah, 2012). The Typhoon rate is less at just over one aircraft each month, achieving 14 aircraft a year. A single Typhoon takes 36 months to build with an extra 12 months if the parts supply chain needs restarting (Martin, 2025; Osborne, 2020).

Ramping up these production rates in times of war seems to be solvable simply by creating many more production lines when needed but this in itself would take years. In World War II, the average time between starting to build an airframe plant and full rate production was 31 months; for aeroengines it was 23 months (Overy, 1987, pp. 90–96). Modern aircraft and engines are much more complicated suggesting even longer times today. Any new aircraft and engine factories set up during a major war would be unlikely to be making useful quantities until well after the war's outcome was decided.

All this means that attrition losses would be hard to quickly make up. However, accurately estimating attrition before a conflict is inherently problematic given the large number of variables. During World War II, the US Army Air Force alone lost dozens of aircraft a day, more than a 1,000 a month (Peck, 2020). More optimistically, in a modern major air war an attrition rate of say only 2% per day might be experienced; that is, 98% of a force would survive each day. Some are more pessimistic albeit using a different basis. A recent Taiwan contingency study assumed an attrition rate of 5% per encounter between Chinese and American crewed combat aircraft (Cancian et al., 2025).

Attrition adds up. Even using the lower 2% daily rate, a nominal 100 aircraft-size combat group would be reduced to half its size in just over a month. This rate would need four of today's F-35 production lines to indefinitely sustain the nominal numbers; the higher World War II average attrition rate would require more than 75 production lines.

Crewed aircraft attrition rates in a major war when set against low production rates implies an air force's crewed aircraft fleets might not recover until post-war. Changes need to be made to ensure modern air forces can stay in the fight in a long, major war. For this, air forces would need to be as they were in World War II: able to quickly recover from losses, able to be rapidly expanded on demand, and of a significant size. In three words: **resilient**, **scalable** and **large**.

3. What can be done?

There are some ways to address today's air forces being ill-suited for fighting long, big wars. Countries could attempt to avoid big wars, however such wars are generally forced on them by aggressive authoritarian states. Ukraine did not choose war but had it imposed on it by Russia's expansionism.

More subject to agency is avoiding long wars. During the Cold War, there was a belief that Soviet armies in a war could rapidly overrun Western Europe. War plans assumed there would be a short opening phase involving conventional forces, quickly moving on to a large scale thermonuclear exchange. Air forces were accordingly designed for intense short-duration operations with no provision made for expanded production in wartime as the war would be over very quickly. The nuclear weapon solution has obvious shortcomings. Fighting a long war may be a poor choice for air forces but is arguably much better than a war drastically shortened by nuclear warfighting.

On the other hand, concerns can be ignored by simply assuming zero attrition, as the Israeli Air Force almost achieved in its 12-day war in June 2025 with Iran; only eight drones were reportedly apparently lost (Malyasov, 2025; Saab & White, 2025). This replicated the air force's success

in June 1982 over Lebanon (Grant, 2002). However, these two short air wars between ill-matched opponents may not be a good guide to long, big wars between major powers. Moreover, Israel in choosing when to start the war was able to fight to its schedule and strategy; this allowed considerable optimised preparation to be undertaken to maximise avoiding crewed aircraft attrition.

An air war involving an aggressive major power may be considerably more difficult. US think tanks studying Taiwan contingencies instigated by China have determined losses of US crewed combat aircraft in their hundreds (Cancian et al., 2025). Military preparedness for a future major war should include the likelihood of aircraft attrition. Not to do so appears militarily unwise and most imprudent, given the nation's survival may depend on not losing the conflict.

If the possibility of a long, major war exists, an option is to double down on crewed combat aircraft, accept attrition will occur and instead build very large air forces in peacetime. These would be sized to last the several years a protracted major war might last given quick recovery from losses is unlikely. Problems with this approach include very high acquisition costs, large infrastructure requirements, substantial continuing skilled workforce demands and high ongoing operating costs.

Unexpectedly, a more viable solution to the crewed combat aircraft problem is being developed and demonstrated in multiple current conflicts involving non-Western forces. The poster child is Russia's long major war against Ukraine. In the war's early months, both the Russian and Ukrainian air forces suffered high attrition rates that were unsustainable. Both air forces needed to quickly change to remain not just useful but also to avoid extinction. Consequently, the two air forces hurriedly moved to carefully husbanding their remaining crewed aircraft while embracing the heterogenous air power model where rockets, missiles and drones take on significant roles.

If traditional air forces were homogenous, the heterogenous air power model is instead characterised by most of the important constituent parts being of a dissimilar kind. The heterogenous model makes tangible an observation made by the recent Vice Chief of Staff of the US Air Force. General James C. Slife discerned that there was a growing realisation that 'We must not allow ourselves to be "affixed by our prefix", only seeing the future fight through the lens of our past platforms. If it operates in the air domain, it is airpower' (Slife, 2024).

Heterogeneous air power continues trends established early last century. In earlier wars, military forces were arranged in a linear, barrier fashion and directly engaged the front of the other fighting force and vice versa using weapons such as swords, crossbows, pikes and, later, muskets. World War I however saw technological developments that allowed firepower to be applied indirectly, well into armies' rear zones behind the front, initially with artillery but then extending into airpower. Warfare shifted from a two- to a three-dimensional fight, and the battlefield bifurcated into notions of the close and the deep battle (Bailey, 2001, pp. 132–153).

This deep battle has now grown to be certainly regional and potentially global but it is a deep battle with different connotations to land forces' combined arms concept. Traditionally, combined arms involves the use of different elements of land combat power to support ground manoeuvre and closing with the enemy (Jensen & Strohmeyer, 2022). Implicit in this are command and control arrangements where the local land force commander prefers to 'own' all the various arms, whether artillery, tanks, infantry, helicopters or crewed close air support aircraft (House, 1984).

In contrast, heterogenous air power applies power across the tactical, operational and strategic levels of war. It is firepower warfare rather than manoeuvre where battlespace mobility dominates thinking. Firepower warfare is instead characterised by extensive synchronisation and planning, centralised command, risk minimisation, focus on the enemy's main strength and destruction by fires (Raymond, 1992, p. 17). Moreover, and arguably a historically new development, is that much of heterogenous air power is uncrewed. These are not similar to say artillery shells of earlier times as these uncrewed systems generally each incorporate precision and can often locate targets independently.

The shift towards the new heterogenous air power model is now arguably dominating contemporary air warfare. Over the past few years, an extraordinary diversity of air systems has been used in conflicts involving Ukraine, Russia, India, Pakistan, Israel, Iran, Hezbollah, the Houthis and Hamas (Borsari, 2025; Clary, 2025; Layton, 2025b).

The new model was well illustrated in the six-week period from early May to mid-June 2025. Across this period, the Houthis continued periodically launching ballistic missiles and drones at Israel some 1,600 km distant, even while Israel undertook significant retaliatory crewed aircraft strikes in response. The Houthis' attacks – amongst the longest-range ballistic missile attacks in history – were mostly defeated by Israel's integrated air and missile defence (IAMD) systems (Al Jazeera, 2025b; Mizokami, 2023).

Early in May 2025, a brief air war erupted between India and Pakistan. This involved subsonic and supersonic cruise missiles, glide bombs, a variety of drones, surface-to-air missile (SAM) systems, ballistic missiles and long-range air-to-air missiles. Crewed aircraft were also used but remained in their own national airspace. Around the same time, two Russian Su-30 fighter jets were shot down in Russian territory by a Ukrainian uncrewed surface vessel off the coast that fired modified air-to-air missiles (Newton, 2025).

By late May, Russia was regularly launching hundreds of drones and comparatively smaller numbers of ballistic and cruise missiles in night-time attacks on Ukrainian cities (Hunder & Mason, 2025). Many were defeated by Ukrainian hard and soft-kill air defence systems. Reversing this, in the last week of May, Russia claimed to have intercepted more than 2,300 Ukrainian drones (Al Jazeera, 2025a).

By then, Ukraine was creating a so-called 'drone wall' to defend against Russian ground forces and prevent their advance. The wall includes counter-drone systems, drone interceptors, drone mining systems, radars and electronic

warfare, and is supported using robotic logistics delivery systems (Velhan, 2025). In early June, Ukraine used 117 drones in a covert attack on airbases deep in Russian territory destroying or seriously damaging some 20 strategic bombers and other aircraft (Strategic Studies Department, 2025).

Finally, in mid-June 2025, Israel launched large-scale air operations against Iran using crewed combat aircraft, air-launched ballistic missiles, cruise missiles, short-range drones, long range/high endurance drones and glide bombs. Iran responded by firing more than a thousand ballistic missiles and drones against Israel; most were defeated by the IAMD and crewed fighter aircraft. This 12-day war, and the Houthis conflict, were most unusual in being almost totally fought in the air. The protagonists did not share a border, making long range air warfare the primary method of waging war.

In considering this busy six weeks in mid-2025, it is evident that heterogenous air power can employ very large numbers, certainly hundreds of elements at a time and sometimes thousands. These are numbers unimaginable with present day crewed combat aircraft and, as the earlier discussion of production rates and times revealed, now unachievable. Relying on crewed combat aircraft alone is no longer enough.

4. Resilient, scalable and large

The heterogenous air power model can address the problems inherent in the long manufacturing times and slow production rates of modern crewed combat aircraft. An air force with its capabilities distributed across crewed aircraft, rocket, cruise and ballistic missiles, and drone systems can be resilient, scalable and large. This model could allow air forces to fight long, big wars.

Resilience involves the speed of recovery from attacks and reducing their impact (Minister of Civil Defence, 2019). Major war attrition rates when combined with low crewed aircraft production rates means an air force's air combat force would steadily decline. Today's air force model built around hard-to-build crewed aircraft is inherently not resilient.

In contrast, the production rate of rockets, missiles and drones is considerably higher than for crewed aircraft. As an example of the relative rates, Russia each month makes about 2 crewed combat aircraft, some 50 Iskander ballistic missiles, 100 cruise missiles, 500 Shahed drones and more than 300,000 First Person View (FPV) drones (Bint & Hinz, 2025; Kovalenko, 2025; Nikolov, 2024; Watling & Reynolds, 2025).

The counter argument is that crewed aircraft are reusable. Rockets, missiles and drones are generally one-use items. In a major war, however, production rates make up this difference. Crewed aircraft, rockets, missiles and drones will all be consumed in a war but only rockets, missiles and drones can have production rates able to keep up with usage rates. A force structure of rockets, missiles and drones is resilient in being able to recover losses; a force structure solely composed of modern crewed aircraft is not.

Furthermore, resilience also includes reducing the impact of attacks. Crewed aircraft and their airbases are difficult to protect as the adoption of agile concepts that aim to widely disperse crewed aircraft recognise (U.S. Air Force, 2022). By comparison, attacks on rocket, missile and drone elements are likely to have less impact as there can be much greater numbers of them to engage, they can be mobile, they are easier to conceal and widespread dispersal is easier.

The heterogenous model also offers scalability. The higher production rates of rockets, missiles and drones allow a much quicker force expansion than is possible with crewed aircraft. An extreme example is FPV drones; one Ukrainian manufacturer is producing 4,000 a day with the country overall making 5 million annually (Fornusek, 2025). Such extraordinary rates are possible using digital technology, fourth industrial revolution techniques and production being distributed across some 150 companies.

Moreover, combat aircrew typically take years to train so that even if large numbers of appropriate aircraft were suddenly available they might be unusable. Learning to operate and maintain rockets, missiles and drones is shorter with FPVs again an extreme example: courses run by accredited commercial operators train Ukrainians to use combat FPVs in 35-37 days (WeTrueGun, 2025).

More broadly, the considerable variation in the production rates of crewed aircraft, rockets, missiles and drones has impacts when an air force rescales. A heterogeneous force structure will have highly differential velocities of expansion with the balance across the force varying almost daily. Such a force gains scalability although at the cost of constant change in what that force materially comprises.

This constant change in force structure could become even more intense given heterogeneous air forces can readily undertake continual innovation. Innovations in uncrewed systems are inherently simpler to achieve and generally more affordable than for crewed aircraft because, with no risk to crews, there are far fewer safety requirements. Innovations in uncrewed systems can be frequent and ongoing. In the Russia-Ukraine War, there is now a three-month innovation cycle of prototyping, experimenting, testing, mass producing and then fielding drones (Molloy, 2024, pp. 57–60). In contrast, it takes several years to introduce innovations into modern aircraft; an exemplar is the many years being taken for the Block 4 upgrade to the F-35 (Decker, 2024).

Lastly, using a heterogeneous force structure air forces can employ mass, that is, large numbers of elements. Just in the first two weeks of February 2025 alone, Russia deployed over 7,500 FPV drones to the frontline and on one day used over 1,000 (Espreso, 2025). Away from the battlefield, Russia's strategic air campaign against Ukraine also reveals the possibilities. On the night of 8/9 July 2025, Russia used some 740 attack drones, decoy drones, cruise missiles and ballistic missiles. Remarkably, it is expected Russia will shortly be able to routinely launch some 1,000 drones per strike package (Harvey et al., 2025).

These numbers would be inconceivable using only crewed aircraft. Moreover, such large heterogeneous air at-

tacks use relatively little infrastructure compared to what an all-crewed aircraft attack would need. Modern air combat aircraft require airbases and airfields of varying sizes. In contrast, drones and ballistic missiles require much smaller launch systems and these can be dispersed widely. A heterogeneous force structure imposes much less demand for specialised infrastructure than the traditional crewed aircraft air power.

Significantly, the mass employed is not necessarily all of one kind or type of element. A heterogeneous air force can include multiple diverse constituent elements, each optimised for specific tasks.

Most future air wars are now likely to involve well-coordinated, large-scale heterogenous air operations behind and at the frontline, during air interdiction missions and in deep air attacks. Such operations would be designed to combine the defensive and offensive capabilities of multiple crewed aircraft, rockets, missiles and drones to most effectively overcome hostile air forces and inflict the necessary damage. An important concern would be managing the crewed aircraft loss rate given their replacement may be both difficult and time-consuming. This management would involve prudently weighing up the likelihood of attrition against operational needs, and a desire to continue operating them as long as practical.

The combination of crewed aircraft, rockets, missiles and drones can destroy almost all types of targets. Given this, two factors will drive air warfare: accurately locating targets and deceiving adversary forces to avoid being targeted. To address these factors the heterogeneous air force design brings an incredible variety of operational and tactical level possibilities; crewed aircraft can provide human 'forward air controllers' at the battle's edge to direct uncrewed systems operating deep, while these uncrewed systems can be as diverse as the needs require (Dahm, 2025). Such air forces can exploit their resilience to prudently discount the impact of attrition, use scalability to be as large as necessary at the times the war requires, and use mass to overwhelm the defences to devastate air, land and maritime target sets.

The air forces that undertake these heterogenous air operations will be remarkably dynamic in actively balancing across the many diverse capabilities, having constantly changing numbers of force elements available, and featuring embedded innovation. To build such air forces will require changes in what the ADF terms the Fundamental Inputs to Capability (FIC) (Department of Defence, 2025). These are ten defined capability elements or inputs that when purposefully combined could create, sustain and continually remake a heterogenous air force.

5. Building a heterogenous air force

5.1. Organisation

Air forces today rarely change organisationally. Given the long in-service life of their crewed combat aircraft, the organisational structures and competencies of traditional air forces can be set and forgotten about for several decades until a new aircraft type is acquired. However, a heterogenous air force would be continually changing to meet strategic and operational needs. This would particularly be the case for the rocket, missile and drone elements of the heterogenous air force, although some believe crewed combat aircraft with new open software may also become more adaptable to new conditions (Dahm, 2025).

The organisations that comprise a heterogenous air force would need to be designed to be adaptable to quickly respond to rapid changes in the multiple diverse capabilities added, improved, degraded, lost or removed from service. These organisations would need to be more aware of their internal states than presently and, unlike in traditional air forces, be constantly looking ahead to influence production types, rates and timings. Rapid organisational learning would be an imperative.

5.2. Command and Management

The inherent complexity of the heterogenous air force design with its diverse capabilities favours the mission command approach of centralised command, distributed control and decentralised execution (U.S. Air Force, 2023). Current conflicts, including the Russia-Ukraine War, have highlighted that adversaries will deliberately attack command and control structures and systems with numerous hard and soft-kill weapons. Moreover, in a future major war involving the great powers, there is likely to be a considerable focus on shattering the adversary's battle networks (Layton, 2023). Heterogenous air forces will need to function within a harsh and hostile command and control environment.

In a technology sense, the inherent complexity noted earlier favours assisting command and management through the use of artificial intelligence (AI). In this, the use of Lavender by Israel in the Gaza War and Ukraine's use of Delta indicates the usefulness of agentic AI in the relational and networked staff approaches respectively (Layton, 2025a). This experience suggests the preferred approach for heterogenous air forces is the adaptive staff approach with its feedback loop and context input by human staff. This approach is resilient when attacked, best leverages real-time monitoring of the battlespace, allows rapid plan adjustment and dynamic force reallocation, and can incorporate own force preparedness data, logistics aspects and estimates of hostile force actions (Jensen & Strohmeyer, 2025, pp. 10–13, 33–38). While not preferred, networked staff could be a viable option and has the advantage of being combat proven.

5.3. Personnel

The diversity of capabilities presents training difficulties in terms of achieving economies of scale; many small training facilities would be a challenge to sustain from a workforce perspective. However, as noted for FPV drones, some drone and missile training may be able to be much more quickly undertaken than that needed for personnel involved with crewed combat aircraft. Moreover, using the AI adaptive staff approach could flatten command and management structures reducing the workforce size.

An issue would be having sufficient personnel to move seamlessly to 24/7 operations when necessary. Rocket, missile and drone forces may in peacetime involve relatively few personnel as the work required would be mostly sustainment. However, the advent of conflict may quickly necessitate large numbers of warfighting personnel. In this case, there may be a role for reserve personnel available and trained to quickly supplement permanent staff. Reserve personnel involved in the rocket, missile and drone elements of a heterogenous air force may be able to make extensive use of virtual training in locations remote to the actual equipment.

In general, the focus in a heterogenous air force would be on having small numbers of skilled personnel albeit with the balance within this favouring support personnel more than operational personnel. Automated uncrewed systems can be operated by small numbers of personnel but require sophisticated technical support to sustain functioning.

5.4. Collective Training

The heterogenous air force is well suited to the emerging high fidelity networked simulation technologies and computer-generated wargames (Jung, 2024). Diverse capabilities can be synthetically used together and the overall force virtually exercised.

On the other hand, the end-to-end testing of equipment and concepts that occurs in real-world collective training is much harder. Rockets, missiles and drones may be only rarely launched and then under tightly controlled, test range conditions. Consequently, it will be difficult to validate whether the whole force can work together without some damaging interference between the various elements. This becomes even more challenging given the dynamic, always evolving nature of a heterogenous air force. The first time the whole force might be tested, evaluated and verified might be in a war and that verification might only be valid for a short time. Until then, the performance of a heterogenous air force will only be known to the level the quality of the simulation and wargaming modelling allows.

5.5. Major Systems

A heterogenous air force by design is balanced across crewed aircraft, rockets, missiles and drones. Its resilience, scalability and ability to generate mass depends on getting this balance appropriate for the war being fought. Britain's latest strategic defence review offers a useful way to think about this. Using its 20-40-40 conceptualisation, 20% of combat power might come from crewed aircraft, 40% from expendable autonomous systems such as rockets and ballistic and cruise missiles, and the remaining 40% from reusable assets like drones (Wharton, 2025). This construct highlights that current homogenous air forces would need to shift to embrace lower cost air systems able to be rapidly produced at scale.

For example, the RAAF operates four Tritons (five from 2028), arguably the world's most sophisticated and expensive uncrewed system, and is buying fewer than ten of the highly capable MQ-28 Ghost Bat. These are high quality drones but can only be afforded in strictly limited numbers. Moreover, in being highly sophisticated there are similar issues to crewed aircraft in terms of slow production rates and long production times. Using the British 20-40-40 conceptualisation, Triton and Ghost Bat will not constitute the 40% of the force mix allocated to drones, only a small fraction of it.

Heterogeneity can tolerate using less sophisticated elements providing these can be acquired in very large numbers. Iran has long done this, allowing Russia to leverage the Iranian Shahed drone design and manufacture large numbers for its war against Ukraine (Layton, 2025b). Between 2022 and June 2025, Russia had launched almost 29,000 Shahed drones at Ukraine (BBC Monitoring, 2025).

In building a heterogenous air force, an emphasis should be placed on designing simplified missiles and drones that can be mass produced quickly and at low cost from readily available local materials and components. Being able to rapidly scale up heterogenous air power to meet urgent strategic and tactical demands arguably requires adopting such an engineering philosophy. Interest in such an approach is growing.

The US Air Force is funding the Rapidly Adaptable Affordable Cruise Missile (RAACM) project (CoAspire, 2025); and Ares Industries, Anduril and Lockheed Martin are developing low cost, quick-to-make cruise missiles. Russia is already using the comparable 250 nm range Banderol cruise missile (Newdick, 2025).

Simplification, however, implies accepting a reduced operational performance including having lower reliability drones, rockets and missiles. Even so, fielding a cruder form of air power can still be effective, as Houthis' success in attacking Red Sea merchant shipping demonstrated.

5.6. Facilities and Training Areas

A heterogenous air force requires a diverse facilities set: some complicated and expensive; others simple and affordable. As an illustration, crewed aircraft require large functioning airbases whereas many missiles and drones might be easily stored for years in hardened warehouses. There is a distinct lack of facilities commonality across the various aircraft, rocket, missile and drone elements.

This shortcoming extends to training areas. Rockets and missiles will usually require tightly controlled instrumented ranges. Drones may have significant constraints on their usage to avoid hazarding civilian crewed aircraft traffic. Crewed combat aircraft have fewer flight limitations but, to maximise the training value of each sortie, should work in an electronic warfare environment that may be classified and adversely impact non-military airspace users.

5.7. Data

The adaptive staff agentic AI command and management approach relies on the various elements of the heterogenous air force all being able to share and integrate secure data. There should only be a single data view, even if the data is stored across multiple disparate systems. Good data hygiene would be crucial; the data needs to be clean,

that is, mostly error free. In contrast, dirty data includes redundant, erroneous and incomplete data, and outdated information. A heterogenous air force would need to have sophisticated data strategies that address data availability, collection, hygiene and governance.

Of note is that the task of cleaning data needs human involvement. Data-cleaning tools can expedite the task by automating many processes. However, these tools are not autonomous and require column-by-column guidance by a skilled data scientist. More complex issues that arise during data cleaning as a result of unknown unknowns tend to be unique to each dataset and, therefore, not well suited for automated tools. Data scientists with experience in specific datasets may be required (Lingel et al., 2020, pp. 37–38).

5.8. Support

From a support perspective, the context in which a heterogeneous air force will operate is dominated by avoiding being targeted. The traditional airbase used by crewed combat aircraft is increasingly vulnerable to rocket, missile and drone attack as these weapon systems proliferate widely. The necessity for basing agility during war now drives support requirements and practices. However, this is inherently problematic for crewed combat aircraft given their maintenance needs and consumables demands, especially for fuel and weapons. Sortie generation rates can drop off albeit attrition from hostile action is also reduced.

On the other hand, rockets, missiles and drones can operate from widely dispersed locations. Their support requirements are quite varied. Rockets and missiles can be all-up rounds that are boxed until use or needing to be returned to a distant maintenance facility for testing and rectification if necessary. However, the launchers that rockets and missiles use can be bulky and difficult to move. For example, a single Patriot SAM battalion, with its radars and four batteries, took 73 C-17 flights to be deployed from a Pacific base to the Middle East (Epstein, 2025). Similarly, drone support varies greatly; small FPVs can be hand-launched while Triton needs a major airbase.

5.9. Supplies and Industry

These two Fundamental Inputs to Capability (FIC) have considerable conceptual overlap as they relate to heterogenous air forces. As noted earlier, the loss rates of crewed aircraft would need to be judiciously managed as they are effectively irreplaceable. In contrast, the production rates and the types built of rockets, missiles and drones would be constantly adjusted to meet the war's changing demands. Folded into all this is the need for continual innovation.

In the Russia-Ukraine War, both sides co-evolved hoping to get a combat edge; this was achievable because of the technology used. In general, uncrewed systems are inherently easier to develop and then manufacture at large scale than crewed combat aircraft. Rapid innovation is both possible and necessary in the context of a major war with both sides using the heterogenous air force model.

Importantly, this innovation would need to be in quick-to-make systems that ideally use locally made components. Most contemporary missiles are high performance but slow to manufacture. For example, Australia's new Naval Strike and Joint Strike Missiles factory will have the capacity to assemble only up to 100 missiles per year from Australian and imported parts (Australian Defence Magazine, 2022). Similarly, the Ghost Bat is high performance but not necessarily quick to make and uses some imported components whose availability may be determined by other nations, not Australia's needs.

In a major war, the nation's defence industrial base would need to have been prepared for continual innovation and quick-start mass production before the peacetime force structure was lost. Such preparation would rely entirely on government funding. Commercial companies do not invest in building factories to be on standby just in case a need for them arises at some future time. In peacetime, there would be a trade-off between using defence budgets to acquire new force structure or instead to prepare the defence industrial base.

Such preparation might include government owned/government operated facilities being established in peacetime to develop new innovative rocket, missile and drone designs to a level that they can be quickly manufactured. As the government would own the intellectual property, in a war these designs could be easily passed through to prearranged manufacturing facilities equipped to mass produce. This approach could meet peacetime needs, provide relevant industrial experience and allow rocket, missile and drone inventories to be gradually built up. However, the approach would be unlikely to provide the scale or breadth of new capabilities as swiftly as a major war might demand.

To address this, government-owned/contractor-operated facilities could also be established pre-war and run by selected private companies to develop innovative technologies. These companies might further use government funding to build suitable dormant mass production factories capable of quick activation to manufacture the innovations the companies have devised. Importantly, both the government and contractor-run facilities are likely to need extensive use of subcontractors.

A problem in this mix of methods is operating in the context of ongoing rapid innovation and fast design change. The network of facilities involved would need to be established years before a conflict to have the processes, subcontractors and skilled staff in place to allow a quick startup. Easing this somewhat is that the production is probably of light-weight small items, rather than large platforms. Small facilities may be able to exploit additive printing, precision machining, composite fabrication and rapid production refreshes to very quickly meet new operational demands.

6. Conclusion

The heterogenous air force model is not a simple one. It adds rockets, missiles and drones to the traditional crewed combat aircraft model which is already at the leading edge of technology. However, the technologies used in rockets, missiles and drones are well-known. Moreover, implementing the heterogenous air force model both makes possible,

and is enhanced, if the rocket, missile and drone designs are simplified, quick to manufacture and affordable.

Heterogenous air forces are not defined by a single piece of equipment: the crewed aircraft. This may trouble traditionalists but the requirement to be able to fight a protracted major war kills old ideas about air forces and air power. In such a conflict, modern crewed aircraft simply take too long to build and this inflicts serious operational deficiencies. To overcome these obstacles, air forces facing the prospect of fighting long, big wars need to become able to quickly recover from losses, be rapidly expanded on demand, and possess large numbers ready for use. You may not like heterogenous air power but as Margaret Thatcher declared about capitalism: 'there is no alternative.'

Submitted: August 20, 2025 AEDT. Accepted: August 26, 2025 AEDT. Published: October 31, 2025 AEDT.

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Simmill, K. (2025). Air Defence Insights From the Ukraine-Russia Conflict. *Contemporary Issues in Air and Space Power*, *3*(1), bp51798635. https://doi.org/10.58930/bp51798635

Air Power

Air Defence Insights From the Ukraine-Russia Conflict

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Keywords: Ukraine-Russia Conflict, Air Defence, Integrated Air and Missile Defence

https://doi.org/10.58930/bp51798635

Vol. 3, Issue 1, 2025

This paper analyses Ukraine's air defence capabilities during the current Ukraine-Russia conflict to derive lessons applicable to the Australian Defence Force (ADF). It explores the evolution of Ukraine's air defence capabilities from 2014 to 2025, highlighting how preparedness, mobility, integration and Western support enabled Ukraine to counter a multifaceted aerial threat. Comparing Ukraine and Australia's strategic environments identifies similarities, including multi-faceted strategic threats and advanced long-range missile threats, and differences, particularly Australia's geographic isolation and lower risk of invasion. From this comparison, the paper identifies five key insights for the ADF's Integrated Air and Missile Defence (IAMD) system: the need for domestic manufacturing of air defence munitions; the importance of agile and broad system integration; the imperative to defend civilian infrastructure; the limitations of purely defensive systems; and the strategic value of offensive strike capabilities in complementing air defence. These insights underscore the importance of IAMD to Australia's defence, and suggest ways to improve this capability in preparation for any future regional conflict scenarios.

1. Introduction

Ukraine's ability to defend against aircraft and missiles has played a key role in countering Russia's invasion. This offers the ADF an opportunity to identify valuable air defence insights, despite the conflict occurring in a very different strategic context from Australia's.

Australia's 2024 National Defence Strategy and 2023 Defence Strategic Review emphasise the importance of Integrated Air and Missile Defence (IAMD) systems to protect Australia and its interests. The proliferation of long-range precision strike weapons in Australia's region has eliminated the protection previously afforded by our geographical isolation (Department of Defence, 2023). Australia's strategic concept of National Defence expands the ADF's responsibility for countering these threats. An ADF IAMD system must therefore prevent adversaries from using these weapons to threaten Australia or its interests (Department of Defence, 2023).

This paper will examine Ukraine's air defence system and review how Russian threats and Ukrainian responses have evolved. It will then assess the Ukrainian experience from an Australian perspective, comparing the strategic environments and their implications for defending against air and missile threats. Finally, it will present insights from the Ukraine-Russia conflict relevant to the ADF. This paper focuses specifically on military air defence systems and does not examine broader civil defence measures, which merit separate study.

2. Air defence in the Ukraine-Russia Conflict

2.1. Ukraine readies air defences in depth

When Russia invaded Ukraine in February 2022, Ukraine boasted a well-equipped, ready and relatively well-maintained air defence capability. This was a significant improvement on their capability eight years earlier when Russian forces occupied the Crimean Peninsula. In 2014, Ukraine's air defences had suffered from years of neglect. Their predominantly Soviet-era equipment had low operational readiness and inadequate logistics, and their personnel were poorly trained. This led to low levels of readiness, which the Russians exploited in 2014 (Sankaran, 2024). However, in 2014 the foundations were in place for Ukraine to establish a potent air defence system. Importantly, Ukraine's armed forces retained a Soviet-style structure, incorporating more ground-based air defence capabilities than a Western military of similar size (Kofman, 2024).

Russia's occupation of Crimea prompted significant improvements in Ukraine's military capabilities and national defence enterprise. Ukraine's air defence system benefitted from these improvements in three ways. First, increased resourcing led to better training and critical maintenance and repair work. This brought air defence capabilities to high levels of readiness (Roblin, 2021). Second, enhancements to Ukraine's military industry and capability acquisition led to the integration of new drones, munitions and networking software into air defence systems (Kuzmuk & Scarazzato, 2025). Third, the loss of Crimea led to significant Western military aid to Ukraine. Initial support was predominantly non-lethal, but included a crucial data sharing agreement with the US (Mills, 2022). As Russia continued threatening

Ukraine's eastern regions, this support expanded to include military capabilities. Western partners provided air surveillance and command and control systems, along with support to integrate these capabilities with Ukraine's existing air defence equipment (Mills, 2025).

By February 2022, Ukraine's air defence system was large, partially modernised and at a high degree of readiness. Long- and medium-range surface-to-air missiles (SAM) provided coverage over almost all of Ukraine's eastern airspace at medium to high altitudes (Sankaran, 2024). Man-portable air defence systems (MANPADS) and anti-aircraft artillery (AAA) could threaten low-flying aircraft and helicopters (Bronk et al., 2022). Early warning radars could track Russian aircraft, and command and control systems could coordinate air defence responses (Ministry of Defense of Ukraine, 2020).

2.2. Survive to deny: Ukraine's air defences stay in the fight

Ukraine's improved air defence system foiled Russia's attempts to gain air superiority in the initial phase of the conflict, surprising many observers. This prevented Russia from providing air support to its ground forces, negating Russia's plans for a quick victory (Zabrodskyi et al., 2022). Ukraine also had some success in protecting Ukrainian forces and infrastructure from the initial Russian air and missile threat (Bronk et al., 2022). The survivability and resilience of Ukraine's air defences when faced with Russia's initial attacks was crucial to these successes.

Russian air forces conducted a missile bombardment, accompanied by air strikes, to support the initial land invasion of Ukraine. Their goal was to destroy Ukraine's air defence capabilities and achieve air superiority over Ukrainian airspace. They targeted airfields, SAM sites and early-warning radars. However, the Russian air forces were not doctrinally prepared to conduct a Western-style suppression of enemy air defence (SEAD) campaign, and the strikes were poorly planned, lacking the necessary scale and concentration of force (Sankaran, 2024). The Ukrainians also knew the invasion and accompanying strikes were imminent, thanks to American intelligence. This allowed them to disperse their air defence capabilities, further limiting the effectiveness of the Russian strike campaign. While 75% of Ukraine's air bases were struck, only around 10% of their mobile air defence assets were attacked in the first 48 hours of the conflict (Zabrodskyi et al., 2022).

Within 3-4 days of the initial invasion, Ukraine was able to re-establish basic air defence operations using mobile SAMs and early warning radars (Sankaran, 2024). They then rebuilt their command and control network, and began sharing targeting information and integrating electronic warfare measures. They kept their SAM systems moving and reduced the electronic signature of both SAM and radars to increase their survivability (Bronk, 2023). MANPADS and AAA were integrated, threatening Russian aircraft at low altitudes. Together, these measures imposed steep costs on the Russian air force and prevented it from operating freely over key areas of Ukrainian airspace (Plopsky & Bronk, 2024).

While denying Russia freedom of action, Ukraine could not achieve air superiority. Long-range Russian SAM located in both Russia and captured Ukrainian provinces targeted Ukrainian aircraft over eastern Ukraine (Layton, 2025). Within weeks of the Russian invasion, a state of mutual air denial was established in eastern Ukraine – a situation that has continued for crewed aircraft on both sides ever since.

2.3. The defensive obligation: responding to new Russian tactics and targeting

Russia seized the initiative in the air war after its initial failures by changing tactics and targets. With Ukrainian airspace deemed too dangerous for crewed aircraft, the Russian military began prioritising missile and drone attacks. As their hopes for a quick victory faded, they began targeting civilians. Ukraine's air defence systems were forced to respond, changing both how they defended and what they defended (Gibbons-Neff et al., 2023).

Russia launched massive, coordinated attacks of drones and missiles at Ukrainian targets. Multitudes of relatively cheap, disposable drones were integrated with less numerous but more dangerous cruise and ballistic missiles. These mass strikes presented Ukrainian air defences with three problems. First, the mass strikes often overwhelmed Ukraine's air defence capabilities, with many, but not all, threats often being defeated (Bronk et al., 2022). Second, Ukraine was forced to find more economical ways to defeat low-cost drones. Third, Ukraine needed to distinguish between the different types of threats, allowing its defences to prioritise the highest threats.

Russia's military began focusing air and missile attacks on civilian targets in the northern winter of 2022. While strikes on Ukrainian forces continued, air attacks were expanded to target water distribution facilities, petroleum processing facilities, and electricity generation and distribution infrastructure (Harmash, 2023; Reuters, 2023).

This shift in tactics and targeting imposed new challenges on Ukraine's air defence systems. They needed to be able to rapidly discriminate drones from cruise and ballistic missiles, share that targeting information, and assign the most appropriate air defences to each target type. They learned that some threats needed to be targeted multiple times to ensure they were defeated, complicating an already complex air defence plan. Most challenging of all, they now had to defend both civilian infrastructure and military forces, constantly prioritising between the two; all while managing a constrained supply of air defence munitions and expendables (Watling & Reynolds, 2025).

2.4. Ukrainian advances and Western aid

Ukraine needed to improve and expand their air defence capabilities to address these new challenges. They also needed to reduce the resources required to counter each Russian threat to ensure their air defences were sustainable. Ukraine addressed these challenges through a combination of local defence innovation, Western military aid and a focus on force integration.

Ukraine's military industry has enabled constant improvements to air defence systems throughout the war, building on pre-war foundations. Soviet-era SAM systems have been modified to fire either Ukrainian air-to-air missiles or Western missiles, allowing more readily available munitions to be used (Di Mizio & Gjerstad, 2025). New systems were also developed, built and introduced into service. This included automated artillery systems for targeting drones, and jamming systems to counter drone control signals and the guidance systems used by Russian cruise missiles (Watling & Reynolds, 2025). These systems were cheaper and more sustainable options for defeating drones and missiles, complementing existing SAM systems. Developing these systems in Ukraine also enabled rapid and responsive system updates as the threat continued to evolve (Kuzmuk & Scarazzato, 2025).

Multiple international partners began delivering Western air defence systems as military aid from late 2022 (Mills, 2025). These systems added capacity and provided different types of capabilities to the Soviet-era systems employed by Ukraine. More military and civilian assets could be protected, and the newer, more effective systems could be used against the most dangerous threats, increasing engagement success (Di Mizio & Gjerstad, 2025). The importance of these systems to Ukraine's defences against Russian air threats cannot be overstated, as reflected in Ukraine's continued requests for more such systems (Reuters, 2024).

Ukraine integrated these new systems with their existing ones by combining Western support, domestic industry solutions, and fixes identified by military operators and technicians (Yaffa, 2022). Quick, simple solutions were prioritised, and distributed rapidly throughout the force (Hakmeh, 2025). Commercially available technologies, including satellite bearers, phone-based chat applications and internet protocol-based communications, were integrated whenever they provided the best solution (Bondar, 2025). Civilian authorities were also integrated, providing air raid warnings and coordinating emergency responses (Malyasov, 2025). These efforts were crucial to fully maximising the capabilities of both new and existing systems, increasing the efficiency and effectiveness of the air defence system as a whole.

2.5. Offence is the best defence

The most recent, and perhaps most significant, change to Ukraine's air defence system is an increased effort to negate Russian air and missile threats before they launch. In November 2024, the United States (US) administration authorised Ukraine to strike targets in Russia with US-made weapons (Stone & Pamuk, 2024). Shortly after, Ukraine launched its largest strikes on targets in Russia, integrating US-made Army Tactical Missile System (ATACMS) ballistic missiles, United Kingdom (UK)-made Storm Shadow cruise missiles and Ukrainian-made strike drones. Several similar strikes have followed, targeting oil refineries, ammunition plants, air bases and aviation fuel distribution infrastructure. These strikes have directly impacted Russia's ability to launch and sustain aircraft, and to launch missiles at Ukraine (Reuters, 2025).

Ukraine has also extended their strike range into Russia through less-conventional means. In May 2025, six Russian airbases, some thousands of kilometres from Ukraine, were simultaneously struck by commercial drones smuggled into Russia (Ryan, 2025). The damage caused by the strike remains unconfirmed. However, initial reports describe the destruction of Russian strategic bomber and strike aircraft. These aircraft had launched cruise missiles from beyond Ukraine's air defence coverage and are irreplaceable in the near term. Their destruction represents a significant reduction in the Russian air threat (Collett-White et al., 2025).

These strikes demonstrate a shift in Ukraine's air defence strategy towards a more offensive approach. This is reflected in Ukraine's recent priority requests for both air defence and strike systems (Poznansky & Wohlforth, 2025). This shift can also be viewed as a continuation of efforts to counter Russian air threats in the most efficient way. Destroying Russia's fuel and airbase infrastructure, or their aircraft before they launch, reduces Russia's threat far more significantly than simply destroying drones and missiles once they are airborne (Ryan, 2025).

3. A comparison of strategic environments and threats

Ukraine's successes suggest there are valuable air defence insights for the ADF. To identify insights that are relevant, the similarities and differences between Australia's strategic environment and that of the Ukraine-Russia conflict must be understood. Relevant insights can then be identified, and inform the ADF's realisation of an air defence capability, which is critical to defending Australia and its national interests (Department of Defence, 2023).

Both Europe and the Pacific region are characterised by competition across the economic, military, strategic and diplomatic spheres (Department of Defence, 2024a). Even before Russia's invasion of Ukraine in 2022, Russia was conducting cyberattacks on Ukrainian institutions and causing unrest in Ukraine's eastern provinces (Anghel & Spatafora, 2025). After the invasion, European countries quickly imposed significant economic sanctions on Russia, while initially still purchasing large quantities of natural gas (Sorge, 2023). This highlighted the multi-faceted relationships and dependencies between countries in the region.

Australia's strategic environment is similarly complex and competitive. Nations in Australia's region have demonstrated the will and ability to coerce other countries and challenge the existing rules-based order (Department of Defence, 2023). These efforts have included economic, military and diplomatic measures. China's imposition of trade restrictions on Australia in 2020, leveraging their economic might, is one such example (Edmonstone, 2024), and has parallels with Russia's leverage over its European gas customers. These challenges are accompanied by an unprecedented military build-up in the region, conducted without any strategic reassurance or transparency (Department of Defence, 2023). Despite these similarities, there are also

significant differences between the threats faced by Australia and Ukraine in their respective environments.

The most significant difference between Australia and Ukraine is Australia's much lower risk of invasion. The 2024 National Defence Strategy (NDS) stated that such an invasion remains only a remote possibility (Department of Defence, 2024a). Australia's lack of land borders, geographic separation from potential adversaries, size and sparse infrastructure, particularly in the north, all make it difficult to invade. There is also no motive for any nation to invade Australia that is comparable to Russia's desire to 'reunite' Russia and Ukraine.

An invasion of Australia is unlikely, and it is also unlikely that Australia would be forced to defend against a missile threat alone. Instead, Australia may become involved in the escalation of one of several regional flashpoints, or a great power confrontation between China and the US, or both (Department of Defence, 2024a). These situations may see Australia targeted directly. But in no case would Australia face a regional threat alone, unlike Ukraine's defence against the Russian threat.

Although Australia may not be at risk of invasion, it is at risk of coercion. Countries in the region possess military capabilities, including modern cruise and ballistic missiles, that can overcome Australia's geographic isolation and threaten Australia. The Chinese Naval Task Group that recently exercised around Australia provides an instructive example of this threat. The cruiser in that task group can carry up to 112 cruise or ballistic missiles, all with a range exceeding 1,500 km (US Army Training and Doctrine Command, 2025). Strike and bomber aircraft in the region can carry missiles able to strike targets in northern Australia, while both intermediate-range and inter-continental ballistic missiles in the region can reach Australia (US Department of Defense, 2024). These missile threats provide a means of influence, and even deterrence, that Australia must be able to counter. The 2023 Defence Strategic Review recognised this, describing an all-domain IAMD capability as a critical capability for the ADF (Department of Defence, 2023).

Ukraine faces a similarly advanced cruise and ballistic missile threat. But it must also defend against mass strikes integrating these missiles with large numbers of cheap, disposable drones. Australia does not face an equivalent threat due to its geographic separation. Cheap, disposable drones cannot generally be launched from ships or aircraft, and lack the range to reach Australia from mainland bases in the region (Hollenbeck et al., 2025). The scale of the missile threat in Australia's region also differs from the Russian threat to Ukraine. Unlike Russian strikes on Ukraine, potential adversaries would need to rely heavily on sea and air-launched missiles to strike Australia. This reliance on sea- and air-launched missiles limits the ability to launch such raids against Australia night after night, over months to years, as Russia has done in Ukraine (Center for Strategic and International Studies, 2025). As lethal as these missiles are, ships and aircraft must return to base to reload. Transporting missiles from a nation's industrial base to air and naval bases, through a potentially contested environment, is a major logistical challenge.

Australia should, like Ukraine, be prepared to counter an adversary willing to target civilian infrastructure. Russia has forced Ukraine's air defence system to protect both critical civilian infrastructure and military forces (Gibbons-Neff et al., 2023). Any regional nation aiming to coerce the Australian Government could achieve this by threatening missile strikes on civilian infrastructure. Such threats may be more effective than threats against military targets. As shown in Ukraine, the aggressor, rather than defender, can often seize the initiative through their targeting decisions.

4. Key insights

This comparison of Australia and Ukraine's strategic environment allows insights to be drawn from Ukraine's ability to defend against Russian air threats. Five such lessons have been identified:

- Australia must manufacture air defence munitions domestically.
- Integration of the ADF's air defence systems must be broader and more agile.
- The ADF must be able to defend civilian infrastructure.
- The ADF IAMD system will not defeat all missile threats.
- A strike capability must complement the defensive capabilities of an IAMD system.

4.1. Domestic manufacturing of air defence munitions is essential

Australia needs to be able to manufacture air defence munitions within Australia to ensure a reliable supply of these munitions during any conflict. Australia currently has no ability to manufacture the sophisticated munitions used by the ADF's air defence capabilities (Blenkin, 2024) and would struggle to replenish stocks of these munitions during a conflict. Ukraine's inability to manufacture missiles for its Soviet-era launchers has made it reliant on existing stock and donations from supporting countries. This limitation has forced careful rationing of a finite resource throughout the conflict and constrained their air defence systems (Watling & Reynolds, 2025).

The strategic context of any Australian conflict would make it even more difficult to resupply air defence munitions. Supporting countries have donated military equipment to Ukraine without having to consider their own needs in conflict. Yet they have still been reluctant to donate capabilities that may be needed in the future, or to significantly reduce their weapons stockpiles (Bayer et al., 2022). In contrast, the ADF would likely be expending air defence munitions as part of a regional conflict. The US, the primary supplier of Australia's air defence munitions, would probably be involved in such a conflict. Would the US be willing to resupply the ADF with the same air defence missiles they themselves are relying on at the time? Even if they were, their ability to transport these missiles to Australia, through a probable conflict zone, is far from assured.

The ADF cannot plan to rely on US resupplies of these weapons during a conflict.

The 2024 NDS and Australian Guided Weapons and Explosive Ordnance Plan describe the need to establish a domestic guided weapons and explosive ordnance manufacturing capability (Department of Defence, 2024b). Currently, this plan only establishes domestic manufacturing of strike weapons. While these weapons clearly contribute to Australia's strategy of deterrence, the Ukraine-Russia conflict has shown that a continuous supply of air defence munitions is critical to defending the nation. Domestic production of these air defence munitions must be incorporated into this plan.

4.2. Integration of the ADF's air defence systems must be broader and more agile

The ADF must better integrate its air defence systems and make its integration processes more adaptive. The ADF's IAMD system currently excels at digitally sharing tactical data between sensor, C2 and weapon platforms. Operational headquarters can receive space-based early warning of missile launches in the region (Australian Defence Magazine, 2024), and integration with other government agencies and civilian authorities has been demonstrated in whole of government activities (Australian Civil-Military Centre, 2024). However, it takes years to introduce and integrate new elements into the ADF's IAMD system (Rhodes, 2024). An air defence threat to civilian infrastructure would require closer, and potentially more automated, integration with civilian authorities and first responders than has been demonstrated to date.

The Ukrainian Air Force has shown the benefits of an adaptive, wide-ranging integration approach. Under the pressure of combat they have rapidly integrated Western and Soviet military equipment to maximise the capabilities of the air defence system as a whole (Yaffa, 2022). They have incorporated US-sourced strategic intelligence into their targeting procedures (Mills, 2022). They have rapidly received and integrated improvements to their air defence systems from the domestic military industry (Kuzmuk & Scarazzato, 2025). They have also prioritised commonly available commercial technologies over bespoke military solutions where they provide the best option (Bondar, 2025). And they have established links with civilian authorities that provide air raid warnings and coordinate emergency responses (Malyasov, 2025). Integration of an air defence system is not a new concept (the I in IAMD gives this away). The force-multiplying effect of a rapid and flexible integration approach has been demonstrated by Ukraine, as has the importance of close integration with civilian authorities. The ADF's IAMD system should be guided by both.

4.3. The ADF must be able to defend civilian infrastructure and the population

The ADF's IAMD system must be able to defend both civilian and military assets. This goes beyond the direction provided in the 2024 NDS, which describes 'missile defence to protect critical Defence infrastructure, Defence facilities and the ADF from long-range and high-speed missile capabilities' as a capability priority in the coming decade (Department of Defence, 2024a). Russia's targeting of civilian infrastructure and population centres to achieve strategic and operational effects against Ukraine highlights the limitations of this focus on Defence infrastructure and facilities.

Unlike Ukraine, an air and missile threat to Australia is not likely to occur alongside a land invasion. Instead, it may aim to destroy key military capabilities. Or it may aim to force, coerce or deter the Australian Government from acting in the country's best interests. Protecting Defence assets, as currently directed by the NDS, only addresses the first of these threats. The threat of a missile strike on unprotected civilian population centres or infrastructure could change the Australian Government's decision-making calculus. Such a threat would negate an IAMD system that only protects Defence capabilities and highlight the shortfalls of the current NDS guidance.

4.4. The ADF IAMD system will not defeat all missile threats

The ADF's IAMD system will never be able to protect all critical Australian military and civilian infrastructure against the regional air and missile threat. Ukraine's air defence system, which is far more extensive than the ADF's, defending an area smaller than NSW, has been unable to completely negate the modern missile threat posed by Russia. Russia's cruise, ballistic and hypersonic missiles still defeat Ukraine's air defences, striking their targets and causing significant damage (Bronk et al., 2022). Few if any countries could defend their civilian population centres, critical infrastructure and national interests from the missile threat faced by Ukraine.

It is similarly unrealistic to expect the ADF to defend all of Australia's critical infrastructure from the regional air and missile threat. The Australian Government must accept that successful missile strikes on Australian military and civilian infrastructure are likely in any significant conflict. Both national strategic and military planning must therefore incorporate ways to mitigate this threat beyond an IAMD system, including emergency response, civil defence and national resilience. The Ukraine-Russia conflict presents insights that can inform such planning, and these deserve further examination.

4.5. A strike capability is an essential part of integrated air and missile defence

To complement a defensive IAMD system, the ADF requires a strike capability that can deter or disrupt potential threats. Ukraine has recently demonstrated that targeting launch platforms, or the infrastructure supporting those platforms, can more efficiently and effectively reduce Russia's air and missile threats (Collett-White et al., 2025). These strikes have forced Russia to change their air basing plan, reduced their ability to overcome combat losses, and

may decrease the size of missile raids that can be launched at Ukraine (Reuters, 2025).

ADF strike capabilities that can target warships, air bases and supporting facilities would contribute significantly to countering the regional air and missile threat. Any nation wishing to deter Australia with an air and missile threat would themselves be at risk, potentially changing their decision-making calculus. In conflict, such capabilities would degrade an adversary's air and missile threat and complement the defensive capabilities of an IAMD system.

5. Conclusion

The ADF has a significant opportunity to learn from how Ukraine has implemented its air defence system against Russian threats. Valuable and relevant insights can be identified by understanding how Ukraine has defended against this threat, and by comparing Australia and Ukraine's strategic environments.

Ukraine's air defence systems have slowed Russia's ground invasion and reduced the threat to Ukrainian forces. They have constantly adapted to new threats, integrated new technologies, and launched offensive operations when possible. Australia does not face the risk of invasion that Ukraine does. But like Ukraine, Australia must be prepared to counter advanced air and missile threats. These threats may be used to coerce the Australian Government or may be realised in a regional conflict.

This paper has identified five insights relevant to the ADF's IAMD system. Australia must manufacture air defence munitions domestically. The ADF must expand the integration of its air defence systems and make its integration processes more adaptive. It must also be able to defend civilian infrastructure. The ADF's IAMD system will never be able to protect all critical Australian military and civilian infrastructure against the regional air and missile threat, and a strike capability must complement the defensive capabilities of an IAMD system. Not all these insights are new, nor will implementing them guarantee Australia's safety against the regional air and missile threat. However, the Ukraine-Russia conflict suggests they can improve the ADF's IAMD capability, and ensure it is ready to defend Australia should the need arise.

Submitted: August 04, 2025 AEDT. Accepted: August 18, 2025 AEDT. Published: September 10, 2025 AEDT.

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Strategy

Tacticisation of Strategy: A Comprehensive Review

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Keywords: tacticisation, strategy, tactics, military domain, political domain

https://doi.org/10.58930/bp53952301

Vol. 4, Issue 1, 2026

Strategy has been expressed in many different ways, such as a course of action that integrates ends, ways and means to meet policy objectives. However, strategy can be replaced by tactics and some scholars have labelled this phenomenon 'tacticisation of strategy'. In the context of this review, 'strategy' means a specific plan concerning the direction and use made of means, by chosen ways, to achieve desired ends. Its function is to cope with a particular historical context in time and space. On the other hand, 'tactics' refers to actual military behaviour or how strategy is executed. This comprehensive review investigates how tacticisation of strategy is conceptualised by analysing a range of different interpretations. The aim is to identify common properties relating to how tacticisation of strategy is conceived, how it manifests, and how it influences strategy. The review demonstrates the near-universal practice of leveraging Michael Handel's work, and the absence of thorough examination by any scholar, has not prevented a proliferation of different explanations for the concept of tacticisation of strategy.

1. Introduction

One of the great challenges of strategy has been the extensive debate about its definition, meaning and use (Betts, 2000; Black, 2020; Freedman, 2013, 2017; Gaddis, 2019; Milevski, 2016; Nolan, 1989; Scott, 2021). Strategy has been expressed in many different ways, for example as a 'course of action that integrates ends, ways and means to meet policy objectives' (Ministry of Defence, 2017, p. 6); a 'plan of action designed in order to achieve some end … a purpose together with a system of measures for its accomplishment' (Wylie, 2014, p. 14); a 'central rule' (Compo, 2022, p. 10); 'the art of creating power' (Freedman, 2013, p. 607); a 'theory of victory' (Cohen, 2002, p. 33); 'a theory of success' (Meiser, 2017, pp. 86–87); and as the mathematical formula 'strategy equals *ends* (objectives toward which one strives) plus *ways* (courses of action) plus *means* (instruments by which some end can be achieved)' (Lykke, 1997, p. 183). Strachan famously asserted the meaning of strategy had become lost through the 'conflation of strategy and policy' and 'strategy's propensity to replace policy' which resulted in the 'militarisation' of policy (Strachan, 2005, pp. 36–43, 52).

Another serious problem of strategy is the reverse of that argued by Strachan: the potential for strategy to be replaced by tactics. Some scholars have labelled this phenomenon 'tacticisation of strategy', arguing it was the cause of devastating strategic failures including Ludendorff's 'last offensive' of 1918, Rommel's North Africa campaign in the Second World War, and America in Vietnam (Handel, 2001, pp. 353–360). Handel claimed tacticisation caused strategy to fail as often as it succeeded by allowing 'operational or tactical considerations [to] influence strategic decisions often as much as they are influenced *by* them' (Gray, 2016, p. 247; Handel, 2001, pp. 353–354). Australia is not immune: its recent contributions in Afghanistan arguably demonstrate the hallmarks of tacticisation (Hocking, 2022, Key Organisational-Level Lessons 1–6, 8). However, unlike strategy, tacticisation of strategy has not been examined in detail by academic literature. Studies that exist are mostly cursory and ambiguous, with authors offering contradictory interpretations. Given the potentially existential consequences of failed strategy, we should not be content with this lack of clarity. Politicians and Defence practitioners responsible for developing and executing strategy are unlikely to be knowledgeable of tacticisation as a concept, and unable to manage its effects.[1] Providing clarity about tacticisation is therefore highly valuable.

In the context of this study, 'strategy' means a specific plan concerning the direction and use made of means, by chosen ways, to achieve desired ends. Its function is to cope with a particular historical context in time and space (Gray, 2010, pp. 8, 9, 15, 83). This should not be confused with the second element of Grey's definition, being a general theory applicable to all contexts (times and spaces), for the purpose of educating strategists. 'Tactics' refers to actual mil-

1 'Tacticisation of strategy' is abridged to 'tacticisation' for the remainder of this study. British grammar is adopted, except for direct quotes adopting American convention.

itary behaviour. Tactics is how strategy is executed (Gray, 2015b, pp. 26, 39, 40).

Here, I review and compare existing literature using a graphical form of the well-known levels of analysis heuristic comprising grand strategy, strategy, operations and tactics. The review begins with the work of the largely unrecognised originator of the concept, former Israeli intelligence chief Yehoshafat Harkabi. Next, I discuss Handel's concept of tacticisation given that his work is the most often cited. I then discuss other scholars' concepts, beginning with those who have provided the least significant contributions, and finishing with Colin Gray who discussed tacticisation in several works. The aim is to identify the characteristics of tacticisation as conceived by these authors, and whether they agree on how tacticisation manifests and influences strategy.

2. Literature review

Only thirteen scholars have analysed the concept of tacticisation explicitly, and the majority only briefly. A range of different interpretations exist, which is notable given the same originating source is persistently cited: *Masters of War: Classical Strategic Thought* (Handel, 2001). Handel himself did not conduct a detailed examination: in *Masters of War*, he addressed the concept as part of a seven-page appendix. This literature review demonstrates the near-universal practice of leveraging Handel's work, and the absence of thorough examination by any scholar has not prevented a proliferation of different explanations for the concept of tacticisation.

2.1. Yehoshafat Harkabi

Harkabi's account of tacticisation, in an Israeli context, is contained in his book *Israel's Fateful Hour* (Harkabi, 1988), which is an English translation of his original work entitled, *Hachraot Goraliot*. While he provided no definition, Harkabi drew on American diplomat George Kennan's metaphor for good diplomacy, distinguishing between 'gardeners' who 'laid the groundwork and nurtured growth' and 'mechanics' who were geared to 'dramatic improvements from a single, decisive move' (Harkabi, 1988, p. 76). Tacticisation occurred when political leaders acted like mechanics, treating war as a 'drastic event' and 'wag[ing] the war as if it were a battle' rather than recognising 'war is not an event, but a process; a battle is an event … [at] the strategic level … a single battle is not conclusive … tactical gain in a battle does not necessarily mean gain in a war' (Harkabi, 1988, p. 93).

The problem conceived by Harkabi was politicians immersing themselves in tactics and ignoring strategy. Tacticisation was a *dual failure* by those in the *political* domain. The first failure occurred when politicians did not provide grand-strategic influence on military strategy:

> [P]olitical leadership must guide the military on major questions, explaining the strategic goals to them as well as how the planned operation fits in with the historical circumstances and with other political and diplomatic activities it is undertaking. It must likewise provide direction as to what should be achieved and what avoided … [not] merely rubber-stamp … a decision that had been made for them without guidance or comment on their part, as if they had no choice (Harkabi, 1988, p. 96).

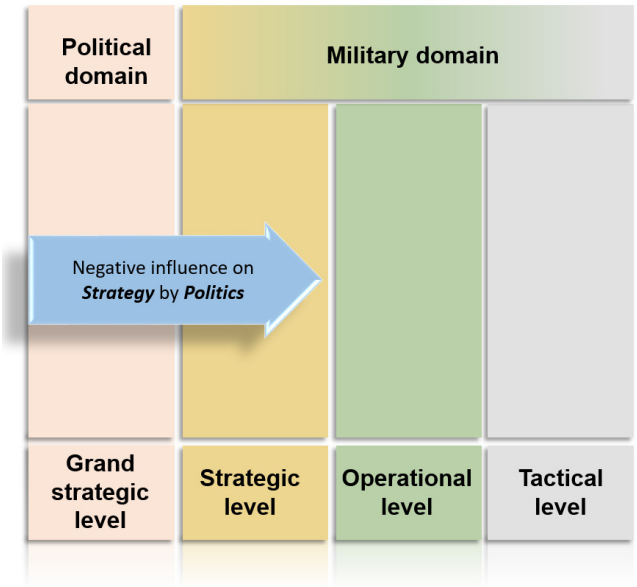

Figure 1. Harkabi's conception of tacticisation as a negative influence of two elements: (1) failure to provide a guiding grand-strategic influence; and (2) failure to refrain from providing unwarranted tactical influence.

The second failure occurred when politicians involved themselves in sub-strategic activity, as Israeli ministers did in the First Lebanon War:

> The Lebanon War … was conducted as a campaign, not as a war … the minister of defence, served as the chief of staff, operating from the forward command posts … the supreme command focuse[d] on the tactical level instead of the strategic (Harkabi, 1988, p. 96).

For Harkabi, tacticisation was the negative influence of politics on military strategy through both act and omission: a failure to provide guiding grand-strategic influence, and a failure to refrain from providing unwarranted tactical influence, *by* the political domain, *directed to* the military domain (Figure 1). Harkabi made clear the phenomenon did *not* manifest as misapplied influence *by* the military domain, *directed to* the political domain. The problem was not that politicians were improperly advised by their Generals. 'The problem was inherent in the way of thinking' within the political domain (Harkabi, 1988, p. 95).

2.2. Michael Handel

Handel (1994) first mentioned tacticisation in his chapter of *The Making of Strategy: Rulers, States, and War*, where he credited Harkabi (1988) as the originator of the concept (Handel, 1994, fn 69). Like Harkabi, Handel criticised Israeli strategy as being reactive, disproportionately prioritising

the immediate problem of national survival over longer-term objectives:

> Israeli decision-makers have acted according to operational imperatives without a clear conception of long-range objectives and without assessing the ultimate consequences of operational success. Instead of strategy governing the use of force, the logic of military operations often determined that of strategy. The domination of military considerations and the fact that the Israeli military determined national security policy and strategy, restricted the scope of Israeli strategy and permitted short-range operational pressures to take precedence over key long-range considerations (Handel, 1994, p. 570).

Handel provided no further analysis but his brief description appears clear enough: tacticisation occurs when military operations determine grand strategy, enabled by the military dominating the political domain. Note the direction of influence is opposite to Harkabi's: Handel argues it is the *military* that exerts improper influence on the *political* domain. Handel reproduces only one element of Harkabi's dual failure, perhaps because the second element makes no sense with the direction of influence reversed: it is nonsensical to argue the military has a responsibility to provide grand-strategic influence into the political domain, and it fails if this is not undertaken.

Handel's later work *Masters of War* provided additional explanation: possibly the reason it is cited by scholars, in lieu of his 1994 work. Notably, *Masters of War* made no attribution for the concept, resulting in most scholars citing Handel, not Harkabi, as the original source. Like Harkabi, Handel provided no clear definition, instead offering three, somewhat contradictory, explanatory statements: 'the de facto primacy of military over political considerations'; 'lower-level operational considerations defining strategy in war'; and 'the operational or military tail wagging the political-strategic dog' (Handel, 2001, pp. 73, 355). The first statement pits the concept as the influence of military considerations (be they tactical, operational or military-strategic) on the political (grand-strategic) level. The second reduces tacticisation to a military problem, specifically the influence of the operational level on the military-strategic level. The third views tacticisation as the influence of the military's operational and strategic levels on the grand-strategic level. The consequence is 'strategy is not consciously formulated, it emerges by default. Instead of being the driving force in war, strategy becomes a mere by-product or afterthought' (Handel, 2001, p. 354).

Handel's conception is interpreted in **Figure 2**. Comparing **Figures 1** and **2**, it is clear that Handel did not replicate Harkabi's conception of tacticisation. This has gone unnoticed by scholars, because the link between Harkabi and Handel is non-existent in the often-cited *Masters of War*.

2.3. Authors dealing cursorily with tacticisation

Around 60 authors refer to tacticisation but provide little explanatory detail (Hood, 2022). In one case (Rabaey et al., 2004, p. 8), tacticisation was referenced in a manner that

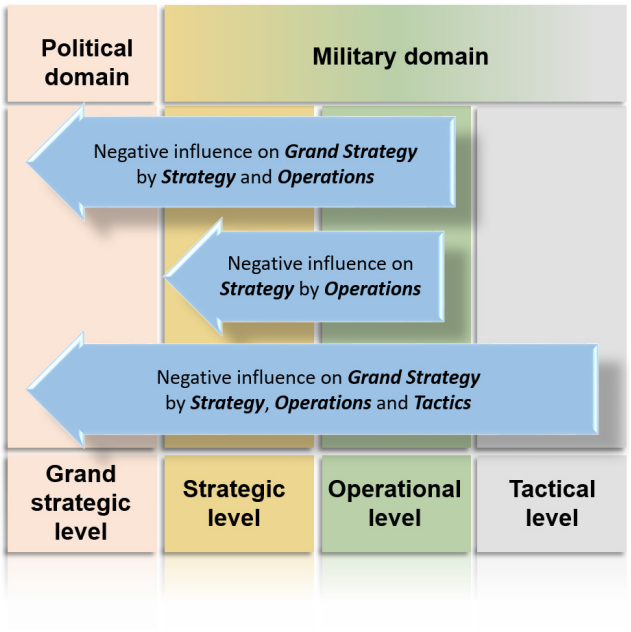

Figure 2. Handel's conception of tacticisation as the provision of unwarranted influence from sub-strategic levels to strategic and grand-strategic levels.

suggested it could provide a *beneficial* influence on strategy. In a later work, however, Rabaey's thinking evolved to view tacticisation as a problematic influence (Rabaey, 2015, pp. 40, 72). Only Sayigh (1992), Naor (2005, p. 235), Lavie (2010, p. 108) and Petrelli (2013, p. 165) cite Harkabi (1988) as the originator of the term 'tacticisation of strategy'. Most works cite Handel (1994, 2001). Smith and Jones (2015, p. 27) attribute tacticisation to Colin Gray.

2.4. Ben Zweibelson

Zweibelson (2011) claimed the United States (US) Army had an 'institutional preference for tacticizing all levels of war,' by being 'inclined to apply knowledge they have acquired from their tactical experiences to their operational functioning sphere' (Zweibelson, 2011, pp. 1–2). Zweibelson's cursory examination is noteworthy insofar as it differs from both Harkabi and Handel. Zweibelson considers tacticisation as a problem wholly contained within the military domain, and being the negative influence *of* the tactical level *on* the operational level (**Figure 3**).

Zweibelson identified the phenomenon of tacticisation in later works but provides no explanation (Zweibelson, 2015a, fn 32; Zweibelson, 2015b, en 55). He also did not credit any source for the term.

2.5. Peter Compo

Compo situated tacticisation in terms of battles that are managed independently from the broader war. Specifically, whenever commanders believed winning a battle was valuable in and of itself, the criteria for 'winning' at the tactical level became independent from the overall strategy. These determinations formed the basis of tacticisation, which Compo described as 'the seduction of a fixed and local defi-

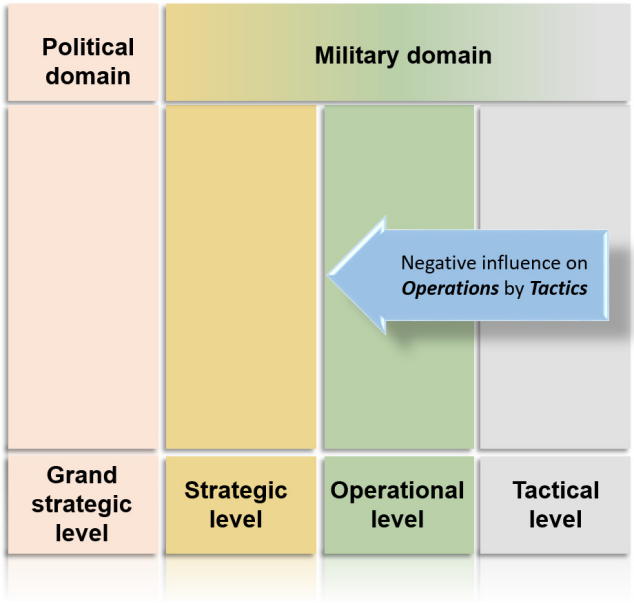

Figure 3. Zweibelson's conception of tacticisation as a negative influence with one element: the inappropriate application of tactical knowledge and experience to the operational level.

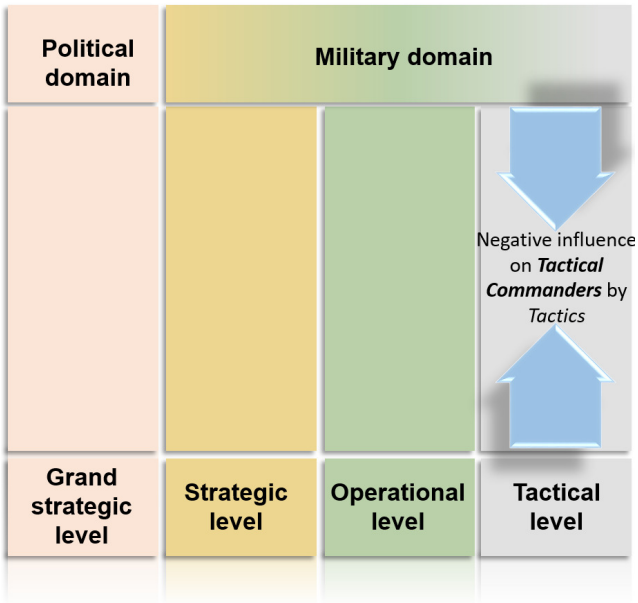

Figure 4. Compo's conception of tacticisation, where strategy is rejected by tactical commanders who focus on tactics (the seduction of local victory).

nition of winning … a seduction by local victories … a strategy violation' (Compo, 2022, pp. 88–89).

Despite crediting Handel (2001) with coining the term tacticisation (Compo, 2022, en 4), Compo's brief examination suggests that he considers tacticisation far more narrowly: the *rejection* of military-strategic objectives, and prioritising of local (tactical-level) criteria focused on tactical victory in isolation. This is somewhat similar to Handel's second (of his three) views on tacticisation – lower-level operational considerations defining strategy in war. However, Compo focusses on the tactical layer, not the operational. For Compo, tacticisation is a phenomenon occurring within the tactical layer itself. As such, Compo does not argue that tacticisation relates to the influencing or replacing of strategy, rather that it is a condition where strategy *is rejected altogether*. For Compo, tacticisation is the *ignoring* of strategy, due to the 'seductive' influence of tactics on local commanders who value tactical victory (**Figure 4**).

2.6. Mohamed Boraik

Boraik (2018, fn 89) credited several authors including Ben-Meir (1995), Handel (1994), Merom (2013) and Peri (2006) for identifying the drawbacks of militarising policy and tacticising strategy.

Boraik (2018) related tacticisation to the balance of power in the civil-military relationship, suggesting if the balance is skewed so the military is more powerful, the military can 'hijack the policy and militarize policy options or "tacticize" strategy' (Boraik, 2018, pp. 35–36, 272). Boraik used Israeli strategy as an example: '[w]hat undermined Israeli strategic practice was [inter alia] the military monopoly on strategy making … militarization and tacticization of strategy making were to be expected' (Boraik, 2018, p. 140).

Consistent with Handel but not Harkabi, Boraik argues tacticisation is the negative influence from lower levels to higher levels. However, Boraik differs from both Harkabi and Handel in one important respect: he conceived tacticisation as manifesting only when the politico-military balance of power is skewed far enough to allow the military to 'hijack' policy and 'militarise' policy options. Arguably, such highly skewed balances of power only occur in militarised societies, for example where the military *is* the government. Such extreme cases are useful because any definition and explanation of tacticisation should accommodate extremes as well as norms.

Assuming the military-strategic level controls lower levels so they cannot unilaterally influence the grand-strategic level (a reasonable assumption: where the balance of power is heavily skewed in favour of Generals, they would almost certainly control attempted influences from lower military levels), Boraik's conception of tacticisation becomes the *negative influence of the military-strategic level on the grand-strategic level* (**Figure 5**).

2.7. Charles Freilich

Freilich (2006) identified the 'tacticalization' of strategy as part of a broader 'pathology' of 'extreme politicization of the Decision-Making Process … reinforced by short-term perspectives, [and which] dictates the political wisdom of avoiding clearly defined policy objectives and of maintaining constructive ambiguity' (Freilich, 2006, pp. 645–646). Freilich did not credit any source for the term.

Frustratingly, Freilich combined his explanation of tacticalisation with another phenomenon, 'dynamic incrementalism'. Elements of his explanation applying only to tacticalisation are therefore indiscernible. Furthermore, Freilich did not define either phenomenon, providing only an expla-

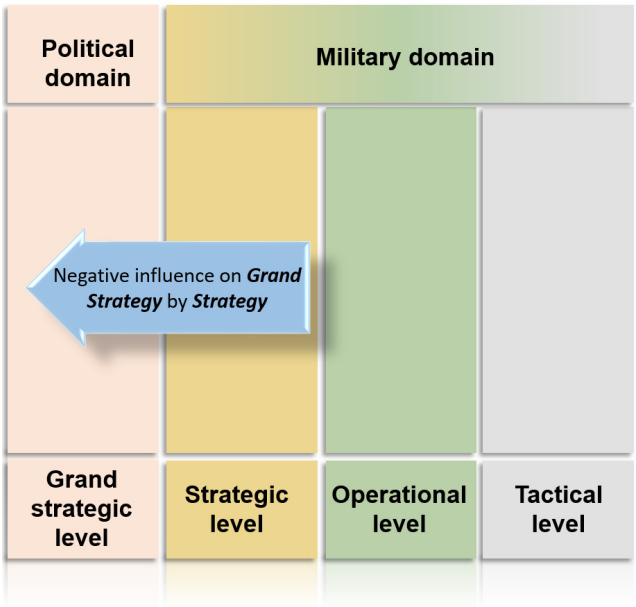

Figure 5. Boraik's conception of tacticisation as a negative influence with one element: the provision of unwarranted influence on the political domain, from the military domain.

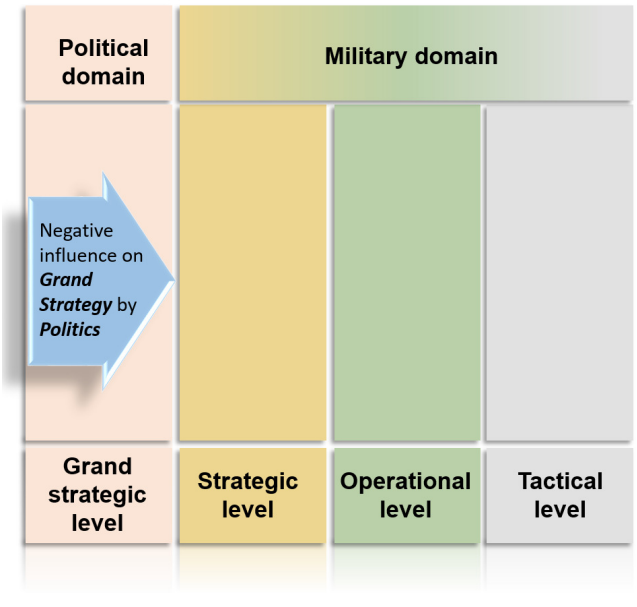

Figure 6. Freilich's conception of tacticisation as a negative influence with one element: the extreme politicisation of political processes.

nation of what the combined phenomena tended to result in:

> Major policy achievements are typically the cumulative, incremental – often unintended –outcome of a series of ad hoc solutions to immediate needs, rather than of a consciously and deliberately chosen course of action. Decision-making is thus characterized by the tactical, rather than the strategic (Freilich, 2006, pp. 646–647).

Freilich's brief examination of 'tacticalisation' in conjunction with 'dynamic incrementalism' means little of value can be discerned other than to recognise his explanation is significantly different from both Harkabi and Handel's. Further, if Zweibelson conceived tacticisation as a problem of the *military* domain, Freilich argued the opposite: tacticalisation is a problem confined to the *political* domain, where 'extreme politicisation' of processes and short-termism negatively influence grand-strategic objectives, biasing them towards ambiguity and ad hocery (Figure 6).

2.8. Dima Adamsky

Adamsky cited both Handel (1994) and Freilich (2006), (Adamsky, 2010, p. 214, en 178). Adamsky provided a definition of tacticisation, albeit one heavily influenced by Israeli geopolitical circumstances: 'replacing strategy with swift military improvisations driven by tactical thinking' and suggested it resulted from environments of 'constant siege, instability, and uncertainty', meaning 'decision-making tend[s] to concentrate on short-run, day-to-day operational matters at the expense of comprehensive long-term

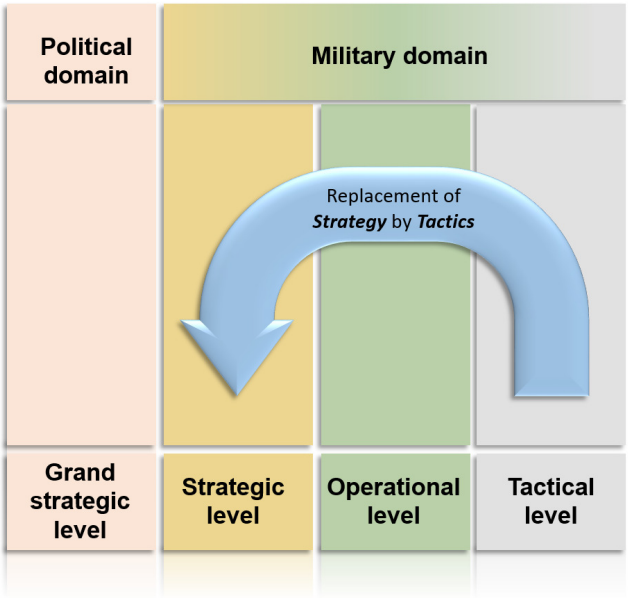

Figure 7. Adamsky's conception of tacticisation: strategy is replaced by tactics.

strategic thinking … result[ing] in providing ad hoc solutions to immediate problems' (Adamsky, 2010, p. 116).

Like Handel, Adamsky conceived tacticisation's direction of movement as being *from* below *to* above. Adamsky's discussion on tacticisation related to military strategy only, as affected by tactical considerations alone (vice other levels of the military domain). Like Zweibelson therefore, Adamsky viewed tacticisation as a military-specific problem. The starkest difference to other scholars is that for Adamsky, tacticisation related not to an improper *influence* on strategy, but to the *replacement* of it (Figure 7).

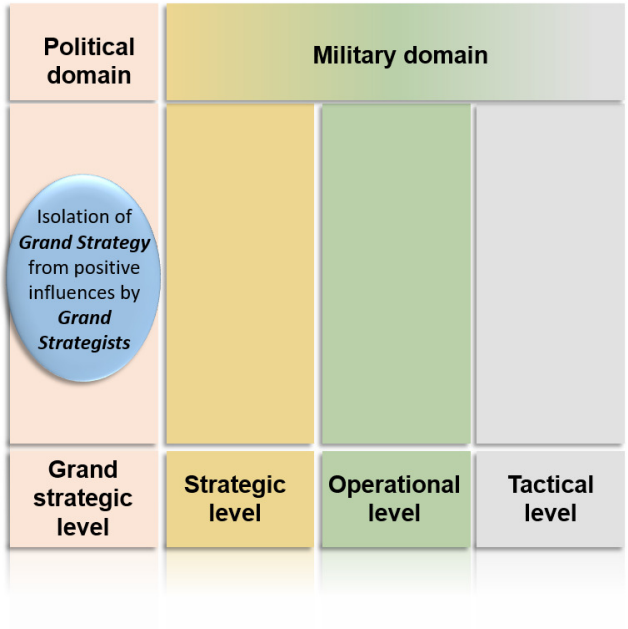

Figure 8. Stoker's conception of tacticisation: grand strategy is isolated from positive influences, by grand strategists.

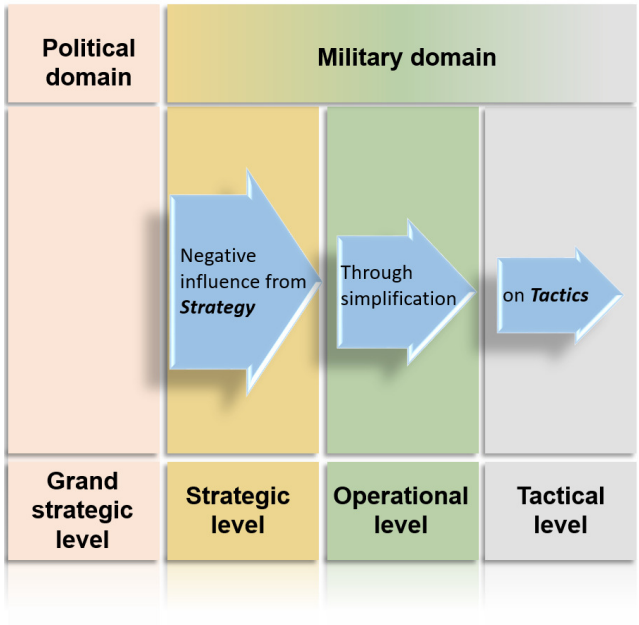

Figure 9. Michael and Ben-Ari's conception of tacticisation, as a negative influence with one element: the simplification of strategy to enable its implementation, through tactics. It is an inherent and intractable problem for the military organisation due to organisational culture and structure.

2.9. Donald Stoker

Stoker cited Handel (2001) for the term tacticisation (Stoker, 2019) but, unlike Handel, argued it applied to political leaders who 'don't understand the political aim … have a poor understanding of the use of force … and fail to commit sufficient forces' resulting in 'badly waged, perpetual, and protracted wars'. Such leaders also perpetuated 'bad ideas' and 'intellectually bankrupt' concepts such as 'hybrid war' and 'Continuum of Conflict', meaning strategy was founded on 'myth and misunderstanding' (Stoker, 2019, pp. 226–229; Stoker & Whiteside, 2020, pp. 33–36).

Stoker's cynicism does not reflect Harkabi or Handel's conception of tacticisation. Harkabi went to some length to explain politicians did *not* require a detailed understanding of warfighting ways and means. Both Harkabi and Handel associated the passivity of the political domain with tacticisation, but it does not necessarily follow that such inaction is the product of ignorance, as Stoker asserted. Like Adamsky, Stoker did not associate tacticisation with *influence*. In contrast, however, Stoker viewed tacticisation not as the replacement of strategy, but as the *self-imposed isolation of the political domain and its grand strategy, from outside influences*. For Stoker, strategy became tacticised when it was constructed by the elite independently from, and without an understanding of, military realities. The *absence* of influence from the military domain was the fundamental problem (**Figure 8**).

2.10. Kobi Michael and Eyal Ben-Ari

Michael and Ben-Ari did not credit any source for the term tacticisation but associated it with the culture and structure of military organisations (Michael & Ben-Ari, 2011, pp. 657–669). Consequently, they – like Zweibelson and Adamsky but unlike Harkabi and Handel – viewed tacticisation as a military-specific phenomenon. Indeed, Michael and Ben-Ari argued tacticisation was an intractable difficulty for the military:

> [S]tructural differentiation within military organizations between the planning and implementing levels … [means] the problem is operationalizing [goals] … translation between higher and lower levels inevitably involves simplification … [which] creates huge difficulties in operationalizing the abstract insights and understanding of the strategic level down to the level of the combat units (Michael & Ben-Ari, 2011, p. 669).

Michael and Ben-Ari therefore conceived tacticisation as the *simplification of strategy through each military level, to enable implementation* (**Figure 9**). It follows that unless the underlying cultural and structural problems are 'corrected' – which would likely result in a range of new difficulties for the military – tacticisation is an issue to be managed, not a problem to be solved.

While the military organisation may be a special case, it is difficult to argue that tacticisation, as conceived by Michael and Ben-Ari, is a problem *unique* to military organisations: any multi-layered entity responsible for addressing complex problems will likely face the phenomenon of tacticisation in some form.

2.11. Eliot Cohen

Cohen provided a definition of tacticisation, being 'the reduction of a large strategic problem to a matter of mere

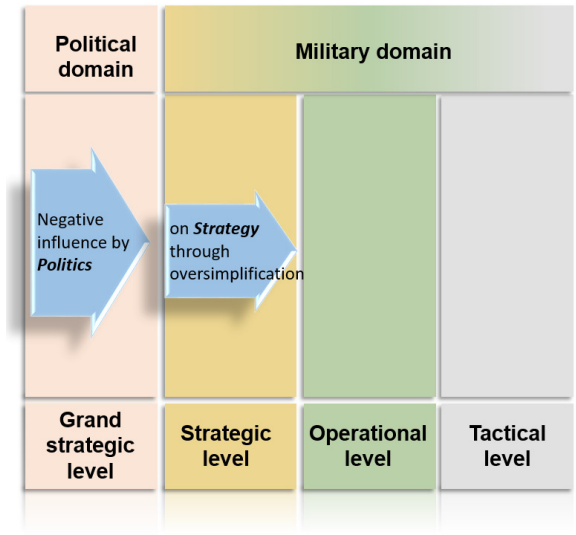

Figure 10. Cohen's conception of tacticisation, as a negative influence with one element: the oversimplification of a grand strategic problem, by the grand-strategic level.

tactics' (Cohen, 2016, p. 137). While Cohen cited Handel for the term tacticisation, he did not identify a specific work, nor did he examine the concept except to provide a single example, being the US government's handling of radical Islam which promoted 'the fetishization of one tool, man-hunting chiefly with missile-armed drones, [which] took the place of a deeper strategic response' (Cohen, 2016, p. 137).

There are parallels between Cohen and Harkabi. First, unlike all other scholars surveyed thus far, both view the direction of tacticisation's influence as being *from* the *political* domain *to* the *military* domain. Second, the nature of this influence is *reductionist*: Harkabi argued tacticisation resulted in the 'tendency to wage ... war as if it were a battle' (Harkabi, 1988, p. 93). Cohen's definition suggests tacticisation is the *oversimplification* of strategy (Figure 10). Cohen does not, however, recognise Harkabi's concept of dual failure. Cohen's concept of simplification differs from Michael and Ben-Ari's because it manifests within the political, not the military domain.

2.12. Avi Kober

Kober discussed tacticisation in several works but did not credit any source for the term. In *Democracies and Small Wars*, he argued:

> [P]olitical control over the conduct of war is usually exercised ... from the upper, grand-strategic level all the way down via strategy ... to tactics. In the postmodern era ... this chain of command has been shattered [by] a combination of societal-political constraints ... and technological capabilities ... Given the particular sensitivities and vulnerabilities of Western democracies involved in LIC [Low Intensity Conflicts] and the existence of unprecedented effective information sources and means of command and control at the political leadership's disposal, the political echelon often finds itself directly interfering in tactical matters. This bypassing of the strategic and operational levels is a manifestation of the 'tacticization' of grand-strategy (Kober, 2003, 2011, p. 160).

Kober's conception is different and interesting in several ways. First, Kober argued certain kinds of warfare – specifically LIC and, from another article, warfare involving high concentrations of firepower (Kober, 2001) – are more prone to tacticisation. No other scholar considers whether the effects of tacticisation vary with the character of war. Second, only Harkabi, Cohen and Kober view tacticisation as a downward influence from the political domain to lower levels. Kober goes further, arguing tacticisation was one of two distinct and simultaneously acting phenomena, the other acting in the *opposite* direction as an influence from the military domain into the political domain. This dual phenomenon was a 'relationship between the higher strategic echelons and the lower ones ... the simultaneous "strategization of tactics" and the "tacticization of strategy"' (Kober, 2016, p. 4). The most extreme form occurred when grand strategy and tactics were connected. Here, the 'political echelon ... finds itself directly interfering in tactical matters and/or restricting operations or battles, bypassing the strategic and operational levels' (Kober, 2016, p. 19). Kober classified the connection between these extremes as the 'tacticization of grand-strategy' and the 'grand-strategization of tactics' (Kober, 2016, pp. 16, 85, 142–143). Kober does not elaborate, but presumably strategisation manifests as the military domain improperly influencing grand strategy by providing tactical 'solutions' as if they constituted strategy (Figure 11).

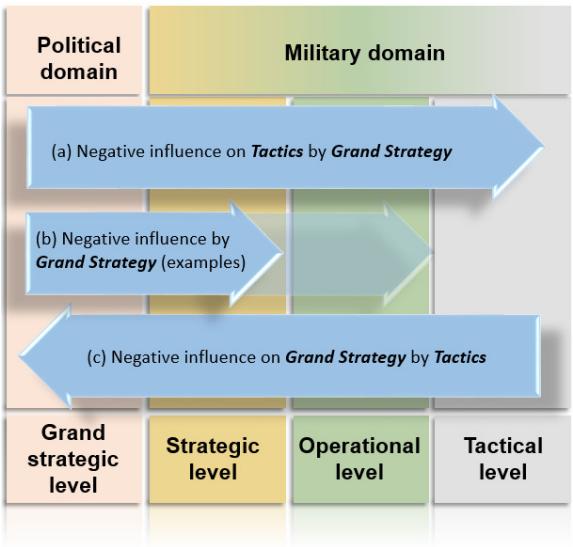

Figure 11. Kober's conception of (a) tacticisation of grand-strategy, (b) examples of tacticisation and (c) grand-strategisation of tactics. Tacticisation's negative influence has two elements: political interference on the military domain manifesting as the imposition of tactical direction; and military influence on the political domain manifesting as the provision of tactical solutions as if they were strategy.

2.13. Colin Gray

Arguably, Gray has contributed most to the subject. He generally cited Handel (1994, 2001) for the term tacticisation but never cited Harkabi (1988). His first articulation of the problem of tacticisation appeared in 1990, well before Handel's adoption of the term in 1999, and only two years after Harkabi's examination was published in English. Gray argued American decision-makers tended to focus on 'the technical, tactical, and – rarely – the operational level of war, but never, at least not competently, on national military or grand strategy' which resulted in a 'fail[ure] to recognize that they have confused tactics or operations with strategy' (Gray, 1990, p. 95). Gray provided various examples, including a scathing critique of the plan to substitute extended deterrence with a policy of 'discriminate deterrence' using advanced, high-precision conventional weapons in place of nuclear weapons. For Gray, the plan was 'counterfeit strategy; it is tactics and technology masquerading as strategy' (Gray, 1990, p. 273).

Gray introduced the term 'tacticisation' explicitly in 2007, with specific relation to airpower. Gray criticised America for having 'a severe strategy deficit,' arguing it 'is, and has long been, guilty of what is known as the "tacticization" of strategy … [It] does tactics well and tends to expect success at that level to translate automatically into strategic victory' (Gray, 2007, p. 4). Unfortunately, Gray says nothing further about the concept, referring readers to Handel's work.

Gray's initial conceptions are inconsistent with both Harkabi and Handel, mirroring instead Kober (**Figure 11**), albeit with somewhat differing causal factors in play. Unlike Kober, however, Gray does not distinguish between tacticisation and strategisation; for Gray, both are elements of tacticisation.

By 2009, Gray had more to say. He argued the misnaming of so-called 'Strategic Forces' such as the US Air Force's Strategic Air Command (USAF SAC) was fundamentally problematic. Not only did it facilitate a misunderstanding of what, *intrinsically*, such military instruments could accomplish (strategic effects, or even strategic ends, in the case of SAC), but it also implied forces not so defined (for example the USAF's Tactical Air Command) could *not* achieve the same effects. In these cases, the 'military instrument itself is collapsed into its consequences [and] what tends to be the result is … the "tacticization of strategy"' (Gray, 2009, p. 41). Gray's conception has changed from his 1990 work: he now described only one influencing path, *from* the military domain *to* the political domain. This conception is a combination of Handel (**Figure 2**) and Boraik (**Figure 5**).

In 2010, Gray published *The Strategy Bridge: Theory for Practice,* the first of a three-volume trilogy on strategy, which demonstrated his thinking had evolved further. Gray now argued tacticisation occurred in the *absence* of strategy, involving 'encroachment on the part of the political, operational, and tactical functions. Such mission creep may be characterized as the politicization and tacticization of strategy … [whereby] enhanced roles for politics and tactics

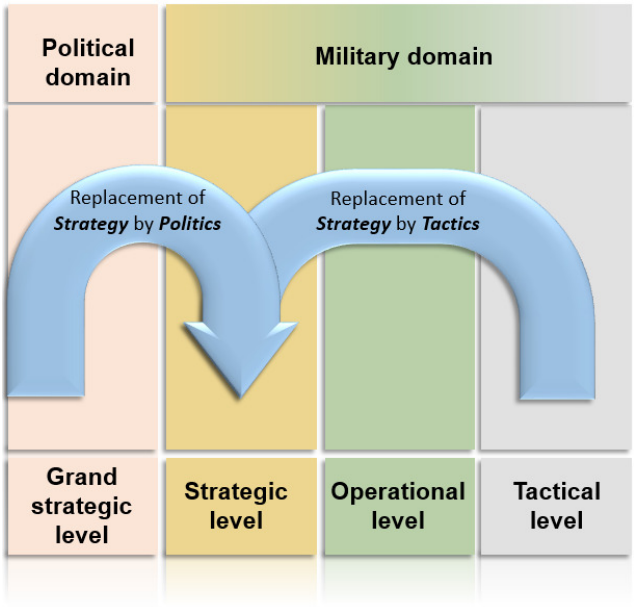

Figure 12. Gray's early conception of tacticisation.

substitute for, rather than capture, strategy' (Gray, 2010, p. 247). Nothing more is said, with readers again referred to Handel for more on the 'malady of the tacticization of strategy'. Gray now saw two forces acting: the 'politicisation of strategy' which encroaches on the strategy void from above, while operations and tactics encroached on the void from below. *Both* influences *replaced* strategy. A later work repeats this conception verbatim (Gray, 2011, p. 43, en 11). This conception can be viewed as an evolution from Adamsky (**Figure 7**): two forces, one from below and one from above, replace strategy (**Figure 12**). It is problematic that Gray continues to reference Handel, because their perspectives are very different: compare **Figure 12** and **Figure 2**.

A monograph published in 2012 provided a consistent, and similarly brief, examination. It emphasised tacticisation occurred in the *absence* of strategy. Interestingly, Gray explicitly acknowledged partial disagreement with Handel. While discussing the distinctive natures of politics and war, Gray argued:

> Indeed, misunderstanding of the connections between war and politics is a notable contributor to what Michael I. Handel somewhat mistook as the 'tacticization of strategy.' In point of fact, when (tactical) military activity itself is confused with its political purpose, strategy (though not strategic effect) is absent, not 'tacticized' … Unwise categorization encourages the tacticization, which means the neglect, of strategy (Gray, 2012b, pp. 38, 48).

Gray also released a book dedicated to airpower in 2012 which referenced tacticisation. Reiterating his earlier objections to conflating tactical tools with the strategic effects they may or may not deliver in each instance of tactical use, Gray argued:

> When a weapon and its consequences are conflated, the result is neglect of the strategic function. It is needlessly difficult to think strategically about the value of a military force when that force is predesignated as inherently 'strategic.' The strategist's question 'So what?' may well not be posed, let alone answered; weapons and actions themselves are defined as strategic. There is no apparent need or room for strategic effect. What the military instrument does is taken to be such effect. This historically familiar phenomenon is characterized as the tacticization of strategy (Gray, 2012a, pp. 34, 247, 291).

Here, Gray argues only for the bottom-up influence of tacticisation, ignoring the top-down influence illustrated in **Figure 12**. In the same volume, Gray extended his previous assertion that tacticisation occurred when strategy was *absent*, suggesting it was the absence of *political ends* which first drove the impossibility of strategy, in turn resulting in the inevitability of tactics supplanting strategy:

> [T]he strategic function requires a purposeful, mutually enabling marriage among (political) ends, (strategic) ways, and (military and extramilitary) means. When the political ends are absent, unclear, or flatly contradictory, strategy worthy of the name is impossible, and one is reduced to an effort comprising tactics alone. This tacticization of strategy is inevitable when the strategy function cannot be performed because of the absence of identified, firm, and achievable political goals (Gray, 2012a, p. 247).

In 2013, Gray published the second volume of his three-volume trilogy, in which he diverged further from his earlier views, and voiced stronger opposition to Handel, by arguing strategy *cannot* be tacticised:

> Despite the popularity of the thesis, it is a categorical error on a major scale to believe that strategy can be 'tacticized'. Strategy and tactics are different in nature and cannot mate to produce a hybrid offspring … Handel['s] … thesis that strategy can be tacticized is a popular but nonetheless categorical impossibility … tactics do not magically become strategy, though they may stand in for them (Gray, 2013, pp. 12, 185–186).

Gray added little by way of explanation, aside from the following:

> [M]ilitary technology appeals to the senses and captures the imagination. The problem is that this seduction can fill all of the limited space available for appreciation and comprehension, so that strategy is not 'tacticized', as frequently mistakenly is claimed, rather it is shorn of its humanity in favour of inert tools, no matter how technically interesting, tactically efficient, and in some cases even aesthetically appealing they are judged to be (Gray, 2013, p. 159).

No scholar – certainly not Handel – contended tactics could *become* strategy by direct replacement, as if the two activities are directly substitutable. *Tacticisation is a problem for the very reason it cannot replace strategy*. Gray's argument concerns semantics more than substance. He contests the inherent logic of the *label*, not the *phenomenon*. His underlying argument remained that there is a problematic phenomenon involving strategy being 'cut down' to the degree it no longer resembled strategy, with tactics then filling the void. Arguing that an imperfect label invalidates the concept confuses the matter.

In the final volume of his strategy trilogy, Gray continued his semantical argument that tacticisation concerned the absence of strategy, and its replacement with tactics:

> Neatly compelling though [tacticisation] may be, it is likely to mislead and confuse, rather than enlighten. The reason is that strategy cannot be tacticized and it is a serious error to express that conception in a way that indicates its feasibility. If tactics are effectively commanding behaviour, then strategy must be absent. There is no tactical variant of strategy; they are distinctive phenomena (Gray, 2014, p. 62).

By 2015, Gray had evolved his thinking again, viewing tacticisation in the following context:

> Although civilian governance needs to listen to professional military advice concerning what appears to be feasible as action … policy is what the use of tactics in pursuit of strategy has to be about … Some scholars have noticed what they have chosen to term a 'tacticization of strategy' … While there are problems in the conduct of war … the 'devouring' of strategy by operations should not be counted among them (Gray, 2015a, pp. 21–23).

Tacticisation was therefore predominantly a problem for military commanders, who needed to recognise the supremacy of politics and ensure political direction was understood and followed. Tacticisation occurred when military commanders failed to comprehend the key role politics and policy play at the grand-strategic level, and substituted strategy with tactics. Gray did however recognise an inherent difficulty, being the:

> 'pragmatic challenge of combat … can be so close to the edge of military feasibility as to pose real difficulty for the higher reaches of the command chain … [the] immediate and pragmatic logic to what needs to be done … all too easily causes strategy to fly out of the window' (Gray, 2015a, pp. 21–22).

Gray had softened his assertions that strategy cannot be tacticised. Further, his earlier conception of tacticisation as a two-element phenomenon, involving forces from both above and below – that is, his earlier alignment with Kober (**Figure 11**) and subsequent evolution towards a new conception (**Figure 12**) – had been simplified. Tacticisation was now to be conceived as a single-element problem associated with military commanders who fail to comprehend the key role politics and policy play at the grand-strategic level and hence substitute strategy with tactics. Gray's conception had returned to a mirror of Adamsky's (**Figure 7**). Gray continued his practice of citing Handel, claiming he provided the 'leading example' in exposing the problem of tacticisation (Gray, 2015a, en 27). This is unfortunate: tacticisation may be 'clear enough' to Gray, but his shifting position on the concept must surely confuse his readers.

Table 1. Evolution of Gray's conceptual understanding of tacticisation.

Period	1990	2009	2010	2010–2014	2015
Conceptual understanding	Similar to Kober	Combination of Handel and Boraik	Adaption of Adamsky	Increasing opposition to the concept of 'tacticisation'. Argued strategy cannot be tacticised.	Reversion to Adamsky
Representation	Figure 11	**Figures** 2 & 5	Figure 12	N/A	Figure 7

Table 1 provides a chronology of Gray's conceptual evolution of tacticisation.

3. Conclusion

The literature review demonstrates that there is little agreement on what tacticisation is, why it manifests, and what can be done about it. Over 60 authors employ the term in their work with no description of what it means. The majority of these authors credit Handel (1994, 2001) as the originator. Only four (Lavie, 2010; Naor, 2005; Petrelli, 2013; Sayigh, 1992) cite the originator of the concept: Harkabi (1988). Of the thirteen scholars that explored tacticisation in some form, none conceived the concept in the same way except for Gray and Adamsky. A wide range of disparate reasons are given for what causes tacticisation, and little is offered from any author by way of managing it. No accepted definition of tacticisation is evident from the literature. One work (Rabaey et al., 2004) argues tacticisation can provide a positive benefit in some circumstances.

Interestingly, the thirteen authors that explored tacticisation conceived of it as occurring along different 'vectors' of influence: top-down, bottom-up and, in one case, horizontal (Compo, 2022). How many vectors are claimed to exist, varies. Further, some authors argue the vector(s) exist within a single level of the four-level heuristic (with little agreement on the actual level), while others argue the vector(s) span two or more levels. This demonstrates the lack of agreement in terms of how tacticisation manifests and influences strategy.

Notably, of the thirteen scholars that explored tacticisation, six are Israeli: Harkabi, Freilich, Adamsky, Michael, Ben-Ari and Kober. This may indicate a relationship between tacticisation and cultural, geopolitical or societal factors. While the Israeli scholars in particular should have known Harkabi's work existed, *none* cited Harkabi (1988) as a source. Indeed, only Adamsky cited any source whatsoever (Handel, 1994). Of the remaining seven scholars, five cited Handel (1994, 2001), with only Handel citing Harkabi (1988), and he did so only in his earlier work. This may suggest that neither Harkabi nor Handel can be considered authorities on the topic.

Submitted: January 31, 2025 AEDT. Accepted: March 07, 2025 AEDT. Published: February 12, 2026 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Dorman, M. (2026). Symbiosis between national power elements: an air power focus. *Contemporary Issues in Air and Space Power*, *4*(1), BP55984100.
https://doi.org/10.58930/BP55984100

Air Power

Symbiosis Between National Power Elements: An Air Power Focus

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Keywords: National Power, Air Power

https://doi.org/10.58930/BP55984100

Vol. 4, Issue 1, 2026

The symbiotic relationship between industry, sea power and the national economy was evident during the industrial revolution. Britian's ability to harness this relationship was a key factor in her rise to power, which is recognised in Mahan's strategy. During World War II, this symbiotic relationship evolved as air power came of age since strategic bombing was a new threat to industry and the economy. This period contains many lessons for Air Force and Capability Acquisition and Sustainment Group (CASG), as competition escalated to conflict and preparedness changed to mobilisation. The Cold War was a period of great power competition that saw rapid technological advancements. The collapse of the Soviet Union illustrates the perils of an unbalanced relationship between the elements of national power. Throughout these eras there are lessons that are applicable to middle powers like Australia.

1. Introduction

Great power competition is not new and has been a feature throughout history. The Anglo-French rivalry spanned a period of 800 years and was followed by a period of competition with a rising German nation that culminated in World War II. Afterwards there was little respite, with the East vs West rivalry and the Cold War commencing in 1947. Therefore, the relatively peaceful 30 years that Western nations enjoyed after the Cold War could be viewed as an aberration in history. With Australia now involved in the United States (US)–China strategic competition and facing the prospect of war in the Pacific, there are lessons that we can learn from history.

The lessons from history can be framed at the national strategic level using the national power elements, which include economic power, military power and national morale. Economic power encompasses industrial and financial systems. Military power is defined by the size and quality of armed forces, with sub-categories including air power and sea power. National morale reflects the population's support for national goals. History shows the relationships between national power elements change as nations move across the peace-war spectrum. Careful management of these relationships can create powerful effects with the national power elements reinforcing each other. Unbalanced relationships can have dire consequences.

This paper argues that the elements of national power should have a symbiotic relationship; and lessons from history can be applied in today's context to ensure this relationship is balanced. First, the symbiotic relationship will be explored during the Anglo-French rivalry, where Mahan made the connection between sea power and economic power (Mahan, 1890/2011). Second, Mahan's strategy is evolved and applied in the World War II context where air power came of age, and there are lessons about preparing for mobilisation. Finally, the Cold War period is explored where space power emerges and there are lessons for sustained periods of great power competition.

2. Mahan's strategy

The early modern period saw great power rivalries and the beginning of the symbiotic relationship between sea power and economic power in a globalised context. The Anglo-French rivalry began in the Middle Ages and persisted into the nineteenth century (Gibson, 1995). The character of this rivalry evolved during the sixteenth century, as developments in maritime technologies enabled colonisation and global trade. Mahan is well known for his strategy that links sea power with the national economy, and this maritime strategy was a key factor in England's rise to power. '[T]he great navy of England, in war after war, swept the seas, insured the growing wealth of the island kingdom through exhausting strifes, while drying up the external resources of French trade and inflicting consequent misery' (Mahan, 1890/2011, p. 61). In times of conflict the English navy protected their trade, while enabling the English to prey upon French trade ships and colonies. This resulted in economic growth and increasing national power within England, while the French economy declined during most of the conflicts in this period. These are early examples of sea power growing the economy and national power in a globalised context. The economy and industry growing sea power is the other half of the symbiotic relationship.

One of the few times the French Navy defeated the British demonstrates the importance of industry in the symbiotic relationship. The French made a concerted effort to rebuild their fleet after the Seven Years' War (1756–1763). Shipyards were provided with increased access to the raw materials required to build and maintain the fleet (Dull, 2007; Williamson, 2016). Maritime infra-

structure was modernised, ship designs were optimised, then standardised to moderate costs during production and maintenance. Improvements were also made to sailor training and living standards. An expansion in colonial trade and the fishing industry also provided a larger pool of experienced sailors that the Navy could draw upon in a crisis (Byington, 2011). These industrious efforts paid dividends when the French entered the American Revolutionary War, only 12 years after the Seven Years' War ended. The French Navy was able to match the British and in 1781 the French fleet was able to aggregate and blockade Chesapeake Bay. This blockade prevented resupply to General Charles Cornwallis at Yorktown, which was a decisive turning point in the war (Byington, 2011). This example demonstrates a concerted effort to uplift all the Fundamental Inputs to Capability (FIC), which improved preparedness and produced results in conflict. Civilian industry's contribution to naval infrastructure, ship building and generating an experienced maritime workforce enabled a strong navy. That navy then protected French colonies and trade while making a decisive contribution to the British losing the American colonies, which again demonstrates the symbiotic relationship. In today's context, Capability Managers need to ensure all elements of FIC are uplifted to drive increased preparedness.

3. Air power and the symbiotic relationship

During World War II, a symbiotic relationship developed between air power and economic power as strategic bombing was a new threat to industry. Air power can make significant contributions to maritime campaigns and affect the relationship between economic power and sea power as described by Mahan. For example, aircraft played a crucial role in the Battle of the Atlantic and the defeat of Germany's U-boats (Parker, 1989, pp. 95–97). However, the ability to strike at a nation's industrial and economic heartland is a unique air power capability. The Allies were eventually successful at defending their airspace and protecting their industrial centres that produced aircraft and other war material. The Allies strategic bombing campaigns also disrupted Axis industries. From 1942 to 1944, British aircraft production grew by 50%. This figure has been normalised by the structural weight of the airframe and labour hours required to construct the aircraft to account for all types of aircraft construction (Postan, 1952, pp. 524–525). Over the same timeframe, the production of individual German aircraft more than doubled but this was driven by increases in fighter production at the expense of large bombers and other aircraft types (Vajda & Dancey, 1998). Therefore, the Allied air campaign against Germany protected the British industrial heartland and enabled British industries to produce a variety of aircraft in increasing quantities. This included aircraft specialised for anti-submarine warfare and contributed to the classical Mahan symbiotic relationship in the maritime domain. Aircraft were also produced for offensive bombing campaigns against German industrial centres, which demonstrates the new character of the symbiotic relationship as air power came of age. On the German side, Allied successes forced the Germans to adopt a defensive posture, which was also reflected in the symbiotic relationship between the Luftwaffe and industry.

While the Luftwaffe and German industry was on the defensive, Germany still managed to produce a substantial number of aircraft. The Germans dispersed their industry in response to the Allied bombing campaign and moved aircraft factories into repurposed tunnels. In some cases, purpose-built underground factories were also constructed. Aircraft designs were optimised for production and supply chains were streamlined by reducing the number of different parts used in aircraft designs (Uziel, 2006). British industry was also dispersed in response to German bombing during the Blitz (Postan, 1952, pp. 271–272). The Royal Australian Air Force (RAAF) and Capability Acquisition and Sustainment Group (CASG) of the Australian Department of Defence need to have plans to protect industry or mitigate the damage from strikes by dispersing industry and ensuring redundancy in industrial capabilities. This requires a shift away from co-locating most of our industry partners on RAAF Bases.

Repairing damaged aircraft is another way to boost industrial output. From 1940 to 1945, 79,000 of the 164,000 aircraft delivered to the Royal Air Force (RAF) from industry were repaired airframes. The percentage of repaired aircraft in the RAF fleet peaked at 55% in 1943. Prewar policy envisioned three RAF repair depots and three contracted repair depots under RAF control. By 1940, it was realised that this was inefficient since the fluctuations in demand for repairs resulted in wasted capacity within repair depots and a system was set up where repairs were spliced into organisations engaged in production. This had the added benefit that it was quicker and cheaper to repair damaged aircraft than building aircraft from scratch. With this change, control of civilian repairs transitioned from the RAF to the Ministry of Aircraft Production (Postan, 1952, pp. 537–545). In conflict, the RAAF is likely to move away from a routine aircraft servicing schedule designed to provide our industry partners with a consistent workload. Phased servicings that maximise aircraft availability are likely to become the norm in a prolonged conflict or crisis. This means our industry partners would experience fluctuations in workload associated with maintenance and repair. Enabling our industry partners to have the capability to manufacture parts is one way to smooth out these fluctuations and alleviate supply chain problems.

Shortages and supply bottlenecks were problems that needed to be overcome. For the RAF, insufficient spares were a problem until mid-1943, with 5–9% of all RAF aircraft unserviceable awaiting spares during this time. From late 1943 the issues with the supply of materials for parts manufacture were resolved. It took this long for the demands on parts to maintain the fleet, and aircraft production needs to be properly understood (Postan, 1952, pp. 543–545). The US mobilisation effort also experienced bottlenecks including shortages of raw materials, tooling, production capacity and transportation services. To effectively align production with national priorities, the allocations of three key materials, steel, aluminium and copper, were controlled. Less critical materials would then proportionately

flow to the companies allocated the key materials. This allocation system also enabled the US military to understand what would feasibly be received from industry, which informed long-range military planning (Maury, 2013). These types of shortages and bottlenecks are likely to affect the RAAF and industry during a future conflict or crisis. Within CASG, the platform-centric system program office (SPO) structure may have the resources to identify bottlenecks affecting individual aircraft types. But the lean higher echelons of CASG probably lack the resources to aggregate the information coming from the SPOs and efficiently resolve bottlenecks at the national level. In a crisis, the RAAF and CASG could consider merging the acquisition and sustainment SPOs to integrate the management of production and sustainment, while potentially enabling the higher echelons of CASG to expand. It is important that control of the supply chain remains within Government departments to maintain the trust of the public.

Within the US, the perception that companies profited enormously from World War I had left the public bitter and contributed to the US's isolationist stance. Before World War II, the US had implemented a tangled web of legislation and excess profit taxes to try to avoid war profiteering. Price ceilings and rationing were also required to prevent inflation during the war. Cost-plus contracts were common along with public-private partnerships to enable industry to scale, or convert to war production, while avoiding profiteering (Maury, 2013). Safeguarding against profiteering keeps the costs of military material down and avoids inflation in the wider economy, while also maintaining the trust of the public. Coordination across Government departments is required to implement these safeguards. CASG and other procurement agencies also need to have the skills, capacity and expedient contracting processes to be able to orchestrate supply chains in a crisis. This control is important to avoid the perception of profiteering or bias in rationing and may be required to maintain a stable national workforce.

Before the US entered the war the growing preparedness program had difficulties finding skilled workers. Despite high levels of unemployment from the Great Depression, these people were not in the right places with the right skills. This necessitated a massive training program in a hundred cities, where vocational schools would run two shifts, training the unemployed during the day and upskilling workers changing careers by night (Maury, 2013, pp. 82–84). In the year after Pearl Harbor, the US also struggled with workforce challenges and aimed to balance the civilian workforce in the agriculture and industrial sectors. These sectors were essential to supplying the military and the nation. The challenge with maximising productivity from a stable civilian workforce mainly came from enlistments in the military, people changing jobs chasing better wages, and companies raiding their rivals' workforces (Maury, 2013, pp. 333–334). Maximising the productivity of the available civilian workforce to meet Defence needs is a challenge we face today with constrained budgets and job-hopping from lower to higher paying companies. These challenges will be increased if preparedness turns towards mobilisation and budgets are increased. CASG contracts should aim to manage wages or prevent uncontrolled movements of the workforce within the aviation sector.

4. Great power competition during the Cold War

There were political, economic and military reasons for the collapse of the Soviet Union at the end of the Cold War. There was also an interaction between the economic and military reasons for the collapse. Soviet military spending is estimated to have ranged between 10% and 20% of GDP and was consistently agnostic of economic performance. Rising military spending at the end of the Cold War compounded Soviet economic issues and consumed resources that President Mikhail Gorbachev could have used to help with economic reform (Ray, 2025). This type of militaristic economic mismanagement is not an isolated occurrence; the devaluation of the Roman currency to grow the military and increase legionaries' pay caused severe inflation and contributed to the collapse of the Roman Empire (Van Sickle, 1930). Therefore the symbiotic relationship between military power and the economy must be balanced. Too much expenditure on military power is unsustainable, while too little expenditure leaves the nation vulnerable. Australian Defence spending was a sustainable 2.9%, on average, throughout the Cold War (Newett, 2025). Australia needs to lift Defence spending back to Cold War levels if we want to credibly prepare for a major conflict. This level of spending should also be sustainable during a prolonged period of strategic competition, but Defence needs to wisely spend this money.

The escalating costs of military hardware are a concern. 'Bombers cost two hundred times … and … fighters cost one hundred times more than they did in World War II' (Kennedy, 1987/2017, p. 442). Kennedy argues the divergence of the armaments industry from commercial, free-market manufacturing is a concern. The few gigantic armaments companies enjoy a special relationship with defence departments and are protected from the marketplace by generous Government contracts. The escalating costs in military hardware are a stark contrast with free-market consumer products where competition and mass production push prices down (Kennedy, 1987/2017, pp. 441–442). Caldwell and Howard also highlight three strategic challenges with contracting for platform availability in military sustainment. The first is managing risks and performance in large-scale contracts. If the risk associated with poor platform availability cannot be transferred to the contractor, then there should not be a risk premium payment for this metric in the contract. Second, outsourcing makes it challenging to retain the skills needed to manage existing and new long-term contracts. Third, the management of, and encouragement of innovation within, the supply network will be a challenge with the prime contractors in between Defence and the supply chain. This is why Defence needs to have a leadership and systems integration role within the platform enterprises (Caldwell & Howard, 2014). The RAAF and CASG need to foster and retain the skills necessary to lead our platform-centric enterprises and perform a systems integration role. This will enable Defence to

integrate innovative technologies onto our aircraft, while also being able to influence the supply chain and reward efficiencies. CASG should also work to counter the loss of buying power within the supply chain associated with several prime contractors managing parts or technologies common to multiple platforms.

The space race was a notable technological feature of the Cold War. Both the US and Soviet governments invested in space research and development. The Soviets took an early lead as the first to launch a satellite, while the Americans were the first to send a man to the moon (History Editors, 2026). Achievements in the space race provided propaganda benefits, since these technological advances were attributed to the superiority of each nation's ideology. The advances in rocketry were also associated with military missile prowess (Griffith, 1985). Successful rocket launches and other space achievements that are highly visible to the public boost morale, which is an aspect of national power. These successes can also be useful in diplomacy. Defence should continue to work with the Australian Space Agency and promote successes. Many space technologies are also dual use. Military technology that benefits the nation also forms part of the symbiotic relationship.

Government investment has influenced technological change throughout history. The risks associated with generating a return from research and development often leads to an under-investment in these activities from private firms. Within public funded research, the defence sector has had the largest budgets from governments around the world since World War II (Mowery, 2010). Numerous military technologies have also benefited the civilian sector. The space-based Global Positioning System and the jet engine are examples that revolutionised navigation and air transport respectively (Lange, 2025). While the development of military hardware is expensive, it can have long term benefits to the civilian sector and forms part of the symbiotic relationship. Defence should continue to invest in research and development, while encouraging innovation within Australian industry.

5. Conclusion

Mahan identified that sea power could protect and grow a nation's economic strength in times of conflict. Conversely, economic strength and industry is required to build a military, therefore a symbiotic relationship is formed. The advent of air power saw the creation of a different symbiotic relationship, where strategic bombing can directly threaten industrial centres. If the symbiotic relationship is not balanced, it can also have dire consequences outside of war, as seen in the collapse of the Soviet Union. Therefore, it is vital that the elements of national power exist in a state of symbiosis. While this essay is not exhaustive, there are several lessons from history that are applicable today, which can help nurture this symbiotic relationship.

Australia needs to increase Defence spending back to Cold War levels and Capability Managers need to uplift all FIC elements to be prepared. To spend the Defence budget wisely, CASG and procurement agencies need to have the skills to orchestrate the supply chain. If competition escalates to conflict, effective Government control of the supply chain is essential to managing bottlenecks and avoid the perception of war profiteering or bias in rationing. The RAAF also needs to be able to protect industry in a conflict and CASG needs a mindset that acknowledges industry is a target. Redundancy in industrial capabilities and dispersal of industry provide defence in depth. In both competition and conflict, innovation is essential. Investment in research and development while encouraging innovation and efficiencies within the supply chain must continue. These all contribute to achieving a state of symbiosis between the national power elements.

Submitted: December 30, 2025 AEDT. Accepted: February 24, 2026 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Ross, Y. Z. (2026). Mobilising Australia for a Whole-of-Nation Defence Era. *Contemporary Issues in Air and Space Power*, *4*(1), BP55957440. https://doi.org/10.58930/BP55957440

Strategy

Mobilising Australia for a Whole-of-Nation Defence Era

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Keywords: Defence Strategy, Air Power, STEM pipeline

https://doi.org/10.58930/BP55957440

Vol. 4, Issue 1, 2026

Australia's evolving strategic environment, marked by accelerating technological competition and rising Indo-Pacific tensions, demands a shift from episodic defence planning towards a coordinated whole-of-nation defence posture. This paper argues that national resilience now depends on integrating government, industry, academia and civil society into a sustained capability framework. It proposes three interconnected initiatives designed to operationalise this approach: (1) a nationwide science, technology, engineering and mathematics (STEM)-to-Defence talent pipeline that builds the human capital essential for emerging air and space missions; (2) a sovereign space acceleration initiative that establishes rapid, sovereign space-launch, production and data infrastructure to secure Australia's access to space-based capabilities; and (3) an air and space reserve network that embeds civilian technical specialists directly into Defence operations through a legally enabled, scalable reserve model. Together, these initiatives synchronise people, platforms and partnerships to deliver enduring strategic advantage, reduce reliance on external suppliers and enhance national preparedness across air, space, cyber and autonomous domains. The paper concludes that adopting such a framework is vital if Australia is to shift from reactive capability development to proactive, long-term sovereignty in an increasingly contested regional environment.

1. Introduction

Australia's strategic growth has reached a turning point. Rising competition in the Indo-Pacific and policies that oppose 'grey zone' operations have sped up the integration of air, space, cyber and information operations, breaking down the barriers that used to separate these areas of protection (Bensahel, 2017; Kumar, 2024; Montolalu, 2022). The 2023 Defence Strategic Review (DSR) shows this trend, stating that Australia's strategic circumstances require a whole-of-nation approach to defence planning and preparedness (Department of Defence, 2023). Building up Australia's defences isn't just the job of the Australian Defence Force (ADF) anymore. It's a long-term national effort that includes the government, businesses, universities and regular people. Like other small states, such as Singapore, Israel and Norway, these initiatives are designed to build citizen preparedness by developing STEM and other essential skills from an early age, ensuring that all Australians have the opportunity to be equipped to support national security.

This whole-of-nation approach marks a departure from Australia's historic approach of developing capabilities in an episodic and reactive manner and reflects a more deliberate understanding of strategy itself. Strategy can be defined as the conceptual framework that connects limited resources to lasting national objectives, while effective defence planning requires linking strategic intent to operational capabilities over long-time horizons (Brands, 2014; Freedman, 2013; Gray, 2016). Australia's previous reactive strategic stance has increased its vulnerability to shifts in power relations, particularly in an Indo-Pacific region which has been characterised by rapid military growth and technological integration in recent years (Dean & Raymond, 2017; Frühling, 2009; Lockyer, 2017). As a result, scholars are now emphasising that evaluating alternative strategic approaches is essential to strengthening Australia's long-term capability planning (O'Neil, 2011). The DSR also emphasises vulnerabilities in new areas – especially space, noting that secured access to space is vital –to national defence, and existing reliance poses a strategic threat (Department of Defence, 2023). Without an enduring capability strategy, Australia faces the danger of staying technologically reliant, financially vulnerable and strategically limited – just when sovereignty is most crucial.

To address these weaknesses, I propose three linked initiatives: (1) a science, technology, engineering and mathematics (STEM)-to-Defence talent pipeline that builds up human capital; (2) a sovereign space acceleration initiative; and (3) an air and space reserve network. Each initiative concentrates on a facet of power, cultivates curiosity and strategic mindsets. The space acceleration initiative aims to develop independent platforms and facilities while the reserve network merges civilian and military capabilities into a versatile mission-prepared reserve. While space is the primary lens for analysis and initiative design, the principles underlying these projects are broadly applicable to related domains such as uncrewed aerial systems (UAS), autonomous air platforms, and operations that produce grey-zone or non-kinetic effects. However, stressing space gives

a targeted vantage point for skill development, while cross-domain application improves strategic relevance without broadening the scope beyond viable implementation. In doing so, the initiatives not only address the space problems that are currently being faced, but they also provide conceptual frameworks that may be utilised in a variety of future operating situations, which is beneficial to Australia's overall strategy. These initiatives could, therefore, collaborate to establish a single, all-encompassing enterprise that has the potential to provide Australia with a long-term strategic advantage, strengthen the military ecosystem and bring the nation's sovereignty together.

2. Building human capital

To secure Australia's strategic edge in air and space power, I propose to establish a STEM-to-Defence talent pipeline envisioned as a Defence-aligned nationwide talent development framework intended to address the structural workforce deficiency identified in the DSR (Department of Defence, 2023; Matthews, 2019). One reason for this is that developing sovereign capability in these domains depends on long-lead human capital formation, yet current approaches rely on fragmented and episodic STEM outreach programs that fail to produce continuity, scale or strategic alignment across the sector (Marc, 2025). Without a more coordinated pipeline, Defence will remain locked into reactive recruitment cycles that cannot meet emerging capability demands (Mahoney & Thelen, 2015). However, Defence cannot resolve this challenge independently. The skills underpinning advanced aerospace, cyber and space systems are formed well before individuals become Defence-eligible, and are largely shaped by education systems, industry pathways and broader societal incentives. Competing directly with industry for scarce technical talent has proven costly and unsustainable, while Defence-only training models are poorly suited to rapidly evolving technological fields (Gray, 2016). Consistent with the DSR's whole-of-nation framing, the STEM-to-Defence talent pipeline would shift early capability formation outside of Defence while preserving Defence influence over the skills, problem-sets and strategic contexts that matter most for future operations.

The proposal for a STEM-to-Defence talent pipeline connects current education to career programs. Instead of replacing current standalone initiatives entirely, the talent pipeline would create a path that ties them together while also expanding them. This would allow students to start learning earlier in primary school, giving them an improved foundation. The pipeline would work to coordinate with programs like the Defence STEM Work Experience Program (Defence Science and Technology Group, 2024), AVISTA STEM outreach (Australian Remote Operations for Space and Earth [AROSE], 2025), and the Defence STEM Cadetship (Defence Science and Technology Group, n.d.) to make it easier for students to go from high school to higher education and then to work in defence-associated businesses after graduation. To achieve this, the talent pipeline would start by developing students ages 5 to 12 interest in STEM skills, encouraging them to think about systems, and covering topics in technology, space and national security. Short talks with Defence STEM ambassadors, university cadets or business leaders as mentors could help reinforce these skills. Digital badges or certificates could be used to show successes and encourage more participation by incorporating elements of gamification such as rewards, levels and challenges to make this learning more engaging and motivating.

In secondary school (Years 7–12), students can use the skills they learned in primary school in more organised lessons. Programs like AVISTA that have already built a foundation connected to the school curriculum could be leveraged on a grander scale to give students greater opportunities to learn about advanced technology and jobs in defence (Australian Remote Operations for Space and Earth [AROSE], 2025). Similar tactics could also be employed with the Defence STEM Work Experience Program, which gives students hands-on, site-based placements and classes to help them learn about careers and get ready for university or an apprenticeship (Defence Science and Technology Group, 2024). At the post-secondary level, the talent pipeline could be intertwined with the Defence STEM Cadetship to give students the chance to use what they've learned in real-life Defence science and technology settings while they are still in university (Defence Science and Technology Group, n.d.).

In this way, the main goal of the STEM-to-Defence talent pipeline is to build a workforce that is ready for the future and has technical knowledge, systems thinking and strategic awareness. This will improve Australia's national security, encourage innovation and maintain the country's control over key technological industries. That said, this approach does entail a number of deliberate trade-offs. Early workforce development would occur beyond Defence's direct control, and outcomes would be realised over longer time horizons than traditional recruitment initiatives. Additionally, there is the risk of a perceived militarisation of education, particularly in the context of educational institutions themselves. By promoting voluntary participation, establishing clearly defined goals, and placing an emphasis on dual-use skills that have clear civilian value, the talent pipeline could be used to help lessen these risks. It would not be considered a failure to migrate workforce into industry instead; rather, it would simply act as an extension of the national mobilisation base, which increases resilience rather than weakening the capacities of the defence sector.

Comparable international models demonstrate the feasibility of this method. The Israel Defense Forces' geospatial intelligence branch (Unit 9900) exemplifies Israel's defence innovation paradigm by recruiting technically talented professionals for specific analytical tasks, many of whom later transfer into the civilian technology industry (Podmazo, 2019). The exchange of expertise between the military and the commercial sector has resulted in increased rates of defence-related start-up creation and dual-use innovation (Broude et al., 2013), illustrating how a deliberately permeable boundary between defence and civilian sectors can accelerate national innovation. The established permeability between the defence and civilian sectors, rather than scale

alone, is an important lesson for Australia. Indeed, Australia appears to have taken the opposite route with the moratorium imposed by Defence, which effectively hamstrings interoperability between defence areas, essentially punishing any recently separated Defence personnel or public servant for trying to enter defence industry, even if they are not decision-makers or entering defence areas unrelated to their previous role (Pittaway, 2023). The lesson from Israel is that it would be more beneficial for Australia to align education, industry and defence routes across extended time horizons rather than replicating scale, requiring compulsory service or limiting access.

Over time, the STEM-to-Defence talent pipeline would nurture a generation that possessed not only technical expertise but also strategic literacy and a concept of defence as a collective national responsibility. The initiative would aim to eliminate structural workforce fragility and strengthen Australia's sovereign innovation base by integrating education, industry paths and defence capabilities requirements. Crucially, the talent pipeline is not intended to internalise all talent within Defence, but rather to broaden the national mobilisation pool from which Defence might draw in times of crisis. In doing so, it would lay the human foundation for sovereign platforms and surge capacity, all of which the other initiatives, sovereign space acceleration initiative and the air and space reserve network, aim to operationalise.

3. Sovereign space acceleration initiative

While the talent pipeline addresses the human capital foundations of future capability, Australia's strategic exposure in space requires an equivalent focus on sovereign platforms and access mechanisms. I propose the establishment of a sovereign space acceleration initiative that would solve a number of significant vulnerabilities identified in the DSR. These vulnerabilities include Australia's growing reliance on space-enabled technologies as well as inadequate sovereignty over their availability, tasking and resilience (Martin, 2024; Moltz, 2019; North Atlantic Treaty Organization, 2019). Securing access to space is essential for almost all the functions that are now being performed by the military and civilian organisations. These duties include intelligence gathering, surveillance and reconnaissance, communications, navigation, logistics coordination, and management of critical infrastructure (Bowen, 2020). According to experts, Australia's existing reliance on allied and commercial systems puts it at risk of disruption, denial or prioritisation threats during times of strategic stress (Chow, 2017; Moltz, 2019). This poses a problem since it restricts the ability to make decisions at the national level precisely when autonomy is most required. Defence cannot mitigate this vulnerability independently. Capital intensity, industrial scale and technical pace of contemporary space systems often exceed the capabilities of defence acquisition and sustainment models (Carlo & Breda, 2024; Teer & Spatafora, 2025). This is particularly true given Australia's narrow and scattered domestic market, which, in comparison to other small states, possesses an even more restricted economic scale necessary to support major, capital-intensive space missions. The national workforce, especially in specialised fields like aerospace engineering, systems integration and space domain awareness, is limited and intensely competitive across several industries. Therefore, being totally self-sufficient is neither a possibility nor a desirable goal for Australia.

A space acceleration initiative, on the other hand, acknowledges that sovereign competence in space is dependent on selective control rather than total ownership. This necessitates collaboration between the government, industry and allied partners, all while maintaining national authority on function that is vital (Australian Space Agency, 2018; Teer & Spatafora, 2025). By shifting from a dependent to a resilient state, Australia would be able to make significant contributions to the operations of the coalition while also maintaining its ability to function independently. Implementation would put speed, flexibility and durability ahead of custom optimisation. A space acceleration initiative would use distributed satellite architectures that are easy to construct, launch and replace quickly. This would reduce the need for single points of failure and speed up recovery times in contentious scenarios. Capability development would occur in iterative, spiral acquisition cycles, facilitating the progressive testing, deployment, evaluation and updating of technology due to this method's effectiveness (Davis, 2025). Defence would still be in charge of governance, but it would be set up in a way that encourages quick decision-making, modular procurement and quick launch partnerships. Data handling and tasking power would still be sovereign. Funding would mix the need for defence with co-investment measures like procurement assurances and challenge-driven awards. This would keep private capital in the country and support domestic business without putting all the financial risk on the government.

It is important to note that this model also entails explicit trade-offs. Smaller, modular systems may not perform as well as larger custom platforms, and bringing speed to capability may sometimes mean accepting capabilities at risk with the understanding that early technical failures may be more common. However, the capacity to recover, replace assets and adjust strategy in challenging circumstances more than offsets these trade-offs. In addition, shared investment frameworks impede the exclusive control of Defence over the development of new capabilities. However, they facilitate cost-sharing, growth and new ideas that would not be feasible otherwise. Independence for its own sake is less significant than interoperability with allied systems, which requires acknowledging integration challenges to maintain credibility and relevance as a deterrent.

Small-state space strategies provide relevant precedent for this strategy. For instance, Norway's satellite policy allows for the country to maintain sovereign control over essential data sources while leveraging private partnerships for launch services, satellite platforms and supporting infrastructure (Norwegian Government, 2021). This method strikes a balance between national authority and cost-effective private sector involvement. It also lets the government get advanced skills without having to depend only

on domestic businesses. Total industrial self-sufficiency is not a measure of success; what matters is ensuring that the whole-of-nation has access to important space-based knowledge, that operations are sustained, and that the nation can bounce back from any disasters or crises. The strategy also focuses on adding commercial data and tools to systems that monitor national security and the environment. This will create a hybrid model where the government can ensure that strategic priorities are met and commercial actors provide flexibility, new technology and the ability to grow. In this way, this model demonstrates how a small state can keep control of sensitive information and important decision-making processes while using the skills of both international and local private sectors to keep operations running smoothly.

Consequently, an accelerated space initiative would use this concept to shift space from a domain of strategic dependency to one of selective sovereign control. Rather than attempting full autonomy, the program would focus on ensuring national tasking authority, resilience in the face of disruption and interoperability across allied architectures. Defence would maintain strategic control over vital operations by anchoring local industry through co-investment and quick acquisition cycles, while harnessing private-sector innovation. In conjunction with human capital pipeline, the accelerated space initiative would provide the technological infrastructure required to sustain operations in contested areas, which the air and space reserve network could then scale during times of escalation.

4. Air and space reserve network: converting expertise into operational effectiveness

Apart from building the human pipeline and establishing an accelerated space initiative, Australia still requires a mechanism to convert dispersed technical expertise into operational effect at speed. I propose the establishment of an air and space reserve network to address a structural force-generation gap identified in the DSR that the ADF lacks a scalable, prepared reserve able to sustain advanced air, space, cyber and autonomous system operations during periods of escalation (Department of Defence, 2023; O'Neil, 2011). These domains demand highly specialised skills that evolve faster than traditional military career models can accommodate and which are increasingly concentrated in civilian industry and research institutions (Singer & Friedman, 2014).

Defence cannot resolve this gap through permanent force expansion alone. Attempting to internalise rapidly changing technical expertise would impose prohibitive cost, accelerate skill obsolescence and exacerbate retention challenges in competition with the private sector. The air and space reserve network therefore adopts an access-based model, recognising that national capability advantage increasingly resides outside uniformed structures. This approach reflects international practice in which civilian specialists are integrated through reserve service, preserving civilian careers while enabling Defence to draw upon current, mission-relevant expertise when required (Dean et al., 2014; Gray, 2016).

For the purposes of mobilisation, security screening and integration into existing command and control arrangements using a formal legislative and governance framework would be required. Additionally, a systematic cooperation between the Australian Space Agency and the Australian Signals Directorate would also need to be established to assure capability coherence and minimise fragmentation. Under this proposed framework the air and space reserve network would be directed by Defence. Instead of aiming for scale right from the beginning, the strategy would need to be developed through a series of phased pilot cohorts that are related within critical mission areas. These cohorts could then be supported by employer partnership frameworks and secure digital infrastructures, where training and readiness would combine using periodic in-person activities with virtual and remote operational integration, enabling national participation while maintaining operational standards. This means that funding would need to prioritise readiness and accessibility rather than continuous employment, which would need to be supported by targeted incentives that recognise dual-career participation and employer cooperation.

Singapore's defence governance and procurement model offers a useful parallel. Singapore's Total Defence model is a centralised, state-led environment that unites developing military capabilities, civil defence, digital resilience and getting the people involved (Bitzinger, 2018; Ministry of Defence, n.d.). In practice, this means that policy, planning and allocating resources are all handled by the same government department. This makes better use of limited staff and faster responses to new dangers. The procurement system is designed to be modular and lifecycle oriented. In this way, skills can be added over time without having to go through big procurement cycles or hire more people. Therefore, equipment and software are designed for gradual updates. The training and operational responsibilities of soldiers are divided between regular and reservists, with the latter able to capitalise on a robust national service system that cultivates technical and civic competencies that can be applied in the civilian sector. Businesses and research institutes are included in the civil-military partnership, which enables the testing and implementation of emerging technologies in defence operations as soon as feasible. Singapore's technological advantage is maintained by the cohesive governance framework that is established by the processes of centralised coordination, modular procurement, lifecycle adaptability and integrated civil-military interaction, despite the country's small defence force.

However, careful consideration is needed due to the inherent trade-offs of this approach. Reliance on reservists reduces peacetime predictability and requires acceptance of variable availability. Integration complexity and security risk are higher than in closed force models (Antai & Hellberg, 2025). However, these costs are offset by access to technically current expertise, surge capacity during crisis and reduced long-term personnel burden. The reserve network accepts depth over mass, prioritising relevance and adaptability rather than force size. Therefore, within this framework, workforce mobility between Defence and in-

dustry will need to be viewed as a strength rather than a weakness, enhancing national resilience while supporting, rather than undermining, Defence capability. Consequently, the reserve network would provide Defence with a systematic method for accessing technically current civilian skills while avoiding unsustainable force build-up. The strategy would increase surge capacity while maintaining economic productivity and innovation by institutionalising mobility between industry and uniformed services. This method embraces higher integration complexity in exchange for increased depth, adaptability and resilience across advanced operational domains. When combined with the long-term talent development pipeline and sovereign space acceleration initiative, the reserve network would result in a scalable whole-of-nation capability architecture that is consistent with the DSR's need for preparedness in an era of strategic rivalry.

5. Overcoming barriers and securing capability

The STEM-to-Defence talent pipeline, the sovereign space acceleration initiative and the air and space reserve network all have similar long-term goals, but they all have to deal with the same problems when it comes to money, leadership, possibility and managing risks. Taking these concerns into account is important for the project's long-term reputation and success. Because financial goals and election cycles change, steady, long-term contributions are becoming increasingly important. If the strategy depended on funding from Defence alone, it probably would not be sufficient for it to operate (Australian National Audit Office, 2023). Another option is to split the costs between the military, education, industry and innovation sectors and use a shared funding method. This method improves consistency, lowers risk, and is backed by co-investment tools like procurement guarantees, challenge grants and matched funds. Therefore, Defence investment should be a market anchor under the space acceleration initiative, not the main source of finance. This will encourage private sector participation and benefits that go beyond military uses.

It is critical to develop certain operational principles and governance in order to keep policies from collapsing and spreading. This is especially true for national-scale government undertakings. Defence would be in charge of monitoring a permanent inter-agency steering committee that would include representatives from the Australian Space Agency, the Australian Signals Directorate, education authorities and industry. Furthermore, a centralised governance system would be required to ensure that the plan continued to progress. Having this committee in place will guarantee that decisions are made honestly and transparently. Furthermore, the planning process must include a thorough assessment of the potential risks involved as well as the chances of successful completion. A thorough assessment is needed because phased implementation reduces execution risk by allowing for the piloting, modification and progressive rollout of modular and scalable programmes across the entire country (Mahoney & Thelen, 2015; Senge, 2006). The Bridgestone World Solar Challenge ((Australian Academy of Technological Sciences & Engineering, 2020; Bridgestone, n.d.)), Healthy Harold (Australian Council for Educational Research, 2021) and Rock Eisteddfod (Rock Eisteddfod Challenge Foundation, 2012), among other Australian programs, show that it is possible to adapt the necessary organisational frameworks rather than building them from the ground up. This is something that can be accomplished. Clear goals, strong ethical oversight, voluntary participation and a focus on dual-use civilian outcomes can all help to avoid big problems like worker fatigue, minimise the belief that education is becoming militarised, address weaknesses in space or cyberspace and the tendency to over-rely on new technology. Using dispersed systems, redundancy and working with friends all make technology more reliable. This enables the Government to continue overseeing critical missions while strengthening its resilience. Despite the complexity of the projects, these indicators suggest that risks can be managed and that the strategic benefits of the initiatives are worthwhile. The proposed initiatives are not autonomous projects in and of themselves. On the contrary, each of them is part of a national capacity structure. The goal of this framework is to encourage collaboration among individuals, platforms and partnerships in order to achieve long-term strategic goals.

6. Conclusion

My proposal to build a STEM-to-Defence talent pipeline, a sovereign space acceleration initiative, and an air and space reserve network could form the basis for a national capability framework that is consistent with the DSR. The talent pipeline would develop a group of technologically skilled and strategically aware Australians ready to strengthen national resilience from their earliest years. An accelerated space initiative would help to build the air and space infrastructure needed to support this workforce in generating operational benefits. And lastly, an air and space reserve network would incorporate civilian expertise straight into Defence operations, facilitating swift deployment and ongoing capability expansion within the most technologically advanced fields. Together, these initiatives could move Australia beyond a reliance on acquisition and towards a proactive framework for capability growth. These initiatives are based on similar small-state experiences while being customised to Australia's strategic geography, alliance setups and workforce constraints. Crucially, they establish sovereignty as a national concept by aligning persons, platforms and relationships over long-term perspectives rather than short political cycles. For this endeavour to be successful every initiative needs to be enacted, financed and managed as a lasting dedication. Temporary trials or fragmented efforts will not be adequate in a time of increasing threats. Herein, Australia requires a whole-of-nation approach that harnesses national intelligence, fortifies sovereign industry and integrates resilience, within both civil and defence organisations. Through these proposed initiatives, Australia can transform its traditional limitations, small population, vast geography and constrained budgets into sources of strategic advantage. In addition to serving as an informed consumer of allied capacity, the nation has the ability to independently contribute

to the region's stability and security. To capitalise on this opportunity, it is necessary to possess a long-term perspective, be determined and prioritise integration. Incrementalism is no longer an option. Australia must establish long-term national capabilities frameworks that safeguard sovereignty and fortify the nation for future generations.

Submitted: December 11, 2025 AEDT. Accepted: February 24, 2026 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Stott, N., Pendlebury, J., & Tracey, P. (2025). Organising Military Innovation: Collaborative Opportunities for Organisational and Military Innovation Scholars. *Contemporary Issues in Air and Space Power*, *3*(1), bp51817458.
https://doi.org/10.58930/bp51817458

Technology & Innovation

Organising Military Innovation: Collaborative Opportunities for Organisational and Military Innovation Scholars

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Keywords: Military innovation, Idea work, Organisational work, Inter-organisational work, Military innovation complex

https://doi.org/10.58930/bp51817458

Vol. 3, Issue 1, 2025

This paper outlines a rationale for more engagement between military innovation and organisational scholars. The paper highlights the 'blind spots' in organisational scholarship when compared with military innovation literature from other fields. It introduces the term 'military-innovation complex' to denote the increasingly opaque interaction of military, state, academic and commercial actors, and provides a framework of innovation work comprising three processes: idea work, organisational work and inter-organisational work. The paper argues these processes bridge the existing literatures and, in doing so, identifies themes in military innovation studies that resonate with current discourses in organisational theory and highlights areas for future research and collaboration.

1. Introduction

Military innovation scholars have explored the complex relationships between military ideas, organisations and technology over time (Ford, 2017; McNeill, 1982; Posen, 1984). A strength of the literature on military innovation is its historical focus on how innovation is generated and resisted in military organisational fields that encompass the public, private and social sectors. Military innovation has been characterised as: the battleground between state, industry and military leaders (Posen, 1984); stemming from experiences of actual battle (Farrell et al., 2013); or inter-service (Sapolsky, 1972) and intra-service cooperation and rivalry (Bacevich, 1986). Others have focused on culture (Adamsky, 2010) and organisational learning (Fox, 2017) as sources of innovation. Yet others have explored power relations between and within organisations (Ford, 2017) and how organisations enable or restrict open collaborative innovation (Cronin, 2020; Kollars, 2017b).

Ideas and practices of management have travelled between corporate, government and military organisations (McCann, 2017), with the military field a key source 'for models, analogies and metaphors' as organisation theory developed (Mutch, 2006, p. 752). There is less movement of *ideas* in the other direction, but evidence of military organisation adoption of management and business practices, or tools, is evident in key strategic documents such as the Australian Defence Force's (ADF) *Defence Corporate Plan* and associated 'outcomes', 'activities' and 'performance measures' (Department of Defence, 2025).

The contemporary organisational literature tends to sidestep the military (Bloomfield et al., 2017, p. 442). Notable exceptions include work on aircraft carriers (Weick, 1987), covert organisations (Shapiro, 2013), war trauma (De Rond & Lok, 2016), sensemaking[1] (De Graaff et al., 2019) and military doctors (De Rond, 2017). Some have used a historical approach to look at intelligence (Grey, 2012), the arms industry (Vergne, 2012) and groupthink (Ahlstrom & Wang, 2009). Such work tends to use military organisations as isolated empirical contexts rather than theorising the field as a whole.

This paper draws attention to the opportunities for, and importance of, theorising the management of military innovation. For instance, militaries provide ample opportunities to extend our understanding of sensemaking (Maitlis & Christianson, 2014), creativity (Thompson, 2018), organisational learning (Argote & Miron-Spektor, 2011) and socio-materiality (Carlile et al., 2013). The military context offers an understanding of innovation in extreme conditions, including intense time, environmental and political pressures. It also offers opportunities to address phenomena left out of the organisational literature, such as resistance, failure, de-adoption (Godin & Vinck, 2017) and 'social exits' (Stott, Tracey, et al., 2025).

Increased attention to military innovation is important as it has a far-reaching impact on organisations and society as a whole (McNeill, 1982; Posen, 1984). Military innovation increasingly absorbs the capacity of researchers, entrepreneurs and commercial organisations. From neuroscience

1 De Graaff et al describe 'sensemaking' as the process through which individuals analyse 'what is going on' and how to respond when faced with ambiguous or new circumstances (De Graaff et al., 2019).

to literature, academia is not immune to the military's 'encompassing tendencies' (Goffman, 1968, p. 15). While fewer people may serve in the military, more now serve the military in lethal innovation work, knowingly or not. The paper argues that the symbiotic relationship between universities, industries, entrepreneurship, governments and the military – the military-innovation complex – sits in the 'blind spot' of organisational scholars and deserves greater scrutiny.

The paper is organised as follows. First, we provide an overview of military innovation, outlining the rise of a 'military-innovation complex', which includes academia, to illustrate how it has shaped innovation management more broadly. We draw on examples from the United States (US), which tends to dominate the military innovation literature, charting the scope and breadth of military innovation studies. We then develop a framework for analysing military innovation comprising three processes: idea work, organisational work and inter-organisational work. We aim to bridge the gaps between the existing literature and our framework and provide inspiration for further collaboration between disciplines.

2. Why do militaries innovate?

Military innovation involves the creation, implementation and diffusion of ideas; organisational forms; and technology to deliver competent and coherent violence: the ability to sustain lethality in the face of the chaos of combat. Organised violence is hard to achieve even for militaries that perceive themselves as well trained, with coherent doctrine and state of the art equipment (Collins, 2009b). As Carl von Clausewitz observed, '[e]verything in war is very simple, but the simplest thing is difficult' (Clausewitz, 1832/2007, p. 65). Human frailty, incomplete knowledge, and the opposition's agency in disrupting the best laid plans all contribute to the chaos of conflict and 'incompetent violence' (Collins, 2009b). When faced with violence we experience an inhibitor, 'confrontational tension/fear', which makes actual violence difficult, ineffective and therefore incompetent (Collins, 2009a, p. 568). Competent violence depends on circumventing fear through emotional control and distance from human targets (Ben-Ari, 1998; Collins, 2009a).

The primary aim of military organisation is to achieve competent, coherent violence. This means militaries need to navigate through 'order and chaos'; a rational organisation attempting to order an irrational environment (Winslow, 2007, p. 84). Order is enforced by hierarchy, discipline and uniformity. Chaos is the violence, sensory overload and fear. In this context, innovation entails fusing ideas (about how to do combat, which is expressed as doctrine), organisational forms, technology and the resilience of military personnel.

3. Organising military innovation

Military innovation involves an opaque web of military, industry and academia, often characterised as the 'military-industrial complex' (Eisenhower, 1961). Or, as we suggest, a 21st century version, the 'military-innovation complex', which now involves entrepreneurs, incubators and innovation ecosystems such as Silicon Valley.

Military organisations frequently graft 'best' practices emerging from research to their ideation, education, and structural forms and operations (although not necessarily successfully). Military research agencies draw from universities for their military utility often through 'innovation/entrepreneurial clusters', thereby framing innovation (Stott, 2025). From neuroscience, robotics and nanotechnology to textiles, food and plant technologies, and semantics, university-based innovators may be unaware of the military applications of their work (Stott, 2025). For critics, the military's 'encompassing tendencies' (Goffman, 1968) are evidence of the inappropriate accumulation of military power and the militarisation (or weaponisation) of ideas, people and things. Whether utilising innovations generated indirectly (civilian) or directly (military procurement) – marked by an increasingly indistinct line – the result is often a 'symbiotic relationship', which intensifies militarisation (McNeill, 1982, p. vii; Stott, 2025).

3.1. The rise of the US military-innovation complex

The US has created a vast research network which is 'public and private, secret and open, working on every frontier trying to build better weapons' (Gholz & Sapolsky, 2018, p. 4). The US has developed think tanks, military universities and research centres. The US has moved gradually from the top-down 'Developmental Bureaucratic State' (DBS) – the military-industrial complex of World War II and the early Cold War – to a decentralised innovation ecosystem of the 'Developmental Network State' (DNS) (Block, 2008), which we label the 'military-innovation complex'.

A key example is the pioneering Defence Advanced Research Projects Agency (DARPA), which, since 1958, has made 'the future happen', transforming industry and society (Jacobsen, 2015, p. 7). Its program managers act as 'entrepreneurial leaders' orchestrating research projects in the US and beyond (Jacobsen, 2015). The core methods, pioneered by DARPA, are 'targeted resources', 'opening windows', 'brokering' and 'facilitation' (Block, 2008). 'Targeted resources' aims to accelerate progress by concentrating resources – modelled after the Manhattan Project, which created the first atomic bombs. In contrast, 'opening windows' encourages numerous actors to innovate, not just the national laboratories, top universities or the major defence corporations. In doing so, DARPA piloted incubation, shared facilities and 'open innovation'. 'Brokering' refers to making connections and encouraging joint work, as well as business brokering to support commercialisation. 'Facilitation' involves collaborations within government to remove or circumvent obstacles to innovation (Block, 2008). In effect, DARPA, by focusing on 'high risk in pursuit of high payoff', 'de-risks' technology for private investment (DARPA, 2025).

DARPA has coordinated innovations which have transformed militaries and society, such as the internet, GPS, stealth technology and drones. It has prefigured technol-

ogy, as demonstrated by its autonomous vehicle research in the 1980s. It has also caused untold damage, for example, with the defoliant Agent Orange, used in Vietnam. DARPA drives a cycle of innovation, attempting to stay one step ahead, as 'competitors' emulate technology (see Jacobsen [2015] and Weinberger [2017] for histories of DARPA). Lauded as an exemplar of public sector innovation, DARPA pioneered modern innovation systems and its methods were emulated by other governments (Block, 2016). What we know of DARPA's current work on autonomous weapons, robotics and bio-augmentation presents numerous ethical dilemmas and far-reaching implications (Scharre, 2018). Many projects are classified, and 10 to 20 years ahead of public domain technology (Jacobsen, 2015).

DARPA is not alone. For instance, the Defense Innovation Unit (DIU), Central Intelligence Agency's In-Q-Tel (established in 1999), and the Defense Innovation Board (DIB) are instrumental in the military-innovation complex (Defense Innovation Board, n.d.). The DIU invests in Artificial Intelligence (AI), autonomous systems, information technology, space and biomedical companies. In-Q-Tel was the first government-sponsored 'non-profit' venture capital firm. It has invested in intelligence-related fields such as data, imaging, voice recognition and DNA analysis, particularly in Silicon Valley (Keller, 2015; Szoldra, 2016). The DIB brings together leaders from companies like Instagram and Google as well as academia such as the Wharton Business School, Duke University and California Institute of Technology to advise on culture, technology and practice.

The DNS is decentralised, encourages duplication and 'built in redundancy', and encompasses academia, commercial and state organisations (Block, 2016). Unlike the command model of the DBS, the DNS is 'far less visible to journalists, scholars and the public' (Block, 2008, p. 174). The US innovation system has moved beyond the big 'defence-unique' suppliers to encompass a vast range of other actors to exploit the cutting-edge research and technologies of the global commercial sector (Simón, 2016). That said, the big defence companies – such as Lockheed Martin, Boeing and BAE Systems – still play a key role in integrating entrepreneurs' and research institutions' innovations into military products (Gholz & Sapolsky, 2018).

In the military-innovation complex, we now have 'metagovernance': 'a plurality of processes that connects government with private and voluntary actors in networks and partnerships, and the point of metagovernance is governance of these interactions' (Christiansson, 2018, p. 266). For instance, in 2017 the US Air Force (USAF) established a community of air force innovators – AFWERX – to be a catalyst for 'engagement across industry, academia and non-traditional contributors to create transformative opportunities and foster an Air Force culture of innovation' (United States Air Force, 2018)). Through metagovernance, a military-innovation complex has emerged in which it is increasingly challenging to disentangle the civil from the military. A global process, the US military-innovation complex draws on entrepreneurship and innovation from across the world. As Russia and China strive to emulate the US, they have developed their own far-reaching military-innovation complexes (Bitzinger & Raska, 2022; Cheung, 2011; Kania, 2019).

3.2. Encompassing academics

Militaries have long incorporated and encompassed academia, with the reach extending well beyond the close connections typified by the military academies that offer new recruits a liberal education in parallel to basic officer training. From the mid-20th century, scholars became embroiled in military innovation through substantial research grants, academic positions and contracts (Rohde, 2013). In 1950, the US Navy and Central Intelligence Agency (CIA) funded Project Troy at the Massachusetts Institute of Technology (MIT) to develop psychological warfare tactics. Project Troy became a model for large scale military/academic collaboration. For many social scientists, military projects became 'integral to their day to day work' (Simpson, 1998, p. xxi).

In 1961, President Dwight D. Eisenhower famously warned against the rise of the military-industrial complex. He defined it as a powerful network of public and private forces that combine a profit motive with the planning and implementation of strategic policy, potentially threatening democracy (Ledbetter, 2011, p. 6). In a draft of his 1961 speech, Eisenhower used the term 'military-industrial-academic complex' reflecting academia's role (Giroux, 2016). Despite his caution, Eisenhower's 1958 National Defense Education Act (NDEA) underwrote university support for the Cold War effort (Mosser, 2010), involving new fields of learning such as computer science, primatology and paleoanthropology (Engerman, 2003). Military expenditure underwrote research projects by social scientists such as Margaret Mead (Wolfe, 2018), and centres like Talcott Parsons' Harvard Department for Social Relations (Patterson, 2001). Indirectly, research which, on the surface, would appear to have no military utility, was encompassed by the military-industrial complex (Bridger, 2015; DeGrasse Tyson & Lang, 2018; Rohde, 2013; Wang, 1999).

The RAND Corporation, in addition to DARPA, is another major research organisation that has been instrumental in incorporating academics into military innovation. Project RAND (Research and Development) was established in 1945 to maintain the wartime links between the USAF and civilian scientists. With a small number of 'deviant thinkers drawn from multiple disciplines, RAND became a major source of ideas' (Augier et al., 2015, p. 1142). It was a template for incubating innovation within the military, and for think-tanks in general (Abella, 2009). In 1948, it launched a social science arm and became a non-profit corporation with trustees drawn from politics, industry and universities. RAND has 'literally reshaped the modern world - and very few know it' (Abella, 2009, p. 3). The most influential ideas resulting from RAND's activities include game theory, organisational economics, nuclear strategy, evolutionary economics and rational choice theory.

After the Vietnam War, many US universities ostensibly severed their military links. However, they shifted to research contractors (often classed as 'non-profits') that had opaque relationships with universities and the military. For

instance, the US Army's much maligned Centre for Research on Social Systems at the American University quietly transferred staff into the non-profit American Institutes for Research (Rohde, 2013). More recently, much of the late Cold War military innovation focused on the so-called 'Revolution in Military Affairs' (RMA) (Freedman, 1998; Shimko, 2010). Alarmed the Warsaw Pact could field three times more troops and equipment than NATO, the US developed a second 'offset strategy' in the mid-1970s, focusing on lethality through high technology (Freedman, 1998). Again, research grants and contracts flowed into universities, largely without the critical attention seen in the Vietnam era.

Post 9/11, investment in social sciences intensified. The occupation of Iraq led to a shift (in the West at least) from the RMA to counter-insurgency. It also led to innovation in systems integration and targeting (Lindsay, 2020). For instance, despite recent cuts in funding under the second Trump administration, the Pentagon's Minerva Initiative continues in its aim to 'leverage the intellectual horsepower of the American academy' in social sciences (Kupferschmidt, 2025; Mosser, 2010, p. 1081). Contentious innovations which embroiled social scientists – anthropologists in particular – included contract research on cultural understanding or 'human terrain' as well as embedded Human Terrain Teams (HTT) in Iraq and Afghanistan (Gusterson, 2017) and the privatisation of military services (Singer, 2008). HTTs led to the rise of the subdiscipline of military anthropology and associated academic posts within military universities (González, 2009) and were immensely controversial within the anthropology community (González, 2018).

Calls for academic input include the US Army's 'Mad Scientist Initiative', which, for 30 years brought military, corporate and academic communities together in 'problem solving within the far future of Armed Conflict' (United States Army, n.d.)[2]. Other calls have included themes such as mega-cities and bio-convergence, as well as for science-fiction stories (Shabro & Winer, 2017). In 'Visioning the Future of Warfare 2030-2050' through 'the art of storytelling, the Army was able to visualize the known, probable, and possible challenges and opportunities that the future holds' (Shabro & Winer, 2017). DARPA is also now collaborating on an AI system to assess the utility of social research – SCORE (Systematizing Confidence in Open Research and Evidence) with the Center for Open Science in Virginia (Resnick, 2019).

In summary, academic involvement in military innovation has become more diffuse, with multiple points of convergence, and more opaque relationships between military framing and application of scholarship.

4. Studying military innovation

Traditionally, military innovation scholarship has been the preserve of scholars whose disciplinary allegiances lie within international relations and history: strategic, security or war studies, and military history in particular. A small cadre of military sociologists and military anthropologists also contribute to the discipline. Military innovation scholars focus on how innovation impacts strategic and operational practice – its scope and scale and resulting effectiveness – with combat being the ultimate audit (Rosen, 1994). Explanatory models examine the interplay of the state and military, intra- and inter-service dynamics and culture (Grissom, 2006). We summarise the key debates in **Table 1**.

Military innovation scholars tend to be closely positioned within political and military organisations (Grey, 2009), such as think-tanks and professional military colleges. Many have 'unparalleled access' to some of the largest organisations in the world, their archives and partner organisations (Griffin, 2017, p. 198). Insider status presents opportunities, but can also be problematic (Pendlebury, 2019). Vested interests, close organisational allegiances, and research funding which privileges practical utility, create a 'theoretical conservatism biased towards applied research' (Griffin, 2017, p. 206). But a question we need to ask is 'what is that research applied to?' Military innovation scholars are not immune from Clegg's criticism of organisational studies: in 'designing a better machine in the interests of those it serves rather than those it damages' (Clegg, 2009, p. 344).

Organisational scholarship tends to focus on particular high-technology industries (Salter & Alexy, 2014), which has opened the 'black box' of managing innovation in the private sector (Phillips, 2014). We suggest that military innovation management could present the next 'black box' for organisational scholars. Military innovation literature on conflict and power also offers valuable insights into innovation management, an area largely overlooked by organisational scholars.

The military innovation literature sets out rich, historical case studies that provide transferable insights into organisational identity, change, learning, power, inter-organisational work and failure (see **Table 1**). Also, military innovation studies explore the interplay of ideas, organisations, and service innovation (Jensen, 2016; Salter & Alexy, 2014). Furthermore, it provides sophisticated accounts of the role of power and politics in innovation, including in multi-national settings. In turn, organisational scholarship can assist Griffin's (2017) call for greater theoretical ambition in military innovation studies, and more critical research and greater engagement with organisational scholars. However, the insights from the literature have rarely been aligned.

2 The Mad Scientist All Partners Access Network (APAN) was decommissioned in October 2025.

4.1. A framework of military innovation work and opportunities for research collaboration

In the following section, we discuss a framework involving three levels of analysis in which debates around military innovation can be situated. The three levels are: idea, organisational and inter-organisational work (**Table 1**). Considering these activities as work acknowledges the agency of actors involved, since the work undertaken by individual and collective actors creates, maintains or disrupts innovation. Here, we align the key debates in military innovation scholarship and organisational studies. By distinguishing these three strands of practice and the relationships between them, we can compare the corresponding debates in military and organisational scholarship. In this section, we also briefly consider future research opportunities, identifying themes of mutual interest.

4.1.1. Idea work

Idea work is the process of generating or resisting ideas (Carlsen et al., 2012). In military innovation, this pertains to ideas on the nature, past and future of war, 'visualizing new ways of war' (Jensen, 2016, p. 15) and 'new theories of victory' (p. 22). Military innovation scholarship is concerned with the propagation of such ideas which lead to the development of new operating concepts and, eventually, doctrinal change. Military idea work is facilitated by safe incubation sites (such as staff colleges, professional journals and 'strategy blogs') to debate ideas and advocacy networks to promote them.

Military innovation has traditionally been a top-down process, performed by senior officers or civilians (Ford, 2017). For example, the German 'blitzkrieg' ('lightning war'), a method combining a spearhead manoeuvre with mechanised infantry that was devised during the invasion of France in 1940, relied on top-down command models. More recently, the experiences of counterinsurgency in Vietnam, Iraq and Afghanistan have led to 'bottom-up' approaches, such as adaptation (Farrell et al., 2013; Neads et al., 2023; Russell, 2011) and organisational learning for military effectiveness (Nagl, 2005), or 'organisational learning under fire' (Carley & Harrald, 1997). Even so, the ability of bottom-up change to produce scalable innovations remains contested (Ford, 2017). A further iteration of military innovation is the approach of middle-out (Ford, 2017), or horizontal innovation (Foley, 2012), in which the engine for organisational change lies in the middle structures of the armed forces (Pendlebury et al., 2025).

While military innovation scholars have sought to understand how ideas are propagated – that is, bottom-up, top-down or middle-out – organisational scholars are more likely to focus on the nature of ideas and how they are generated. One area in which we see the most potential for greater mutual interest is 'user innovation' – the participation of user organisations or end users in developing products or services (Von Hippel, 2005). Further exploration of this in military contexts could prove fruitful, because it offers an understanding of the 'micro-processes' involved in generating ideas; that is, processes on the scale of individuals, teams or lower-level units. User innovation may seem to be antithetical to a military environment. Yet, there is a long history of innovation by 'mavericks' and clusters of relatively junior officers. For instance, Jensen (2016) documents the 'micropolitics of innovation', explaining how, in Iraq, the sustained advocacy work of officers – who had direct experience of organisational failure to adapt in the field – coupled with the positional legitimacy of general officers converted to the idea, brought about innovations in counterinsurgency approaches. Recent examples of innovation in the field by the Ukrainian Army, particularly through leveraging the use of cheap and plentiful drone capabilities, demonstrates the power of tactical and operational level innovation, even in the face of overwhelming conventional military power (Halem, 2023). These studies raise questions about when, and under what circumstances, military organisations suppress, tolerate or encourage user innovation.

Intriguingly, 'bootleg' innovation – user innovation undertaken with no formal organisational support, but to benefit the organisation (Criscuolo et al., 2014) – also occurs in a military context. Rigid planning processes are not conducive to the need to rapidly solve 'everyday' problems, especially in combat. Grassroots military bootlegging occurs when initiative or bottom-up feedback mechanisms are constrained, particularly when existing solutions do not work in extreme and unpredictable situations. In an organisation which privileges standardisation and consistency (Hill, 2015), bootlegging may provide a 'sanity check' or safety valve. For example, bootleg innovation can solve low-level procurement niggles or equipment or process failure. But the question remains as to whether it can lead to lasting or scalable innovation. Because of the extreme circumstances in which military bootlegging occurs, further collaborative research could improve our shared understanding of the micro-processes and impact of unsanctioned idea work.

4.1.2. Organisational work

We define this work as the process of organisational action to deliver or resist innovation. Innovation can also be studied at the organisational level, and while much of the military literature has focused on top-down examples, more recent scholarship has examined distributed innovation processes, military culture and organisational learning. How organisations assimilate new learning (exploration) and use it (exploitation), in other words, moving from intuition to institutionalisation, affects their performance and sustainability (Crossan et al., 1999; Vera & Crossan, 2004). Organisational learning has become central to military scholarship debates as militaries that do not learn, or cannot integrate learning rapidly enough in combat, tend to suffer.

Military scholarship has focused on themes overlooked in organisational studies, such as implementation and diffusion/adoption (Dias & Ferreira, 2019). Also, power and politics are integral to military studies, but neglected in organisational learning scholarship, which has a 'consensual and conflict-free flavour' (Easterby-Smith et al., 2000, p. 794). Gender, race and LGBTQIA+ politics, policy and prac-

Table 1. A framework of military innovation work

	Idea work	Organisational work	Inter-organisational work
Definition in relation to innovation	The process of generating or resisting ideas on innovation.	The process of organisational action to deliver or resist innovation.	The process of inter-organisational action to deliver or resist innovation.
Example	First World War British Army doctrine development and sharing (Fox, 2017); Human Resource Teams (McFate, 2018); UK Defence Medical Services (Ford et al., 2017);	The Pentomic Division (Bacevich, 1986); US counterinsurgency doctrine (Nagl, 2005)	Armoured Fighting Vehicles: Bradley/Abrams (Haworth, 1999); Artificial intelligence (Webb, 2019); B-1 bomber (Farrell, 1993); 'Five Eyes' intelligence and technology sharing (Defence Science and Technology Group, 2025); M-16 rifle (McNaugher, 1984);
Key debates in military innovation literature	**Bottom-up innovation:** as adaptation from below (Farrell et al., 2013; Farrell & Terriff, 2002; Russell, 2011) **Middle out/Horizontal innovation:** exchanging best practice between units (Foley, 2012) change originating from the middle of the military-innovation complex (Ford, 2017) **Innovation as a matter of organisational learning:** learning 'under fire' (Carley & Harrald, 1997) **Improving military effectiveness through organisational learning:** (Catignani, 2012; Fox, 2017; Nagl, 2005) **Innovation as a social construct:** (Bousquet, 2009; Ford, 2017, 2019; MacKenzie, 1990; McNaugher, 1984)	**Top-down innovation:** as a result of military leadership (Posen, 1984) through intra-service rivalry/ cooperation (Bacevich, 1986; Rosen, 1994) as a result of limited resource allocation and intra-service rivalry (Sapolsky, 1972) **Distributed innovation:** (Morris, 2017) how technologies diffuse and affect patterns of innovation (Ford & Gould, 2018; Horowitz, 2010) **Innovation as a matter of organisational learning/memory:** as organisational learning (Dyson, 2019; Hasselbladh & Ydén, 2020; Nagl, 2005) as organisational memory (Hardt, 2018) **Innovation as a matter of military culture:** as a cultural phenomenon (Adamsky, 2010) as the product of doctrine and culture (Kier, 1997) as cultural predisposition (Farrell & Terriff, 2002; Mahnken, 2002) as mastery (Kollars, 2017a)	**Top-down innovation:** as a result of government /civilian and military leadership (Posen, 1984) through inter-service rivalry/cooperation (Bacevich, 1986; Rosen, 1994) as a result of limited resource allocation and inter-service rivalry (Sapolsky, 1972) as a response to threats (Evangelista, 1988) **Innovation as a middle-out and an outside-in process:** as a matter of power relations between and within organisations/constituencies (Ford, 2017; Ford et al., 2017) 'open innovation' (Kollars, 2014, 2017b) **Innovation through technology diffusion between nations/states:** how technologies diffuse and affect patterns of innovation (Ford & Gould, 2018; Horowitz, 2010) **Innovation as resistance to industry or empowered by industry:** bureaucracies unable to change so encourage market solutions (Dombrowski & Gholz, 2006) industry unwilling to innovate so they 'gold plate' (Kaldor, 1982; McNaugher, 1989)
Parallel debates in organisat-ional literature	Creativity (Thompson, 2018) Emotions (Zietsma et al., 2019) Organisational learning (Argote & Miron-Spektor, 2011) Sensemaking (Maitlis & Christianson, 2014) Socio-materiality (Carlile et al., 2013) User innovation (Von Hippel, 1986, 2005)	Emotions (Zietsma et al., 2019) Legitimacy (Suddaby et al., 2017) Organisational learning (Argote & Miron-Spektor, 2011)	Cross-sector partnerships (Gray & Purdy, 2018) Cross-sector work (Vurro et al., 2010) Emotions (Zietsma et al., 2019) Inter-organisational relations (Cropper et al., 2008) Legitimacy (Suddaby et al., 2017)

tice have also received extensive academic consideration (see Caforio & Nuciari, 2018), whereas the organisational learning literature often considers politics a 'perversion or a "necessary" dysfunction or evil within organisations' (Easterby-Smith et al., 2000, p. 793), and are therefore relatively silent on key vehicles of power, such as race, gender, class and sexuality (Devos, 1996; Martin et al., 2018; Teller, 2022).

A key debate in the literature is whether military leadership and bureaucracies facilitate or hinder learning. For Hasselbladh and Ydén (2020), military organisations 'are attuned to *reproduce sameness*': predictability, control and codification are emphasised and learning is often the outcome of retrospective sensemaking (Hasselbladh & Ydén, 2020, p. 489). Dyson (2019) distinguishes between informal and formal military learning, with the former disseminated through informal networks and focusing on ad hoc and short-term problem solving, such as in user innovation. Meanwhile, the latter focuses on creating organisational structures and processes to identify, manage and implement lessons (Dyson, 2019). For example, the study by Morris (2017) of US strategic bombing theory in World War II explains how the strategies took root gradually – with no clear single catalyst – as a distributed phenomenon within a highly bureaucratic environment. This involved persuasion, experimentation, demonstration and significant infighting.

Military innovation scholarship has explored decentralised learning and connects with organisational literature – in particular, literature on 'communities of practice', 'activity systems' and 'ecologies of knowledges' (Easterby-Smith et al., 2000, p. 788). For instance, Jensen (2016) explores advocacy groups, and Fox (2017) explores networked learning: 'the interconnectedness between top-down, bottom-up, incidental, and horizontal approaches' (Fox, 2017, p. 7).

Dyson calls for comparative scholarship on organisations operating in a 'High-Velocity and Turbulent Environment' involving 'high-risk, complex and rapidly-changing contexts' such as fire, health, police, nuclear industry and railways (2019, p. 123-24). Decades of organisational work during recent wars have arguably made the US forces as, if not more, agile and adaptive than leading private companies (Russell, 2011). Exploring organisational work in extreme situations, such as the military, could improve our collective understanding of innovation within 'high reliability organisations' (Weick et al., 1999).[3] However, questions remain. How are military organisations creating space for more decentralised and collaborative organisational learning? How do military organisations manage the tension between innovation and continuity? How do they learn under duress?

Organisations that operate in the 'shadows' could be a valuable area for further research. Scott (2013) suggests organisations operate in a continuum from transparent to shaded, shadowed and dark. The degree of visibility is linked to audience, membership, law and regulation as well as the degree of legitimacy or stigma associated with the organisational form. For instance, Vergne (2012) saw the stigmatisation of the arms industry contributing to their 'relative isolation from the rest of society, thereby turning secrecy and discreetness into assets' (Vergne, 2012, p. 1047). Such organisations tend to be poorly understood and in 'greatest need of empirical study' (Scott, 2015, p. 505).

4.1.3. Inter-organisational work

Innovation, at the level of inter-organisational work, involves action between multiple organisations to deliver or resist ideas. This is of particular importance in military innovation, due to the complex and high stakes nature of warfare. There is a normative rhetoric (Selsky & Parker, 2010, p. 22) that 'grand challenges'[4] require collaboration, but inter-organisational work is often prone to conflict (Ashraf et al., 2017; Crosby & Bryson, 2010). Military inter-organisational work appears to be less prone and often presents interesting examples of successful cooperation under pressure. For example, DARPA created 'collaborations between heterogeneous actors who hail from different fields or who hold radically different world views' (Hampel et al., 2017, p. 575). Additionally, multinational commands, such as NATO, have successfully fought wars and achieved collective objectives (King, 2019). There have been extensive studies of state command (the DBS) and the interaction between prime defence contractors and universities in earlier phases of military innovation work (see Baime, 2014; Edgerton, 2005; Gansler, 2011; Sparrow, 2011). These analyses of inter-organisational work are rarely referenced in non-military organisational studies.

The practices of military inter-organisational work resonate with the burgeoning literature on inter-organisational relations (Cropper et al., 2008) and cross-sector work, 'the new organisational Zeitgeist' (Vurro et al., 2010, p. 40). Increasingly, lone organisations (or sectors) lack the competence or resources to tackle 'grand challenges'. Inter-organisational work is undertaken by 'autonomous actors' who construct shared rules, norms and structures to tackle issues of mutual concern (Gray & Purdy, 2018). New forms of organising have arisen 'in response to changing conditions within institutional fields' (Gray & Purdy, 2018,

3 Weick (1987) and Weick et al. (1999) make the important distinction between high *efficiency* and high *reliability*. In this literature, efficiency represents the more 'conventional organisational issue', driving organisational behaviours toward the generation of value and profit maximisation. Conversely, 'high reliability organisations' place greater emphasis on reducing operational errors. Classic examples of high reliability organisations include those involved in aviation, space travel, nuclear reactor management and oil rigs (Weick, 1987).

4 We define a 'grand challenge' as one for which there is no single identifiable causal factor, and for which no single actor possesses the resources or understanding to solve it. Climate change is an example of a contemporary grand challenge.

p. 36). Such 'boundary spanning' work has become legitimised (Kislov et al., 2017).

Even though inter-organisational work is portrayed as the future for organising (Gray & Purdy, 2018), the literature has struggled to move beyond simple proscriptions and checklists. A better understanding of military inter-organisational work could contribute to organisational theory, offering insights relevant to other fields.

Militaries obsess over, and plan for, numerous threats – internal and external – including climate-induced conflict. Until recently, the US Department of Defense long perceived climate change as a present security threat (Bierman, 2025), not purely a long-term risk which will 'disproportionately affect fragile and conflict-affected states' (Department of Defense, 2015, p. 14). While war between 'big' states for resources is an ever-present danger, in the short term at least, access to water (potable and agricultural), food and climate migration are likely to compound existing tensions (Kurth et al., 2024; Stott, Pendlebury, et al., 2025; Welzer, 2008/2012). Climate 'events' will require humanitarian relief and inter-organisational work at a scale and intensity rarely experienced outside war. Understanding how military organisations plan and implement inter-organisational humanitarian relief will be crucial to responding to such crises. Important lessons can be derived from researching the numerous inter-state organisations (past and present) which focus on the preparation, deterrence or execution of combat, such as NATO and US strategic and unified combatant commands. Such organisations appear to overcome barriers and evolve processes and products for interoperability and complex metagovernance.

Etzion and Gehman (2019) recently urged organisational scholars to 'show up' and engage with the 'big, important, real world issues and [participating] in devising thoughtful, meaningful ways to deal with them' (Etzion & Gehman, 2019, p. 489). Avoiding war, driven by climate change or escalating competition between big states, is such an issue. While military innovation work provides numerous insights, it is also problematic. War is a progenitor of innovation. The perpetual wars in Iraq and Afghanistan have intensified the military's encompassing tendencies and blurred the civil-military relationship. There is extensive literature that addresses 'the civil–military problematique: how to make the military an effective defender of the state without also making the military a capable threat to the state' (Feaver, 2017, p. 326). However, this literature overlooks the democratic consequences of military-innovation complexes, as well as the threat posed by military innovation in setting academic and entrepreneurial wheels in motion. Solving scientific, technological or entrepreneurial puzzles in quantum, nanotechnology, robotics and AI, as well as expanding our social and cultural understanding, can lead to new ways of warfare, and accelerate subsequent arms races. Given the deadly consequences of military innovation work, it is time that organisational scholars reflect on the relationships between academia and military organisations. They must 'show up' and not avoid 'unsettling' research contexts (Claus et al., 2019).

5. Conclusion

Further study of 'idea work' and 'organisational work' in the extreme and high-stakes contexts of the military can offer important insights for researchers seeking to understand innovation management. This would entail bridging the fields of scholarship in military innovation and organisational theory. In this endeavour, we suggest that further study of bottom-up models of innovation, such as user innovation, could prove valuable avenues for further research for both disciplines. In the Australian context, the Royal Australian Air Force's Plan Jericho is a potential host for such a body of work, given its focus on embedding a culture of disruptive and ground-up innovation within the framework of a traditional, hierarchal military organisation (Barnes, 2018).

In addition, we assert that collaborative research into military 'inter-organisational work' is especially urgent. The nature of climate-related crises likely to assail us in the not-too-distant future means the ability of organisations to cooperate without conflict will be crucial. Inter-organisational work is the fabric of the 'military-innovation complex', which, we argue, sits in a 'blind spot' of organisational scholarship. This blind spot deserves greater attention for two key reasons: first, because the opaqueness of the relationships involved – between universities, the technology industry, commercial entrepreneurship, governments and the military – undermines effective engagement in innovation. Second, because without appropriate oversight, democratic control over this complex is rendered impossible.

Questions remain regarding how military framing, facilitation and investment shapes innovation organising, as well as the processes and practices involved. For instance, what impact do organisations like DARPA have on the culture and leadership of innovation? In what ways has private sector innovation been shaped by military agendas? Has the institutional distance (Phillips, 2014) between military and non-military organisations shrunk? If so, what are the implications for both? How does military innovation work frame, enhance or distort organisational fields? What are the tensions created by the encompassing tendencies of military innovation work and how do researchers, entrepreneurs and organisations manage such tensions?

At a more macro level, how could military innovation contribute to *reducing* the likelihood of conflict – an objective central to Australia's 'Strategy of Denial' in the *National Defence Strategy* (Commonwealth of Australia, 2024, p. 7) – rather than simply improving battlefield lethality and operational effectiveness? Put another way, how can military innovation support whole-of-government stabilising activities that deter international actors from initiating conflict? This last question warrants scrutiny as the international community grapples with geopolitical crises that have brought the globe 'the closest to global catastrophe it has ever been' (Mecklin, 2023); crises that traditional approaches to military force structures and postures seem incapable of addressing.

While the contours of military innovation work in the West are discernible with effort, much remains hidden. Most organisations manage their transparency to some extent. Military innovation still operates within dark organisations and the intensifying relationships with universities, companies and entrepreneurs are shaded or shadowed. Military innovation scholars have shed some light, not least in historic cases (Ford, 2017), but the need for more research to map the changing contours of military-innovation complexes remains.

We therefore encourage research which maps these relationships, as this can offer significant insights into how military innovation works in practice and, in doing so, contribute to a critical discourse. We hope that in providing scrutiny of the ever more invasive military-innovation complex, researchers can create greater awareness as well as strengthen democratic checks and balances.

Acknowledgements

The authors would like to thank Drs Michelle Darlington, Bill de Marco and Matthew Ford for their invaluable input to early drafts of this paper.

Submitted: August 12, 2025 AEDT. Accepted: September 02, 2025 AEDT. Published: December 11, 2025 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Tomlinson, C., & Ivimey, S. (2026). Resilient by Design: Enhancing the Survivability of Australian Military Airbases in an Era of Strategic Uncertainty. *Contemporary Issues in Air and Space Power*, *4*(1), BP55849562. https://doi.org/10.58930/BP55849562

Air Power

Resilient by Design: Enhancing the Survivability of Australian Military Airbases in an Era of Strategic Uncertainty

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Keywords: Australian airbases, resilience, exercises, RAAF Base Tindal

https://doi.org/10.58930/BP55849562

Vol. 4, Issue 1, 2026

The airbases supporting Australia's military air capability face rising threats to operational sustainability and effectiveness. The Australian military bases at RAAF Darwin, Tindal, Curtin and Learmonth face challenges due to their distance from major support hubs and their vulnerability to severe weather events and sophisticated enemy attacks. This paper investigates the resilience of Australian military airbases in the face of geographic isolation, climatic extremes and strategic threats. Drawing on open-source data and operational case studies, we outline key priority areas for action: (1) infrastructure hardening involving strengthening shelters, fuel systems and command centres; (2) operational dispersal, which involves positioning aircraft, command capabilities, maintenance functions and personnel across several sites lowering vulnerability; (3) rapid damage recovery, including workforce training and equipment to promptly evaluate damages and restore operational capabilities following an attack or natural disaster; (4) community resilience, which requires protecting and informing personnel, families and base communities; and (5) exercises and validation. The work provides actionable recommendations to enhance national defence preparedness under increasingly contested and uncertain conditions. Operational outcomes at airbases will depend on resilience amid rising uncertainty and disruption. Investing in durable airbases enables Australia to strengthen its national security framework while maintaining regional stability and enhancing its deterrence capabilities.

1. Introduction

Australia's military airbases serve as essential components of national defence. These bases provide crucial capabilities for rapid air mobility and enable force projection while enhancing homeland security and supporting joint and coalition operations. Enhancing the resilience of Australia's northern RAAF bases is essential to achieving the strategic objectives outlined in the 2024 National Defence Strategy (NDS) and 2024 Integrated Investment Program (IIP). The term resiliency is mentioned over 20 times in the NDS with a specific focus on enhancing survivability of our northern bases to defend our northern approaches (Department of Defence, 2024b). The NDS states and directs that enhancing resilience be one of the IIP's six immediate priorities (Department of Defence, 2024b, p. 38). The IIP has dedicated $14-18 billion (out to 2034) to enhance our northern bases (Department of Defence, 2024a, p. 87). This money is separate to the billions of dollars which are also allocated to airbase operations through more resilient command-and-control networks and improved theatre logistics. Therefore, Defence needs to take action to enhance airbase resilience and survivability. This paper seeks to provide further argument to support this line of effort, provide specifics on how to enhance airbase resilience, and discuss some of the challenges that Defence needs to overcome.

The paper focuses on Australia's northern airbases, as the challenges for enhancing survivability in an era of uncertainty are most acutely felt. These bases include RAAF Darwin, Tindal, Curtin and Learmonth. The paper is set out in four sections. First, it will introduce key concepts and definitions regarding airbases, their resilience and contribution to national defence. Second, it will discuss key strategic challenges facing Australia's military airbases; this includes geographic isolation, climate threats and strategic uncertainty. Third, it will outline the five key elements to build resiliency: infrastructure hardening, operational dispersal, rapid recovery, community and family resilience, and exercising. Fourth, it will synthesise all these points into a case study on RAAF Base Tindal which demonstrates Australia has the capability to build greater airbase resilience across the country.

2. Key concepts and definitions

The joint force and Air Force has a significant amount of doctrine on air power, airbases and airbase resilience. Defining, understanding and applying these terms is key to grounding any argument about enhancing our airbase resilience and improving our national security. This paper seeks to apply these terms to our current circumstances and use a specific case study to argue that we need to widen our

understanding of resilience to incorporate concepts such as civilian preparedness, community support and cohesion.

- **Airbase.** The ADF Air Power Integration doctrine defines an airbase as 'A defined area containing an aerodrome and infrastructure that supports air power activities' (Air and Space Power Centre, 2023, p. 50).
- **Airbase Operations.** There are several roles that an airbase performs and not all of RAAF's airbases function to the same level of capability. The spectrum spans from a main operating base (MOB) that provides the infrastructure and services for hosted units to conduct training, operations and maintenance support, forward operating base (FOB) from which air missions are launched in support of the joint force and down to a landing zone, the specific area of land or landing deck for rotary winged aircraft (Royal Australian Air Force, 2022, pp. 4–6). This paper defines RAAF Darwin as Australia's MOB in its northern approaches and RAAF Curtin, Learmonth, Tindal, Townsville and Scherger as FOBs. Other MOBs in Australia include RAAF Amberley, Edinburgh, Richmond and Williamtown; however, the primary focus of this paper will be looking at Australia's northern airbases.
- **Airbase Functions.** Air Force's Air Power Manual states that 'the level of support provided to an airbase will differ depending on the type and location. The contribution to joint effects provided by airbase operations will be made up of one or more of the following airbase functions': command and control (C2), airbase protection, operations support, logistics support, aerodrome engineering, health support, safety, network operations and emergency response (Royal Australian Air Force, 2022, pp. 4–5, 4–7)
- **Airbase Dependence.** Air power, distinct from other forms of military power, is highly dependent and reliant on other capability and support systems to enable the generation, employment and sustainment of military power. The Air Power Manual outlines that 'this level of dependency typically requires an established airbase ... which [relies] on a complex supply chain' (Royal Australian Air Force, 2022, pp. 3–5). A key component of this supply chain is a reliance on civilian infrastructure, including emergency services. Furthermore, Australia must overcome difficulties regarding airbase defence and continuity planning. Due to its geographic layout, Australia has military bases distributed over large areas, usually far from population centres. Geographic isolation creates logistical challenges and lowers redundancy levels while extending emergency response times.
- **Airbase Resilience.** Given today's strategic demands, airbases must enhance resiliency, which is essential to their survival. The ADF defines airbase resilience:

> Airbase resilience is the ability of an airbase or network of airbases to withstand an attack or other adverse event, continue to perform essential functions while degraded, and to recover. Resilience pertains to facilities and infrastructure design and maintenance, workforce training and organisation, command and control (C2) and major systems (Australian Defence Force, 2022, pp. 83–84).

Resilience goes beyond technical and engineering tasks. It requires a change in culture, ongoing leadership focus and continuous investment. Achieving resilience demands interagency coordination between military and civilian organisations and moving from a mindset of safe havens to preparing for contested spaces. This paper investigates Australian military airbases' main difficulties while identifying essential resilience-building areas, explaining methods to test these enhancements, and discussing the practical challenges that need resolution.

3. Key challenges facing Australian military bases

Developing resilience at Australian military airbases is a multi-faceted undertaking that involves more than creating plans and investing in infrastructure enhancements. Building resilience for Australian military airbases demands continuous collaborative efforts that affect every part of the base and extend over a lengthy period.

3.1. Geographic isolation

Historically, geographic isolation has been a factor that has enhanced airbase survivability. Strategic requirements, as well as historical factors, have resulted in many northern airbases being situated in isolated and thinly populated regions. Historically, this has been a factor that enhanced airbase survivability; however, in the age of long-range precision strike weapons and the emergence of cyber and space threats, this advantage has been eroded.

RAAF Curtin, Darwin and Learmonth stand hundreds to thousands of kilometres distant from key population areas and logistical networks and have limited immediate support (Royal Australian Air Force, n.d.). The isolation means that these airbases suffer from extended supply chains. The civilian infrastructure around medical facilities, airports and road networks often lacks the capacity to sustain surge operations. Transport routes add further vulnerability, as single highways and ports form long, narrow logistics lines that can be disrupted during wars or natural disasters (Parliament of Australia, 2020). During emergencies, the arrival of reinforcements, emergency repair teams and even basic supplies can take several days.

Australia's distinctive geography creates additional barriers to developing resilience capabilities. Effective resilience requires defence collaboration with civilian authorities, contractors and local governments through partnerships that can lack strength or prior establishment – especially outside of our MOBs and FOBs. Resilience planning should include clear thresholds for transitioning from Defence Assistance to the Civil Community (DACC) to combat posture, with rehearsed handover points to civilian agencies.

The natural protection against opportunistic attacks that isolation provides, comes with the challenge of sustaining high-tempo operations, especially when the base sustains damage. Self-sufficiency for long-term resilience

requires bases to focus on fuel storage capacity, onsite maintenance capabilities, water security systems and medical service availability. Military installations need to practise functioning independently while receiving minimal outside assistance. Innovative approaches such as prepositioning, distributed logistics hubs, modular fuel systems and uncrewed logistics drops are required to reduce the practical effects of isolation.

3.2. Climatic extremes

Australia's northern bases face, at an increasing rate, extreme weather events. These events undermine the endurance of airbases. The events include tropical cyclones, extreme heat and storms – all of which are exacerbated by their remoteness. For example, RAAF Darwin and Tindal in the north endure yearly cyclone seasons, which bring dangers that disrupt various airbase functions. The effects include wind damage to buildings which can impact on logistics and C2, flooding which can impact runway and maintenance operations and high temperatures which can overwhelm operational cooling systems and test personnel's physical limits. Climate change projections show that environmental pressures will become stronger, leading to higher baseline stress on military infrastructure (Department of Defence, 2024b, p. 14).

Researchers predict that climatic hazards will occur more often and intensify throughout the upcoming decades. To strengthen against climatic extremes, we need both strengthened physical infrastructure and flexible contingency approaches. Design of bases should account for extreme environmental situations that may include cyclone-proofed structures; critical facilities require both fire breaks and suppression systems to prevent fire damage, as well as elevated and flood-resilient fuel and supply storage, backup water supplies and airfield drainage systems.

3.3. Strategic threats

Australia's strategic environment is deteriorating, bringing into sharper focus some of the potential military threats we may face. Consequently, airbases must enhance their physical and cyber security to enhance survivability. Australia's airbases confront growing threats from targeted physical and cyber-attacks and can 'no longer rely upon distance for protection' (Australian Defence Force, 2022, p. 84). Some countries in the region have advanced technical and kinetic capabilities, such as precision long-range missiles that have the capability to attack stationary facilities such as airbases. These attacks can now occur at extremely long ranges of hundreds to thousands of kilometres (Layton, 2021; Needham, 2024). To counter this threat, the Integrated Air & Missile Defence System (IAMDS) could enhance base protection against precision strikes by providing layered warning, cueing and intercept capabilities. The conflict in Ukraine has shown the impact low-cost uncrewed aerial systems (UAS) will have on modern conflict. These UAS pose a new threat and can be launched within or outside Australian territory. This means that Defence needs to implement improved physical and electronic warfare security systems to counter UAS threats.

The cyber domain will increasingly impact airbase operations. Airbases face complex attack surfaces, as they depend on hundreds of IT systems that were not originally designed to withstand disruptions. Third-party dependencies also create vulnerabilities, since civilian suppliers and contractors may introduce weaknesses that provide unauthorised access points. Cyber intrusions and sabotage can compromise command-and-control systems, air traffic control, logistics management systems and fuel distribution networks (Kilcullen, 2023). Moreover, information operations are an emerging threat where base functionality can be undermined through civilian access disruption, dependent-targeted disinformation, and psychological operations without direct physical attacks. In addition, grey-zone activities, such as undercover sabotage accompanied by insider threats can incapacitate a military base during periods without an official war declaration (Kilcullen, 2023). Cyber resilience requires ongoing maintenance and is frequently overlooked (Kilcullen, 2023).

The contemporary nature of warfare renders our traditional concepts of security through geography and 'rear area security' obsolete. Bases should operate under the assumption that they will face immediate targeting during any upcoming conflict. This drives a requirement for movement and distribution of vital resources like aircraft and fuel and demand for robust command-and-control systems. It also requires redundant, hardened command-and-control systems. Most importantly, base operations should include permanent cyber defence teams to defend localised systems in the same way that intelligence teams are embedded at the base level. These cyber defence teams must complement component, theatre and national level defences.

4. Five priority elements for building airbase resilience

This paper argues that there are five areas that Defence should prioritise to build airbase resilience: infrastructure hardening, dispersal, rapid damage recovery, community and family, and exercising and validation. Each element is mutually supporting and enabled by continual exercising. A framework is in **Figure 1**. This paper acknowledges that there are other frameworks, such as the ADF's components of airbase resilience, that can be used (Australian Defence Force, 2022). However, the framework provided in this paper provides practical initiatives commanders can take and aligns them to the NDS and IIP. It aims to provide specific examples and case studies to enhance doctrine and SOPs, which already form the conceptual basis for airbase resilience.

4.1. Infrastructure hardening

The ADF recognises physical infrastructure as a critical airbase capability and it has been prioritised in both the NDS and IIP. Therefore, physical infrastructure also stands as a critical, and in this paper's assessment primary, de-

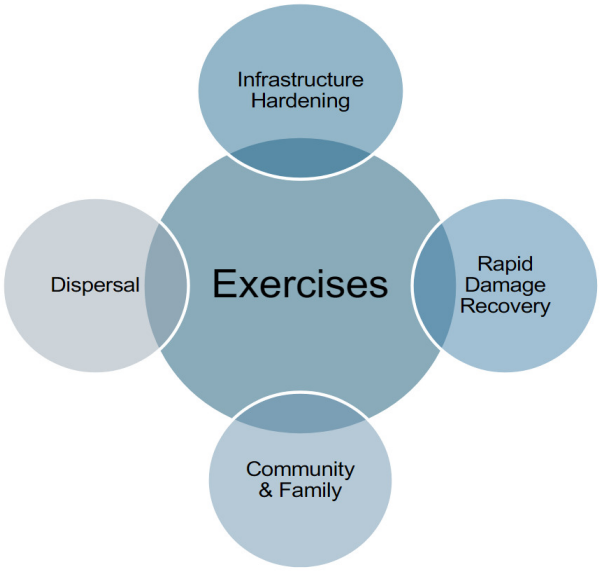

Figure 1. Airbase Resilience Framework Diagram

fence layer in every resilience strategy. The ability to sustain operational functionality during environmental or targeted threats defines the resilience of Australian airbases. Infrastructure designs should support multi-role use, including the re-tasking of facilities for medical, logistics or humanitarian roles under contingency conditions; for example, gymnasium floors that can double as emergency accommodation. Resilience benefits from the standardisation and replication of essential systems across all bases, which provide functional redundancy, cross-base logistics and cross-base training to personnel.

Practically and financially, budget constraints and the long lead time for infrastructure improvements delay resilience building upgrades. The creation of hardened shelters, dispersed operating sites, mobile command posts and backup energy grids requires substantial financial investment, yet these projects rarely deliver quick or visible benefits. Budget constraints and high up-front costs often force decision-makers to prioritise the acquisition of new aircraft and weapons systems over resilience measures. The steps taken in the IIP are important to remediating this historical shortcoming.

Infrastructure hardening should aim to protect essential resources such as aircraft, fuel storage and command centres from physical harm. It should also aim to maintain essential airbase power, communications and medical functions after an attack or disaster. Most importantly, the system should be able to deploy deliberate damage mitigation strategies alongside repair mechanisms to ensure quick recovery after attacks or disasters.

Infrastructure hardening entails hardened aircraft shelters (HAS). HAS is essential to store aircraft in reinforced structures that can endure near-miss missile strikes, shrapnel and blast overpressure. HAS designs must also protect against regional environmental dangers, such as cyclone resistance in northern areas (Kopp, 2008). Concurrently, infrastructure hardening should reinforce C2 facilities. Structures housing base headquarters and air traffic control nodes need protection against kinetic attacks and electromagnetic pulse (EMP) effects. Rapid activation procedures must be established for secondary and tertiary command nodes in case the primary HQ becomes compromised.

Airbases need to consider fuel, ammunition and energy storage and security, a point emphasised throughout the NDS. Dispersed fuel and ammunition storage supports airbase resilience. Airbases should avoid high-risk material centralisation by distributing fuel farms and ammunition depots throughout the base area and using underground or blast-protected storage when possible. Apart from fuel, the airbases must have energy security by incorporating independent power solutions such as micro-grids and solar power while having hardened backup generators to ensure mission-critical systems remain operational during grid disruptions or hostile attacks (Department of Defence, 2024c). The resilience of airbases is tied to maritime fuel supply via Sea Lines of Communication (SLOC). These routes require naval escort, redundancy through alternative ports, and prepositioned bulk fuel reserves.

Infrastructure hardening requires hardened communications nodes. The primary communications centres need defence against physical and information attacks through reinforced physical structures and electromagnetic shielding. Base designs require physical protective landscaping and barriers to incorporate berms, blast walls, flood-barriers and firebreaks, which serve dual purposes of passive protection and directing possible damage away from critical infrastructure.

Exercising infrastructure hardening involves a series of drills and simulations designed to test both personnel readiness and the resilience of hardened facilities. 'Button-up drills' train personnel to quickly close and secure facilities upon receiving attack warnings. Damage simulation exercises provide opportunities for staff to practise recovery procedures, such as starting emergency power systems and redirecting communications channels. Infrastructure stress testing is also carried out through controlled simulations, including high-wind scenarios and minor explosive tests, to confirm compliance with hardening standards.

The exercises must prove both structural integrity and operational functionality under stress to verify that hardened buildings remain functional after sustaining damage. Infrastructure hardening faces several issues and challenges. One of the most significant is cost: construction and material transport to remote locations demand considerable funding. Risk management also requires difficult prioritisation decisions, since limited resources make it impossible to harden every facility. Many Australian bases were constructed before modern missile and cyber threats were a concern, and these legacy designs complicate efforts to upgrade them. In addition, environmental regulations, heritage protections and community concerns can restrict the implementation of hardening measures.

Infrastructure hardening is non-negotiable for airbase resilience. Creating resilient installations requires strategic prioritisation, ongoing funding and redesigning base layouts to ensure they remain operational under threat con-

ditions. Paradoxically, hardened facilities can become attractive targets, and their visibility may signal high-value functions. This demands integrated deception strategies and layered redundancy to protect against targeting.

4.2. Operational dispersal

Operational dispersal maintains airbase functionality during attacks by distributing assets, including aircraft, personnel and C2 nodes, across multiple locations. The key objectives of operational dispersal are to protect aircraft, fuel supplies, maintenance facilities and command operations from concentrated risks, and to maintain functionality even when operating from compromised or secondary locations. The distribution of assets, personnel and capabilities throughout wider areas enhances survivability by decreasing the chances that operations will be crippled by one attack. Dispersal also complicates adversary targeting and weapon apportionment strategies (Australian Defence Force, 2022, p. 100).

Operational dispersal has several components. On-base aircraft dispersal involves moving individual aircraft or small groups into hardened shelters and alternative ramps or positioning them in discrete open areas divided by terrain features rather than parking them wingtip-to-wingtip on open aprons. Effective dispersal requires extensive ground support equipment, tow vehicles and detailed movement coordination, often resembling a complex Tetris scenario, particularly under tight timelines. Alternative operating locations are also essential, with military bases needing to establish and maintain relationships with civilian airports and remote airstrips that can function as backup operating sites (Reynolds, 2026). Mobile command-and-control capabilities enable the rapid re-establishment of air traffic control and mission management and C2 nodes at alternative locations, achieved through deployable modules such as hardened containers and mobile vans (Department of Defence, 2024c). Maintenance and logistics must also adapt, with teams capable of servicing aircraft at multiple dispersed sites using minimal equipment, and with fuel, munitions and spare parts hubs either pre-established in various locations or designed to be mobile. Personnel flexibility is equally important, requiring airbase staff to relocate to alternative facilities, adapt to austere conditions and sustain operational autonomy when separated from central command.

Exercising operational dispersal is critical to ensuring effectiveness. Aircraft dispersal drills allow operational squadrons to practise moving aircraft to shelters or alternative sites in response to simulated attack warnings, working under aggressive timelines such as positioning 80% of operational aircraft within 90 minutes. Alternative base operations should also be carried out by conducting full flying operations at civilian or secondary airfields, testing the readiness of these sites through logistics resupply, air traffic control coordination and the implementation of security measures. Mobile command-and-control exercises further test resilience by activating mobile centres during base denial scenarios, while ensuring the continuity of both command functions and flight operations. In addition, maintenance and refuelling exercises conducted under degraded conditions allow teams to demonstrate their ability to sustain operations with limited support at austere or alternative sites.

Several issues and challenges complicate the effective execution of operational dispersal. Many alternative locations lack essential infrastructure, such as fuel farms and maintenance facilities, requiring significant investment and coordination with local authorities. Training is another challenge, as dispersed operations demand skills in improvisation and independent decision-making that are not usually emphasised in standard garrison training. Logistics becomes increasingly complex, with the need to supply multiple sites placing additional strain on networks and creating both transport demands and new security risks. The use of civilian airfields also requires close civil–military integration, including pre-crisis coordination, legal agreements and unified security procedures, which are generally not developed during peacetime. Dispersal to civilian facilities raises the question of turning these facilities into military targets, so needs to be planned with due consideration for avoiding collateral damage to civilians and infrastructure. This requires ongoing legal planning and consultation. Further, the pressure to maintain dispersed mission management and C2 nodes can stretch the provision of relevant ICT equipment. Ensuring that dispersed C2 systems are functional and secure will increase in difficulty the longer dispersal is maintained. Finally, dispersed operations inevitably slow the generation of sorties compared to centralised operations, meaning that expectations must be adjusted and plans adapted to account for a reduced operational tempo.

Australian airbases rely on operational dispersal as an essential means of surviving strategic threats and environmental dangers. When proper planning, resources, exercises and cultural adoption are executed throughout base operations, operational dispersal can transform base weaknesses into operational strengths.

4.3. Rapid damage recovery

Major attacks or severe natural disasters can cause significant damage to even the most fortified dispersed airbases. Airbase combat power depends on its capability to evaluate damage quickly and restore operational capabilities. ADF doctrine defines recovery as 'the prioritised set of activities ordered by the air base command post to return the airbase to operability above a directed minimum level as soon as possible' (Australian Defence Force, 2022, p. 101). Recovery efforts also aim to maintain logistics and communications systems during periods of infrastructure degradation. The overarching objective is not to achieve absolute invulnerability, but rather to limit disruption and manage consequences when attacks inevitably occur. The focus should be on rapid recovery that prioritises speed. The rapid recovery of essential systems such as runways, taxiways, fuel supply and communication channels should happen before an adversary can launch a follow-up attack or take advantage of the disruption.

Rapid damage recovery has several components. Rapid runway repair (RRR) teams must be properly trained and equipped to quickly identify and remove damage such as craters and debris, and to conduct fast repairs that return landing zones to service. These efforts must always be preceded by explosive ordnance disposal, which requires thorough preparation and rehearsals to ensure safety and realism. Expeditionary engineering teams also play a role, with the ability to deploy quickly to repair airfields and other critical infrastructure such as power plants and communication towers. Mobile damage assessment using drones and uncrewed ground vehicles allows conditions to be evaluated immediately after an attack while reducing risk to personnel (Department of Defence, 2024c). Prepositioned repair kits, including materials such as quick-setting concrete and steel matting, are essential for rapid response, avoiding delays caused by waiting for external resupply. Bases must also identify secondary or tertiary runways and taxiways, along with alternative landing zones, that can be activated when primary runways are unusable. Finally, survivable command-and-control infrastructure, either in hardened structures or mobile units, ensures that base operations can continue even if primary headquarters are damaged.

Exercises are essential for validating rapid damage recovery capabilities. Runway damage simulations create craters and debris fields, requiring RRR teams to activate secondary runways and demonstrate their ability to restore surfaces under strict time limits. Full-base damage drills expand this approach by simulating simultaneous impacts on fuel depots, power plants and command centres, demanding coordinated responses from multiple functional areas. Drone-based training helps operators practise rapid mapping techniques, which speeds up triage and repair prioritisation. Mission continuity exercises further test resilience by requiring operational squadrons to generate sorties from alternative runways or compromised facilities.

Implementing rapid damage recovery comes with a range of issues and challenges. Personnel resilience is a key concern, as the physical and mental demands of recovery operations quickly erode performance through fatigue and decision overload. Effective resource management is also vital, requiring strong leadership and prioritisation skills to allocate limited repair assets when multiple damage points must be addressed simultaneously. Time pressure presents another difficulty, particularly when adversaries employ multi-wave attacks that strike again as recovery teams are working. In such situations, repair operations must be carried out quickly and discreetly to succeed. Equipment survivability is also a concern, as engineering and repair vehicles must be hardened or dispersed to ensure readiness during critical moments. A potential solution to this problem is the rapid contracting of civilian equipment to be used by uniformed personnel. Finally, successful recovery depends on seamless integration across multiple functions, including engineers, security forces, logistics and command staff – something that can only be achieved through established relationships and prior practice.

Rapid damage recovery extends beyond runway repairs, enabling military units to regain operational strength amid active attacks. Australian military airbases require the establishment of agile and resilient recovery capabilities integrated across all functions and prepared through training and exercises before disasters or attacks occur. Rapid repair efforts must be cyber-secure, particularly regarding the certification processes that restore airworthiness and inform command chains. False-positive or premature certification could create cascading risks.

4.4. Community and family resilience

Community and family resilience is an overlooked aspect of airbase resilience. In fact, family or community are not mentioned in the ADF's capstone doctrine on airbase operations (Australian Defence Force, 2022). In peacetime, maintaining morale, mental strength and community cohesion is one of the most difficult aspects of prolonged resilience operations. In conflict these problems are compounded as personnel face difficulties maintaining operational focus during crises when they are unsure about the safety and welfare of their family members. Building community and family resilience is essential to operational effectiveness. It must extend beyond basic welfare measures. Fostering community resilience entails creating an inclusive and cohesive community, one that caters to all segments – all services in the integrated force, APS, contractors and civilians. Defence could explore expanding the following proposals to all members of the community, not just those in uniform. This requires nuance because there remain important distinctions between uniformed and non-uniformed members and their conditions of service and unlimited liability.

Airbase operational capacity relies on more than their physical structures and aircraft resources. Its operational success depends heavily on the stable and resilient community support network, which includes the families of military personnel and local civilian workers, including those contracted to Defence. The key objectives of community and family resilience are to implement protective measures that maintain support systems for families and non-combatants throughout crises, to ensure that operational personnel can focus solely on mission-critical tasks without distractions, and to sustain cohesion, morale and public trust across extended emergencies. Australia's bases located in remote areas must prioritise community and family resilience, as evacuation proves challenging and outside help may face delays.

Community and family resilience has several components. Family evacuation and shelter plans provide practised procedures for dependants to respond safely to crises ranging from missile attacks to natural disasters. Protected shelter facilities within military installations offer hardened or secure spaces to shield family members and essential civilians from threats such as blasts or cyclones. Resilient communication channels are also crucial, giving families access to multiple dedicated lines – such as hotlines and community apps – that provide accurate information during emergencies. These platforms must employ

end-to-end encryption and operate on defence-validated systems to prevent exploitation or disinformation, including through applications such as Signal. Dependants' resilience training can form another component, by offering spouses, children and civilian staff basic instruction in emergency procedures and survival skills relevant to their specific locations. In addition, Community Emergency Response Teams (CERTs) build capacity by training volunteer family and civilian members to respond at the base level during extensive incidents (Kilcullen, 2023). Finally, strong local civil–military coordination with councils and essential services – such as police, fire and health departments – ensures mutual support during significant base or regional emergencies.

Exercises reinforce these resilience measures. Family evacuation drills, conducted annually as optional activities, allow families to practise sheltering or relocating in a controlled, stress-free environment. Information cascade drills measure the speed and effectiveness of delivering emergency instructions to all civilians and dependants while achieving base-wide alert status. Regular community first aid and survival workshops further strengthen preparedness by teaching trauma response, sheltering practices and basic survival techniques. CERT activation exercises provide additional assurance by testing community-level responses to simulated crises such as cyclones or cyber blackouts.

A number of issues and challenges complicate the development of community and family resilience. Some families may resist participating in drills or training, requiring innovative engagement strategies to encourage voluntary involvement. Resource prioritisation presents another difficulty, as funding for civilian protection measures such as shelters competes with operational infrastructure needs. Managing information flows is equally complex, with commanders needing to balance transparency with operational security during crises. They can introduce family stress and evacuation fatigue, where repeated drills and ongoing uncertainty may lead to burnout (Kilcullen, 2023).

Effective coordination with civil authorities can prove difficult, particularly when overlapping jurisdictions create risks of redundancy or conflicting messages during emergencies. Jurisdictional confusion can occur when military and civilian agencies face overlapping or conflicting responsibilities during crises. Legal and regulatory hurdles also create friction, as the use of civilian airfields, requisition of private resources and family evacuation procedures remain constrained by peacetime legislation. Finally, public perception must be carefully managed, since large-scale military activities such as evacuation drills or visible base fortifications may trigger public concern or panic without clear communication.

Families and communities are at the core of base resilience instead of on its outskirts. Sustained community stability and dependant protection enable military personnel to engage in combat operations while also repairing and recovering with undivided attention. Developing community resilience requires forward-thinking strategies and resource allocation while recognising the essential role people play alongside aircraft. Defence can also draw upon the community resilience research that local and state authorities (AdaptNSW, 2025) have conducted in response to the 2019-2020 Black Summer bushfires and other natural disasters such as flooding. This research integrates strategy, science, policy and experience to provide a toolkit to different practitioners.

4.5. Exercising and validating resilience measures

Exercises and validation are both an independent factor that improves resilience but also an enabling function that force multiplies the previous four essential factors. Exercises and validation refer to the testing and improving of processes. Airbase resilience exercises test resilience measures under realistic conditions to ensure they operate properly during actual situations. They identify gaps, friction points and unexpected interdependencies, and prepare personnel to manage operations when faced with degraded conditions or system failures. They build base-wide muscle memory for crisis response. This is important to build a resilience culture.

Defence's cultural inertia is one of the major challenges to overcome in building airbase resilience. This inertia can be overcome with clear-eyed assessments, as laid out in the NDS, and backed up by real-life exercises. Established bases during peacetime conditions often develop habits of comfort and routine. The notion that 'it has always worked this way' becomes a dangerous mindset. Resistance to change is common, as both personnel and leadership often oppose adjustments to established routines that introduce daily difficulties, such as dispersing aircraft or operating from austere field locations. Units also show reluctance to conduct degraded exercises, preferring polished, high-performance drills over the messy reality of resilience training. Finally, a persistent underestimation of adversary capability fosters complacency, with assumptions that Australian bases are either out of range or not high-value targets.

Creating resilience plans and infrastructure requires testing to confirm their effectiveness beyond theoretical assumptions. Untested plans demonstrate failures when they first encounter real crises. The practice of testing and authenticating resilience measures transitions from theoretical understanding into operational benefit. Remote or exposed Australian airbases need continuous, realistic training exercises to identify weaknesses before adversaries find them. Exercise design must balance training realism with operational security constraints by classifying critical elements and decoupling specific timelines or methods from public knowledge.

There are a variety of exercises that can be used to improve airbase resilience. Designing effective exercises requires attention to several key principles. No-notice elements should be included to test adaptability and response under surprise conditions. Cross-functionality must be evaluated by examining how engineering, flying squadrons, security, logistics, families and base services interact under stress. Graded realism is important, beginning with manageable scenarios and advancing to multiple simultaneous failures. Exercises should incorporate objectives and key

performance indicators of success. Post-exercise analysis, including hot washes and After-Action Reviews, is essential both to identify lessons and to confirm that corrective actions are implemented. Finally, exercises should include dependants and contractors to reflect the full community footprint rather than focusing only on uniformed personnel.

Tabletop simulations are low-cost exercises which enable key decision-makers to walk through crisis scenarios within a structured setting (Rees, 2026). They focus on crisis decision-making under uncertainty, command-and-control redundancy plans, communication flows under degraded conditions and the challenges of civil–military coordination. Examples include an exercise replicating a sudden missile attack while testing cyber system weaknesses, and a base evacuation for families during an approaching cyclone. A key performance indicator could be implementing a decision within a specified timeframe.

Short notice functional drills allow for real-time testing of specific resilience capabilities. Focus areas include activating rapid runway repair teams to fill crater damage, deploying mobile C2 vans within set timelines, ensuring aircraft are dispersed within two hours during simulated warning exercises, and conducting a family sheltering activation exercise (Department of Defence, 2024e & 2024f). Examples are a sudden dispersal exercise moving one fighter squadron to secondary parking without notice, and an emergency power transfer drill for air traffic control operations. A key performance indicator could be moving all aircraft to the secondary parking location within a specific timeframe.

Full-scale field exercises and extended multi-use exercises simulate base operations under continuous attack or disaster conditions. Focus areas include operating with limited communications, flying from degraded or alternative runways, sustaining fuel systems during periods of damage and security challenges, managing medical surges for mass casualties, and maintaining security under sabotage and insider threat scenarios. Examples include a simulated two-wave missile attack combined with a complete breakdown of communications, and three consecutive days of air operations from field shelters supported by emergency logistics. A key performance indicator could be achieving an 80% sortie rate from the field shelters.

War-gaming exercises incorporate dedicated Red Team that conduct realistic attacks on base systems of the Blue Team through both physical and digital means. Focus areas include cyber penetration assessments on command-and-control systems while operations are ongoing, physical sabotage against perimeter security, and information disruption aimed at families and civilians. Examples range from a Red Team network hack designed to test runway recovery operations to a simulated disinformation campaign directed at base family members. A key performance indicator could be that less than 20% of the family members believed or engaged with disinformation.

5. Case study: building resilience at RAAF Base Tindal

Examining RAAF Base Tindal demonstrates both advancements achieved and possible avenues for additional development at this significant northern Australian airbase. Resilience must be approached holistically. It requires a coordinated effort across command structures, logistics, operations, security services and community support systems. Resilience requires a unified effort from the whole defence enterprise rather than the responsibility of a single department or agency (Department of Defence, 2024b). RAAF Tindal also demonstrates the intersection of the three main challenges facing airbases: geography, climate and strategic uncertainty, and the five key elements of resiliency building.

Tindal is located near Katherine in the Northern Territory, about 320 km south-east of Darwin. Outside of the RAAF Base it has a population of only 8,000 people and a single supermarket (Katherine Town Council, 2025). RAAF Tindal is a crucial northern hub for air combat operations and forward defence in Australia. RAAF Tindal currently operates F-35A Lightning fighters, provides facilities for air mobility elements, and functions as a crucial FOB for regional operations and exercises.

Supply chain vulnerability is a persistent issue, as limited road and rail connections make the base highly susceptible to flooding and transport interruptions during the wet season. Civil–military coordination also remains complex. While RAAF Tindal maintains strong ties with the Katherine community, further work is needed to improve coordination with national-level civilian organisations such as emergency management authorities and aviation regulators.

Building resilience at RAAF Tindal requires the following:

- **Close-knit community.** The geographic isolation of RAAF Tindal makes family and community resilience the cornerstone to enhancing survivability. The challenges at this remote base are considerable. Consequently, RAAF Tindal fosters an extremely close sense of community, where family members know and support each other. This is supported by regular family-friendly social events. Furthermore, Tindal works closely with local emergency services and government to coordinate disaster response and evacuation planning, while maintaining strong links with the Katherine community. Family readiness is also emphasised through seasonal information sessions, mental health resources and cyclone preparation briefings designed to strengthen the resilience of dependants.
- **Infrastructure hardening**. Recent upgrades at RAAF Tindal highlight a broad approach to resilience. Runway and apron works have expanded (Caisley, 2026) and reinforced the airfield to support larger aircraft, including existing rotations of US B-52 bombers (Booth, 2022). Fuel resilience has also been strengthened through new bulk facilities that include under-

ground storage, providing protection against blast damage and environmental wear (Department of Defence, 2024a, pp. 78–79; Kilcullen, 2023). Climate resilience is integrated into RAAF Tindal infrastructure. New maintenance and command facilities have been designed to withstand Category 4 cyclones, featuring reinforced roofing, advanced drainage and modern water management systems. While improvements have been made, C2 redundancy is incomplete. RAAF is making promising progress through mobile systems (Bellhouse, 2023), but fully hardened secondary nodes still require further development. Cyber protection is an expanding challenge, with resilience difficult to sustain across operational networks that now rely on multiple layers and contractor-managed components.

- **Efficient dispersal**. The principle of dispersal is exercised at Tindal. Exercises have dispersed aircraft to remote Northern Territory airfields such as Batchelor and Daly Waters, although sustaining operations from these sites remains logistically difficult. Within Tindal itself, alternative parking configurations have been adopted to prevent the concentration of aircraft in a single area. Aircraft dispersal trials have also been run to evaluate timelines and procedures for relocating high-value assets during threats.
- **Rapid recovery.** Tindal showcases the principle of rapid recovery. Combat Support Group elements at the base maintain rapid repair capacity through prepositioned engineering units able to conduct basic runway repairs, restore power and recover fuel points. Expanded trials are testing the use of drones to assess runway and infrastructure damage quickly after cyclones or strikes. Emergency communications testing has simulated network degradation, validating alternative methods such as satellite and mobile relays to ensure continuity of command and control.
- **Exercises.** Tindal conducts a range of exercises and initiatives to confirm the effectiveness of its resilience measures. Exercise Pitch Black demonstrates the base's ability to sustain rapid deployment and maintain realistic operational tempos during large-scale multinational air combat activities (Department of Defence, 2024d; Kilcullen, 2023). Annual cyclone response drills simulate landfall scenarios to test evacuation procedures, shelter management and infrastructure protection systems.
- **Adaptive to challenges.** While RAAF Tindal has made significant progress in enhancing its resilience, several challenges remain that require continued attention. Cyber redundancy across operational networks is still incomplete, with contractor-managed systems introducing potential vulnerabilities that complicate defence integration. Logistics bottlenecks persist due to limited road and rail access, particularly during the wet season, which can delay resupply and emergency responses. Coordination with national-level civilian agencies – such as aviation regulators and emergency management authorities – also requires strengthening. These gaps highlight that resilience is not a static achievement but a dynamic capability requiring sustained investment, interagency collaboration and adaptive planning.

5.1. Lessons learned from Tindal

Experience at Tindal highlights several key lessons for building resilience. Resilience is incremental, achieved through sustained, phased investment rather than one-off projects. Community acts as a force multiplier, as collaboration with civilians significantly strengthens the base's capacity to respond to environmental disasters. Training must also embrace chaos, with exercises designed to replicate degraded conditions instead of concentrating solely on ideal scenarios.

The case study demonstrates that substantial advancements in operational capabilities are attainable. Yet it also reveals that resilience is not a one-off achievement. Resilience demands ongoing maintenance while requiring adaptation and constant revalidation to stay effective as threats develop and environments transform. In a future operational environment marked by rapid developments and unpredictable disruptions, survival will determine which bases achieve victory.

Integration is critical. The resilience of operations depends not only on engineers and security forces but also on the participation of flying squadrons, families, contractors and civilians. RAAF Base Tindal has progressed toward functioning as a resilient airbase that can withstand attacks and environmental disasters. Resilience represents an ongoing process that demands persistent cultural dedication, operational awareness and resource allocation. Tindal's operational history provides guidance and cautionary advice for Australia's network of airbases operating in an expanding contested strategic landscape. While infrastructure hardening enhances resilience, it may also signal increased militarisation to regional observers. Strategic communications must manage perceptions alongside capability development.

6. Conclusion and recommendations

Australia's military airbase resilience is a fundamental operational necessity. The combination of geographic isolation, severe climate conditions and increasing strategic threats presents Defence planners and commanders with distinct operational challenges. RAAF Darwin, Tindal, Curtin and Learmonth operate at the forefront of strategic pressures while functioning as essential assets and possible targets.

Building resilience is a multifaceted endeavour. The case study of RAAF Tindal demonstrates the five essential elements of building resiliency. Infrastructure hardening is needed to protect critical assets from attack or environmental damage. Operational dispersal reduces vulnerability by spreading high-value resources across wider footprints. Rapid damage recovery ensures mission functionality can be restored quickly after disruption. Community and family resilience is needed to support personnel and respond to

changing circumstances. Lastly, exercises are needed to test, validate and strengthen all these elements.

This analysis leads to several recommendations for enhancing the resilience of Australian military airbases:

- **Institutional resilience.** Resilience must be institutionalised as a core Defence priority, with readiness evaluations and capability strategies elevating resilience to a fundamental metric rather than a secondary concern. Funding must be sustained and expanded through dedicated channels that support infrastructure, training and community integration projects across the Defence estate. Resilience requirements should also be embedded into major Defence policy documents, including White Papers, Capability Plans and strategic infrastructure frameworks.
- **Family and community resilience.** This essay uncovered that family and community resilience is overlooked in our current airbase doctrine. Given it is an essential element to airbase resilience our doctrine must be updated to reflect this reality.
- **Exercise resilience.** Annual resilience exercises should be mandated at each major airbase, involving flying squadrons, security teams, engineers, families and civilian agencies. Dispersal networks and agreements with civilian airports, isolated airstrips and alternative logistic hubs must be formalised to ensure practical support solutions. Mobile command-and-control packages should be developed and deployed, allowing essential airbases to maintain independent operations if main facilities are compromised.
- **Prioritise cyber domain.** Cyber resilience must be prioritised through continuous penetration testing and the establishment of cross-functional response teams at major airbases. Community and family resilience programs should also be expanded, providing training, resources and support networks for dependants while integrating families into planning and crisis exercises.
- **Develop a culture of resilience.** Degraded operations training should be normalised as part of everyday practice, ensuring personnel are prepared to function under less-than-ideal conditions. Leadership must also foster a resilience culture, prioritising adaptability, improvisation and problem solving as core operational skills.

Maintaining airbase resilience requires a long-term commitment rather than quick fixes. Achieving airbase resilience demands comprehensive approaches that include technical solutions, cultural changes and financial support, alongside intelligent logistics strategies, multi-agency cooperation, and investments in personnel and equipment. We must address the barriers identified in this paper and develop strategies to ensure our resilience efforts withstand real-world challenges. Ultimately, resilient airbases contribute directly to deterrence by complicating adversary targeting and ensuring operational continuity under contested conditions – preserving Australia's ability to project power, respond to crises and maintain strategic stability in the region.

Submitted: August 28, 2025 AEDT. Accepted: January 21, 2026 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Rees, A. L. (2026). Taking it to the next level: a necessary evolution in combined multinational exercises. *Contemporary Issues in Air and Space Power*, *4*(1), bp55098253. https://doi.org/10.58930/bp55098253

International Relations

Taking It to the Next Level: A Necessary Evolution in Combined Multinational Exercises

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Keywords: interoperability, combined military exercises, command post exercises, table-top exercises, live fire exercises, field training exercises

https://doi.org/10.58930/bp55098253

Vol. 4, Issue 1, 2026

This paper considers optimal ways to expand the conduct of combined military exercises with partner nations and achieve the objectives of developing relationships, interoperability, networking and collective resolve. It considers different reasons for conducting combined military exercises, the Australian Government's renewed support for combined military exercises, the global context of combined exercises increasing in frequency, and successful examples of combined military exercises in the region. It considers how different ways of conducting combined military exercises apply to the goals articulated in Australia's 2024 National Defence Strategy. Ultimately, it suggests Command Post Exercises should be progressed with partner nations, and that existing regional security architecture offers a useful means through which to establish them. This paper is written for defence strategists, international engagement planners, defence exercise planners and potential exercise participants.

1. Introduction

Australia's 2024 National Defence Strategy (NDS) directs the Australian Defence Force (ADF) to pursue combined military exercises with partners and allies (Department of Defence, 2024). The NDS calls on Australia to use defence exercises with Southeast Asian nations to 'strengthen our relationships, build robust and interlocking networks of partners, increase interoperability and demonstrate collective resolve' (Department of Defence, 2024). The NDS emphasises harnessing all arms of national power to deter adversary actions that would lead to conflict, coercion or direct action against Australia's interests. To be prepared and resilient enough to achieve this objective means reinforcing international partnerships. Beyond Australia's allies, the strategy calls for development of practical interoperability with Association of Southeast Asian Nations (ASEAN) and the Five Power Defence Arrangements (FPDA) partners and notes increased work with partners can 'build depth and trust, support collective deterrence and demonstrate our value as a partner' (Department of Defence, 2024).

By partner nations, this paper refers to nations with whom Australia collaborates on some security initiatives and shares some strategic interests. Unlike Australia's alliances with the United States (US) and New Zealand, there is not necessarily a formal security treaty with a partner. Partner nations are distinct from allies. Australia's partners would include ASEAN and Southwest Pacific nations with whom Australia does not have a security treaty, and some external to the Indo-Pacific region who hold similar strategic outlooks. Many nations with whom Australia conducts exercises like Pitch Black or Talisman Sabre would fall into the category of partner nations.

Military exercises are the predominant means of conducting 'collective training' for military forces. Collective training is one of the fundamental inputs to capability (FIC), and refers to training ranging from that done by small teams to multinational task force exercises that enable Defence capability to be optimised to deliver government outputs (Australian Defence Force, 2021). ADF doctrine says exercises involve the simultaneous and sequential performance of related tasks to produce group outputs and outcomes. An exercise is fundamentally a military manoeuvre or simulated warfare operation involving planning, preparation and execution (North Atlantic Treaty Organisation, 2013). Here, a variety of possible types of exercise will be explored. An exercise can be conducted at the component level (which includes maritime, land, air and special operations forces), jointly between components, or as a combined exercise between nations. ADF doctrine has stated that regular and realistic exercises are the most effective way of generating, demonstrating and evaluating the ADF's preparedness for operations (Australian Defence Force, 2018). Preparedness is the measurable capacity of Defence to generate sustainable military power to achieve government-directed objectives over time. It describes the combined outcome of readiness and sustainability (Australian Defence Force, 2024).

While making these fundamental contributions, exercises also have a secondary role that the NDS seeks to promote. As Bernhardt (2020) explains, exercises can be a vehicle to advance national security policy and strategy. Nations can use the mechanism of exercises to show solidarity and present a deterrent to potential aggressors. The NDS directs Australia to do as such. While Australia currently invests predominantly in exercises that focus on tac-

tical interoperability with partner nations, these investments do not meet the expectations of the NDS. Australia would need to pivot its exercise program to do so.

There can be many reasons why militaries from two or more countries conduct combined exercises. Drivers for combined military exercises arguably fit into one of two broad groupings, readiness assurance and international strategy. Readiness assurance encompasses the drivers of capability assurances and interoperability. On the other hand, international strategy encompasses the drivers of relationship building, strategic alignment, deterrence and the collective ability to resolve strategic problems. Laksmana et al (2024) assert exercises can be seen as a 'defensive' signal of reassurance between allies and partners, as 'offensive' demonstrating coercive pressure against a third party in preparation for aggression, or both. Likewise, Bernhardt (2020) also suggests drivers for participating in combined military exercises include the need for partnerships and that this need is felt both by major and smaller power nations. Bernhardt goes on to suggest that the gains of combined military exercises include a stabilising effect and an economic benefit in that they deliver 'a decrease in the likelihood of engaging in a militarized interstate dispute and an increase in the value of arms traded between states'. Broadly, nations may conduct combined military exercises for a variety of possible strategic reasons encompassing intent to coerce, signal, stabilise or increase trade. Australia's NDS direction acknowledges the importance of interoperability but emphasises the international strategy drivers when it calls for exercises to demonstrate collective resolve.

The drivers outlined above can motivate Australia's partners too. Yaacob and Sato (2024) list two key reasons why member states of ASEAN have participated in multilateral or bilateral combined exercises. The first is to enhance interoperability against a common security concern, often underpinned by a security treaty. For example, the US-Philippines Balikatan series of exercises is bound by the Mutual Defense Treaty between Washington and Manila. The second reason is to build trust between states, especially if they have competing interests, the Aman Youyi combined execise between China and some ASEAN states is such an example (Yaacob & Sato, 2024). The engagement with Australia's regional partners opens and sustains avenues for Australia to conduct combined military exercises. However, on the negative side, this means that competition for opportunities exists, and the relative strategic significance with a potential partner must be measured against the significance of the other exercises that the partner participates in. Hence, to maximise the meaning and importance of the combined exercises with partners, Australia must therefore carefully calibrate the design and implementation of those exercises.

Here, I argue that strategic and operational level problem solving is an area Australia should develop in its exercise regime with partner nations. I will consider optimal ways of meeting the NDS guidance to conduct military exercises with partner nations. Notably, the NDS does not elaborate on what kinds of military exercises should be conducted, which appropriately leaves the ADF to determine which types of exercises will best achieve the objectives stated in the NDS. To achieve the NDS objectives and demonstrate 'collective resolve', combined exercises must practise the ability to act together with partners to confront realistic mutual challenges. Exercise design must target NDS objectives. As such, I argue that an exercise participated in by a command post or headquarters offers the best way to achieve NDS objectives. However, at present, Australia primarily conducts tactical exercises with partner nations. While field exercises establish tactical interoperability and build trust amongst participants, exercises participated in by a command post could provide strategic and operational complexity for senior decision makers and therefore create pathways for collective problem solving. As the ADF leans into the NDS guidance, choosing the right type of exercise will ensure a genuine combined capacity to resolve strategic problems shared with partners. When partners select the optimal exercise type, they can calibrate the design to achieve the strategic effects the NDS demands.

2. Types of exercises

Several varieties of exercise exist for planners to draw from, with a number of options to achieve different objectives. The NDS strategic objectives should drive the type of exercise Australia chooses to conduct with partners. US exercise doctrine says 'as a general rule, collective joint training does not require fielded forces supporting the training event in order to meet the Training Objectives for the joint training audience' (US Joint Chiefs of Staff, 2019). The same point can apply to Australia's combined military exercises with partner nations. Possible types of combined military exercises include:

- Table-Top Exercises (TTX), where participants might play a structured strategy game to determined different outcomes to a specific scenario.
- Command Post Exercises (CPX), where a simulated or constructive strategic problem stimulates decision-making at a command post or headquarters level under realistic circumstances but no actual tactical actions take place.
- Live Fire Exercises (LFX), where weapons are released in firing ranges.
- Field Training Exercises (FTX), where tactical forces conduct real manoeuvres.

Any of these exercise types can practise a scenario at any point on the spectrum of conflict. The framework of any exercise could range from component level activity; for example, exercising an airborne maritime patrol role to a joint activity practising integration of several components. The degree of partner involvement could range from bilateral, mini-lateral to multilateral. Given the different possible frameworks for exercise design, it stands to reason that some exercise frameworks will be more suited to achieving NDS goals than others. Tactical field training and LFX are essential for confirming the ability to achieve tactical actions, while TTX could stimulate creative thinking and problem identification. To an observer, FTX are

highly visible and impactful. However, they largely occur at the tactical level and therefore do not necessarily explore how to integrate decision-making when confronting a mutual strategic challenge. Arguably, FTX promote tactical excellence and the development of military skills. However, demonstrating collective resolve demands more, such as how to act collectively with partners for a specific outcome. However, the operational and strategic levels of the command post must be practised to respond to realistic challenges as warfighting hierarchies if they are going to succeed with collective action in a domain of combined operations. Shared and sovereign interests exist in a state of tension and a command post exercise at the operational and strategic level is a vehicle through which to discover how to resolve this tension.

There are synergies associated with different exercise types in each of the NDS objectives of relationships, networks, interoperability and demonstrating collective resolve.

Relationships. These include the interpersonal but also the systemic, for example, processes for communication and decision-making, which exist at different levels of command. It is the systemic relationships at the operational and strategic levels that enable strategic consultation, decision-making and combined action. Relationships at the tactical level support seamless execution of tactical action. All relationships are important but the ability to consult about a strategic issue of mutual significance and then decide on a mutually satisfactory approach is an essential precondition of combined tactical action. Successful strategic and operational relationships call for combined intelligence analysis, integrated planning and integrated decision-making. TTX and CPX pave the way for these outcomes. They are not outcomes achieved through efforts to increase excellence in tactical integration. At the operational and strategic level, TTX and CPX facilitate the ability to conduct combined appreciation and planning. They can also build appreciation of constraints of the partners' military, political and legal systems. Effective relationships build trust. Trust enables partners to build strategic alignment and tactical interoperability where feasible. Building strategic and operational relationships through CPX would enable partners to resolve strategic challenges together.

Networks. The concept of a network can imply various levels of formality, but a good network in the military sense infers a hierarchical structure with interconnected communications systems. The beauty of a CPX is that it tests decision-making and communication between operational hierarchies. Realistic, effective networks from national through strategic and operational to tactical levels of command are the backbone of the CPX. The conduct of a CPX is an excellent way to develop and test networks between participating entities.

Interoperability. The North Atlantic Treaty Organization (NATO), a strategic grouping that depends highly on interoperability, defines the concept as the ability of forces, units and systems to operate together effectively (North Atlantic Treaty Organization, 2023). It involves sharing common doctrine, procedures, infrastructure and bases. Interoperability can increase capabilities, shape the strategic environment and reduce resource demands. This is honed at the tactical level, but the operational and strategic levels of command need to be cohesive to achieve successful combined interoperability. Tensions with interoperability can include differing perspectives on matters of international law, the limits of national policy and differing planning processes to name a few. Partners who mutually design and execute a CPX at the strategic and operational level will build a shared understanding of what may get in the way of interoperability. Understanding these factors will improve the likelihood of successful combined operations occurring.

Progress in the domain of interoperability can be gained by developing and rehearsing common procedures and systems, for example, the Code for Unplanned Encounters at Sea (CUES)[1], common Standard Operating Procedures (SOPs), common command, control, communications, cyber and intelligence (C4I) systems, and logistic requisition systems. Where these do not exist, a CPX provides the opportunity to identify whether they should.

Collective resolve. Of the outcomes the NDS encourages, this is the most difficult to develop through the conduct of any type of military exercise. Participants may communicate strategic policy positions externally but how these are intended to be understood by the international community may not always be clear. An FTX sends a visible public message and keeps the door ajar for collective resolve to be negotiated. Arguably, the facts of the contribution to an exercise are a more important message about what the exercise represents than a finely crafted statement. But a CPX, collectively designed against a common problem, has a chance of uncovering the collective resolve which actually exists under specified strategically challenging circumstances, and where the obstacles to alignment will present. A collectively designed exercise can infer collective resolve. An FTX gives an outward display of collective resolve while a CPX can explore the limits of what collective resolve really exists.

3. Mutual design of exercises

Given the range of possible alternatives for combined military exercises, participants should give careful consideration to exercise design. Doing this together would imply mutual respect and recognise that all partners are seeking different objectives from the same activity. What is certain is that other nations would not go into a combined exercise to satisfy Australian NDS objectives. Combined exercise de-

1 The Code for Unplanned Encounters at Sea (CUES) is a non-binding multilateral agreement that standardises safety protocols, basic communications and basic manoeuvring at sea for ships and aircraft. In 2014, more than 20 countries adopted the code at the Western Pacific Naval Symposium in Qing Dao, China (Western Pacific Naval Symposium, 2014).

sign capturing all participant goals would be essential to achieving authentic integration. Mutual design of exercises could build the depth and trust the NDS seeks and contribute to interoperability and collective resolve. It would result in an exercise framed to explore the objectives of multiple participants.

Mutual design starts with agreeing on a problem set which partners confront. The type of problem over which an exercise could coalesce could include any regional security scenario emergent in the 'global commons' which impinges on the sovereignty of one or more partner nations. Such scenarios are well suited to combined exercises. They can reveal the advantages of collaborative effort over unilateral effort, be threat agnostic, be highly visible and affect the prosperity of all. Sub-surface, surface, air, space and cyber threats to transportation, fishing, resource harvesting, tourism and other industries in the maritime domain would provide a canvas for a mutually beneficial scenario to be developed.

The NDS points to increasing strategic great power competition and a military build-up in Australia's region as key themes of concern. Australia's Foreign Minister Senator the Hon Penny Wong (2024a, 2024b) specifically mentions Australia's imperatives of working with ASEAN to increase mutual resilience and ensure waterways that serve us all remain open and accessible. As such, possible scenarios of mutual interest to partner nations are wide ranging. After agreeing to a scenario the hard work of building a combined exercise would then start.

NATO has a relevant model for designing combined military exercises. The Joint Warfare Centre facilitates incident development and scripting workshops which collaboratively build a script that is fit for purpose (Joint Warfare Centre, 2025). More than 200 participants are brought together to design an exercise, comprising Training Audiences representatives from NATO Centres of Excellence, non-governmental and international organisations, subject matter experts, exercise planners and scenario developers.

A well-run CPX demands hundreds of inputs and many response cells to deliver dynamic inputs to the participants in order to create the realism needed to test headquarters and staff. To be able to deliver them in a coherent and synchronised way, Australia and its partners would need a coherent design process. There are also substantial practical aspects to be determined, like how to link communications systems, locations, schedules, etc. Starting small might be a good idea. The gradual evolution of a CPX might begin with a Table-Top exercise between HQ representatives, building to a small-scale bilateral CPX and onto a multilateral CPX. There would be a cost in time, effort and resources associated with designing and delivering any combined CPX.

Using existing regional security architecture as a backbone for mutual design and exercise scheduling offers some practical benefits and could enable the establishment of the coherent processes needed to sustain an exercise series.

4. Opportunities provided from regional security architecture

In 2024, the Australian Minister for Defence Industry, the Hon Pat Conroy, stated in his Defence Partnership for the Future Statement that 'ASEAN and its sectoral bodies play a critical role in supporting an inclusive and rules-based approach to maintaining regional security and stability' (Conroy, 2024). He called for Australia's international engagement activities, including with ASEAN, to focus on 'achieving outcomes that contribute to regional security and stability and strengthen deterrence against the threat of military coercion or a major conflict'. The Minister announced that the Australian Government is enthusiastic to leverage the ASEAN security apparatus to expand military exercise partnerships. The Government pledged to commit $64 million over the next four years to enhance Australia's Southeast Asia Maritime Partnerships (Wong, 2024a). The stated Government enthusiasm for multilateral exercises reinforces the NDS direction.

Developing collective security through an existing multilateral organisation can more substantively contribute to Australia's NDS aims like 'building interlocking networks of partners' because doing so uses mechanisms partners are already committed to. The lessons drawn from exercises conducted within existing arrangements would have greater potential to endure. Arguably, exercises outside of existing security frameworks might infer less mutual resolve to collaborate when real strategic pressure is applied. Integrating within existing strategic constructs would be a superior way of achieving NDS aims than, for example, an invitation to partners to participate in an Australian-designed exercise in Australia's back yard.

Within ASEAN, there is already some internal momentum towards combined military exercises. The ASEAN Defence Ministers' Meeting (ADMM) forum in 2024 declared the intent to deepen defence and security cooperation and engagement between ASEAN and Plus Countries (ADMM+) (The ASEAN Secretariat, 2024). This objective aligns with Australia's NDS objectives. Australia has access to the ASEAN security apparatus as an ASEAN dialogue partner and member of the ADMM+ grouping. The seven Expert Working Groups (EWGs) of the ADMM+ are existing mechanisms for establishing combined exercises. These working groups have designed and conducted TTX and FTX. The Maritime Security EWG may be the most pertinent of the working groups to the NDS objectives. ASEAN has made progress on combined military exercises under its banner. The Maritime Security EWG has facilitated security seminars, conferences, FTX and TTX since the ADMM+ inception in 2011 (The ASEAN Secretariat, 2025). Given the momentum of the Maritime Security EWG, maritime challenges present as a scenario around which Australia could pursue a multilateral CPX with ASEAN partners.

The ASEAN exercises that Australia has thus far participated in, could be a stepping stone to higher end collaboration, but presently fall short of the scope of current Australia-led partner nation exercises. They have focussed on niche activities like medical responses and have not

yet broached high-end combined joint-force warfighting. ASEAN is a valid vehicle for this ambition because, as a credible architecture for security cooperation, it offers a backbone on which to build the robust and interlocking networks to which the NDS aspires. Australia's seat at the table of the ADMM+ Maritime Security EWG provides an opportunity to engage as equals with ASEAN states who, like Australia, wish to use the existing security architecture to discover ways of confronting and solving contemporary maritime security problems collectively.

While ADMM+ exercises are in a nascent state, exercises between Southeast Asian nations outside of the ASEAN apparatus have larger scope and are growing in frequency. Laksmana et al (2024) suggest combined exercises are one of the core pillars of the Asia-Pacific security order and are part of a wider framework of defence diplomacy. Furthermore, ASEAN proper has embarked on combined exercises, including a multilateral maritime field training exercise, the ASEAN Solidarity Exercise, in 2023. This exercise demonstrated collective ASEAN intent to confront mutual security challenges. All 10 ASEAN members participated, with Brunei, Indonesia, Malaysia and Singapore deploying warships (Yaacob, 2023). This momentum should encourage Australia to pursue its NDS goals through the ASEAN apparatus.

The narrower strategic organisation of the Five Power Defence Arrangements (FPDA) has also advanced combined exercising in our region. The FPDA has a goal of defending Malaysia and Singapore during military crises. A joint communique from 1971 commits the participants to consult and decide on measures in the event of an attack on or threat to Malaysia or Singapore. The FPDA has infrastructure in terms of combined doctrine, exercise and planning documents which can enable collaboration on exercises (Sleeman, 2025, p. 59).

The FPDA has a mature and robust exercise regime and a cycle of FTX and CPX has been running for over 20 years. This legacy will have streamlined the ability of partners to operate together in defence of Singapore and Malaysia. FTX Bersama Shield and Bersama Lima practise combined and joint tactical level air, land and maritime integration (Five Power Defence Arrangements, n.d.). They include integration at the operational headquarters level. The Suman Warrior and Suman Protector CPX form a series that tests the partners' ability to collaborate to resolve a mutual strategic challenge. Suman Warrior is an annual land-based CPX. Suman Protector occurs every five years and is the culminating activity in the FPDA exercise program. It is an operational level CPX designed to exercise an FPDA Combined and Joint Task Force headquarters to plan for and execute a military operation for the defence of Malaysia and Singapore against a conventional threat (Five Power Defence Arrangements, n.d.). The FPDA exercise series is a mature collaborative series that can be a model for Australia to build its contemporary exercise aspirations on with a wider series of partner nations.

The Cobra Gold exercise series offers another robust regional example. Having run for 43 iterations and now with 30 partners, it is the longest-running international exercise. Senior US leader Lt. Gen. Xavier Brunson, commanding general of I Corps notes 'Cobra Gold provides a platform to refine our strategies, test our readiness, and cultivate the friendships that are the foundation of effective multinational cooperation' (Vincent, 2024). As an established exercise, it offers a model worth considering. In 2024, it comprised a CPX and several FTX events. Building interoperability and collective resolve in a creative and innovative way it also comprised a component of humanitarian and civic assistance projects showing genuine collaboration between nations in the real world and not just the hypothetical. Post-exercise reporting in 2024 indicated the multinational CPX component simulated a large-scale combat operation which challenged international leaders and staff to coordinate effectively in a complex, multilingual and procedurally diverse environment (Bocanegra, 2024). A Joint Task Force (JTF) is composed of assigned or attached elements of two or more Services and/or groups established for carrying out a specific task or mission. Incorporating a JTF in a CPX is a prime example of nations meeting the objectives to which the NDS aspires – demonstrating interoperable networks and collective resolve in a practical way.

Benefits of including a JTF in combined military exercises include strategic–to-operational interoperability, civil-military interplay, a focus on operational authorities, senior leadership decision-making and working with international boundaries. In short, a JTF construct develops partners' ability to work together through operational complexity and uncertainty. Australia must aspire to replicate the level of integration exemplified in the region in order to satisfy the NDS goals for combined exercises with partners.

5. Global trend towards multinational exercises

As the existence of the Cobra Gold series indicates, the extent of military integration already occurring between Australia's partners places constraints on how Australia might achieve NDS goals. Since the end of the Cold War, the number of combined military exercises held each year has been steadily increasing globally as has the number of countries participating in exercises together. While all the elements of increasing globalisation have probably contributed to this, so too has the increasing extent to which the security of any one country is tied to that of many others. The more than 300 different combined military exercises held in 2016 was a six-fold increase from the number held in 1990 (Bernhardt, 2020). Bernhardt also observes that the number of pairings of countries to have conducted at least one military exercise together has increased from around 1% during the last decade of the Cold War to close to 20% of all possible pairings in 2016. The US participated in at least one military exercise with around 80% of countries in 2016. China, Russia and India conducted at least one joint military exercise with around 30% of countries in the period. From 2021 to 2023, Southeast Asian nations participated in 525 joint military exercises at the bilateral or multilateral level. The US, Australia and Japan participated in more than 60% of these (Yaacob & Sato, 2024). Australia is clearly not the only nation with a national strategy demanding participation in combined military ex-

ercises. With so many combined military exercises occurring, the significance of any one exercise is vulnerable in comparison to others. This places additional pressure on Australia's goals of conducting combined military exercises with partners.

Another key trend beyond the raw increase in combined military exercises is that the growing number of combined exercises far outstrips any increase in formal military alliances (Bernhardt, 2020). This suggests that participant nations view combined military exercises as an opportunity to make strategic gains without necessarily carrying the strategic risk that an alliance commitment might. Combined exercises (in the absence of an alliance treaty) can imply a level of partnership that is somehow short of an actual commitment. They might infer a peacetime partnership but not one that assures a coalition during times of strategic risk. They may not infer 'collective resolve'. Reporting on combined military exercises in 2005, the Australian Parliament noted:

> Ad hoc coalitions are fragile and demand constant attention if they are to survive. Coalitions based on extant alliances have the durability to nurture a range of capabilities that can be developed over time, for example 'through sustained cooperation on military exercises and training, the networking of information flows and of forces, and shared experience in joint operations' (Parliament of Australia, 2006, para. 4.3).

However, 20 years later, Australia finds itself in a strategic environment where ad hoc military exercise groupings outnumber alliances. As their incidence increases, the strategic significance of any one combined military exercise arguably decreases. The current 'global economy' of combined military exercising makes it particularly important that whatever combined exercises a nation conducts are calibrated effectively to achieve the right strategic effect.

5.1. Current Australian combined military exercises

Australia hosts several multilateral tactical combined military exercises at the component and joint levels. Pitch Black, an air combat exercise, is such an example. Other such exercises occur in the land and maritime domains. Australia's premier joint force combined military exercise, Exercise Talisman Sabre, is a distinctly multilateral military exercise that has been rapidly expanding in size. Talisman Sabre has increased from a bilateral exercise with the US to a multilateral exercise with an increasing number of partner nations over its past three biennial iterations. The Talisman Sabre series enhances Australia's capacity to cope with an inflow of partners and achieve tactical integration but has some inherent shortfalls. First, an all-encompassing exercise like Talisman Sabre risks trying to dilute Australia's cooperation across too many partners at the same time. The further participation in an exercise extends, the weaker is the ability to infer collective resolve. Second, a tactical exercise cannot infer 'collective resolve' at the strategic level. It does not reflect an ability to collaborate to solve a realistic strategic challenge. To develop the robust interoperable network of partners that is demanded by the NDS, exercises should offer partners greater operational and strategic integration opportunities.

5.2. Future combined exercises

To meet NDS objectives, Australia should exercise with its partners in ways it used to do with its allies. The 2005 parliamentary report evaluating Australia's combined military exercises with the US explained the benefits of training at the operational level of command when it stated:

> operational level planning may be conducted using a Command Post Exercise or Map Exercise. This level of exercise play is increasingly enabled by sophisticated computer based simulations. Commonality of 'architecture' for such simulations will allow future interactions to occur without forces leaving their home bases, even if these are on different continents. Where 'real' exercise play is involved it is often the large scale deployment, operational manoeuvre and logistic support that create the most significant training advantage at this level of command (Parliament of Australia, 2006, para. 4.8).

At present, Australia focusses on the fielded force aspects of exercises with partner nations and ignores the others. Bolstering combined CPX opportunities as part of a comprehensive suite of exercises with partner nations will get Australia closer to achieving NDS objectives.

A mutually designed CPX between like-minded nations who are looking to explore the possibilities of interoperability and collective action presents a valuable opportunity to build relationships, networks and interoperability and develop collective resolve. CPX can more precisely target Australian and partner nation decision makers at the operational and strategic levels of command to explore aspects of integration that an FTX does not. CPX are also advantageous because they may require a smaller resource impost compared to an FTX. CPX have a smaller personnel and equipment commitment and use of fewer training areas with lower financial burden.

6. Conclusion

Australia's NDS calls on the ADF to increase its exercises with partner nations in order to enhance relationships, interoperability, networks and collective resolve. The Government's recent promises of financial and policy support to combined military integration suggests a window of opportunity exists for enhancing exercise programs with partner nations. To achieve the best outcomes in these endeavours the ADF must evaluate which types of exercises are best suited to developing integration with partners. There are many exercise types to choose from and each offers different advantages to participants.

The CPX can pose realistic challenges for the command elements of different nations to confront together. In doing so, participants will come to understand what obstacles hinder preferred outcomes in a given scenario. They will grow to understand the political, strategic and operational decision-making processes of the other participants, and

the limits national policy places on the scope of their operations. They will grapple with the challenge of communicating operational information and orders between national command elements. Over several iterations, participants in a series of CPX stand to learn how to devise collaborative responses to shared strategic problems and how to implement these solutions together.

As combined tactical exercises increase in frequency, it is less clear that 'collective resolve' can be implied from the fact of nations conducting tactical training together. Building on Australia's firm foundation of tactical level FTX, operational level CPX would offer an opportunity to pursue the more robust integration with partner nations that the NDS desires. There are several mature regional and global examples that Australia and its partners could use as models for how they might embark on CPX together. Building combined exercises into existing security architecture would increase the likelihood of achieving enduring outcomes. A decision to confront a mutually agreed strategic problem in an operational level CPX builds a pathway towards strategic cooperation and success in combined operations. The ADF should therefore look to establish simulated strategic and operational problem solving through the mechanism of a CPX with its partner nations to satisfy NDS goals.

Submitted: May 27, 2025 AEDT. Accepted: August 14, 2025 AEDT. Published: February 17, 2026 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

McDermott, T. (2026). The Future of Australian Air Power: A Soldier's View. *Contemporary Issues in Air and Space Power*, *4*(1), BP55950229. https://doi.org/10.58930/BP55950229

Air Power

The Future of Australian Air Power: A Soldier's View

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Keywords: Airmindedness, Air Power, Littoral warfare, Air Littoral, All-domain orchestration

https://doi.org/10.58930/BP55950229

Vol. 4, Issue 1, 2026

This paper provides a soldier's view of the future of Australian air power. It argues that the professional experiences of the last 25 years are increasingly irrelevant, given the uncontested nature of the airspace during that time. A return to great power competition, and an accelerating change in the character of warfare, means we must re-imagine 'airmindedness' for the middle decades of the 21st century. The paper proposes one way of addressing this is a shift from air-land integration to all-domain orchestration. The paper then examines how such a re-imagining might take place, through the medium of the ongoing transformation of the Australian Army. It proposes new concepts, unified by the 'big ideas' of manoeuvre and targeting. It considers adjustments to command and control (C2), with a particular focus on airspace below 10,000 feet and the ideas of 'supporting/supported' command. It examines next generation capabilities. Finally, it considers a unifying culture between the Australian Army and the Royal Australian Air Force. The paper concludes by proposing that amphibious and littoral warfare should be the litmus test for integration: the most complex of military operations, and the place where we must orchestrate if we are to thrive.

Introduction

I have been supported by air power throughout my 25 years as a soldier. I recall standing as part of an armoured battlegroup in Kuwait on the eve of the invasion of Iraq in 2003, watching with wide eyes as Tomahawk cruise missiles flew over us to start the war. Just 7 years later I was in Afghanistan, at the peak of the Predator-era, leveraging what was at the time the most sophisticated aerial surveillance system constructed in human history to find, fix and strike insurgent networks. I returned to Afghanistan towards the end of the campaign to command an air-mobile Brigade Reconnaissance Force. Here, I not only leveraged lift and attack aviation to outmanoeuvre the insurgent but I did so under comprehensive ISR and close air support. At a highpoint of our tour, my Joint Terminal Attack Controller (JTAC) and I had no less than 17 assets allocated in our 'stack'. I have always had the air power guardian angel above me.

My appreciation for this has grown over time. As a young officer my vision was firmly focused down at my compass and my feet, or at most a couple of thousand metres along the barrel of a tank main armament: blinkered by inexperience. But as time passed, I become increasingly aware of the value of the air domain that existed all around me. In air power parlance, I developed 'airmindedness' (Royal Australian Air Force, 2022). I would not have survived without it.

As I stand here in the early years of a new era of great power competition, however, I have come to a realisation. Almost all my previous experience is irrelevant, for one principal reason: at no stage in my career has the airspace been contested. The alliances and coalitions I have fought for have manoeuvred in the air domain with impunity, uncontested and supreme.

It is the opposite today. The airspace of the modern battlefield is – and will now always be – highly congested and viciously contested. The full gamut of traditional threats is being applied by peer (and indeed beyond-peer) adversaries, with both a mass and precision not seen since World War II.

Even more confronting are the new threats emerging as the character of war changes at the fastest rate certainly since the industrial revolution, if not in human history. The spectre of massed and truly-autonomous remote systems, kinetic space weapons, cyber-attacks and electronic warfare make the air domain an increasingly lethal space.

As an Australian soldier, it is therefore clear to me that I must re-imagine my view of the utility of air power from my perspective on the land. I must take into account a number of thorny factors: Australia's strategic challenges, our revised National Defence Strategy (NDS) (Department of Defence, 2024), the emergence of new domains of war, the remarkable impact of technology, and the evolving cultures and characters of the Services, to name but a few.

This paper is my attempt at this re-imagining, an effort to bring my airmindedness into the middle decades of the 21st century. It proposes one way of grappling with the challenges of the future: through a shift in thinking from air-land integration, to all-domain 'orchestration'.

The transformation of the Australian Army: looking up at the sky, not just out to the sea?

The Australian Army is in the midst of its most significant transformation in generations, as it strives to meet the direction of the NDS to 'optimise for littoral manoeuvre with a long-range land and maritime strike capability' (Department of Defence, 2024). Both elements of this direction have significant implications for the Army's relationship with the air domain, and for the frame of our airmindedness.

This starts with the establishment of the littoral as the Australian soldier's primary operating environment. The littoral is described in its simplest terms as 'the part of the country that is near the coast', drawn from the Latin *littoralis* meaning 'of or pertaining to the seaside' (Australian Army, 2024). It immediately conjures a mental image of a land/sea interface: a battlefield beset by brown water, shallows, mangroves, coastal urban sprawl, beaches and rivers. The Army's capstone publication has on its cover a determined infantry soldier valiantly dragging himself out of the surf (Australian Army, 2024). He is, perhaps unsurprisingly, looking down at the beach, probably considering his life choices.

This mental image is, however, insufficient. The Army's conceptualisation of the littoral must be inclusive of all domains: of the airspace above, the space terrain and the entirety of the electromagnetic spectrum (EMS). Such a realisation should make our soldier instinctively, and probably nervously, glance up at the sky above; at the hundreds and indeed thousands of kilometres of manoeuvre space that have clear access to the beach.

The breadth of this battlespace is only increasing, particularly when one takes into account the second part of the NDS direction to the Army – the requirement for 'long-range land and maritime strike'. The more military explanation of the littoral is 'the area of the sea that influences the land, and the area of the land that influences the sea' (Australian Army, 2024). This has traditionally been measured in the tens of kilometres. The introduction into the Army's arsenal of the High Mobility Artillery Rocket System (HIMARS) and the Precision Strike Missile (PrSM) will soon extend this to up to 1,000 kilometres, with an apogee of missile flight in the tens of thousands of feet (Conroy, 2025). The concept of the littoral, while still firmly tied to the coast, can now have a horizon far beyond its traditional meaning.

This airspace has long been congested but there is now a new factor: persistence. During the invasion of Iraq in 2003, the only flying assets owned by my battlegroup were the bullets, tank rounds and artillery shells at our disposal. Their flight was dumb, predictable and designed to be terminal. The exponential growth of remote and autonomous systems – from First Person View (FPV) drones to loitering munitions – has changed all that. It is now entirely realistic for a land force to have a form of intimate 'close air support' in the air, all the time, at every echelon from squad to brigade, and all controlled at that echelon (or even operating without human direction). The airspace below 10,000 feet has now become so cluttered that some air power experts have started referring to it (helpfully or otherwise) as the 'air littoral', distinct from the 'blue air' above (Bremer & Grieco, 2021).

The demand for the Army to re-conceptualise the littoral is telling of the scale of change in the environment. It is no longer good enough for the Australian soldier to be fixated on the horizontal plane. Every soldier stood on coastal terrain must be able to perceive it in all three dimensions, thousands of feet high, and potentially with a horizon of hundreds of kilometres. The need, however, is for aviators who can do the same in return: able to understand the complexity of the littoral in all domains, and the conduct of operations within it.

Indeed, one can argue that a new era of air-land integration is needed, one characterised by an inter-Service and all-domain empathy that goes far beyond anything we have achieved so far.

Of echelons and autonomy in the littoral: the shift to all-domain orchestration

Air-land integration has a long pedigree, particularly in World War II and the Indo-Pacific. General Dwight D. Eisenhower was clear in the aftermath of World War II that Operation Overlord would never have succeeded without the closest coordination between the air and land forces in Normandy (Eisenhower, 1948, pp. 539–540). In the South West Pacific Area (SWPA), from Buna-Gona to Aitape-Wewak, the integration of the missions of General George Kenney's Fifth Air Force, including the No 9 Operational Group of the Royal Australian Air Force (RAAF), with United States (US) and Australian amphibious and littoral operations lay at the heart of McArthur's island-hopping strategy (Wright, 2024). By the early 1980s the US Army had captured the need for deliberate integration of air and land operations in the concept of 'AirLand Battle': a significant intellectual step that went much of the way to set the stage for the tactical and operational successes of the 1991 Gulf War and beyond (Skinner, 1988).

Today, however, the ideas of 'integration' and 'coordination' seem insufficient. They are too slow and leave too many seams to be exploited. I believe the Australian Defence Force (ADF) needs to go beyond these historical concepts and explore an approach of all-domain orchestration in order to succeed on the modern battlefield. Orchestration should bring into the mind of the reader the image of a musical conductor and an orchestra: the seamless weaving together of various specialist instruments of military power to make the whole far more than the sum of its parts. This is a complex blend of science and art. But how to achieve it?

The Chief of Army Lieutenant General Simon Stuart recently described the Australian Army's transformation through the medium of 'four Cs': concepts, command and control, capability, and culture (Laird, 2025). This is a useful tool to consider how we might better achieve orchestration of the air and land (and indeed all) domains.

First to 'concepts'. A mere glance at the NDS and the evolving character of warfare in the wars in Ukraine and the Middle East makes it clear that we will need to develop

a range of concepts that, if not truly unique to Australian military culture, are certainly new, unusual and challenging.

Remarkable advances in missile and surveillance technology, for example, imply a very real and tangible threat of short-notice, very-long-range strike against Australian assets, both in the near region and domestically. This threat is new. Combine this with the accelerating proliferation of remote and automated/autonomous systems of all sizes, and the need for a sophisticated Australian Integrated Air and Missile Defence (IAMD) concept is obvious and pressing. Similarly, the wholesale Army tilt towards a focus on littoral and amphibious warfare, one that taps into the character of the Pacific War but with the added potential for hypersonics and layered electronic warfare (EW) attack, requires new concepts of joint littoral warfighting fit for the battlefields of the 21st century. Even newer is the potential for an offensive land-based missile/strike contribution to the control of the air or the sea. The list goes on.

I do not intend to develop these concepts here (other far-more qualified professionals are already doing this work). I will instead consider the method by which they might be orchestrated. Like a musical composition, each concept will need to consider how to weave together all-domain actions in time and space to achieve the desired outcome. An orchestra rightly does not approach this by committee; it relies on a composer or conductor. In the ADF, this has manifest in the idea of 'Joint Force Integrators': a Service that takes the conductor role for a given concept, when it predominately resides in their traditional domain. For IAMD, this is rightly the RAAF. For joint littoral warfare, where the outcome is most often on the land, it is the Army. In theory, the conductor ensures that concepts are developed through careful consultation, but without the dangers of consensus.[1]

This is a strong approach, but I argue that we also need to agree a series of core, cornerstone ideas that tie it all together. The first requirement, I believe, is to double down on our collective commitment to the philosophy of manoeuvre warfare. The most used definition of manoeuvre is that of the US Marine Corps, who describe it as 'a warfighting philosophy that seeks to shatter the enemy's cohesion through a variety of rapid, focused, and unexpected actions which create a turbulent and rapidly deteriorating situation with which the enemy cannot cope' (US Marine Corps, 1997). This remains the most suitable unifying approach for a modest-sized military such as ours, one with a necessary focus on asymmetry within a strategy of denial.

Nothing that has emerged so far in the changing character of war fundamentally challenges this. The codification of new domains has not definitively demanded alternatives to manoeuvre theory; it is still just as useful and relevant to speak of 'manoeuvring' in space and cyberspace to achieve positional advantage over an enemy. Despite all the talk of a 'drone revolution' in Russia's illegal and immoral invasion of Ukraine,[2] both sides continue to strive to achieve manoeuvre (although this is now exceptionally hard in a continental, land-based attritional war in Eastern Europe).[3] The inherently psychological idea of manoeuvre should, I believe, continue to unify the ADF's new multi-domain warfighting concepts.

The second unifier should be the practice of 'targeting'. For soldiers this has long, and I argue unhelpfully, been the province of specialists or experts: an outcome of the post-9/11 Predator-era innovations of the global war on terror (GWOT). This separation is now a false doctrine, which requires renunciation. Targeting must become a common practice for soldiers, aviators and sailors of all ranks and specialisations, one that brings us together through a single lexicon, unified doctrines and a connecting mindset. Achieving this will require genuinely new approaches. On the land, the training and exercising of ground force commanders has traditionally focused on combined arms tactical manoeuvre, with targeting often left as a specialist adjunct. This must evolve to a far more reasoned balance for commanders of the skills of tactical manoeuvre and the skills of targeting. This is the case from Battlegroup to Divisional level: the echelons where orchestration is turned into violent action most effectively.

Importantly, a common practice of targeting does not imply a common approach to weaponeering. This remains, rightly, a single-Service expertise. As a ground force commander, I do not need to understand the intricate workings of F-35 munition selection, any more than a P-8 pilot needs to understand the data-systems that underpin a HIMARs strike. But we do all need to be talking the same language about the targets we are selecting, why we are selecting them, and the psychological effect we are seeking to have on the enemy by striking them at the time and place of our choosing.

An understanding of common concepts brings us neatly to the second 'C' of command and control (C2). Form follows function, and therefore our systems of C2 need to

1 For the dangers of a 'consensus' approach, one need look no further than the wisdom of Margaret Thatcher in the Sir Robert Menzies Lecture at Monash University in 1981. In her speech, Thatcher described consensus as 'the process of abandoning all beliefs, principles, values and policies in search of something in which no-one believes, but to which no-one objects – the process of avoiding the very issues that have to be solved, merely because you cannot get agreement on the way ahead. What great cause would have been fought and won under the banner "I stand for consensus"?' (Thatcher, 1981). Later in life she concluded that consensus was 'the absence of leadership'.

2 Australian Prime Minister's statement on Russia's illegal and immoral war of aggression against Ukraine (Albanese et al., 2025).

3 In a recent RUSI *Insight Papers*, for example, respected analyst Dr Jack Watling discusses how the Ukrainian Armed Forces are developing new and emergent approaches to combined arms manoeuvre. These emergent approaches remain rooted in manoeuvre theory, rather than rejecting it (Watling, 2025).

evolve in line with new approaches of orchestration. Starting at the forward line, the JTAC employed at the Company-level should likely remain as the mainstay of terminal control. This highly respected and understood model is underpinned by nearly two decades of air-land integration in the GWOT, and there is little sense or reason to discard it. It has value as a steady cultural connection between ground and air forces, if nothing else. Evolution is, however, probably required at every level above, driven by the need to grapple with the challenging space that some refer to as the 'air littoral'.

As highlighted earlier, the airspace below 10,000 feet is becoming increasingly congested, with persistent and loitering air and aviation assets being deployed at every echelon, and in an intensely contested EMS.[4] New ADF C2 constructs need to resolve the C2 of this airspace. The possessive ground commander in me instinctively wants to control this important aspect of my Area of Operations (AO), with freedom to decide what flies where and when, and more importantly what munitions enter and leave the battlespace.

Nevertheless, I am long enough in the tooth to know that this aspiration is likely impractical and outdated: even if it was feasible, I would be woefully unprepared within my headquarters to assume such a responsibility. A far more realistic model below 10,000 feet is the 'supported/supporting' command relationship that is becoming common in modern warfare, underpinned by far greater integration of air and land C2 nodes at each echelon. 'Supported/supporting' relationships can work when underpinned by pragmatism, clarity of intent, humility and personal empathy between commanders.

The Australian Army is taking steps to optimise our C2 structures for better orchestration between the air and land domains. The 7th Brigade Headquarters (HQ) is increasingly tailored for the execution of air-land strategic force projection as the Army's Contingency Force Brigade (Brennan, 2023). The creation of the 10th Brigade, inspired by the US Army's multi-domain task force, provides the platform to orchestrate long-range fires and medium-range ground-based air defence into all-domain operations (Sydenham, 2025).

The most substantial and important change, however, is the re-elevation of the Division as the Army's unit of action. This is founded in the judgement that the Division is the best echelon from which we can orchestrate truly all-domain tactical actions for littoral and land warfare. The Divisional HQ is the sweet spot: the place where 2-star command experience, situational awareness, intelligence, secured communications and tactical engagement authorities all come together. It is, in my judgement, where the RAAF might best evolve its scarce land C2 footprints: in conceiving the future form of the Tactical Air Control Party (TACP). This is where the challenge of command and control should be addressed.

The final layer for C2 consideration, with just one degree of separation from the Division, is at HQ Joint Operations Command (HQ JOC). Here, I offer support to the work already underway. HQ JOC's shift to a component model of C2 is the optimal approach to allow orchestration of air and land operations, specifically at the theatre level. The focus here is rightly on the effective force-generation, synchronisation and enduring sustainment of the ADF's precious air assets across a primary theatre that includes 51% of the earth's surface, ensuring that they are available at the right time and place to provide the best net military benefit.

Again, I believe a common mindset and lexicon of 'manoeuvre' and 'targeting' will support a healthy relationship between the Army-provisioned Joint Force Land Component Commander (JFLCC) and Joint Force Special Operations Component Commander (JFSOCC), and the Joint Force Air Component Commander (JFACC) – no matter who is 'supported' or 'supporting' at any given moment. HQ JOC is also the natural place for integration into coalition C2 structures for the air domain: a practice well founded on the RAAF's generational investment in relationships with the US Air Force.

New concepts and C2 structures are then underpinned by the third 'C': capabilities. This is where the NDS's focus on an 'integrated force' should come to the fore. The ADF's next generation of air-land capabilities must be integrated by design, from first principles, if we are to successfully create a technological nexus for orchestration. It will not be enough to come together at the point of convergence. The most urgent areas of focus are increasingly clear, mostly centred on common systems to enable C2: data backbones and standards, joint targeting networks and machine-speed processing at the tactical edge. The careful alignment of the air battle management project (Conroy, 2024) and the land command, control, communications, computers and intelligence (C4I) modernisation project (AusTender, 2025) demonstrates that this work is already broadly underway, and I do not need to repeat it here. The ADF is working hard to pull the sensor, the decision-maker and the shooter closer together.

What I do seek to emphasise, however, is the importance of realism in context. Those responsible for integrating ADF capabilities in an era of great power competition must all approach it from a common understanding of the environment in which we are going to fight. To me, this means war. Not crisis, not conflict, not limited intervention, but full-scale war – likely as an underdog and against a beyond-peer adversary. Our project plans and slide presentations tend to sanitise this reality but Ukraine and Gaza show us that war remains as Clausewitz described it, as a phe-

4 It should be noted that aviation assets are considered a 'land power' capability; force generated and operated by the Army as part of the land warfare combined arms fighting system.

nomenon of brutal violence, inherent unpredictability, paralysing fear and confounding friction.

This visible zeitgeist of modern war should make us suspicious of anyone who offers a 'silver bullet': a single system or capability that will make the battlefield predictable, 'transparent' or that will offer a decisive edge. History, including the last four years, tells us that they are almost certainly wrong. Quite simply, if drones, satellites, missiles or cyber operations were truly revolutionary in modern war, then the war in Ukraine would be over by now. It is not. Because they are not.

So instead we must develop capabilities, both on the ground and in the air, that are fit for the realities of Clausewitzian, full-scale war. These cannot rest on an assumption of perfection. As then Lieutenant Colonel H. R. McMaster wisely told us in 2003, this is a dangerous fallacy (McMaster, 2003). Our capabilities must instead be built for friction and degradation. They need to be 'good enough' to survive in a highly contested EW environment. They need to be able to take hits and keep on fighting. We need to invest in the mundane as much as the hyper-technical: common logistics and airfield engineering equipment as much as attack aviation and fifth-generation aircraft. Manoeuvre is still reliant on sufficient mass, so assets need to be cheap enough and simple enough that we can regenerate them quickly, domestically and at reasonable cost. Above all, our next generation of capabilities must be ready to be adapted once the true character of war reveals itself. Simplicity, it is worth remembering, is a principle of war. These are perhaps the most relevant lessons of Ukraine and Gaza.

The greatest challenges, and perhaps the greatest risks, lie in the effective application of autonomy and artificial intelligence (AI). Our status as a tech-savvy middle power with a modest-sized military demands that we make the most of this opportunity. It is the only pathway to achieving the mass we will need to manoeuvre against numerically superior adversaries, and the only way we will grapple with the data-heavy complexity of modern war. But we must be clear-eyed on the environment within which we are seeking to apply these technologies, and realistic about what they can achieve and when. The air domain seems like the ideal place to experiment with autonomy and AI: it carries an impression of being clean and clinical (the domain of 'surgical strikes'), where the dispassionate calculus of analytics can presumably thrive. We must not be persuaded by this. The air and land domains are intrinsically intertwined and likely to be equally chaotic in a full-scale, regional war.

Take, for example, one of the best examples of friction in war: air-land fratricide and target misidentification. This has been a problem since at least 1943, when 34 C-47 transport aircraft of the US Army Air Force were shot down by friendly fire in just two days in Sicily, decimating the 82nd Airborne Division (Meilinger, 2013). It remained a problem 60 years later in the invasion of Iraq. I vividly remember the fear I felt as US Marine Corps Cobra gunships, to which we had no communications, fired missiles into abandoned enemy armoured vehicles just metres away from our tanks. We were not sure if they know who we were, or if we were next. Tragically, two A-10 Thunderbolts of the 190th Fighter Squadron got it wrong just days later, mis-identifying and strafing reconnaissance troops from our colleagues in the Blues and Royals, killing Lance Corporal of Horse Matty Hull (Ministry of Defence, 2003). Russian aircraft friendly-fire losses in Ukraine suggest that the addition of two decades of technology has made no tangible difference (Zabrodskyi et al., 2022).

So, will autonomous systems, or those controlled by AI, accentuate or reduce this risk? Optimists will assure us that it will be the second: that autonomous systems will be more effective at identification and discrimination than humans. Again, we should carry a healthy suspicion. Like most things in autonomy and AI, the core questions are likely to be about sufficiency of trust and confidence, set in the context of war. What level of system positive identification (PID) confidence should be required before last-mile autonomous terminal guidance is unleashed into Australian systems, amongst Australian troops? 100%? 95%? Or does expediency in war demand it to be much lower? How well will this trust and confidence stand up against the fog, fear and friction of real battle? How important is social licence in the use of these technologies? Such questions should be front and centre as we consider the most advanced air-land capabilities of the future.

The final 'C': culture and the profession of arms

The final 'C', that of culture, is deserving of a section of its own. Despite all the technological discussion above, both the Army and the RAAF remain rightly committed to being people-centric organisations. This is where we are already most united. While we may seem very different as military branches, we recruit from the same gene pool: intelligent, fit, adventurous young Australians who want to serve their country. It is often no more than a sliding-doors moment of decision that defines whether a recruit wears the light blue of the RAAF or the khaki of the Army. Soldiers and aviators are connected by their nationality, attitude and motivation. By Australian culture.

These cultural connections provide the ideal foundation for a new, intimate era of all-domain orchestration. The best medium to achieve this is easy to identify: it is the 'profession of arms'. The fact that soldiers, aviators and sailors all belong to a common profession, in the traditional sense of a profession like law or medicine, is one of the strongest opportunities we have to come closer together. We are well poised to do this; indeed it is directed to us at the highest level. Chapter 6 of the ADF's capstone doctrine, Australian Military Power, makes it clear that every member of the Defence Force is part of a common Australian profession of arms (Australian Defence Force, 2024, pp. 67–76).

The team in ADF HQ have invested heavily this last four years in codifying a common set of professional ideas in the series of publications entitled 'The Ethos of the Profession of Arms'. From character to ethics, leadership to command, the core foundations have been established (Australian Defence Force, 2026). The existence of a common Australian martial profession is therefore not a matter for conjecture

or debate: it is instead a stated position of ADF doctrine and policy, to which all Services must adhere.

The idea of a Western profession of arms has its historical roots in the land domain, and it is therefore unsurprising that the Australian Army is strongly committed to it. The Army's current senior leadership sees strengthening the Army's professional foundations as a vital factor in our comprehensive response to the NDS. In 2024, they commissioned a holistic 'review of the state of the Army profession' (Stuart, 2024a, 2024b, 2025). Note the use of the language of 'the Army profession'. This is an important nuance. It is not for the Army to review or critique the ADF's capstone expression of the profession of arms. It is instead for us to consider how the Army best expresses that direction within the land domain's cultural sub-set: how we adhere to the ADF's professional standards when providing our specific expertise of fighting wars on the land.

This review has helped us 'see ourselves' as a Service. Importantly, it has also helped us explain ourselves to our sibling Services. A year into the review, I believe the approach has value for better all-domain orchestration, and I commend it to the RAAF as being potentially useful. Like a Venn diagram, I contend that all three Services require a distinct expression of the ADF's unifying profession of arms. We each have strengths specific to our domains, the result of decades if not hundreds of years of institutional experience of fighting in the air, on the land, or on and under the sea. This diversity is a strength in itself, which must be embraced and protected. It is what makes the whole more than the sum of its parts. The better defined the Service 'circles' of the Venn diagram, the better we can analyse and draw together the best overlaps without diluting the richness of Service culture.

The ADF is particularly suited to a cultural approach defined by Service professions and then unified by the profession of arms. Each Service maintains a highly developed training and education system optimised to teach warfighting within their specific domain. These systems are genuinely world-class. The ADF's highly developed joint professional training and education enterprise then creates the interconnecting sinews between them. All that is needed are some tweaks to optimise how we best use this network for professional adaptation. First, we might draw together closer relationships between ab-initio schools. Just 20 kilometres separates the Army's 1st Recruit Training Battalion from the RAAF's No 1 Recruit Training Unit, so it makes sense that the 'airmindedness' journey for the Army's recruits could start from the very outset. Second, both Services might invest in a shared professionalisation of NCO education (an area of traditional underinvestment in comparison to officer development).

Finally, and in an enduring theme, the whole enterprise could be more sharply focused on a common context of the study of war and large-scale warfighting. The case-in-point here is the Australian Defence Force Academy (ADFA). With the current Chief of Air Force (Royal Australian Air Force, n.d.), Chief of Navy (Royal Australian Navy, n.d.), Vice Chief of the Defence Force (Australian Defence Force, n.d.-b.) and the Chief of Joint Capabilities (Australian Defence Force, n.d.-a) all as graduates, ADFA is rightly the jewel in the ADF crown for developing inter-Service cultural connections at the very outset of the profession. The last 20 years, however, have seen the curriculum and faculty increasingly focus on science, technology, engineering and mathematics (STEM), as well as cyber and business degrees, with a commensurate reduction in investment in the traditional study of war as a phenomenon: the canons of war studies, military history, classical strategy, civil-military relations and politics (Mazanov, 2018).

In an era that the NDS describes as the 'most challenging strategic environment since the Second World War', I believe this comparative investment represents a risk (Department of Defence, 2024, p. 5). The need for STEM degrees in a high-tech ADF is undeniable, but all professional study should be grounded in the brutal realities of war's nature if it is to be relevant for an age of great power competition. This sharpens ADFA's original purpose: the teaching of undergraduate studies in a military context as the foundation of the profession of arms (something civilian institutions cannot do). A reinvestment at ADFA towards this purpose might prove confronting, but a clear-eyed, common understanding of war is essential for adaptation. It will benefit not only the Army/RAAF relationship but also the ADF's readiness for war as a whole.

Therefore, I commend a profession of arms cultural approach to all-domain orchestration. For this to work, though, one final principle must be in place. All soldiers, aviators and sailors must consider themselves part of a shared profession. This sounds self-evident but it cannot be taken for granted. Samuel P. Huntington, one of the original architects of the modern profession of arms, argued in the late 1950s that 'military professionalism is synonymous with officership' (Huntington, 1957). The modern Australian Army challenges this division between officers and enlisted, arguing that everyone who wears the uniform must be part of the same profession, connected by a common code of honour and conduct (Stuart, 2024b). This has triggered a valuable cultural debate within the Army. Do all of Australia's aviators consider themselves part of a shared Air Force profession? Or is there perhaps a divide between pilots and ground crew that would test the RAAF's collective will to fight in war? It is not for me to answer these questions, but I respectfully believe they are worth asking.

Conclusion: amphibious and littoral warfighting as the litmus test

For the last two years, RAAF Glenbrook has kindly hosted the senior leadership of the Australian Army for a strategic framing discussion. It is a beautiful and historic venue. First World War artwork adorns the conference room: images of biplanes, bombs and leather jackets, and the proud faces of the first Australian military aviators. It never takes long for someone (Army or RAAF) to reflect that these are as much Army memories as those of the Air Force, given the Australian Flying Corps' roots in the Army in 1912 (Australian War Memorial, 2021). The reality is that both Services are cut from the same historical cloth and should be close, institutional siblings. The two World Wars,

Vietnam, and Iraq and Afghanistan have all made the importance of effective air-land integration clear. This is not a point of contention.

Our ability to achieve effective integration over the last hundred years, however, has not always been smooth. Air Vice Marshal Stephen Edgeley tells us, for example, that the Australian Army Air Corps was formed as a direct result of the RAAF's decision to deprioritise light aircraft support to the Army in the 1950s (Edgeley, 2023, pp. 14–18). The Army has, at times, failed to make its own priorities and needs clear, and the RAAF has often emphasised high-tech strike to the detriment of less-glamorous investments in forward air controllers and air liaison officers. Protectionist behaviours have manifest most when budgets are tight, and shared institutional catastrophes like the 1996 Blackhawk incident have left scars. However, when it has really mattered – in war – both Services have quickly broken down such barriers. This was particularly the case in the Pacific War, where (as Alan Stephens tells us) 'Australian soldiers received blue ribbon service from their nation's air arm' (Edgeley, 2023, p. 26). When the chips have been down, the Army and the RAAF have been there for each other.

The evidence is mounting that we are now approaching another of those times. A new era of great power competition is combining with a character of war that is changing faster than perhaps at any time in human history. This environment threatens large-scale war against beyond-peer adversaries. Time is not on our side. We need to adapt now, avoiding the traps of inter-war thinking; as Field Marshal William (Bill) Slim argued after Burma, 'in peace, the function of tactical air support of land operations is apt to fade, but in war it's urgency will increase' (Mankowski, 2016).

I have argued in this paper that this environment demands an approach that goes beyond air-land integration, to all-domain orchestration. A new era of collective airmindedness. This is feasible, but it will require focused consideration and aligned investment across our two institutions: in concepts, in C2, in capability, and particularly in culture. Importantly, we must work hard to make the most of the collective strengths of our unique Service identities, but without blurring or diluting them. Integration is a means to a battlefield end, not an end in itself.

How will we know if we are succeeding? My final conclusion is that we should look at amphibious and littoral warfighting as the litmus test for progress. These are rightly viewed as the most complex and challenging of military operations. They are also the most likely medium where Australian air and land assets will fight together for real in our region. If we cannot thrive fighting together in the archipelagic battlespace in our north, or in our own littoral regions, then we are highly unlikely to be able to defend Australia effectively. The tests of each Talisman Sabre, and other like-minded exercises, are therefore critical. The performance of the Amphibious Task Group Headquarters, the ADF's best lightning rod for joint tactical action, should be a dominant marker.

As with most things in history, however, this is not the first time we have faced such a challenge. It last emerged in 1942 with the Imperial Japanese attacks on Darwin, and with the need to transform the Australian military for the defence of Australia, and for the trials of the Pacific War. The years of amphibious and littoral warfighting that followed stand as the apogee of the relationship between the Army and the RAAF, perhaps the finest hours in our shared history. From the Kokoda Track to Lae, neither Service could have succeeded without the other (Air Power Development Centre, 2020). This is a collective experience we should work hard to exploit, especially as it ended in an outcome that is increasingly rare in modern war: that of victory.

Submitted: February 12, 2026 AEDT. Accepted: February 19, 2026 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Sobb, T., & Turnbull, B. (2026). Prioritising Mission Survivability through Defensive Cyber Operations: A Unified Mission Assurance Approach. *Contemporary Issues in Air and Space Power*, *4*(1), BP55879751. https://doi.org/10.58930/BP55879751

Other Operating Domains (Maritime, Land, Cyber)

Prioritising Mission Survivability Through Defensive Cyber Operations: A Unified Mission Assurance Approach

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Keywords: Cyber, Mission Assurance, Survivability

https://doi.org/10.58930/BP55879751

Vol. 4, Issue 1, 2026

Air missions are reliant on interconnected subsystems comprised of cyber, physical and human components. A breakdown in, or loss of, a component that delivers a mission essential service will have flow-on effects to operational lethality and survivability. In the cyber domain, taking a mission-centric approach to defending infrastructure instead of a traditional system-centric approach is called 'mission assurance'. Cyber operations for mission assurance purposes focus on protecting critical mission services instead of simply securing cyber infrastructure. This work offers a novel approach to mission assurance in the form of a Unified Mission Assurance (UMA) framework. This framework simplifies the mission assurance process into a four-phase operation that can be applied cyclically over enduring operations to ensure that systemic resilience is improved over time. The model is described in detail and then applied to an emergency response scenario use case. Future work is detailed and the impact that the UMA framework can provide to build systemic resilience against emergent phenomena is discussed.

1. Introduction

Cyber services underpin critical aspects across the modern battlefield, with their effects transcending into the air domain. Communications systems, navigation, command and control, and weapons systems all rely on cyber to deliver mission outcomes. Subsequently, a precision-targeted strike within the cyber domain can have devastating kinetic consequences, sending ripple effects across wider military campaigns. Cyber systems exist to meet an articulated service need within an organisation. Within a military context, that service need translates to capabilities that achieve missions, and so effective cyber assurance is a pathway to 'mission assurance'. This term was first defined by the United States (US) Air Force, as the 'process to protect … the continued function and resilience of capabilities and assets … critical to the execution of DoD mission-essential functions' (U.S. Air Force, 2019, p. 9). This approach brings a mindset shift away from system-centric forms of thinking where protection of cyber resources is seen as the main goal, into a mission-centric form of thinking where protection of cyber-infrastructure is seen as a means to an end to achieve ultimate mission success. In this mindset, operations with mission assurance are capable of mission success even in the presence of cyber-attacks, and do not simply aim to prevent them (Bigelow, 2017). This approach to cyber security is especially applicable in sectors that undergo enduring essential operations, such as military missions, financial sectors, government and national critical infrastructure.

Mission assurance is related to, but distinct from, the concept of cyber-worthiness. Cyber-worthiness, as used in Australian Defence, ensures a system, platform or network can continue operating effectively in a hostile, degraded or contested cyber space environment (Coyle, 2021). Whilst cyber-worthiness also incorporates complex systems, cyber and security, in practice it takes a more 'cybernetics' approach, of which cyber security is only one factor. Cyber-worthiness is achieved by using a Test and Evaluation (T&E) approach for a system's goals, identifying threats, vulnerabilities and associated risks, and implementing security controls for these (Boswell et al., 2021). These processes are analogous to other cyber security risk management frameworks, with an emphasis on system goals. However, criticisms of cyber-worthiness note that there are limitations in the processes, noting the need for ongoing adaptability in systems that are largely static in response to changing environments, and the tension between compliance and security (Shahzad et al., 2024).

Cyber-worthiness is distinct from mission assurance because it is based in purposeful engineering design and a focus on the delivery of cyber products to end users that meet their requirements. This is different to mission assurance, which takes a temporal, agile approach to defending cyber terrain in response to mission priorities. The two terms are not mutually exclusive. Instead, a system that is cyber-worthy – that is, able to maintain its cyber functions in its operating environment – is better positioned for the delivery of mission assurance. In simple terms, defending a system that was built poorly is significantly more difficult than defending one that is pre-fortified and fit-for-purpose. Cyber-worthiness ensures the design of secure, ready and compliant systems; whereas mission assurance is an applied approach to ensure the delivery of critical mission outcomes.

This paper presents a novel Unified Mission Assurance (UMA) framework that can cyclically be applied across mission sets to improve their resilience against threats. This is consistent both with advances in international cyber-resilience research and also with cyber-worthiness paradigms used in Australian Defence.

The remainder of this paper is structured as follows. Section two describes the background and identifies the research gap. Section three introduces and explains the UMA framework, including each of its phases. Section four provides an in-depth case study of the UMA, where it is applied to an emergency response scenario. Finally, section five discusses future work and provides conclusions.

2. Background

The US Air Force created the concept of Mission Assurance out of the requirement to maintain mission essential functions regardless of periods of potential degradation, attack or outage (U.S. Air Force, 2019). They define it as the 'process to protect … the continued function and resilience of capabilities and assets … critical to the execution of DoD mission essential functions' (U.S. Air Force, 2019, pp. 2, 9). Effective mission assurance through the cyber domain requires the ability to assess cyber security events and their corresponding impact within the mission environment (Rheaume, 2019). Core to mission assurance are the concepts that a portion of all systems are compromised in integrity, confidentiality or availability and that, despite this, mission needs are paramount. This necessitates responses in cyber defence processes to ensure that mission success and/or survivability are not compromised. Within NASA, mission assurance integrates with the domains of hardware quality, software quality, cyber security, reliability, safety and electronic parts (Brace, 2005; Wilf, 2023). In this way, mission assurance involves consideration of the wider ecosystem that justifies cyber security.

Methods for mission and asset dependency mapping is a significant research area within the literature for mission assurance, as it is used as a prerequisite to determine which cyber assets correlate to mission outcomes. Prioritisation of Mission Essential Functions (MEFs) and decomposing them into sub-functions that cyber capabilities support is one method through which this mapping can occur (Jabbour & Muccio, 2011). Dependency graphs or trees were used as the basis for some methods, whilst others explored the feasibility of ontological applications (Buchanan et al., 2012; Cam & Mouallem, 2013). There are several challenges to mission mapping ventures, including that the defence departments only own a fraction of information infrastructure on which national security missions depend, and bottom-up mission mapping misses critical infrastructure that is outside of defence control (Jabbour & Muccio, 2013).

Determining the risk and impact to mission is a core component of the mission assurance process and is a significant research area within the literature. In one study, mission assurance levels were determined using binary or multi-valued logic decision diagrams, with the security status of cyber assets determined via Petri net modelling (Cam & Mouallem, 2013). From these outputs, it described a risk management scheme to assist decision-makers with real-time mission assurance decisions (Cam & Mouallem, 2013). Another framework for mission risk management consists of a four-pronged breakdown of cost benefit analysis where the economic goals are to spend as little on mission assurance as possible, whilst minimising the cost of failure, increasing the cost to an adversary and lowering the adversary's return-on-investment (Jabbour & Muccio, 2013). Tools specifically made to meet defence force needs are also available, with the Cyber Evaluation and Management Toolkit offering a method for cyber security risk evaluations for complex cyber-physical systems (Fowler et al., 2024). Whilst these processes are useful for understanding risk thresholds within tolerance levels, they are primarily compliance-based and consider business impact instead of temporal mission impact.

Several frameworks are also introduced within the literature as methods to approach and apply mission assurance processes. Cyber-ARGUS is one such framework that contains a three-phase approach of mission design analysis, collection of mission and cyber data, and assessment of mission impact (Barreto & Costa, 2019). This approach incorporates an understanding of mission characteristics, vulnerability discovery and enemy behaviour modelling as part of its analysis in order to develop relevant assessments that calculate the combined effects produced by attacker and defender plans (Barreto & Costa, 2019). Alternatively, Jabbour and Muccio present a five stage mission assurance process that incorporates MEF prioritisation, mission mapping, vulnerability assessments, mitigation and red teaming (Jabbour & Muccio, 2011). This approach prioritises stopgap measures to assure systems in a contested cyber environment, where systems may already be compromised. A Cyber Preparedness framework is also offered in the literature as a way to characterise cyber threats, determine the level of preparedness needed to ensure mission success, set objectives and establish decision priorities (Bodeau et al., 2010).

Tactical applications for mission assurance are also discussed in the public domain literature, including methods for implementing mission assurance behaviours at the practitioner level. Proactive techniques such as network segmentation and moving target instrumentation, and reactive techniques including deception strategies, are methods that modify the attack surface and impose cost on the adversary (H. Goldman et al., 2011). Building resiliency through specified objectives is also examined, with different actions chosen to reflect temporal mission assurance priorities including protection, deterrence, detection, isolation, recovery and adaptation (H. G. Goldman, 2010). The nature of the objective most suitable to a system will be shaped by the system's environmental context, with factors such as mission criticality, time and threat influencing the appropriate outcome. For example, as protect scenarios improve the defence of systems and disincentivise malicious actors, they are resource intensive and are therefore most suitable to high-value systems that exist to complete a specific temporal mission. Command and control systems, census collection and electronic election voting platforms are

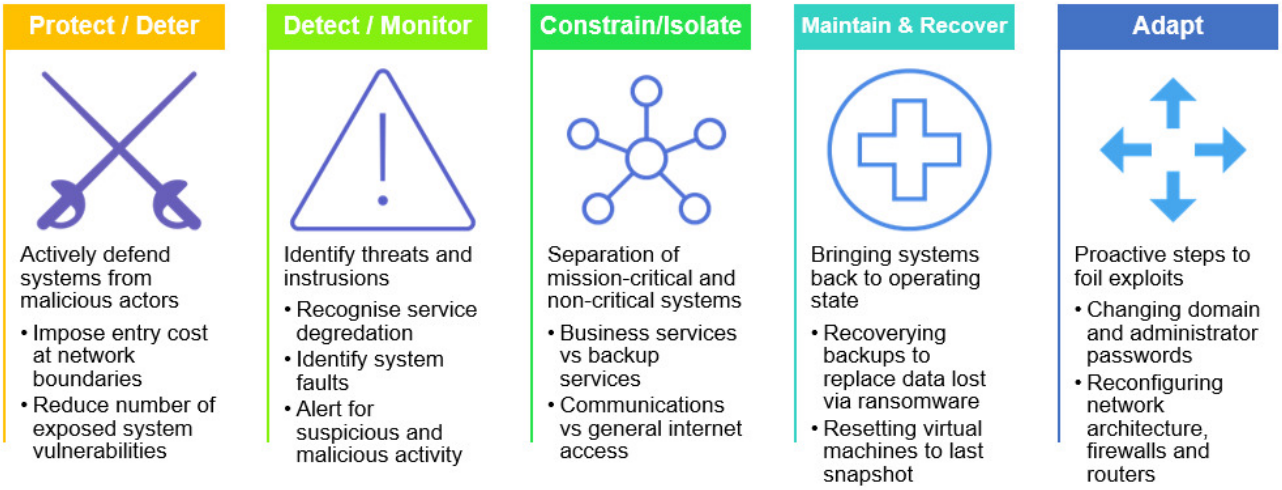

Figure 1. Applied examples of different objectives for resilient architecture. Adapted from H. G. Goldman (2010) .

all examples of systems that would be suited to a protection mission assurance objective. Conversely, a monitor approach consists of the deployment of sensors to collect information over long periods and is therefore more suited to systems requiring ongoing assurance. Examples of such systems include logistics platforms, air traffic control and business datacentres. Figure 1 demonstrates different applied methodology techniques for each objective.

Existing research relating to mission assurance broadly falls into the categories of defining and expanding the term, mission mapping methodologies, risk and mission impact assessments, frameworks and models, and tactical applications. Typically, this research base looks at the nature of mission assurance and applying it to specific operational scenarios. The current literature lacks a holistic approach to mission assurance that can be applied at an operational level, and implemented cyclically through agile development methods to improve resiliency steadily over time. Mission assurance needs to be integrated into existing project management and development paradigms at all stages of mission planning and operation. This is extremely important for critical enduring organisations, such as military forces and national critical infrastructure, where cyber threats may remain persistent and consistent. For the missions of such organisations to be assured, temporal tactical mission assurance is not enough, and there is a requirement for long-term shock absorption and resiliency.

3. Unified Mission Assurance

Organisations require the sustainment of operational capability and delivery of effects over extended periods, where environmental circumstances require agility and adaption. As cyber is a critical underpinning capability of mission effects, providing a methodology to sustain mission assurance efforts within this context is critical to operational needs. This paper presents a new framework for mission assurance that leverages developments from the literature and fills the need for a long-term cyclic option for mission sustainability in complex adaptive environments. Its strength comes from defining the parameters in which previous and future mission assurance research can be applied, whilst also addressing the critical research needed to offer mission assurance solutions that are both long term and adaptable. UMA is a whole-of-life continuous defence framework that can be applied across mission sets to increase their resiliency to cyber threats and enhance overall mission survivability. The framework is designed to be scalable; and can be applied to a single mission thread or a larger mission set. The UMA framework has been specifically developed for organisations that have critical business and mission outcomes that must be sustained over extended periods, where traditional short-term temporal mission assurance approaches are less appropriate. The UMA approach is therefore a novel model that can be used to enhance the defensive cyber posture of essential service organisations including defence forces, financial institutions and national critical infrastructure such as power grids and water. It takes a mission-first multi-domain approach to cyber defence that serves to adapt security measures as environments change in order to maximise mission assurance effects.

The UMA is a cyclic model with four key phases, as shown in Figure 2. Each phase has a specifically defined purpose, method and end-state that contributes to the mission assurance effects for that defined mission. The phases can be delineated based on whether they are administrative or cyber-based tasks, and whether they are conducted in a mission-ready posture or a post-mission posture, as illustrated in Table 1. As the model is cyclic, UMA is something that is a constant goal. Whilst individual temporal missions may change, the overall process to assure those missions strategically maintains the priority. It extends beyond tactical defensive actions during mission-execution periods and encompasses proactive protective activity across the entire mission lifecycle. Through UMA, cyber architecture is secured, mission services are protected, and therefore mission capabilities become more survivable due to the continuous cyclic nature of the model.

Figure 2. Unified Mission Assurance (UMA) framework.

The UMA framework differs from traditional cyber worthiness, mission assurance and vulnerability assessments. The variance in the nature of these methodologies is highlighted in **Table 2**, with the UMA framework notably being the most adaptable, mission-focussed framework that evaluates security outcomes over the whole system lifecycle.

The **Mission-centric Analysis** phase refers to the process of synthesising and overlaying mission, threat and infrastructure relevant information. The format of mission-centric analysis is heavily informed by previous mission assurance models such as cyber-ARGUS (Barreto & Costa, 2019). Mission-centric analysis also involves the active mapping of cyber infrastructure to mission essential functions, generating identifiable mission links that must be protected (Jabbour & Muccio, 2011). This is explained visually in Figure 3.

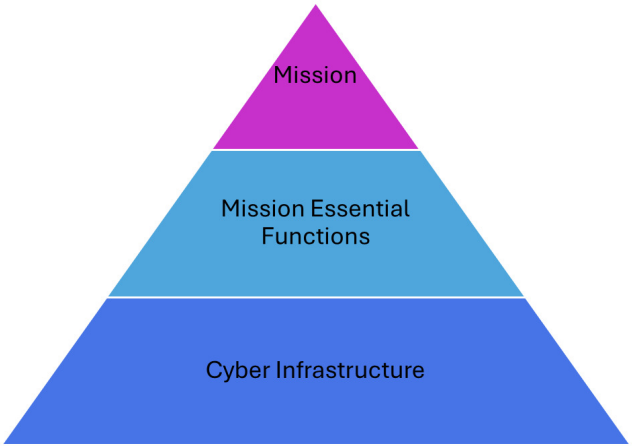

Figure 3. Visual representation of mission mapping hierarchy.

The **Applied Environments** phase refers to events in which mission assurance activities or actions are taken on a network. These may include, but are not limited to, real-world mission assurance tasks on operation, exercises, simulations, digital twins and other forms of testbed environments. In essence, these spaces allow for conditions through which mission assurance principles can be planned, tested and executed.

Table 1. Unified Mission Assurance phase delineators.

	Administrative Task	Cyber Task	Mission-Ready	Post-Mission
1. Mission-centric Analysis	X		X	
2. Applied Environments		X	X	
3. Employed Lessons	X			X
4. Resilient Infrastructure		X		X

Table 2. Framework comparison.

	Applicable across whole of system lifecycle	Unforeseen and multiple mission set adaptability	Focuses on mission over system compliance	Tests and evaluates security components
Unified Mission Assurance	X	X	X	X
Traditional Mission Assurance		X	X	X
Cyber Worthiness				X
Vulnerability Assessments				X

The **Employed Lessons** phase refers to the taking of lessons identified out of the Applied Environments phase, and inputting them into policy, business continuity planning, procedures and capability acquisition to increase resiliency for the future. This phase may include bureaucratic ventures or may initiate projects to address fundamental flaws identified throughout the mission assurance process.

The **Resilient Infrastructure** phase involves the implementation of actions and changes to the cyber system to increase its resiliency. This could involve actions designed to minimise the effects of disruptive adversary action or outages on the system affecting the overall mission, security uplifts based on vulnerability assessments, diverse network reconfigurations or the implementation of pre-emptive deception plans (H. Goldman et al., 2011).

4. Technical case study

In this section, the UMA approach will be applied to an Emergency Management Centre (EMC) scenario. This scenario was chosen because it is representative of a typical dual civilian or military service, with parallels to other use cases including logistics hubs, command and control centres, and airfield operations. Each phase of the UMA will be cycled through, illustrating the depth and scope of considerations required as part of the analysis process. As the UMA process is one of continuous improvement, this worked example will show the first iteration only.

4.1. Scenario background

An EMC requires 24-hour operations. EMCs are responsible for a variety of tasks including emergency call taking, emergency vehicle dispatch, emergency response management and emergency evacuation support. The service packages for the EMC are sourced from the National ITS Reference Architecture (Office of the Assistant Secretary for Research and Technology (OST-R), 2025).

In this scenario, this specific EMC has been identified as a critical service provider and requires cyber security support to ensure that its services remain online and available. Other critical service providers including the local hospital and Red Cross have experienced cyber-attacks over the last week, and authorities are concerned that the EMC may be a potential target.

It is important to note that approximately 30% of the employees work from home, relying on Remote Desktop Protocol (RDP) and Microsoft Teams to work.

The network architecture of the EMC consists of five subnets (**Appendix 1)**. The Servers subnet contains the domain controller, file server, mail server and web server. The Administration subnet is used by the EMC network administrators to manage the wider network, using RDP to manage hosts. The Call Centre subnet receives emergency calls. The Emergency Response subnet manages emergency events. Finally, the Management subnet contains the EMC's chain of command.

The typical workflow of an emergency starts with an emergency call coming into the Call Centre via VOIP over the internet. The Emergency Response group manages the event tickets within wider incidents and coordinates the dispatch and liaison with other external to EMC entities. These may include other emergency response services such as air-medical transport, the fire brigade, hospitals and police force. They are the central liaison between these services. The Management group monitors operations and closes incident tickets if required.

The file server contains the incident records for the EMC, both current and historic. They are kept in a Microsoft Access database. Entries are organised by date, incident call time and incident ID. The records include data from emergency services, call logs, recordings and images.

The webserver hosts updates on current emergency information that is pertinent to the public. This includes significant weather events, road warnings and national disaster information. It relies on external API feeds to third party government and commercial systems

4.2. Mission-centric analysis

Upon being given the task to provide mission assurance to the EMC, the first step as part of the UMA process is to conduct mission-centric analysis. In this step, task, threat, infrastructure and options will be analysed to develop a comprehensive plan for securing the network.

Task analysis. Within task analysis, an understanding of the expected outcomes and success factors is required within the context of the mission. The EMC is a critical service, providing a point of contact for people in dangerous situation and connecting them with emergency services.

The EMC's mission can be broken down into four mission essential functions:

- MEF 1. To receive emergency calls from the community
- MEF 2. To liaise with emergency services over the phone and internet
- MEF 3. To track and manage emergency incidents
- MEF 4. To provide emergency information to the community via the EMC website

The EMC's MEFs are time sensitive and crucial. Thus, maintaining each is critical to achieving overall mission success.

Threat analysis. The last six months has seen a general uptake in general botnet attacks against the internet-facing firewall of the EMC domain. There have been no reported incidents.

There have been previous financially motivated cyber-attacks on similar critical service providers including two local hospitals and the Red Cross. One of these attacks was attributed to the actor Exotic Lily, a ransomware group that uses software including Diavol and Conti (Taylor, 2022). APTs with the capability and intent to attack a critical public service such as the EMC include APT41 and the Lazarus Group (Htet & Rostovcev, 2019; 2025a).

Across these three APTs, a selection of tools, techniques and procedures (TTPs) are used to progress through the kill chain to achieve their actions-on-objectives. **Appendix 2** shows a selection of techniques that the actors use for different phases of their operations. The most common TTPs

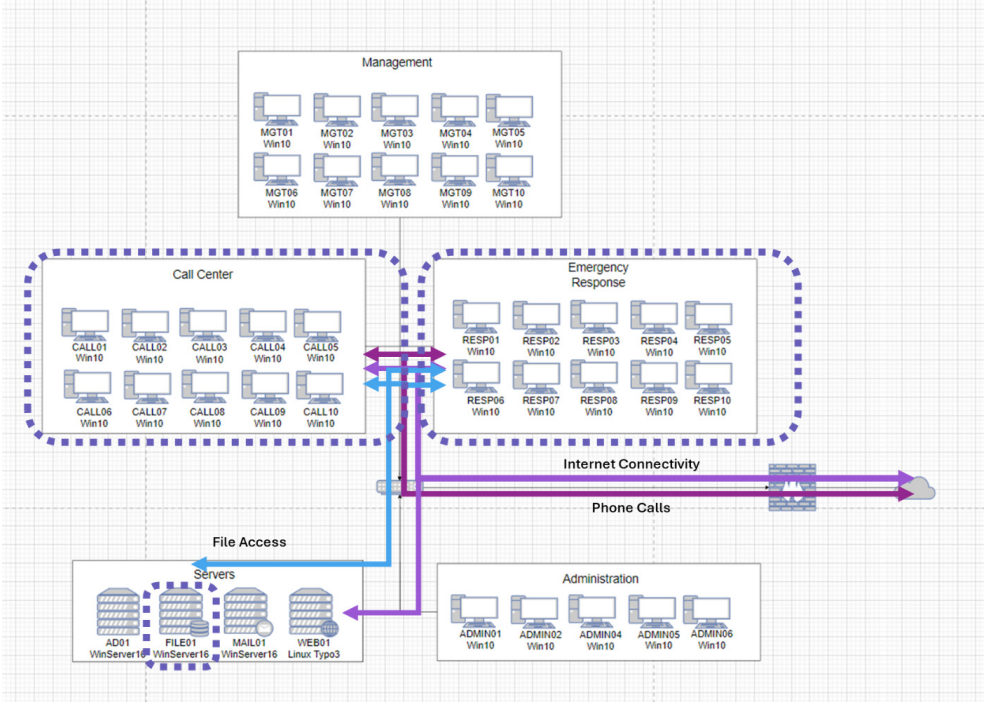

Figure 4. Emergency Management Centre critical mission infrastructure overlay.

to note as part of the threat analysis have been determined through a MITRE overlay of the three identified most likely threat actors. **Appendix 3** describes the most likely TTPs to be used by the identified threats by phase.

In the **infrastructure analysis** step, the cyber terrain of EMC is analysed to determine its defensive characteristics and capabilities. Firstly, the cyber-critical components within the network must be identified. These are the elements of the network that are essential to the maintenance of standard network service operations, agnostic of mission or task.

Appendix 4 shows the critical cyber overlay of the terrain. The domain controller hosts the active directory and the DNS for the domain and is therefore critical to enabling the management of the EMC network. This includes services such as user logins and computer management. The Administration subnet is critical cyber terrain because it is through this subnet that the network administrators can maintain, administer and control requisite network functions. The central router is critical terrain because it is the central point through which all traffic in the network must route. Finally, the firewall is cyber-critical terrain because it serves an essential cyber-security function of limiting external access to the domain.

Next, the mission essential functions (MEFs) are considered analysed and overlaid over the cyber terrain, to determine any mission-critical infrastructure. **Figure 4** shows the output of this analysis. Each MEF that was derived as part of the task analysis must now be applied to the infrastructure analysis (**Table 3**). By considering the cyber and mission-critical terrain, there is now a firm understanding of what portions of the EMC network infrastructure must be prioritised to maximise mission assurance outcomes.

Within the **option analysis**, a series of sequences are devised, tested and validated as potential courses of action to support the EMC's mission assurance outcomes whilst still maintaining the cyber priorities. Three options are developed that represent different approaches to achieving the mission assurance objectives of the EMC, as shown by **Figure 5.** They each achieve the same set of cyber priorities, such as having a map of network architecture up to network boundaries and having an up-to-date network architecture; however, they implement different sets of methodologies to meet these ends. When considering each option, it must be evaluated in terms of its suitability, feasibility and appropriateness to the current task and mission.

Option 1 is heavily focussed on improving the security standing of the network before transitioning to an active defence posture. It prioritises actions that gain the greatest visibility of the cyber terrain and in particular the current vulnerabilities that the network has. Follow-on actions focus on hardening the cyber terrain and reducing the potential attack surface that a potential threat has available to them. This style of approach has the benefit of hardening any potential vulnerabilities upfront but comes at the cost of potential downtimes and outages, and equipment is taken offline to enable reconfigurations and updates. This approach also provides the least current threat-visibility. It is highly system and engineering focussed, with limited actions implemented to monitor for and respond to potential malicious actors on the network. It is therefore more suited to missions that require a 'system-uplift' style approach, where the risk of an adversary infiltration is low.

Option 2 takes a more active defence approach that prioritises methodologies that have the least impact on EMC services. For threat visibility, it utilises passive and native methods of data collection that do not require the instal-

Table 3. Mission essential functions infrastructure analysis.

Mission Essential Function	Infrastructure Analysis
MEF 1. To receive emergency calls from the community	Call Centre hosts must be available and able to receive phone calls over VOIP
MEF 2. To liaise with emergency services over the phone and internet	Emergency Response hosts must be able to connect out of the EMC network to emergency services, via VOIP or the web
MEF 3. To track and manage emergency incidents	Both the Call Centre hosts and the Emergency Response hosts must be able to access the incident database hosted on the file server
MEF 4. To provide emergency information to the community via the EMC website	Hosts within the Call Centre and Emergency Response subnet should be able to access and edit files on the webserver, and external-to-EMC internet users should be able to view and access an up-to-date version of the EMC's website

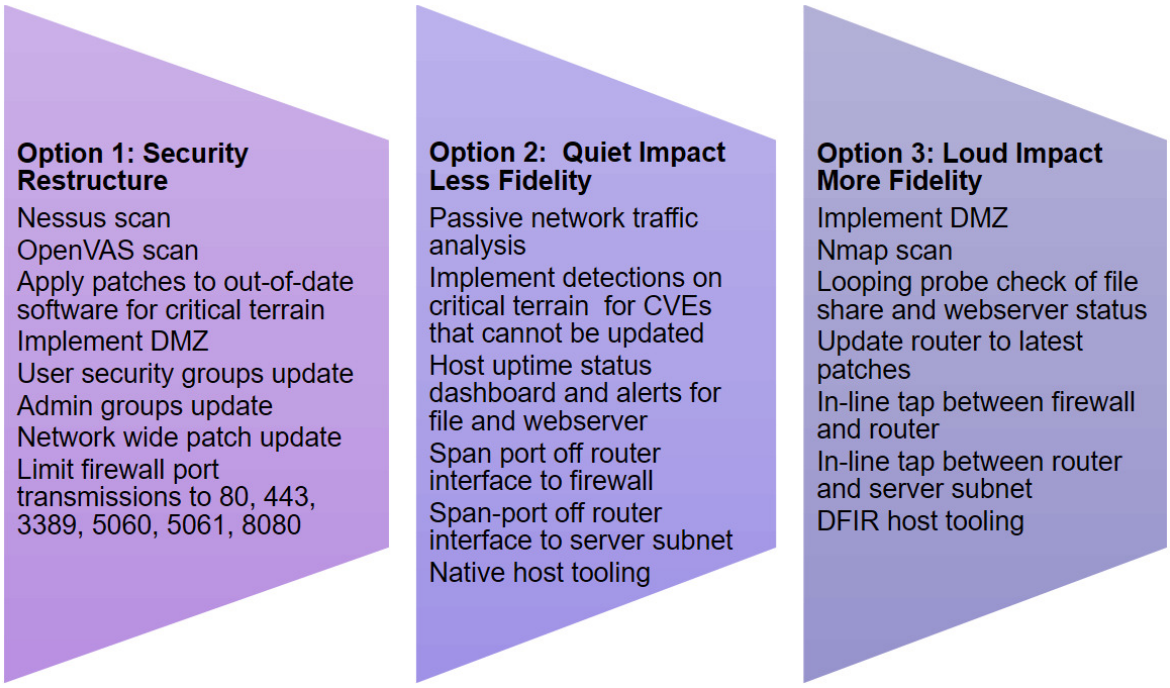

Figure 5. Options for EMC Mission Assurance Approach.

lation of additional tools to the EMC network, reducing the number of disruptions made to the EMC system. The approach still hardens vulnerabilities but prioritises those which pose the greatest mission risk rather than bulk updating all services and causing large downtimes. This is beneficial because it causes the least service disruption to the EMC but comes at the cost of compromising speed and fidelity in tooling for the cyber security team.

Finally, option 3 takes a more direct approach that prioritises active defence measures regardless of service impact. This includes installing software onto computers on the network and physical network taps to collect data. Activities to check and monitor the network are noisy, meaning that a potential threat actor would likely identify defensive actions occurring on the systems. There are clear benefits from a cyber security perspective in terms of freedom of tooling and visibility, but this comes at the cost of EMC service impacts through the installation and running of these additional tools.

Table 4 shows a summary of each option and the comparative factors for consideration. Considering that the team has been brought in specifically because of a concerned threat targeting the EMC, Option 1's *low* threat visibility makes it an unsuitable candidate for this assignment. Due to the criticality of the EMC's services, its MEFs impact to system is prioritised over other factors, disqualifying Option 3's *high* impact to system. Therefore Option 2 presents the best balance of methods to achieve mission assurance outcomes in the EMC environment given the priorities and constraints.

4.3. Applied environments

Temporal scenario. Execution of the EMC mission assurance plan occurs as part of the Applied Environments phase. The applied environment for this scenario is a real-world execution environment.

The phase begins with the configuration and implementation of host and network collection tooling, followed by

Table 4. Option analysis summary.

	Network Hardening	Threat Visibility	Noise Level	Impact to System
Option 1	High	Low	High	High
Option 2	Medium	Medium	Low	Medium
Option 3	Medium	High	High	High

their validation. The cyber team can then follow through with the methods described in the option developed as part of the mission-centric analysis.

In this hypothetical scenario, during the execution period, the cyber team is made aware that an unauthorised user is using John Dorian's administrator account. Based on initial triage, it is identified that that administrator account has logged into the domain controller (AD01), one of the cyber-critical hosts. A persistence sweep of the network identifies two outlier registry keys that do not conform with the rest of the domain's configuration (**Appendix 5**).

John Dorian's administrator account is logged in to the domain controller via remote desktop protocol from a suspicious IP address. That same suspicious IP address is also connected to a computer in the Call Centre, CALL06, and a computer in the Emergency Response subnet, RESP10. This second computer is the same host that has the outlier registry key.

Triage across these three hosts identifies process injection into the runtimebroker process on the domain controller, and the Microsoft Edge process on the other two hosts. This is enough data to transition the category of this incident from anomalous to malicious.

Framing mission risk in a mission assurance approach. In the current state, an actor has compromised three machines, including one that is critical to the EMC network functioning, and has active command and control from each of them. They also have at least one administrator password, and have employed mechanisms on each machine that will re-spawn their access if they are cleared from the network. The assessed risk to EMC operations is high.

Because this is a mission assurance task, maintaining the four EMC mission- essential functions is the priority. The current network adversary poses a direct threat to those mission essential functions, through their potential disruption, denial or further exploitation of the network. It is therefore a mission assurance imperative to stop the adversary's kill chain progressing.

Unfortunately, conducting a traditional incident response where the three infected hosts are taken offline for slow time forensics is not an option because this will also stop critical mission essential functions. This network does not have a back-up secondary domain controller, which is critical for the network to function, and the other two infected hosts are currently being used to manage real-time emergency incidents and cannot be taken offline.

Temporal scenario update. The system administrators update that the RYUK ransomware has been deployed on the Administration subnet, with all files being encrypted control being lost of each host (Haase, 2022). A quick-response survey of the rest of the network identifies that the domain controller has a mounted network share with the Administration subnet. A new share is seen opening between the same domain controller and the file server and main server. At the same time, the infected host in the Call Centre mounts a network share with five computers in the management subnet. **Appendix 6** shows a summary of the intrusion set.

Mission-prioritised eradication. The assurance of the delivery of the EMC's mission essential functions is the utmost priority of the cyber team. This intrusion set poses a direct threat to this mission, with a mission risk of extreme. The actor has demonstrated the capability to deploy ransomware and, by opening the shares to the file and web server, is demonstrating the intent to deploy it to these critical EMC services.

Stopping the ransomware deployment and then eradicating the threat actor is a priority over all other cyber security or forensics ventures. The first action of the cyber defence team is to stop the ransomware deployment on the servers, as this poses the largest risk to the EMC's mission essential functions by including the mission-critical file and web server. This is done by dropping the remote desktop session to the domain controller and stopping the injected threat on that computer. The second action would be to stop the Management subnet ransomware deployment, which occurs second because this subnet is not critical infrastructure. This is done by stopping the injected threat in Microsoft Edge on the infected Call Centre computer. Next, the priority is to remove any mechanisms enabling persistent access to the network and to stop all other forms of in-memory execution. This is to stop the adversary from re-spawning their tools once cleared from the network and removing any current footholds they have. This is completed by deleting the two registry keys identified in **Appendix 5**, and then stopping the process injection in Microsoft Edge on the compromised Emergency Response computer. After validating these initial steps, the network is monitored immediately for the malicious IP address to see if it is logged again within the EMC, which would indicate that a foothold was missed.

Post-eradication actions. This approach prioritises mission needs over security needs. Once the initial threat has passed and it is confirmed that the actor has been eradicated, then post-eradication security actions can be taken in the network. These include the resetting of compromised credentials, including John Dorian's administrator account, the administration of digital forensics to understand the nature of the historic compromise and to feed the intelligence cycle, and the resetting of the network back to its original configuration.

The forensic analysis of the EMC network paints a narrative of the entire intrusion set, from initial entry to actions on objectives. A summary of the forensic outcomes identified in this analysis is presented in **Appendix 7**.

Considering the most likely threat TTPs discussed in the Threat Analysis phase, several corresponded with actions conducted by the adversary on this operation. The overlap between behaviours observed in the scenario and those predicted in the threat analysis are detailed in **Appendix 8**.

From the indicators of compromise (IOCs) identified as part of the post-incident forensic analysis, it is identified that the TTPs aligned with those associated with the malicious cyber actor Wizard Spider (Haase, 2022; Millington & Gayda, 2025). Whilst this was not one of the threat actors specifically named in the threat analysis, Wizard Spider is closely linked to Exotic Lily, which was identified as a likely threat actor to the EMC (Taylor, 2022).

4.4. Employed lessons

Post-incident analysis and forensics, there are several lessons identified that can be taken and applied to EMC's governance, management and procedures.

Whilst working on the network, it was identified that there was no data backup policy pertaining to the file server, which contained information critical to current and historical emergency incidents. This posed risks to the network, as the potential corruption, exploitation or loss of service of the file server would leave the network with no alternative service solution. An administrative solution to this problem would be the implementation of a routine backup policy, enshrined within the system's designated operating procedures. This would assist in minimising the effects of future ransomware attacks (Thomas & Galligher, 2018).

Across the wider network, it was noted that the EMC system administrators did not have a broader recovery or contingency plan for incident response or for when infrastructure experienced outages. Such plans are critical for assigning responsibility, streamlining tasks and delegating authorities in crisis situations; without which the network is left at an increased risk of prolonged service disruption. It is recommended that the EMC system administrators establish both an incident response plan and disaster management procedures in order to enable business continuity planning between critical service interdependencies (Fisher et al., 2017). Such plans should include business risk management, security, technological and psychological considerations, and continuous improvement processes that harness learning and adaptation over time (Savolainen et al., 2024).

As revealed during the post-incident forensics, an Outlook scraper was successfully used to acquire the credentials for one of the EMC's users, Courtney Stones. This occurred because a password reset email had been sent to her that had stored her new password credentials in plain text. To administratively address this to reduce the risk of such an event happening again, password reset policies should be updated to ensure that password resets send each half of the new credential in a separate email to the member and their supervisor respectively. This reduces the risk of identifying both halves of the password together with a scraping tool.

Through the implementation of these administrative lessons into policy, governance and procedures, EMC will be able to mitigate the risks associated with an incident such as those experienced in this case. Importantly, paper-based implementations must be followed through with cognisant cultural acceptance and technique application for them to be truly onboarded successfully. This takes both organisational and individual accountability, active change management and dedication (Ramluckan et al., 2020; Watson et al., 2020) .

4.5. Resilient infrastructure

In this section, changes to the engineering baseline of the EMC network are discussed. Some of these relate specifically to stopping an actor like the one seen in the historical intrusion set from repeating their attack, whilst others are more general. These changes are designed specifically to protect critical services, assure mission essential functions, and build the network's overall resilience to attacks, outages and disruptions. **Appendix 9** summarises key infrastructural improvements to be made based on observations from the intrusion.

Through the implementation of these hardware and software recommendations, the Resilient Infrastructure phase is completed. This concludes the first cycle of the UMA framework. From here, cyber defenders are positioned for future iterations based on upcoming tasks or system needs. These may be in operationally live, exercise, simulated or test environments, depending on the mission context. Finalising this phase brings to conclusion the first cycle of the UMA process. From here, a new iteration can occur, that can encompass and adapt to new and changing needs in the system, mission and threat environment.

5. Building mission resilience

Critical mission services, whether in a military or industrial context, must be able to deliver outcomes throughout turbulent and adverse conditions. It is the resilience of these systems that informs their parent mission's ultimate survivability. In this section, critical elements enabling resilience will be discussed in the context of the UMA framework to inform mission assurance applications.

Adaptability enables change in response to new environments and situations. It is essential for resilience because a system that cannot adapt to new stimuli becomes vulnerable and not fit-for-purpose. The UMA approach is designed to be adaptable through its iterative cyclic design. Each cycle allows for temporal changes, such as new environmental data, mission updates and architecture modifications, to be encompassed within the upcoming loop. This continuous cycle forces cyber security updates to be made, regardless of how much the environment has changed, leading to greater continuous improvement outcomes overall. From a resilience perspective, the benefits are two-fold. First, legacy systems that have been in a state of inertia are

forced into resilience-improving cycles. And second, agile systems or missions with changing variables and environments can be suitably accommodated for at each variation.

Scalability enables the effective absorption of increased demand or expansion of work without the compromise of performance. In rapidly changing environments, services must be able to shift in scale to meet demands. The UMA is built with this in mind. It is not bound to a particular scope, be that the boundary of a computer system or a particular mission-set. It is scalable, able to be applied across the tactical, operational and strategic levels of organisations. This enhances its adaptability, so that it can be implemented in sectors where it is most needed regardless of scale of mission set or cyber infrastructure. Through this scalability, a wider range of systems can be encompassed by UMA, making it a resilience enhancing asset for organisations.

Sustainability refers to the ability to maintain a service over an extended period. It is a key feeding factor to resilience, as systems, services or missions that cannot be sustained or are stretched 'too-thin' become weaker and are less able to react to and absorb turbulent events. UMA builds sustainability by directly bolstering both the procedural and technical cyber defensive measures of a system. A system that is better secured, tested and robust will be more able to sustain services when under attack than one that is not. Human, physical and cyber domain factors all contribute to building sustainable systems that feed mission essential services. This sustainability feeds resilience against outages, attacks and emergent events.

Survivability is directly related to resilience. If resilience is the ability to absorb and 'bounce back' from adversity, then survivability is the ability to continue to exist, function and deliver outcomes regardless of damage received. UMA is designed explicitly to ensure that cyber systems are better equipped to assure the success of missions. This cannot happen if the cyber infrastructure or services are not survivable. Each stage of the UMA framework takes a different action towards the improvement of system survivability. Together, the entire UMA cycle advances system survivability, which in turn strengthens service resilience, and conclusively assures the ultimate mission.

6. Lessons for the Australian Defence Force

There is some existing ADF literature regarding the application and development of cyber warfare capabilities that can inform how approaches such as UMA can best align with ADF objectives and requirements. These documents assist in illustrating the problem space in which solutions like UMA may be applied.

First and foremost, the cyber must be recognised and applied as capabilities that integrate and extend across the other physical domains of space, air, maritime and land. The ADF's Capstone doctrine, Australian Military Power, supports this idea (Australian Defence Force, 2024). What this effectively means is that the ADF recognises the independence of cyber as its own domain, whilst simultaneously accepting its embedding and influence across the physical domains. Acknowledging the nature of this causal relationship is the first step in taking proactive cyber action that assures military action across all domains, that is, mission assurance.

In 2024, the 2024 National Defence Strategy was released as a guide for the delivery and transformation of the Australian Defence Force (ADF) into an integrated, focused force (Australian Government, 2024). The document specifically highlights that cyber's capability priority for the force is to 'strengthen situational awareness, the ability to project force and decision advantage' (Australian Government, 2024, p. 38). Doctrinally, it is established that the cyber domain itself is integrated across and through the other warfighting domains, making it a key enabler (Australian Defence Force, 2024, pp. 33–34).

Applying the UMA framework, especially due to its cyclic and phased nature, gives the opportunity to encompass the range of cyberspace mission sets across the system lifecycle. It enables the achievement of both building inherent resilience and denying adversary temporal advantage within a single procedure that can be applied at scale across the organisation. UMA's cyclic model allows for continuous and adaptive learning, collaboration and objective optimisation across all mission stakeholders; breaking it free of the temporal limitations of traditional defensive mission assurance and the other siloed cyberspace mission sets.

Finally, the impacts of applying UMA in the context of the Defence Cyber Security Strategy is considered (Department of Defence, 2022). This document was released before the NDS but still contains much of the principles and direction that guide cyber security activities in the military domain to this day. The five principles that guide the Strategic Vision of the strategy are mission-focussed, threat-centric, contemporary, best-practice and strong partnerships. Whilst the UMA framework is a new model to Defence, it fulfils each of these principles, strengthening cyber outcomes. The UMA framework is inherently *mission-focussed*, with mission assurance being at the core of the model's design. This innately links in with *threat-centric*, with temporal proactive threat analysis applied to mission scenarios that give operators the most up-to-date intelligence. UMA is not only *contemporary* in terms of its newness as a model, but also is inherently designed to integrate new, cutting edge and evolutionary technologies into each revolution of its life cycle, making it system agile. UMA also aligns with existing *best-practice* models, with the seamless integration of governance, standards and cyclic assessments of systems to continuously evaluate and uphold existing and future requirements. Finally, the nature of UMA encourages *strong partnerships* through the integration of different cyber subject matter experts towards a common mission-oriented goal. Cyber warfare operators have the opportunity to engage with specialists from the cyber engineering trade, in addition to linking with industry partners. This collaborative approach not only strengthens these individual relationships but has a positive emergent effect on the mission assurance culture as a whole.

Ultimately, these strategic level documents excel at providing principle-based guidance to the explanation and application of capabilities within the cyber domain; under which the UMA framework clearly aligns. They do not how-

ever tangibly and explicitly direct the ways and means to which these cyber outcomes can be achieved, and that is where options such as UMA stand out. UMA is an additional tool in the cyber toolset, adding and expanding beyond existing methodologies such as traditional vulnerability assessments, incident response, hunt and mission assurance. Its benefit is that it is built to be adaptable and encompass any of these tasks within its assurance cycle if required, making it less prescriptive and more descriptive in nature. Whilst it may not suit all mission sets, the UMA model provides a new mission-holistic approach to cyber defence that excels beyond the limitations of existing models and directly aligns with prevailing ADF strategic requirements.

7. Future work and conclusions

Mission systems, national critical infrastructure and essential services have interdependent reliance on cyber systems. To enhance technological innovation and achieve technological advantage for air superiority, Air Force must have mission assurance through the cyber domain. In extended operational circumstances, this mission assurance approach must be scalable, sustainable and adaptable in order to ensure mission survivability in contested environments.

Traditional cyber security approaches prioritise system security, whilst mission assurance approaches instead prioritise the delivery of essential mission services to the parent organisation. Historical research within the mission assurance space has been relatively limited to methodologies to conduct tactical mission assurance and assess organisational risk through this lens. These perspectives are temporal in nature, bounded by mission sets, space and time.

This paper extends and enriches this body of knowledge by presenting a UMA framework, which provides a holistic long-term approach to applying mission assurance principles to systems beyond discrete mission sets. The UMA is designed to be implemented cyclically with adaptive learning attitudes, to enable continual mission assurance over time that prioritises system resilience to emergent phenomena. This makes it well suited for environments where critical operations must be assured continuously, including military forces, financial services, power infrastructure, healthcare and emergency services. The framework builds mission resilience as a fundamental output, which is supported by its adaptability and scalability, and its contributions to sustainability and survivability.

Opportunities for future work within the scope of UMA include building out a comprehensive second-level architecture for each phase of the framework, as this is currently descriptive and not prescriptive. The development of such an architecture would provide more fidelity for mission assurance assessments and would build upon methods previously developed and described in the literature. This would improve the model's reliability across different user implementations based off skill and prerequisite knowledge, building model robustness and fitness for purpose.

Ultimately, the UMA framework offers a novel approach to applying long term mission assurance effects to critical service sectors in order to develop systemic resilience and adaptability over time. It equips defensive cyber teams with a structure through which they can understand the mission priorities they are trying to protect, translate those into cyber protection priorities, apply their defensive actions, and implement change at the policy and cyber infrastructure level. By completing iterations of the UMA cycle over time, service-critical organisations can have increased trust in the robustness and resiliency of their essential services against emergent phenomena, such as outages and cyber-attacks.

From an Air Force perspective, the UMA framework poses an opportunity to scope assurance in the cyber domain beyond tactical tasks, into strategic long-term assurance that is resilient to the turbulence of contested environments. Whilst consistent with Australian cyber-worthiness paradigms, it is also consistent with the broader international processes and provides a more expansive option for mission-focussed cyber operations. It offers an approach to defensive cyber activities that is compatible with commander's intent and delivers effects that prioritise the survivability of air missions above system security. In this way, applying UMA through the cyber domain directly contributes to the strengthening of air power.

Submitted: September 18, 2025 AEDT. Accepted: December 05, 2025 AEDT.

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Supplementary Materials

Prioritising Mission Survivability through Defensive Cyber Operations: A Unified Mission Assurance Approach

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Visser, L. (2026). Autonomy and the Future of Australian Air Power: Artificial Intelligence, Decision Making, and the Human Operator. *Contemporary Issues in Air and Space Power*, BP55958540. https://doi.org/10.58930/BP55958540

Air Power

Autonomy and the Future of Australian Air Power: Artificial Intelligence, Decision Making, and the Human Operator

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Keywords: Artificial Intelligence, Decision-making, autonomous weapons, future conflict, Air Power

https://doi.org/10.58930/BP55958540

In modern conflict, the Royal Australian Air Force (RAAF) requires a decisive edge and the on-boarding of new capabilities will unmistakably sharpen the RAAF's ability to deliver precise effects. Foremost among those capabilities is artificial intelligence (AI) and its contribution to air power autonomy. Here, I explore three categories to illustrate how autonomous systems could be used: (1) command autonomy; (2) functional autonomy; and (3) where a human operator sits in the control loop. These categories are assessed using hypothetical scenarios to assess the integration of AI and autonomous decision-making with a human operator. A case is made that despite the availability of new capabilities, their integration with a human operator will remain critical to provide decisive edge in the future. A careful assessment of autonomous processes reinforce the delegation of a human in the loop as the ultimate decision-maker, in line with doctrine.

1. Introduction

On 9 August 1945, President Harry Truman dwelled on the decision to use nuclear bombs on Japan in World War II. He wrote to Senator Richard Russell, "…I am not going to do it unless it is absolutely necessary… My object is to save as many American lives as possible but I also have a humane feeling for the women and children in Japan" (Truman, 1945). Truman's dilemma is an example of the extremes of presidential decision-making in conflict, contemplating the use of an unknown wartime technology and coming after years of intense fighting throughout World War II. Nevertheless, nearly 80 years later, the integral human element of Truman's decision-making remains salient, reflected in contemporary debates over proposals to prohibit autonomous systems from initiating nuclear launch without meaningful human control (Klare & Rostampour, 2023).

We conjure overwhelming images when characterising a modern conflict zone: fleets of drones tethered by fibre-optic cables across fields in Ukraine; fifth-generation aircraft decimating an entire country's air defence infrastructure without loss; satellite constellations enabling mesh networks; and uncrewed aircraft loitering for persistent full-motion video. The image of a modern conflict zone is fast, information-dense, and deeply dependent on networks. The obvious response is to question how human decision-making will keep up—and the obvious criticism is that humans are too slow, may make mistakes, and might lose. The obvious answer is to turn to machines, and with the rise of artificial intelligence (AI), the temptation to integrate AI into modern conflict aligns with the expectation of a decisive edge.

In this modern conflict, the Royal Australian Air Force (RAAF) does require a decisive edge. On-boarding new technological capabilities will sharpen the RAAF's ability to deliver precise effects. Current RAAF capabilities include: crewed multi-role stealth fighter such as the F35A Lightning; crewed aircraft for advanced airborne intelligence, surveillance and reconnaissance (ISR) and electronic warfare such as the MC-55A Peregrine; multi-role, uncrewed combat aerial vehicle such as the MQ-28 Ghost Bat; high-altitude long endurance uncrewed aerial vehicle (UAV) such as the MQ-4C Triton; and standoff weapons such as extended range joint air-to-surface standoff missile (JASSM-ER). These capabilities describe a future of warfare for the RAAF that will provide, and depend upon, extensive situational awareness at ever-increasing ranges, a key priority in the Integrated Investment Program 2024 (Department of Defence, 2024), with the lynchpin being accurate information at the right time, delivered fast. Militaries worldwide are adapting decision-making processes to provide a fighting edge. In one example, Brînză (2025) argues that AI's role is central to emerging decision-making situations in modern conflict and must be considered, but must be paired with security and ethical safeguards. And so, the RAAF turns to autonomy and to the question: When information is overwhelming and speed is critical, can AI be trusted to make an autonomous command decision?

In a military context, there are levels of autonomy already carried out by human-operators as they relate to decision-making. There is system level autonomy, whereby decision-making is enabled by policy and direction set at the strategic level and guided by senior decision-makers. There is delegated autonomy, whereby decision-making power is deferred to an autonomous process to follow set direction and rules in the absence of input. Finally, there is operational and tactical autonomy, whereby decision-makers are empowered to execute decisions to achieve intent, and an autonomous process focuses on restrictions and limitations to set its path to achieving a commander's intent. For this paper, autonomy is defined as the ability to execute desired tasks in order to achieve a commander's intent with minimal input and in the absence of additional

guidance or direction. The focus is specifically on air power and the human implementation of air power effects.

There are a number of assumptions in arguing that AI and autonomous decision-making are inevitable in the application of air power. Such as, reliable sensors providing accurate and timely information; contested information environments whereby communication is degraded and disrupted; a shift in political and legal constraints on the military use of autonomy; and, the capability and resources to research, acquire and implement autonomous processes faster than an adversary. This article focuses on the integration of AI and autonomous decision-making with a human operator, rather than the replacement. The sources in this article are contemporary and use a doctrinal and literature-based synthesis: reviewing publicly available Australian and allied doctrine, official program releases, and open research to derive a practical framework and vignettes for autonomy in RAAF operations.

2. Autonomy in contemporary air power

Aviation has gradually delegated discrete functions to machines, especially where aviation safety is the foremost concerned. However, autonomous functions have proliferated as information requirements have increased and distances have expanded across any area of operation. In civil aviation, aircraft have progressed from heavy operator input to more streamlined autonomous processes to ensure that modern aircraft, especially for the rate of effort that civilian aviation maintains, create a safe flying experience. Autopilot is the quintessential example of an autonomous process in aviation that has replaced constant operator input and has enabled long-distance aviation. Autopilot includes a diverse range of automated processes that ensure routes are maintained in conjunction with an array of information inputs, up until the critical moment of taking off and landing, where a human operator will operate the aircraft. However, these autonomous processes have not entirely replaced the human operator. They have augmented the ability of a human operator to extend their endurance and enhance their awareness without taking away the function of a human operator to takeover should it become necessary at any moment. These autonomous processes are integrated with human operators.

Autonomy in aviation already demonstrates the enhancement of operator-centric processes through the application of autonomous processes aimed at enhancing the human operator. In a military context, these autonomous processes continue to evolve and embed themselves in processes whereby accuracy and efficiency are demanded by decision-makers and human operators. The interconnectedness of modern fighter jets to an ecosystem of information provided by uncrewed platforms demonstrates a progressive delegation of discrete functions to autonomous machines, enabling speed and precision, but still centred on a human decision-maker. Likewise, the rise in drone warfare has demonstrated a future of conflict whereby swarms of lethal autonomous aircraft can be coordinated to produce lethal effects – planned by human operators. Added to these technological improvements, the rise of AI has accelerated the enabling of data fusion, pattern recognition, and dynamic replanning in contested environments. However, despite these technological advancements, the criticality of a human operator remains at the centre of decision-making.

3.1. Command autonomy

There is an inherent hierarchy to military decision-making, devised in orders and explained with intent, to ensure that military actions are understood and actioned to achieve desired outcomes. Command authority sets direction, tone, discipline, tempo, and provides the justification for action. Adding autonomy to command authority may provide opportunities for commanders at every level to organise oversaturated information and competing demands more quickly and precisely—especially in a force so reliant on information for a competitive edge

However, the intangible elements of command authority are responsibility and accountability. Who is blamed if something goes wrong, and who bears the consequences? These elements are conferred to commanders with their authority. Weighing responsibility and accountability is a subjective, ethically and morally bound judgement reflecting an individual's leadership. International humanitarian law constrains the application of force, including proportionality and civilian protection—requirements that underscore the need for human judgement (Négyesi, 2025). AI may not reliably fulfil such principles without human oversight, particularly where target discrimination and proportionality are at stake (Négyesi, 2025).

There is nonetheless a case for the autonomous commanding officer in the sense of autonomy-enabled command support. Air power often fights at long range in dense, cluttered electromagnetic environments that can cut off tactical elements from higher headquarters. Australian doctrine already accounts for this with centralised command and decentralised execution supported by distributed control, contingent on shared understanding and commander's intent (Australian Defence Force [ADF], 2023 p. 88). Under protracted, distributed conflict, air power may execute disaggregated from main bases under agile operations and must execute orders as delivered. In such conditions, autonomy can help interpret data, propose courses of action, and maintain alignment with intent—even beyond a complete air tasking cycle—provided a human retains authority for judgement and direction).

3.2. Functional lethal autonomy

Separate to the subjective art of decision-making responsibilities and accountabilities, there is the objective appreciation of rational autonomous systems that are programmed to make decisions. The rise of AI has been rapid, and the pursuit of self-learning AI tools is strong. At the consumer level, AI has created the impression that small, non-consequential decisions can be delegated to ease everyday life. The military debate is more consequential. Advocates contend AI can accelerate autonomy for vehicles, targeting, surveillance, aerial combat, and cyber oper-

ations, improving interpretation and response time during crises (Agarwala, 2023). Others emphasise that AI's predictive capabilities can improve planning, coordination, and simultaneous execution, but still require careful human direction (Agarwala, 2023).

Technology is incrementally progressing towards a scenario where lethal force can be conducted autonomously. In Ukraine, a ground-based robotic system outfitted with a .50 calibre machine gun, operated remotely by a human operator, held back Russian troops along a line of offensive for several months (Khomenko, 2025). The robotic system was implemented to minimize risks to Ukrainian troops who are at a numerical disadvantage compared to Russian Forces. However, military industry is clear that the implementation of autonomous programming within the lethal robotic systems is the next step, if not already iteratively being utilised within the fast-paced Ukrainian theatre. One example is the Sky Sentinal system used in Ukraine to autonomously find, track, and provide firing solutions as an anti-drone capability, shooting down Shahed drones and even, in some cases, cruise missiles (Baker, 2025). The bridge between AI enabling lethal force and deciding to use lethal force is narrowing in modern conflict.

At its core, AI is about data—fusing, collating, and summarising to support decision rules and generate answers. There are opportunities in using AI as a form of autonomy for the RAAF, especially in data-rich environments where speed matters. As Tadjdeh (2020) summarises from United States Air Force leadership, the aim is to streamline repetitive tasks and free human cognition for higher-order reasoning and judgement. The obvious extension in air power is greater autonomy in uncrewed systems. These systems already exist and have been used in recent conflicts. For example, public reporting describes target-recommendation systems in Israel that accelerate ISR-to-strike workflows while retaining human decision authority (D'Evereux, 2024).

3.3. The human in the loop

Ultimately, the role of autonomy in Australian air power comes down to individual operators delivering effects. As Goztepe et al (2015) note, the human factor remains a determiner even in sophisticated decision systems and intuitive skills bridge the gap between machine output and human judgement.

Four subjective aspects underscore the need for a human in the loop. First, prioritisation: while data collection can be automated, deciding what matters most is inherently contextual and subjective, shaped by factors like personalities, politics, international relations, economic effects, and violent conflict. Second, intent: capability can be measured objectively, but the intent to deploy an aircraft, strike a target, or disrupt an operation remains a human judgement. Third, piloting and control: while some responsibility is delegated to automation, keeping a human operator in the loop preserves subjective decision-making in high-stakes, high-tempo situations—and reflects the observe-orient-decide-act (OODA) loop's human-centred design (Boyd, 1996). Fourth, human reaction: subjective responses to complex inputs can generate 'micro-doses of chaos' that create disruption and opportunity. For the RAAF, creating opportunities to generate such micro-doses of creative chaos through aviator ingenuity makes spaces for decisive action against a better-equipped adversary.

4. Hypothetical operational case studies

The following case studies help to illustrate hypothetical scenarios where autonomous processes augment human operators to create an operator-centric operational environment where AI does not make decisions, but does enable human operators to make the best decision at the right time. Here, I explore three scenarios: (1) a long-range strike under degraded communications; (2) teaming between manned and unmanned aircraft; and (3) distributed ISR informing a strike package. Each scenario explores how autonomous processes create an operator-centric autonomous environment and assessed with respect to functional autonomy, operator judgement, trust mechanisms and execution. Here, functional autonomy refers to the autonomous processes operating within existing capabilities. Operator judgement refers to the human operator's decision-making, complimented by functional autonomous processes. Trust mechanisms refer to how functional autonomy and operator judgement is integrated to enhance decision making. Finally, execution refers to the outcome of a functional autonomy and human judgement

A careful calibration of autonomous processes reinforce the delegation of a human in the loop as the ultimate decision-maker, in line with doctrine. Calibrating autonomous processes also helps to emphasise how critical it remains for the RAAF to exercise familiarity with autonomous processes in order to bolster trust in human made decisions and identify space for a human operator to exercise their subjective decision-making autonomy.

4.1. Strike under degraded communications

Scenario: In a high-threat environment, an F-35A pair receives a pre-planned strike tasking against a hardened facility using JASSM-ER. Shortly after entering the area of operations, the aircraft experience severe communications degradation, reflecting the expected contested electromagnetic environments in which the RAAF will operate (Vedula et al., 2023).

Functional Autonomy. The F-35A's mission systems continuously assess the threat environment via integrated sensor fusion in line with the platforms mission system design. Once released, JASSM-ER autonomously refines approach and aim-point via on-board guidance and survivability features designed for GPS-challenged environments (Hansen, 2006).

Operator Judgement. The pilots retain authority to proceed, abort, or re-task in line with mission command principles that emphasise human judgement under degraded command and control (C2). With limited contact from higher headquarters, they assess fuel, threat levels, and collateral risks from cockpit data and decide to continue with an adjusted ingress to reduce exposure.

Trust Mechanisms. Training intimately with the platforms operating systems, aided by clear displays of system status and logic within the pilot interface, builds trust in autonomous processes. The aircrew validate that autonomy-driven updates remain within commander's intent and pre-briefed parameters before weapon release.

Execution. From standoff range, the F-35As release JASSM-ER and the weapons navigate a contested environment (Henley, 2026). The aircraft withdraw under emissions control with no further C2 contact, demonstrating an autonomy model where machines handle adaptation and optimisation, while humans exercise intent, risk judgement, and go/no-go authority.

4.2. Manned–unmanned teaming (MUM-T)

Scenario: During a major air campaign, an F-35A element conducts a Suppression of Enemy Air Defence (SEAD) mission alongside uncrewed MQ-28A Ghost Bats. The operating environment is dynamic, with pop-up surface-to-air threats and heightened radar activity typical of modern integrated air defence systems.

Functional Autonomy. Ghost Bat employs on-board autonomy to maintain formation and conduct sensor-led search and classification (Boeing, n.d.). Through its autonomous functions, Ghost Bat produces a machine-generated recommendation to adjust formation geometry and sensor tasking to manage an emergent threat.

Operator Judgement. The F-35A mission commander evaluates the recommendation against mission priorities and imposes human-defined constraints, retaining authority over lethal effects and broader sequencing in line with concepts of operator supervision within a MUM-T system (Howitt, 2009). The mission commander authorises the Ghost Bats to execute micro-level manoeuvre decisions while maintaining control of the overall execution of the SEAD plan.

Trust Mechanisms. Building trust in a MUM-T process requires repeated training events, transparent confidence indicators, and consistent autonomous behaviour to develop human and machine teaming principles (BAE Systems, n.d.; Mayer, 2021).

Execution. Ghost Bat executes the authorised manoeuvres to manage radar attention, enabling the F-35A formation to prosecute SEAD tasks while the human commander retains responsibility for effects and risk. This case study illustrates shared autonomy where humans set direction and boundaries and overall discretion and judgement for the mission, and autonomous systems deliver speed, optimisation, and threat-reactive agility.

4.3. ISR-to-Strike

Scenario: As part of distributed maritime surveillance, an MQ-4C Triton and an MC-55A Peregrine operate as a paired ISR constellation monitoring a contested archipelago, according to their platform roles and the requirements of maritime patrol and reconnaissance missions (Laird, 2023). An unexpected hostile surface action group enters the area of operations. Intelligence gaps emerge as the vessels disperse and vary emissions.

Functional Autonomy. The MQ-4C autonomously reprioritises sensor tasks based on what is detected, while the MC-55A fuses multi-source ISR to tag vessels for further attention—per open descriptions of the MQ-4C's autonomous sensor management and MC-55A's strategic ISR role.

Operator Judgement. The ISR mission commander evaluates the reprioritisation and retains authority to escalate to a strike package, balancing proportionality and reporting confidence. They further consider whether additional information is required before recommending action.

Trust Mechanisms. Consistent machine performance in autonomous functions correlated with track-quality indicators and clear explanations for any autonomous prioritization builds trust and confidence. Prior exercises and rehearsals with similar logic where human operators are involved in scenarios where autonomous processes augment their capabilities further reinforce human confidence in autonomous processes.

Execution. The ISR constellation executes the autonomous reprioritisation while the mission commander informs higher headquarters. Where a strike package is then tasked, it receives a target derived from machine-generated information and human validation, demonstrating a division of labour where autonomous processes conduct continuous sensing, fusion, and prioritisation, and humans apply operational judgement and authority to effect – ensuring the appropriate decision makers are informed (Laird, 2023).

5. Progressing towards operator-centric autonomy

Throughout the case studies, AI performs discrete tasks and human operators remain in charge of command decisions. Therefore, the next step for AI is to ask: Can AI be trusted to make a command decision? Experiments demonstrate significant potential for complex autonomy in air operations. For example, the Have Raider demonstration showed autonomous planning and execution of strike missions, formation flight with a manned aircraft, and dynamic reaction to changing threats (Lockheed Martin, n.d.). Proponents argue effective manned–unmanned teaming reduces cognitive load and allows war fighters to focus on creative and complex planning (Lockheed Martin, n.d.). In circumstances where a command decision results in the delivery of lethal effects that are likely to include human casualties, the primacy of a human decision maker remains. The future of autonomy in Australian air power ultimately resides with aviators who will make critical decisions daily. Operator-centric autonomy will be achieved through equipping operators with the tools and training to deliver effects more precisely and efficiently than the adversary—and through clear commander's intent that can be enacted even when cut off from higher command.

There are several recommendations that could be considered to progress towards operator-centric autonomy and increased lethality that would come through information

processing efficiencies enabled by AI, but not replacing operators and their decision making responsibilities.

Exercising degraded C2 environments. Air Force must prioritise exercising in environments where communication is degraded and information is disrupted. Integrating AI processes in these circumstances is critical for understanding the advantages of accelerated information processing and for understanding the limitations of technological input for decision-making if it were to become a standard process, highlighting the key-role of an operator in making decisions.

Practicing delegated autonomy and decision-making. Similarly to degraded C2 environments, specifically exercising the delegation of decision-making to different tasked entities will contribute to iteratively improving procedures and processes in degraded environments. In particular, practicing delegated autonomy and decision-making in subjective grey-areas are critical to ensure that human operators are making ethical, legal decisions enabled by AI, and the enabling effects of AI can be seen to be contributing to, not contradicting, ethical and legal decision-making.

Iterative tactics, techniques and procedures. Air Force should adopt software-style iterative development cycles for TTPs, replacing rigid, fixed-development approaches with continual refinement based on operational learning. An iterative development pipeline for TTPs can be red-teamed by AI to be understood and executed by operators. Further, the accumulated and accelerated number of serials exercised can expose procedural improvements at an increased rate.

"Micro-doses of creative chaos"— *exercising the unplanned and unexpected*. Instead of replacing the operator with artificial intelligence, and despite efficiencies that may be facilitated by AI in iterative planning, putting operators against AI planners with a focus on subjective decision-making presents an opportunity to exercise a creative chaos. This creative chaos is not easily replicated by AI. Shifting the emphasis from whether AI makes a better decision, and instead focusing on where a human operator decides differently, presents an opportunity to devise how a human operator might integrate into an AI enabled environment without being solely reliant on AI to execute.

On-boarding new capabilities while upscaling existing ones. The rapid pace of technological change puts pressure on legacy systems that have been acquired to do the job today, but might not be able to do the job tomorrow. The temptation to acquire the new capability as soon as it is available is compelling, but unsustainable to resource. There is required a shift in perspective towards capability management that emphasizes upscaling existing capabilities within what is possible in addition to on-boarding new capabilities to address emerging mission sets. Fundamentally, this approach can achieve two objectives: 1) air power is fight tonight capable and 2) air power has redundancy in processes, procedures and knowledge that might be enhanced with AI but in its absence can still be used to achieve a desired effect.

Operator-level integration with AI. Finally, there is an imperative need to exercise with AI enabling and assisting with decision-making in order to rapidly increase operator familiarity with AI processes but also to consolidate operator-centric integration with AI. Failing to exercise this integration now means that habits, processes and familiarity with AI will be gained through commercial use cases that individuals are already utilising and the implementation of AI into assisting decision-making processes will require a reprogramming of AI usage to ensure operators are capable of their own autonomous processes.

6. Conclusion

Truman displayed the intrinsically human element of decision-making during conflict as he was rationalising the use of a nuclear weapon in World War II, and the continuing debates around autonomous decision-making regarding the use of nuclear weapons goes to show that human decision-making during conflict matters. However, autonomous command support can enable commanders with information and analysis that improves decision-making. A human still, ultimately, pilots autonomous lethal machines either through programming or direct input. The decisive factor in future conflicts will still involve humans in decision-making and judgement because, ultimately, conflict remains a human endeavour suffused with subjective and emotive elements. AI should enable autonomous actions - it should not implement autonomous decisions. Somewhere, a human must still be in the loop to judge an action to be taken. Where a human remains in or on the loop autonomy should be integrated as a tool to enable decision-making, not to make decisions.

Submitted: November 28, 2025 AEDT. Accepted: February 24, 2026 AEDT.

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Air Power

Autonomy and Australian Air Power

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Keywords: Autonomy, Autonomous Collaborative Platform, Collaborative Combat Aircraft

https://doi.org/10.58930/bp55893452

Vol. 4, Issue 1, 2026

Australia's strategic requirements as articulated in the 2024 National Defence Strategy demand an innovative approach to air power that is constrained by geography and demography. This paper argues that Autonomous Collaborative Platforms (ACPs) and Collaborative Combat Aircraft (CCAs) are essential to overcoming challenges of combat mass, range, survivability and personnel constraints. Autonomy enables extended endurance, reduced reliance on vulnerable infrastructure, lower acquisition costs, and sovereign manufacturing that fosters resilience and innovation. CCAs such as the MQ-28A Ghost Bat enhance lethality and survivability, while large numbers of lower-cost ACPs provide affordable depth. Together, these systems – integrated with crewed aircraft and innovative operational concepts – position the Royal Australian Air Force to deliver sustainable combat power that is tailored to contemporary strategic realities.

1. Introduction

The Australian Defence Force (ADF) today faces a force design dilemma that it shares with all modern militaries – how to integrate uncrewed systems with differing levels of autonomy into force structures and operating concepts. The proliferation of uncrewed systems in recent conflicts has led analysts to draw often-conflicting conclusions on their effectiveness and utility in modern warfare, as well as how best to structure and operate a force of crewed and uncrewed platforms.

The air domain is no stranger to this dilemma caused by emergent technology, where force design based on analysis drawn from previous conflicts often has unanticipated outcomes. This is particularly true when the nature of conflict and the technology path differ from what was envisioned, as was found (and still debated) with concepts such as strategic bombing in World War II. The initial performance of an Air Force in a crisis or conflict is often determined by how well the nature of the conflict, and the development of the technology, are understood and anticipated, and how well the force can rapidly adapt.

This paper explores the employment of uncrewed and autonomous systems in Australia's air domain through the lens of our unique strategic context, including geography, demography and strategic objectives. This paper will explain how Australia's geography and demographic realities make autonomous systems, particularly Autonomous Collaborative Platforms (ACPs), essential to delivering effective national air power within its broader defence strategy, enabling significant capability advantages when combined with emerging concepts such as Agile Combat Employment (ACE) as well as offering the potential for rapid capability expansion in the event of crisis or conflict.

2. Australia's strategic context

2.1. Strategic guidance

At the outbreak of World War II, the Royal Australian Air Force (RAAF) had approximately 250 aircraft – only slightly less than that are in service today, although the relative quality and capability of today's Air Force is significantly greater. The 1939 permanent Air Force had approximately 3,100 personnel from Australia's population of 7 million (0.05%) (Gillison, 1962, pp. 55–57). By 1944 the Air Force had reached over 182,000 personnel (2.5% of the population) and over 6,200 aircraft (Australian War Memorial, 2025). The personnel strength and number of platforms figures represent the force design decisions of a government at the extreme ends of the spectrum of warfare, and are a useful guide when framing the problem space for 2026. Of interest, today's Air Force numbers once again are close to 0.05% of the population, a similar proportion to 1939.

At first glance, a RAAF with over 6,000 aircraft seems far beyond the needs and capacity of Australia in 2026. A comparison of the Air Force's activities in 1944 with the expectations of the Government in the 2024 National Defence Strategy (NDS), however, reveals many similarities. All the major roles of the Air Force in 1944 could be captured with the NDS five tasks, namely:

- Defend Australia and our immediate region;
- Deter through denial any potential adversary's attempt to project power against Australia through our northern approaches;
- Protect Australia's economic connection to our region and the world;
- Contribute with our partners to the collective security of the Indo-Pacific; and

- Contribute with our partners to the maintenance of the global rules-based order. (Department of Defence, 2024, p. 25)

Naturally this does not mean Air Force should immediately seek to replicate its 1944 size and capability – much has changed in Australia politically, economically, socially and militarily since 1944 and such a force would be difficult to justify and sustain. These figures, however, should be considered a target in the event of escalation should Australia once again be involved with a great power conflict in the Indo-Pacific, and although Australia has evolved significantly as a nation since 1944, its geography remains unchanged.

2.2. Geography

There are two geographical frames to consider in this analysis: the first is Australia's own geography, including its distribution of population and infrastructure, with the second frame the geographic area described in the NDS as the *primary area of military interest*. The NDS defines this area as 'the immediate region encompassing the Northeast Indian Ocean through maritime Southeast Asia into the Pacific. This region includes our northern approaches' (Department of Defence, 2024, p. 21). The NDS goes on to state that this area should be the focus of the 'Government's defence strategy, capability plans and resources' (Department of Defence, 2024, p. 22) where the ADF should be able to project and sustain deployed forces, as well as maintain a high level of situational awareness.

These two geographic frames are vast and critical to understanding Australia's strategic context:

- *The primary area of military interest* defines the Government's expectation of the areas and distances at which the ADF may have to project force in support of the five tasks.
- *Australia's geography* defines the operating bases and means from which this force is generated and sustained.

For example, threats to shipping, critical to Australia's economic connection and the third ADF task in the NDS, may occur at many locations throughout the primary area of military interest, many thousands of kilometres from Australia's population centres or even forward operating bases. For task two (deterring through denial), existing and emerging long-range weapon systems allow potential adversaries to project power against Australia from distances throughout the defined area and beyond. The ADF and Air Force must be able to generate sufficient combat mass to deter, shape and respond to these threats, and the ability to generate this combat mass at range remains one of the key challenges for Defence force designers and planners.

The ADF's Air Domain Concept ASPECT clearly articulates the challenge in Australia's geographical frame:

> Despite a vast territorial landmass and surrounding geographic areas of interest, Australia is one of the world's most sparsely populated countries … The population is concentrated in urban areas, particularly on the eastern, south-eastern and southern seaboards … ADF force generation sites and the national support base, essential for ADF support and sustainment, are also concentrated in these population centres. (Department of Defence, 2025, p. 3)

Many Australian force design decisions, including the development of the RAAF bare bases in northern Australia and most recently the MQ-4C Triton and AUKUS conventionally armed nuclear-powered submarine programs have been influenced by this reality. Australia has developed an enviable expeditionary capability as a necessity, however, the sheer size of the country and primary area of military interest challenges the ADF's reach and logistics capability. For Air Force in particular, the decision to seek qualitative superiority has resulted in a force structure consisting of a relatively small number of high capability platforms, many which come with a significant support and basing overhead. Air Force's small number of platforms can generate significant air power effects but only over an area constrained by platform, sensor and weapon range, logistics capability and personnel numbers. Rapid expansion to a much larger order of battle of similar types of aircraft would be difficult for a country with a large area and modest population such as Australia. The increased number of operational and support crews required would challenge Air Force's ability to recruit and train sufficient personnel. This tension between geography (distance) and demography (population) remains one of the key challenges for force design in Australia and for the RAAF.

2.3. Combat mass

Another key challenge that needs to be considered in Australia's strategic context is the combat mass required against potential adversaries. Deterring or defeating a more capable adversary requires a greater combat mass to minimise risk or avoid unacceptable loss of platforms and personnel. Australia's demography again comes into play here – a country with a small population is less able to accept losses of aircraft and trained personnel in conflict, particularly with a small number of complex systems that require specialised training and qualifications. Concept ASPECT acknowledges that 'Australia now faces potential adversaries with advantages in scale, technology and economic weight …These actors have developed potent capabilities designed to counter how the Australian Defence Force (ADF) develops, employs and sustains air power' (Department of Defence, 2025, p. 7). The ability to generate combat mass over the primary area of military interest while concurrently protecting and preserving capability is an additional dilemma for the ADF and Air Force.

2.4. Allies and partners

The final aspect of Australia's strategic context in this brief examination is the impact of allies and partners. The NDS emphasises that 'Australia's Alliance with the US is fundamental to our national security and the ADF's capacity to generate, sustain and project credible military capability' (Department of Defence, 2024, p. 46). The NDS also

notes the importance of strengthening engagement with the US for acquisition of technology and capability as well as to 'drive interoperability and interchangeability in the development of the ADF's force structure' (Department of Defence, 2024, p. 46). The need for interoperability with the US requires that the ADF's crewed and uncrewed systems must be able to operate together effectively with similar allied forces, both technically and procedurally. Interoperability is strong with current capabilities in service, and must be a key consideration for future acquisitions, particularly with sovereign systems designed and manufactured in Australia. Australia cannot afford to fall behind its allies and partners in any aspect of its order of battle, with trust being a key consideration for coalition operations with uncrewed systems.

This strategic context, including geography, demography, and allied and adversary considerations, presents a force design dilemma for the ADF and Air Force, for which uncrewed and autonomous systems have been frequently called for as a solution. The use of these systems in the Australian strategic context will be explored in the next section of this paper.

3. Understanding uncrewed and autonomous systems in Australia's strategic context

3.1. Terminology

Terminology for uncrewed and autonomous systems in the air domain has been constantly evolving with different services, nations, coalitions and industry favouring different terms. This section will explore the key terms currently used in Australia, namely Autonomous Collaborative Platforms (ACPs), and Collaborative Combat Aircraft (CCAs).

Autonomous Collaborative Platforms (ACPs) is a term favoured by UK and NATO doctrine, with the following ACP definition from the *Royal Air Force Autonomous Collaborative Platform Strategy*:

> A series of uncrewed vehicles which demonstrate autonomous behaviour and are able to operate in a collaborative manner with other assets. (United Kingdom Ministry of Defence, 2024, p. 15)

The UK definition is supported by the NATO definition of **autonomy**:

> A system's ability to function, within parameters established by programming and without outside intervention, in accordance with desired goals, based on acquired knowledge and an evolving situational awareness. (United Kingdom Ministry of Defence, 2024, p. 16)

The current ADF definition of ACP is less prescriptive: 'Any uncrewed vehicle that is primarily controlled by on board autonomy and/or artificial intelligence software systems' (Department of Defence, 2025, p. 33). The distinction between the two definitions is subtle and reflects the source documents, however, it is important to note that neither definition requires an ACP to be fully autonomous – 'demonstrat[ing] autonomous behaviour' (UK) and 'primarily controlled by on board autonomy' (ADF).

These definitions allow for different levels of autonomy, a key concept to consider when integrating uncrewed systems into force structures and operating concepts. There are currently no categories for autonomy in the air domain defined in ADF doctrine, so it is useful to consider the international industry standard categorisation from the Joint Authorities for Rulemaking of Unmanned Systems (JARUS). Automation Levels for Unmanned Aerial Systems from the *JARUS Methodology for Evaluation of Automation for UAS Operations* are summarised in **Table 1**.

Commanders in any domain must have an effective understanding of these levels and their operational implications when employing a force of uncrewed and crewed systems. Similarly, an agreed framework for defining the levels of autonomy within the ADF and Australian Government, as well as with allied and partner forces, is critical in developing integrated policy, operational procedures and risk management activities prior to the employment of these systems.

There are numerous other criteria currently used to classify uncrewed and autonomous systems including by size, mission and type of propulsion. From the force design perspective, it is useful to also categorise uncrewed systems in terms of their expected survivability and expendability. The RAF proposes the following tier system for ACPs:

- **Tier 1 disposable.** ACP with a life-cycle of one or very few missions.
- **Tier 2 attritable.** ACP that are expected to survive the mission, but losses are acceptable.
- **Tier 3 survivable.** ACP of high or strategic value; their loss would significantly affect how the RAF will fight. (United Kingdom Ministry of Defence, 2024, p. 5)

Both the level of autonomy and the ACP tier have a significant impact on the design, production and cost of uncrewed platforms, as well as how they are best integrated with existing and future systems in a multi-domain force.

Collaborative Combat Aircraft. The other commonly used term in the autonomous system discourse is Collaborative Combat Aircraft (CCA), a term more favoured in the US that is yet to have a formal definition in ADF or allied doctrine. CCAs are 'large uncrewed aircraft (UAS) powered by jet engines' and designed to operate with 'new and existing crewed fighter jets to enhance operations in contested airspace' (DiMascio, 2025). An Australian definition may differ from this as the concept is further developed in the ADF. CCAs may be considered a subclass of ACPs with Collaborative Reconnaissance Aircraft, Collaborative Bomber Aircraft, Collaborative Mobility Aircraft and Collaborative Training Aircraft. (Anderson, 2025) The MQ-28A Ghost Bat is considered a CCA.

3.2. Key considerations for autonomy

Two key considerations for autonomy in the force design context can be derived from these definitions and categorisations.

Table 1. JARUS Levels of Automation (Joint Authorities for Rulemaking of Unmanned Systems, 2023, pp. 21–24).

Automation Level		Description	Human-Machine Teaming
0	Manual Operation	The human manually executes the function, receiving no support from the machine.	Human led
1	Assisted Operation	The machine operates in an out-of-the loop supporting role to the human in executing the function.	Human-In-the loop
2	Task Reduction	Control and monitoring are shared between the human and the machine.	Human-In/On-the loop
3	Supervised Automation	The machine executes the function under the supervision of the human who is able to monitor and intervene with the operation at any time.	Human-In/On-the loop
4	Manage by Exception	The machine executes the function, alerting the human in the event of an issue. The key distinction from lower levels is the human is no longer required to continually monitor the function in real time.	Human-On-the loop
5	Full Automation	The machine is fully responsible for function execution, and the human awareness of dynamic operational parameters is limited or non-existent.	Human-Off-the loop

The first consideration is that autonomy is not only a function of the hardware and software on the platform, but how it is employed. Systems which may be capable of Level 5 Full Automation may be employed in a Level 1 mode if required by the mission, risk assessment and/or rules of engagement. Similarly, the hardware, software and, critically, the test and evaluation requirements required for an autonomous decoy are significantly less than for an air combat or strike platform. This in turn drives the cost and speed to capability, critical in the event of rapid escalation or adaption. Force designers need to be able to assess the relative values of large numbers of low-end and single-role systems against high-end and/or multi-role systems in the likely scenarios and operating environments.

The second consideration is the balance between systems that are remotely operated and autonomous. Remotely piloted aircraft that are directly controlled by an operator are generally simpler and cheaper as they do not require the software and hardware that enable system autonomy. These aircraft should be also considered in the force structure but have two main disadvantages in the Australian context. Remote operation requires secure communication links that can be difficult to maintain over the extreme ranges and are vulnerable to compromise by adversary action. Additionally, autonomous systems require fewer personnel to operate as they approach Level 4 and 5 in the JARUS framework, making them suitable for an Air Force with fewer personnel. This saving could only be realised, however, if the system autonomy is suitably trusted and meets the appropriate legal and ethical requirements for a given mission and objective.

4. The importance of autonomy in the Australian strategic context

4.1. Key advantages of autonomy

On 8 December 2025, a RAAF MQ-28A Ghost Bat successfully launched an Advanced Medium Range Air-to-Air Missile (AMRAAM) against an airborne jet target for the first time. Following the launch, the Chief of Air Force, Air Marshal Stephen Chappell, noted:

> [The MQ-28A] will provide three things. It's going to give us the combat mass to contribute further to the integrated forces strategy of denial. It's going to give us enhanced lethality of our crewed platforms. And it's going to give us enhanced survivability of our crewed platforms as well. So, a real force multiplier and combat mass in a way that we haven't previously had in the Royal Australian Air Force. (Conroy et al., 2025)

This effectively captures the key effects CCAs have in the battlespace and highlights the value of ACPs in achieving the objectives in the National Defence Strategy. The key CCA advantages of mass and increased lethality and survivability are an effective response to many of the issues highlighted in the previous section, particularly regarding combat mass and survivability of complex combat platforms and personnel. These are not the only attributes of ACPs and CCAs that make them highly suited for Australia's strategic context. The following paragraphs will briefly summarise other key reasons why this technology should be part of the Air Force's order of battle.

4.2. Range and endurance

The key advantage that ACPs have when considering the extreme distances in the primary area of military interest is range and endurance. ACPs are not limited by human crews and can remain airborne as long as they have sufficient fuel and munitions. ACPs also have the potential to be less reliant on infrastructure than current crewed systems and may be easier to store and deploy. Disposable and attritable ACPs will have greater range and endurance than platforms that will need to be safely recovered and would be a new operating paradigm for the Air Force.

4.3. Agile combat employment

An advantage of ACPs – linked to their reduced reliance on infrastructure – is the potential for Agile Combat Employment (ACE). ACE is an emerging US Air Force operating

concept that 'shifts operations from centralized physical infrastructures to a network of smaller, dispersed locations that can complicate adversary planning and provide more options for joint force commanders' (U.S. Air Force, 2022, pp. 3–4). The concept is designed to increase survivability and reduce the effectiveness of enemy targeting by moving aircraft away from vulnerable main operating bases. This agile approach to operations is highly suited for Australia's northern geography and force structure (Chappell, 2025), with the RAAF exercising the concept since 2023. ACE introduces additional logistics, personnel and command and control requirements that may be difficult to address with complex systems such as the F-35A. ACPs, however, particularly those specifically designed for distributed operations, can generate sustained combat mass in a threat environment using ACE, with survivability enhanced though effective dispersal and deception.

4.4. Cost

A core objective of ACP and CCA programs is reduced cost when compared with conventional crewed platforms – the MQ-28A goal is to cost 10% of a crewed combat aircraft (Conroy et al., 2025). This allows more platforms to be acquired and further increase combat mass, resilience and combat depth. The Australian Strategic Policy Institute (ASPI) special report *Aligning for advantage: Integrating autonomous systems into the Australian Defence Force* concludes:

> A mix of large numbers of low-cost autonomous systems to provide mass, together with an ability to collaborate and team with higher end autonomous and uncrewed systems and traditional crewed platforms, needs to be the goal of ADF policy in the acquisition of future autonomous capability. Defence's focus on high-end platforms, such as the Ghost Bat and Ghost Shark, is relevant and important, but it needs to be complemented by the acquisition of larger numbers of lower cost autonomous systems. (Davis, 2025, p. 15)

This is further supported by the 'heterogeneous air power model' as proposed by Layton (Layton, 2025).

The lower cost systems mentioned in the ASPI report are not necessarily less capable, and the cost of autonomous systems can be reduced if single-role systems are considered as well as multi-role platforms. Conventional combat aircraft such as the F-35 must be multi-role due to their large cost and support requirements, however, savings may be made with single-role ACPs such as decoys, Intelligence, Surveillance and Reconnaissance systems and Collaborative Transport Aircraft. The level of autonomy, and hence software and sensor requirements, may be less in these roles, reducing cost and complexity and allowing for a larger number of systems. A coordinated effort among allies to develop and test different types of single-role ACPs could also reduce costs across several platforms.

4.5. Sovereign manufacturing and adaptation

A key lesson from the MQ-28A program is that ACP capabilities can be designed and built in Australia. Sovereign industrial capability is a core objective of the NDS, which notes:

> A sovereign defence industrial base is vital for developing higher levels of military preparedness and self-reliance. It also accelerates innovation and capability delivery. (Department of Defence, 2024, p. 57).

The importance of rapid innovation and adaption is one of the key lessons from the Ukraine conflict (Molloy, 2024, pp. 57–64). A sovereign ACP manufacturing capability supports adaptation and innovation as well as providing a resilient supply chain, with the potential for export opportunities. Developing this capability in Australia may be easier if priority is given initially to less complex single-role ACPs mentioned in the previous section.

4.6. Potential for rapid force expansion

The final advantage of autonomy in Australia air power is the potential for rapid expansion in the event of crisis or conflict. ACPs can be rapidly manufactured if the sovereign or allied supply chains and infrastructure are in place, and do not require the proportionate increase in personnel and training. This is critical in two areas: Australia's relatively small population would be stretched in the event of a major conflict and ACPs offer the potential of a significant capability increase for a lower personnel cost. Additionally, it is expected an adversary would have drawn similar conclusions from previous conflicts and would be fielding large numbers of autonomous platforms – this would require a proportionate response from the ADF with counter-ACP systems, which may also be in fact ACPs themselves.

5. Conclusion

Australia's National Defence Strategy requires an ADF and Air Force that can generate combat mass at range over a large geographic area from a support base limited by geography and demography. The characteristics of Autonomous Collaborative Platforms make them highly suitable in the Australian environment when operated in conjunction with existing and future crewed ADF systems using innovating operating concepts such as Agile Combat Employment. Australia should seek to develop a sovereign ACP manufacturing and innovation capability, incorporating not only highly capable multi-role Collaborative Combat Aircraft such as the MQ-28A, but also large numbers of lower-cost systems that may be single role and/or disposable or attritable.

A future Air Force integrating both crewed and uncrewed platforms, with a mix of high-end and low-cost systems collaborating with each other and allied systems, could rapidly reach the level of capability reminiscent of the Service at its peak in 1944. This would provide a range of highly responsive and operationally relevant options for the ADF

and Australian Government across the spectrum of operations in peacetime, competition, crisis and conflict.

Submitted: December 12, 2025 AEDT. Accepted: February 10, 2026 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Grimberg, M. R. (2026). Managing dual-use technology in an era of great power competition. *Contemporary Issues in Air and Space Power*, *4*(1), bp53914519.
https://doi.org/10.58930/bp53914519

Technology & Innovation

Managing Dual-Use Technology in an Era of Great Power Competition

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Keywords: Great power competition, middle powers, balancing national interests, dual-use technology, semiconductor technology, securitisation, export controls

https://doi.org/10.58930/bp53914519

Vol. 4, Issue 1, 2026

Advanced technologies is the central theme of the great power competition between the United States (US) and China, which has broadened the concept of national security. Technology and national security are intertwined and the private sector has increasingly become the catalyst behind developing new technologies. For example, semiconductor chips are vital for enabling other emerging technologies, such as artificial intelligence, which in turn is expected to become increasingly important for both civilian and military applications. Here, I discuss lessons learned from the Netherlands' experience in managing its dual-use technology in an era of great power competition between the US and China. The most important lessons learned are the power of open and transparent communication with all actors involved, the adaptation of a whole-of-nation approach, and the awareness that sovereign nations have the power and ability to make their own decisions. The cooperation between the Dutch Government and a private company that designs and manufactures lithography machines essential for producing chips positively evolved and effectively contributed to pursuing both the Netherlands' economic and national security interests.

Introduction

Since the 2010s, the geopolitical environment is predominantly defined by strategic competition between the two great powers; the United States (US) and China (Jones, 2020, p. 1; S. A. Park, 2023). A central theme of the US–China rivalry, advanced technologies, has broadened the concept of national security significantly. This is the result of new technologies increasingly having a dual-use function, both military and civilian, and are therefore perceived to be potential threat multipliers to national security (Drezner, 2024; Walker-Munro, 2023). Technology and national security have always been interconnected; however, the private sector has increasingly become the catalyst behind developing new technologies, making technological development and trade less visible for governments (Okano-Heijmans et al., 2024, p. 12). Whereas governments were previously mainly involved in welfare facilities, such as healthcare, education and public transport, the national security aspect and dual-use character of many new technologies forced governments to be more involved in markets by regulating trade (Okano-Heijmans et al., 2024, p. 12).

One of the most recent and striking examples of technology that experienced state intervention, and is at the heart of US–China rivalry, is advanced semiconductor technology. Semiconductor chips are vital for enabling other emerging technologies, such as artificial intelligence, which in turn is expected to become increasingly important for military application (Allen, 2023, p. 6). Since the effects of economic measures are easier to control than the effects of military conflict, US–China competition has been increasingly characterised by geoeconomic measures. With export controls, the US aims to deny China access to critical technologies to decrease China's competitiveness with the West (Allen, 2022, pp. 1–2; Hijink, 2023a, p. 205; S. A. Park, 2023, p. 1). One of the key characteristics of the semiconductor industry is that all steps of the chip production process are owned by only a few companies (Miller, 2023, p. 315). However, none of these companies is able to operate independently, and they do not belong to a single country (Muns & Miller, 2024, p. 21). Therefore, in order to execute export control measures effectively, thereby creating a 'chokepoint' against China, it is inevitable for the US to rely on its allies (Miller, 2023, pp. 315, 329–330). One of the most important allies of the US in this matter is the Netherlands with its semiconductor company ASML[1]. ASML designs and manufactures the lithography machines that are crucial for producing chips (ASML, 2024a). This includes both deep ultraviolet (DUV) lithography machines and its more advanced successor, extreme ultraviolet (EUV) litho-

1 ASML is not an abbreviation of anything anymore but a trademark of a world-leading manufacturer of chip-making equipment.

graphy machines (ASML, 2024b; Gehrke & Ringhof, 2023, p. 14). The vital role of these lithography machines within global production processes has brought the Dutch Government to an extremely difficult position. Whereas the US is the Netherlands' most important security partner, China is one of the most important trading partners. Consequently, the Netherlands needs to constantly balance its economic and national security interests, including its relations with both countries.

This paper focuses on the lessons that can be learned from the Netherlands' experience in managing its dual-use technology in an era of great power competition between the US and China, particularly since 2018. The most important lessons learned are the power of open and transparent communication with all actors involved, the adaptation of a whole-of-nation approach, and the awareness that sovereign nations have the power and ability to make their own decisions.

First, I will provide an overview of the literature around economic statecraft. Second, I will examine the Netherlands' involvement in, and response to, trade restrictions on advanced semiconductor technology in an era of great power competition. Third, I will derive lessons from the Dutch case study, to provide insights for other countries. I conclude that the Dutch Government considered various forms of statecraft in pursuing its interests, and it effectively adopted a whole-of-nation approach. Furthermore, ASML's key position in the semiconductor industry and its in-depth technological knowledge proved to be of significant importance. I argue that, over time, the cooperation between the Dutch Government and ASML positively evolved and effectively contributed to pursuing both the Netherlands' economic and national security interests.

2. Economic statecraft and the pursuit of national interests

Globalisation has made the world increasingly interconnected and its political system more multistate-focused. The interconnectedness has changed the dynamics between states and the nexus between their national interests. As a result, states need to holistically consider many different interests and measures, including diplomatic, economic and military (Hirschman, 1945, p. 13). This paper argues that, in the light of great power competition between the US and China, states have increasingly utilised measures known as economic statecraft, rather than military measures. Both economic statecraft and geoeconomics are based on the idea that not military competition but economics will be fundamental to power competition (Luttwak, 1990, pp. 21–22). The distinction between the two concepts can be made as follows; whereas geoeconomics, like geopolitics, studies the system, economic statecraft focuses on a state's foreign policy (Aggarwal & Kenney, 2023, p. 9; Lee, 2024). Consequently, one concept cannot be studied without the other. Blackwill and Harris provide one encompassing definition for the two concepts:

> The use of economic instruments to promote and defend national interests, and to produce beneficial geopolitical results; and the effects of other nations' economic actions on a country's geopolitical goals (Blackwill & Harris, 2017, p. 20).

The reference to 'geopolitical goals' is particularly interesting from an international relations perspective because it emphasises that economic statecraft is part of a broader concept: grand strategy (Wigell et al., 2019, p. 90). Paul Kennedy states that:

> The crux of grand strategy lies [...] in the capacity of the nation's leaders to bring together all of the elements, both military and nonmilitary, for the preservation and enhancement of the nation's long-term [...] best interests (P. Kennedy, 1991, p. 5).

Clausewitz studied these 'elements' from a military perspective, arguing that 'war is simply a continuation of political intercourse, with the addition of other means' (Clausewitz, 1832/2008, p. 605). This applies to all forms of statecraft, including economic statecraft (Baldwin, 2020, pp. 65–66). They should be studied in conjunction with others forms of statecraft (that is, DIME – Diplomacy, Information, Military, and Economic) and as elements of a nation's overarching grand strategy, rather than as isolated elements with their own goals (Baldwin, 2020, pp. 65–66; Early & Preble, 2021, p. 371). A state's ability to apply these forms of statecraft largely determines its manoeuvrability in the international political domain, and its effectiveness in achieving its national objectives.

Even though both grand strategy and economic statecraft are often considered as concepts for major powers, they are in practice employed by all states. However, larger powers generally have more capabilities at their disposal to conduct their economic statecraft (Farrell & Newman, 2019, p. 54). Consequently, this influences the power dynamics within the international political system, in which larger and smaller powers manoeuvre and interact with each other. This includes the pressure that states can exert on others to pursue their national interests.

3. Economic statecraft and great power competition

Globalisation has made states become increasingly involved in the international political economy. States participate in international trade as buyer or seller, or both. In doing so, states can influence and target the trade of other states, for example by continuing or blocking their export or import. Hirschman argued that sovereign states have this ability because they control their own borders and population. He argues that, even though the sender state will also bear the consequences of the economic measures it takes, it is generally capable of shaping the conditions to make sure that the target state will be worse off (Hirschman, 1945, pp. 15–16).

Consequently, states increasingly utilise the tools of economic statecraft. Early and Preble provide a broad, conceptual framework to understand how decision-makers apply economic statecraft in various contexts to pursue their country's national interests (Early & Preble, 2021, p. 371).

Most relevant and applicable in the context of great power competition is the objective of 'balancing', which aims to hinder other states' ability to become the dominant actor in their exchange with other states. Considered from a realist's perspective, this means that if great powers are not able to dictate the circumstances themselves, they will aim to balance the allocation of power between other great powers and themselves. States have a variety of balancing measures at their disposal, including the establishment of partnerships with other nations, and the execution of policies that aim to decrease or diminish another great power's strength (Early & Preble, 2021, p. 378). An example of these policies are strategic trade policies, which great powers use to bolster their own alliances while at the same time restraining adversaries from gaining more power. For instance, states can enhance their allies' power by providing them access to strategic technologies. In contrast, export controls can hinder the transfer of strategic goods to adversaries, such as specific raw materials or advanced technologies (Fuhrmann, 2008, p. 634).

The application of strategic trade policies has increased since the 2010s. This has led to an increase in market intervention by governments, pursuing their national interests (Lim, 2019, pp. 31–32). The increased state intervention in markets is the result of three global developments: the existence of great power competition; the expansion of populist political campaigns, which generally oppose international, regulated trade regimes; and economic policy domains which have become increasingly securitised, because they are progressively seen as interconnected to domestic security affairs. Examples of these domains are 'trade, technology and education' (Ferguson et al., 2023, pp. 1156–1157).

The interaction between these developments, and the subsequent increase of state intervention in markets increased the interdependence and securitisation of trade. This has particularly been the case for the connection between advanced technologies and national security, so-called 'technonationalism'. Whereas previously 'industrial policy [was] oriented toward developmentalism, [it has now shifted] to security-oriented geoeconomics' (S. A. Park, 2023, p. 3). Simultaneously, the concept of Global Value Chains (GVCs) has increasingly been considered to be of strategic importance to national security (S. A. Park, 2023, p. 3). GVCs comprise all production steps necessary for the production of goods or services, in which each step adds value to the product, and with two or more steps performed in different nations (Antràs, 2020, p. 553). Furthermore, the focus of technonationalism has shifted from single, sovereign states to cooperation between multiple states, with shared GVCs with alliance partners and like-minded countries. This approach has been stimulated by the 2010s geopolitical environment, which proved it to be both impossible and impractical for a single nation to monopolise an entire GVC (S. A. Park, 2023, p. 3).

As a solution, states use various techniques to gain access to foreign strategic goods. Kennedy and Lim distinguish three options: 'making', 'transacting' and 'taking' (A. B. Kennedy & Lim, 2018, p. 556). First, 'making' involves the provision of state assistance to domestic companies in developing new products, for example, by financial aid or by safeguarding them from overseas competitors (A. B. Kennedy & Lim, 2018, p. 556). Second, 'transacting' is about trading with international companies, for which cooperation of those companies is essential. This pathway includes the procurement of foreign technologies and investments in foreign manufacturers that own the desired technologies. 'Transacting' is most effective when combined with domestic innovation endeavours (A. B. Kennedy & Lim, 2018, p. 557). Third, 'taking' encompasses gaining access to foreign technologies without transactional methods, which is generally seen between more and less technologically developed countries. This includes the gathering of open-source information and information from international authorities, and taking 'intellectual property' without prior consent (for example, espionage and theft) (A. B. Kennedy & Lim, 2018, p. 557). All three pathways are focused on the cross-border exchange of intellectual property and technologies, and they heavily rely on the cooperation between governments and companies. Since the 2010s, this has significantly changed the interaction and interdependence between governments and firms.

4. Collaborate to balance economic and national security interests

The shift in technonationalism has increased the cooperation between states and technology manufacturers. Governments and firms have always been mutually dependent for security, employment and tax purposes, however, today's highly technological economy and geopolitical environment have made states become more reliant on the in-depth technological knowledge of domestic firms. This has significantly increased these firms' role and influence in foreign relations (Babic et al., 2017, p. 22; Babić et al., 2022, p. 6; S. A. Park, 2023, p. 3). Consequently, this has increased the need to balance the interests of all actors involved. The nexus between security and economic interests, but also between other domestic and international forces that are in play, often results in opposing interests and inevitable trade-offs (Luttwak, 1990, p. 17; Vihma, 2018, p. 4). These trade-offs are directly related to the difficult choices governments and firms are facing in collectively balancing their economic and security interests.

This had broadened the perception of security, which in turn has made GVCs, particularly those of advanced technologies, become a more central element in state-firm cooperation. These GVCs can be utilised strategically to pursue national interests (S. A. Park, 2023, p. 3). One way to strategically utilise a GVC is by creating a 'chokepoint effect', which denies adversaries access to certain technologies (Miller, 2023, pp. 327–328). In doing so, states have the ability to coerce adversaries (Hirschman, 1945, pp. 14–15). However, chokepoints have limitations and disadvantages. They are generally most effective when executed by one or only a few states (Miller, 2023, pp. 329–330). Even though single actors can be very influential in a certain GVC, they hardly ever possess enough power to fully dominate all steps, which underpins the importance of alliances (Miller,

2023, p. 315). Furthermore, the control over domestic technologies not only puts states in a central role in the creation of chokepoints, it also exposes them to pressure from international actors (Okano-Heijmans et al., 2024, p. 10). The increased cooperation between governments and firms, as well as the advantages and disadvantages of playing a critical role in a GVC, serves as the transition into the next section: the case study of the Netherlands' semiconductor industry, and the Dutch role in and response to contemporary great power competition.

5. The Netherlands' semiconductor industry

5.1. The Netherlands as 'middle power', and early export control measures

More than 80 years ago, during World War II, the overall trend in Dutch political thinking was that international cooperation, in the form of an Atlantic pact with permanent support from the US, would be the best guarantee for national security (Hellema, 2010, p. 114). Combined with increased European integration, this would be beneficial for both international political relations and economic cooperation in Europe (Hellema, 2010, pp. 124–125). Eelco van Kleffens, Dutch Foreign Minister throughout World War II, declared the Netherlands to be a 'middle power', and nowadays it is still considered an established 'middle power' (Hellema, 2010, pp. 114–115; Oosterveld & Torossian, 2019). Middle powers can be defined as states that have both the interests and sufficient capacity to collaborate harmoniously with other states to build and strengthen 'institutions for the governance of the global commons' (Robertson, 2017, pp. 366–367). As a middle power, 'the Netherlands has an interest in ensuring the continuation of the liberal-democratic world order' (Oosterveld & Torossian, 2019). In 2019, Mark Rutte, the then Dutch Prime Minister and now Secretary-General of NATO, addressed an audience at Australia's Lowy Institute and said:

> For middle powers like Australia and the Netherlands, working together is the best way to influence and shape international debate. As middle powers, we must act in concert if we want to make sure our voices are heard (Doherty, 2019).

An example of collaboration to influence and orchestrate the international political system, is the 1995 Wassenaar Arrangement, in which both the Netherlands and Australia participate. The Wassenaar Arrangement was the first agreement under which participating nations regulate export controls over items and technologies mentioned on the so-called 'List of Dual-Use Goods and Technologies and the Munitions List'. This list includes semiconductor technology (Hijink, 2023a, p. 191; Wassenaar Arrangement Secretariat, 2019). However, in an era of great power competition, the Wassenaar Arrangement is not considered fit for purpose. It was initially established with a focus on tangible items, such as nuclear weapons. Furthermore, the Arrangement's decision-making philosophy is based on consensus, which lacks the agility and flexibility now that Russia has created a stalemate, and new technologies evolve rapidly (Allen & Benson, 2023, p. 10; Okano-Heijmans et al., 2024, pp. 3, 16). Therefore, the Wassenaar Arrangement is not seen as a useful mechanism to hinder China's technological capabilities in a timely manner, which would allow China to bridge the technological gap with the West.

5.2. The start of increased Dutch involvement

Today's geopolitical environment and the rapidness in which new technologies emerge ask for responsive measures. Consequently, due to the Wassenaar Arrangement's rigidity the US felt compelled to develop additional trade restrictions on semiconductor technology (Hijink, 2023a, p. 203; Miller, 2023, pp. 327–328). When the Dutch Government granted the export licence to ASML for selling its EUV machines to China in 2018, the US was able to convince the Netherlands to revoke that licence. Subsequently, the EUV machine was added to the Wassenaar Arrangement's list for dual-use technologies (Gehrke & Ringhof, 2023, p. 14; Van der Lugt, 2024; Wassenaar Arrangement Secretariat, 2023). Nevertheless, as standard procedure when a more advanced technology has been developed (that is, EUV), the DUV lithography machine was taken off the list in 2014 (Hijink, 2023a, p. 202). To frustrate China's technological development even further, the US attempted to get ASML's DUV machine back on the list (NOS, 2023). However, export controls are a national affair, which significantly increased the Dutch Government's involvement in the US–China technology war (Okano-Heijmans et al., 2024, p. 8). As a result, the US was forced to rely on the Netherlands to effectively conduct their desired, additional export control measures, and thereby create a chokepoint against China (S. Park, 2023, p. 10). Therefore, the US started a diplomatic mission, largely focused on the Netherlands and Japan, with the aim to gather the support of the most important actors in the semiconductor industry (Mead, 2024).

This has brought the Dutch Government to an extremely difficult position, in which it needs to balance its economic and national security interests. Whereas the US is the Netherlands' most important security partner, China is one of its most important trading partners, especially when it comes to semiconductor technology (CBS, 2023; Van der Veere, 2024, p. 12). At first, the Dutch Government, supported by neighbouring countries Germany and Belgium, was unwilling to obey the US request to put the DUV machine back on the list. The government agreed with ASML that it had already made enough concessions by adding the EUV machine to the list, which inherently impacted its trade relationship with China. Nevertheless, the US consideration to implement the 'foreign direct product rule' was enough to pressure the Netherlands to come up with national trade restrictions, parallel to the Wassenaar Arrangement. The foreign direct product rule would significantly control and potentially limit the Netherlands' sovereign decision making when it comes to exporting products that contain foreign technology. Whereas the US was previously only involved if a machine contained more than 25 percent US technology, the enforcement of this rule would block the trade of products that contain any US technology, which is the case for ASML's semiconductor machines (Eitel, 2024;

Hawkins et al., 2024). Consequently, ASML and the Dutch Government would no longer control the export of national semiconductor technologies, inherently changing the power balance between the Netherlands and the US. Eventually, the Dutch Government gave in, and made its first explicit move concerning this matter towards the US (Hijink, 2023a, pp. 202–203).

In the following years, the US pressure remained present and became more explicitly aimed at China, and the export control measures on semiconductor technology were tightened even further. In October 2022, when the Biden administration declared additional export restrictions to strengthen the chokepoint against China, the semiconductor industry became further constrained (Allen, 2022, p. 1, 2023, pp. 6–7). However, even though the Dutch Government had announced additional trade restrictions from the national level, there were still machines being sold to China (Muns & Miller, 2024, pp. 21–22). Although these were not the advanced EUV machines, the US decided to further tighten export controls in October 2023. Again, the Netherlands announced its respective additional restrictions, which broadly aligned with those of the US (Okano-Heijmans et al., 2024, p. 3). Although not officially stated, it appears evident that the Netherlands' decisions are driven by the threat of enforcing the 'foreign direct product rule' by the US. Speculations about the enforcement of the rule have significantly influenced ASML's market value in recent years (Eitel, 2024; Hawkins et al., 2024). However, this time the Dutch Government formulated three strategic objectives:

- preventing a situation in which Dutch goods contribute to undesirable end use, such as military deployment or weapons of mass destruction
- preventing undesirable long-term strategic dependencies
- preserving the Netherlands' technological leadership position (Ministry of Foreign Affairs, 2023; Okano-Heijmans et al., 2024, pp. 14–15).

The combination of these objectives shows the integration and execution of various forms of statecraft (DIME) by the Dutch Government. For example, the Dutch Government's condition was that the global shortage of chips would not further increase as a consequence of the trade restrictions (Hijink, 2023a, p. 203). Even though controlling the export of critical, dual-use semiconductor technology is considered vital from a security perspective, so is maintaining an adequately functioning semiconductor GVC (Muns & Miller, 2024, p. 23). Ultimately, as mentioned before, the semiconductor's GVC is highly interconnected and interdependent (Miller, 2023, p. 315; Muns & Miller, 2024, p. 21). Furthermore, the government's close relationship with ASML shows the holistic approach to the trade restrictions on semiconductor technology, even though trade restrictions come with undesirable trade-offs. The relationship is also one of reliance because, in line with the shift towards technonationalism, the Dutch Government strongly relies on ASML's in-depth technological knowledge and its position as a major player in the international political economy. An example is ASML's role in preparing Dutch political leaders for international meetings concerning geopolitics and trade, which includes visits of then Dutch Prime Minister Rutte to the US and China to meet with Presidents Biden and Xi Jinping (NOS, 2024c; Tweebeeke, 2023; Woo & Cao, 2024). In addition, ASML's former CEO, together with the CEOs of the other key players in the semiconductor GVC, personally attended meetings with the US President (Hijink, 2023a, p. 225; NRC, 2024).

5.3. The Netherlands sets its boundaries

To this day, China's access to semiconductor technology is still one of the most important topics between the US and the Netherlands. Export control measures will likely be updated continuously, and the impact of these updates will depend on the development of both the chip market and China's capabilities (Muns & Miller, 2024, p. 22). However, this does not mean that the Netherlands will keep following the US export control measures. In 2023–2024, the US continued to exercise the coercive effect of the 'foreign direct product rule' (Eitel, 2024; Hawkins et al., 2024; Kasteleijn, 2023c). Furthermore, the US has tried to persuade the Dutch Government to terminate ASML's service contracts for machines that have been sold to China in previous years. These measures would severely limit China's capabilities, and potentially, depending on the type of machine, shut down factories in weeks or months (Hijink, 2024; Kasteleijn, 2023c). In September 2024, the Dutch Government announced that 'from now on, companies will have to apply for an authorisation when exporting this type of advanced manufacturing equipment' (Klever, 2024). In doing so, the Dutch Government will maintain full responsibility over the export control measures, which includes servicing contracts and export licences of machines that contain US technology. This means that export, both of machines and service contracts, outside of the European Union (EU) is not completely banned, but will be considered by the Dutch Government on a case-by-case basis (Klever, 2024; Sterling, 2024b). So, even though the Dutch measures broadly align with those of the US, the Dutch Government's announcement shows that it maintains control over its own political and economic decision-making process. In doing so, the Dutch Government stays loyal to its historical approach towards foreign trade, which seeks to promote transparency and open trade (Ministry of Foreign Affairs, 2022).

Nevertheless, it is unlikely that the Dutch Government's decisions in this matter will drift far away from the US, and future decisions will still come with trade-offs. Ultimately, the US remains an important security partner to the Netherlands, and the Dutch Government is well aware of the significance and dual-use character of semiconductor technology. Therefore, this technology needs to be monitored and controlled accordingly. In 2023, outgoing Prime Minister Rutte stated that we should collectively think about 'how … we ensure that we, as the Western world, remain safe, and how [we can] maintain our technological advantage. That is also in the interest of the Netherlands' (Tweebeeke, 2023).

5.4. The alignment between the Dutch Government and ASML

The interests of the Netherlands, however, are not homogenous. Interests differ per actor, even domestically. The collaboration between the Dutch Government and ASML does not necessarily mean that they are fully aligned on the export control measures on ASML's semiconductors, or the impact on the industry at large. Both former CEO of ASML Peter Wennink and current CEO Christophe Fouquet have openly expressed their criticism about the trade restrictions on semiconductor technology. Fouquet explicitly questioned the motives of the US for their export control measures against China, arguing that the restrictions have increasingly become economically motivated. He stated that saying 'that this is about national security is getting harder and harder' (Sterling, 2024a). In an interview in September 2023, Wennink also expressed his reservations. He argued that Western protectionism might be a trigger for deglobalisation, which eventually will encourage countries such as China to become more innovative themselves. Protectionism will put efficiency under pressure, which in the longer term will cause rising costs and inflation. Wennink argues that 'we must be careful, we cannot afford to fall behind' (Wennink, 2023). In that same interview, he calls for a whole-of-nation approach, in which the Dutch Government, its industry and its universities must act collectively to protect the Netherlands' welfare, provide adequate education and healthcare, and enhance its security; both physically and digitally. Wennink argues that the government should be facilitating this, and that firms and universities should contribute by investing in infrastructure and knowledge building (Wennink, 2023). Cooperation between all actors involved would benefit the collective pursuit of the national interests.

However, in the early days of trade restrictions on Dutch semiconductor technology, there was hardly any collective approach, or at least not an openly observable approach. This caused divergence, and ultimately tensions between the Netherlands' political and industrial interests. Even though ASML is decades ahead of its competitors, and the demand for chips will likely increase in the future, the trade restrictions will anyhow impact the company's growth, its ability to innovate and potentially its competitiveness in the long run. As a result of the trade restrictions on its most advanced machines, the number of machines ASML sells will decline (Muns & Miller, 2024, p. 23). It was inevitable that the interaction and relationship between the Dutch Government and ASML would become somewhat rigid. To illustrate the situation in March 2024, Wennink said that 'there is a significant gap between what the business community thinks is necessary, and what parliament thinks is necessary' (NOS, 2024a). This had made ASML's leadership question the suitability of the Dutch business climate. Next to the recurring trade restrictions, there had been changes in tax benefits for expats, and the political climate towards immigration has gradually changed. With approximately 40 percent of its employees working in the Netherlands coming from abroad, these developments are unfavourable for ASML (Hijink, 2023b; Kasteleijn & Schallenberg, 2024; NOS, 2024b). Consequently, it might push ASML to move to a less restrictive country.

However, according to Wennink, in 2024 the then outgoing Dutch Cabinet (that is, 'Cabinet Rutte-IV') proved to be more receptive than parliament with regards to what is needed to maintain the Netherlands' technological advantage. For example, Cabinet Rutte-IV had initiated the so-called 'Operation Beethoven' to organise the harmonious cooperation between industry, local residents and national and international politics to prevent companies such as ASML shifting their investments to other countries (BNR Nieuws, 2024; NOS, 2024b; NRC, 2024). In doing so, the Dutch Government conducted the strategy of 'making' to assist ASML in maintaining its competitive advantage, while at the same time keeping an important technology in Dutch hands. In July 2024, when a new Cabinet had only just been sworn in, a letter was sent by interest group ChipNL, in which more than 30 Dutch chip-related companies are represented. Their main request to the government was, after its assistance to ASML, to invest even more in the broader Dutch chip industry (Kasteleijn, 2024).

5.5. Recent developments and future challenges

The initiatives to strengthen the relationship between the Dutch Government and ASML, and the more recent developments with regard to ChipNL, significantly challenge the balancing act between the Dutch economic and national security interests. When the Dutch Government decided to tighten the trade restrictions again in September 2024, the then Dutch Minister for Foreign Trade and Development, Reinette Klever, stated that she 'made this decision for reasons of security [because] technological advances have given rise to increased security risks associated with the export [of semiconductor technology], especially in the current geopolitical context' (Klever, 2024). Other than the US, the Dutch Government does not focus solely on China, calling its measures 'country neutral' (Kasteleijn, 2023a, 2023b; Okano-Heijmans et al., 2024, p. 3; Woo & Cao, 2024). It seeks a more nuanced approach to maintain the Dutch economic relationship with China; especially since China's minerals are critical to many GVCs, including the semiconductor GVC, and China has announced export restrictions to indicate its displeasure and demonstrate its power (Baskaran, 2024; Nurmamat, 2024; Reuters, 2023). However, the Dutch Government has not been consistent in its 'country neutral' approach. In its National Security Strategy, it mentions China directly after Russia and argues that both countries are 'challenging the existing international order' (Ministry of Justice and Security, 2023, p. 13). As an example, reports have shown that China and Iran have managed to gain possession of chips, including chips that were made with Dutch machines. Some of these chips have been used in Iranian drones and other military equipment, which later have been used by Russia in its war against Ukraine. Even though the involved chip companies complied with the export control regulations, these chips have been smuggled or were stolen from other machines (NOS, 2022; Sietsma & Houthuijs, 2023). This clearly shows

the dual-use applicability of semiconductor technology, and that regulations have loopholes that enable other states to conduct a strategy of 'taking' to gain access to this advanced technology. This significantly contributes to the US and Dutch justifications for continuously tightening the trade regulations.

To counter these hostile actions and maintain security, while simultaneously pursuing an open trade environment, the Netherlands seeks cooperation with like-minded countries. Next to the Netherlands' bilateral partnership with the US, it largely focuses on the EU (Okano-Heijmans et al., 2024, p. 1). Together with other EU members, the Netherlands aims to strengthen the EU's strategic autonomy, which can be defined as 'the capacity of the EU to act autonomously … in strategically important policy areas' (Van der Veere, 2024, p. 27). However, even though the European market is largely self-sufficient, like the US market, this pursuit for strategic autonomy might have the perverse effect of 'reshoring' steps of the GVC back into the European theatre. Consequently, what Wennink warned about, this might result in deglobalisation, risking a decrease in efficiency and an increase in prices. Ultimately, this undermines the competitiveness of the Western world. Hence, the promise of the Dutch Cabinet in 2024 to execute the export control measures 'in a careful and targeted manner … to minimise the disruption to global trade flows and value chains' (Klever, 2024), while simultaneously weighing 'the economic interests of ASML … against other risks' (Reuters, 2024). Without knowing exactly how significantly the trade restrictions will limit the wrongful use of semiconductor technologies, as well as the impact on the Dutch economic and national security interests, the Dutch Government's approach does show that various elements of statecraft are taken into consideration.

6. Lesson learned

Various lessons and considerations for decision making can be drawn from the Netherlands' experience in managing its semiconductor technology in an era of great power competition.

First, as a middle power, the Netherlands shows the importance of open and transparent communication with all actors involved, as well as the awareness of its position in the geopolitical system. Throughout the discussions around trade regulations, the Netherlands had close contact with both great powers and with like-minded countries in similar positions, such as Japan. So far, these interactions involved different forms of statecraft (DIME) and were generally open and transparent, which aligns with the Dutch strategy for foreign trade.

Second, the Dutch experience shows the importance of a whole-of-nation approach, especially when the challenges at hand impact a variety of actors. The Dutch Government's decisions show that it values the alliance with the US as its most important security partner. However, the Dutch political position evolved over time and increasingly demonstrated the importance of cooperation with the domestic industry, which corresponds with the global shift in technonationalism. Furthermore, the Dutch Government's 'making' strategy does not only seek to be beneficial to ASML but to the whole country, and most tangible to ASML's direct region.

Third, and most important, the Dutch Government's approach demonstrates that sovereign nations, regardless of their size, have the power and ability to make their own decisions. Even though states have to engage in a global political system that has become increasingly interconnected and multistate-focused, they still have control over and responsibility for their own borders and population.

The lessons learned from the Dutch semiconductor case can provide useful insights for countries that find themselves in a similar position. An example is Australia, whose lithium industry more recently got exposed to US intervention. Australia heavily relies on China for processing its lithium, and now the US has announced it will potentially terminate US subsidies on lithium that has been processed in China, or by a company that is partly owned by China. Like the Netherlands, Australia is a middle power that is now forced into a position in which it has to choose between the US and China, respectively its most important security partner and one of its most important trading partners. Consequently, Australia's lithium industry will likely be securitised. Therefore, the years of experience of both the Dutch Government and ASML, as well as the Dutch Government's market intervention, can provide insights to countries such as Australia when managing emerging trade challenges.

This paper specifically focused on a middle power's experience with trade restrictions on its advanced semiconductor technology, which went along with considerable pressure in an era of great power competition. Whereas some conditions, forms of economic statecraft and experiences might be similar to other countries and their industries, some may not.

7. Conclusion

This paper has focused on the lessons that can be learned from the Netherlands' experience in managing its dual-use, semiconductor technology in an era of great power competition. It discussed the efforts and challenges of the Netherlands, as a middle power, in balancing its economic and national security interests. Based on the case study, this paper concludes that the Dutch Government considered various forms of statecraft in pursuing its interests, and it effectively adopted a whole-of-nation approach. In line with the global shift in technonationalism, ASML, as the Netherlands' most important firm in the semiconductor GVC, proved to be of significant importance. Despite the impact of the enforced export control measures on its operations, it was able to use its in-depth technological knowledge and key position for both domestic and international interests. Over time, the cooperation between the Dutch Government and ASML positively evolved and effectively contributed to pursuing both the Netherlands' economic and national security interests.

The case study shows important lessons for middle powers in managing their economic and national security interests. It demonstrates that an open and transparent pol-

icy, combined with communication with all actors involved, forms the basis when confronted with conflicting interests and difficult choices. Furthermore, it shows the importance of alliances and partnerships from both an economic and a security perspective, and that it is not in the interest of a middle power to specifically target other states. Another lesson is that even though long-term protectionism can contribute to deglobalisation and a decrease in innovation, it is in a state's economic interest to support its own industry. Lastly, sovereign states should remember that they have the power and ability to make their own decisions, regardless of their relative size.

Submitted: October 08, 2025 AEDT. Accepted: November 19, 2025 AEDT. Published: February 17, 2026 AEDT.

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Contemporary Issues in Air & Space Power
Air and Space Power Centre

Robinson, A., Silva, L., & Linder, J. (2026). Better, Faster, Smarter: Scalable Aircrew Training for Modern Air Power. *Contemporary Issues in Air and Space Power*, *4*(1), BP55099219. https://doi.org/10.58930/BP55099219

Air Power

Better, Faster, Smarter: Scalable Aircrew Training for Modern Air Power

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Keywords: pilot training, fifth-generation, air power, cognitive, turboprop, air force

https://doi.org/10.58930/BP55099219

Vol. 4, Issue 1, 2026

Australia's evolving strategic environment, limited fighter mass and finite jet-trainer life-of-type place increasing pressure on the pilot training pipeline. Recent reforms have strengthened early-phase training, but the last phase of the training (or Phase 4) remains bottlenecked by high-cost jet utilisation at Operational Conversion Units (OCUs). Here, we propose a specific model for modernising the Phase 4 Lead-In Fighter Training (LIFT) of the Royal Australian Air Force (RAAF) to increase throughput, improve cognitive readiness and reduce cost-per-graduate while protecting fifth-generation standards. A training-effect–based task-allocation model is proposed, assigning cognitively rich but non-jet-dependent events to a high-performance turboprop with embedded mission-system emulation and Live–Virtual–Constructive (LVC) integration, while reserving the Hawk 127 for the small set of manoeuvre, weapons and adversary-air tasks requiring jet performance. A Portfolio Budget Statements (PBS)-anchored cost methodology quantifies effects across flying-hour sustainment, synthetic utilisation, instructor effort, Red Air demand and OCU time-in-training. Modelling shows that a Hybrid Phase 4 design can increase airborne exposure, reduce remediation and lower cost-per-graduate while preserving standards. A gated pathway ensures progression to an Optimised model only when measurable improvements in throughput, OCU duration, instructor utilisation and Red Air predictability are demonstrated. A cognitively focused, turboprop-heavy Phase 4, integrated with protected jet-only envelopes, offers a scalable, affordable and standards-safe approach to generating fifth-generation aircrew. By flying more, and flying smart, the RAAF can deliver the cognitive capacity and operational competence required for contemporary and future air warfare.

1. Introduction

The character of contemporary air warfare has shifted decisively. Advances in sensing, data fusion, human–machine teaming and multi-domain integration have expanded the cognitive and tactical demands placed on aircrew beyond the traditional competencies emphasised by legacy pilot training systems (Harrigian & Marosko, 2017; Lemons et al., 2018). Modern aviators must still demonstrate airmanship – discipline, skill, proficiency, knowledge and command judgment – but they must also manage information at tempo, make autonomous decisions under pressure, and coordinate effects within joint, complex and often degraded battlespace conditions (Dahm, 2025; Dahm et al., 2025; Hubbard, 2023; Kern, 1997). These requirements emerge while many air forces, including the Royal Australian Air Force (RAAF), must grow output and readiness within finite resources and training fleets (Australian Government, 2025).

Australia's strategic environment concentrates this demand. In the Indo-Pacific, accelerating military modernisation, grey-zone coercion and the potential for high-intensity conflict elevate the premium on adaptable, integrated air power (Woltjer et al., 2024). The 2023 Defence Strategic Review frames an Australian Defence Force (ADF) transformation towards agility and technological integration, but also implies that the full value of advanced platforms – including F-35A, EA-18G, P-8A and future uncrewed systems – depends on training systems that prepare aircrew to exploit cognitive and informational advantages, not just platform performance (Department of Defence, 2023; Dibb & Brabin-Smith, 2023).

This paper advances a RAAF-specific case, that is generally applicable to tier one air forces, for optimising the pilot training system through modernising Phase 4 Lead-In Fighter Training (LIFT) by reallocating tasks to the lowest-cost platform that can credibly deliver the intended training effect, while preserving a ring-fenced jet-only envelope

for transonic/high-energy manoeuvre, selected weapons work-ups and defined Red Air roles[1]. The objective is not only to improve training outcomes within Phases 1 through 4, but to deliver whole-of-pipeline, including in operational conversion (OPCON or Operational Conversion Unit [OCU]) and advanced tactics training through developing contemporary competencies earlier. The central proposition is to shift training realism from a narrow emphasis on kinematic fidelity to cognitive relevance – the disciplined cultivation of information-management, prioritisation under ambiguity and team integration – delivered through a blended live-synthetic system (Hubbard, 2023, 2023). The approach aligns with Defence's system trajectory and budget discipline as detailed in the 2024 National Defence Strategy, 2023 National Defence: Defence Strategic Review (DSR), 2024 Integrated Investment Plan (IIP) and 2025-2026 Portfolio Budget Statements (PBS) framework (Australian Government, 2024a, 2024b, 2025; Department of Defence, 2023).

Strategic context. Fifth-generation[2] aircraft such as the F-35 are qualitatively different: they fuse multi-spectral data, distribute decision-making to the tactical edge, and demand that pilots orchestrate effects across crewed and uncrewed partners (Lemons et al., 2018; Lockheed Martin, 2025). Mastery shifts from pure handling performance to systems thinking and time-critical judgement. These dynamics apply across roles – air combat, surveillance, mobility and electronic warfare – where networked, mission-adaptable employment is now routine and where operators must retain effectiveness when connectivity is degraded (Everstine, 2025; Jensen, 2025).

The Modern Aircrew Requirement. To be genuinely ready for fourth-, fifth-, and next-generation operations, trainees need structured exposure to cognitive load early: managing sensor timelines, datalink discipline, fused data feeds, communications and mission leadership under time and operational pressures (Dahm et al., 2025; Hubbard, 2023). Live flying remains indispensable because physiological and psychological stressors, such as G-onset, vestibular effects, thermal load and the non-trivial consequences of error – shape decision-making in ways simulators cannot fully reproduce (Self, 2025; Tornero-Aguilera et al., 2025). At the same time, high-cost jet hours are scarce and should be reserved for training events that genuinely require jet performance. The problem is therefore not 'more jet' or 'more sim,' but more airborne learning on the right platform, complemented by high-quality synthetic preparation, within a coherent, integrated training ecosystem and a fixed sustainment envelope (Woltjer et al., 2024).

This paper contributes an integrated, two-step Phase 4 design for the RAAF: (1) a measured Hybrid model that considers shifting the majority of cognitive/mission-system events to a high-performance turboprop with embedded simulation and Live-Virtual-Constructive (LVC) while retaining an Advanced Jet Trainer for the jet-only envelope; and (2) progression to an Optimised model with a conservative approach to balancing upload and download of curriculum elements, allowing force structure designers the flexibility to adjust the upload/download as required.

In line with explicit signals of a pipeline/capacity focus, such as the 2024–2025 consolidated parallel ab-initio pilot training at RAAF Base East Sale and RAAF Base Pearce to raise throughput, the Future Air Mission Training System (F-AMTS) at East Sale, and consideration of commercially provided Phase 1 aircrew training – this analysis considers Australian conditions: force structure, program direction and PBS constraints – and avoids prescribing foreign hour norms, while providing general advice for other tier one air forces (AusTender, 2025; Conroy, 2025; Lancaster, 2024; Wilkins, 2022). International comparators are considered in the paper to illustrate method and outcomes, not to set standards. Section 2 defines the Australian drivers and the specific RAAF training problem with program evidence; Section 3 explains why and how to fly more, but smart; Section 4 details the turboprop role; Section 5 the trade-offs; Section 6 the competency- and data-enabled pathway; Section 7 sets out the PBS-anchored cost method; Section 8 delivers the recommendation, governance and gates; and Section 9 conclusions.

2. Strategic drivers and the specific RAAF training problem

The case for modernising RAAF training is shaped by three interlocking realities: operational (what aircrew must do), institutional (what Defence is already changing) and resource (what the budget and fleets will bear). Together they define a practical problem statement that can be solved within Australia's existing trajectory.

Fifth-generation employment reframes the pilot's role from kinetic shooter to information-centric decision-maker (Dahm et al., 2025; Hubbard, 2023). F-35A mission systems create a fused picture that must be interrogated, prioritised and acted upon in real-time; the aircraft is a distributed command and control node as much as a weapons platform (Dahm, 2025; Lemons et al., 2018). Training must therefore front-load information-management, a joint mindset but with tactical autonomy as required and four-dimensional situational awareness – well before operational conversion – so that valuable OPCON hours can concentrate on integrated warfighting effectiveness rather than remedial cognitive skills (Hubbard, 2023; Self, 2025).

1 Phase 1 – Elementary; Phase 2 – Basic; Phase 3 – Advanced; Phase 4 – Lead-In Fighter Training; Red Air = Adversarial air role.

2 'Fifth generation' aircraft are defined as 'capable of operating effectively in highly contested combat environments, defined by the presence of the most capable current air and ground threats, and those reasonably expected to be operational in the foreseeable future' (Harrigian & Marosko, 2017). Currently fielded RAAF fifth generation aircraft include the F-35A, with fourth generation aircraft including the F/A-18F and EA-18G.

These demands extend beyond fighters. Electronic warfare, intelligence, surveillance and reconnaissance operators, and even air mobility platforms all require fluency in networked, mission-adaptable employment – as demonstrated through the United States Air Force's (USAF) 2025 Department-Level Exercise with the Airlift-Tanker Open Mission System – and resilience when connectivity is degraded (Everstine, 2025; Jensen, 2025). Public explanations of the RAAF's Air Warfare Instructor Course (AWIC) and their associated Diamond-series exercises consistently emphasise team cognition – planning, integrated execution and rigorous debrief – as instructor-led, collective competencies that must be preserved at the high end (Magee, 2024). Downloading prerequisite cognitive skills earlier onto lower-cost platforms, supported by robust synthetics, helps focus and preserve those higher-end skills (Alenljung et al., 2025; Department of Defence, 2022a, 2022b; Woltjer et al., 2024).

2.1. Institutional and programmatic signals in Australia

Defence has already taken steps that point directly toward the training system design now required. Parallel ab-initio pilot training at East Sale (1FTS) and Pearce (2FTS), and ongoing exploration of enhanced Phase 1 elementary flying training, signal a deliberate effort to increase throughput and strengthen pipeline resilience (Department of Defence, 2022b; Lancaster, 2024; Lim, 2025). New AIR5428 Pilot Training System synthetic training devices at Pearce – designed to replicate the PC-21 cockpit and raise annual training capacity by approximately 25% – further compound the integrated aircraft, simulation, courseware and learning-management processes now embedded across ab-initio training (Australian Defence Magazine, 2025, 2025). The Future Air Mission Training System (F-AMTS) extends this integration philosophy to mission aircrew and controllers, providing the connective tissue required for data-enabled, evidence-based training management and force-wide competency assurance.

Until the introduction of the current Pilot Training System (PTS) in 2019, Phases 1 (elementary) through 3 (advanced) were conducted almost entirely airborne, with only limited synthetic support during LIFT and OPCON. The introduction of the PC-21 under AIR5428 has significantly improved training efficiency across these early phases – both through higher-quality ab-initio instruction and by 'downloading' training elements previously conducted on air combat aircraft into the advanced trainer. The effectiveness of this approach was recently demonstrated when the RAAF graduated its first full cohort of Introductory Fighter Course (IFC) pilots since the Hawk 127 entered service in 2000 (Casey-Maughan, 2025).

A complementary institutional signal is Defence's recognition that Australia has historically under-emphasised the human dimension of capability – training and education – relative to platform acquisition; a gap that risks constraining the operational return on advanced systems such as the F-35A if aircrew development does not evolve in parallel (Dibb & Brabin-Smith, 2023). Australia's air force is potent, modern and highly capable, but it remains geographically exposed and without the mass of larger forces. With a 108-aircraft fighter fleet tasked with securing an extensive maritime region, 'every dollar spent on Defence [must go] to improving the capability of the Australian Defence Force', making training system efficiency central to maintaining credible air power (Khalil, 2025). This imperative is sharpened by indications that F-35A pilot numbers are already trending below planned levels, further underscoring the need for a modernised training system that can generate and sustain the required aircrew pipeline (Nelson, 2024).

These developments are not abstract aspirations; they define the operating environment into which Phase 4 must now fit, and they collectively reinforce the requirement for a training system that increases throughput, builds cognitive readiness earlier, preserves scarce jet hours and aligns with Defence's broader strategic intent.

2.2. Resource realities and platform life-cycle constraints

Within the PBS sustainment envelope, hours flown on high-cost platforms displace other needs; hours on lower-cost platforms that achieve equivalent learning expand airborne exposure without expanding total spend (Australian Government, 2025; Bridel et al., 2021). The Hawk 127 Lead-In Fighter Trainer (LIFT) remains essential but finite. It, and any future Advanced Jet Trainer (AJT), should be protected for specific jet-only training events – transonic/high-energy manoeuvre, specific weapons work-ups and selected adversarial air roles – rather than consumed by tasks that a turboprop-plus-synthetics construct can deliver earlier and cheaper (Calcagno, 2025);(Durrant, 2018; Mezzanotte, 2000). A disciplined task-allocation model is therefore proposed.

Within a fixed PBS sustainment envelope, the RAAF must: (1) increase production, throughput, scalability and capacity of aircrew; (2) improve pre-Operational Conversion Unit (OCU) airborne exposure and cognitive readiness so OCU can focus on integrated warfighting; and (3) preserve finite Hawk/AJT and frontline jet hours for jet-only events and planned Red Air – without lowering standards (Australian Government, 2024a, 2025; Department of Defence, 2023). These needs are evidenced by real changes already underway, such as the dual 1FTS/2FTS schools to lift pipeline capacity, the Future Air Mission Training System investment to expand integrated synthetic training, and consideration of dedicated Phase 1 aircrew training – indicating Defence's intent to grow output and data-enable training quality (Australian Government, 2025; Lancaster, 2024; Lockheed Martin, n.d.).

What remains is to translate those signals into a Phase 4 design that allocates each task to the platform or modality that delivers the intended training effect at the lowest credible cost and is assessed by measurable outcomes. The remainder of this paper develops that design.

3. Fly more – fly smart: airborne experience and cognitive readiness

The evolution of air combat has elevated the value of airborne experience not because of tradition but because live flight exposes aircrew to cognitive, physiological and emotional stressors that synthetic environments struggle to fully emulate. Contemporary operations demand aircrew who can perceive, decide and act effectively within time-compressed, information-dense and often degraded settings. These attributes are developed through both synthetic and airborne means, but only airborne training provides the full spectrum of cues and consequences that shape the kind of real decision-making skills that defines airmanship (Wojton et al., 2019; Woltjer et al., 2024).

The irreplaceable value of live flying. Simulators excel at procedural training, mission rehearsal and controlled exposure to complexity; however, they cannot reproduce the interplay of physiological load, subtle motion cues, unexpected environmental variation and genuine consequence that influence judgement in real flight. Studies show that while simulators can approximate cognitive workload, they fall short of replicating the physiological stress envelope of actual flying (Tornero-Aguilera et al., 2025). Real-world demands – such as diverting under fatigue, operating with degraded systems or managing ambiguous cues – shape airmanship in ways that synthetic environments cannot fully replicate (Self, 2025).

Live airborne exposure therefore remains essential for developing resilience, situational awareness and decision-making under stress. The question is not whether to fly, but how to maximise airborne value within constrained resources.

The right balance. High-fidelity simulators and ground-based live, virtual and constructive (LVC) environments provide indispensable preparation for airborne events. They enable repetition, debriefing and exposure to multi-platform scenarios without operational risk (Alenljung et al., 2025; Woltjer et al., 2024). Airborne LVC complements this by injecting synthetic threats and cues into real aircraft, creating complex tactical stimuli while still preserving physiological immersion (Laird, 2025b).

The role of simulation is therefore to prime airborne learning in order to shape mental models, tactical expectations and cognitive routines so that each sortie generates maximum value. Simulation enhances airborne training; it does not substitute for it.

Limits of synthetic-heavy pipelines. Experiments in reducing live flying, such as the USAF's Pilot Training Next and Reforge, demonstrate the benefits of synthetics but also their limits. Feedback from operators and instructors highlights concerns that overly synthetic pipelines can suppress confidence, adaptability and intuitive decision-making in real environments (Laird, 2025b; Tirpak, 2021). These findings reinforce the principle that high-quality simulation improves performance only when paired with sufficient airborne volume.

Cost, access and the case for re-allocation. Live flying remains fundamental to developing airmanship, judgement and captaincy. Yet access to frontline aircraft is increasingly constrained by cost and operational demand. In the US, for example, fighter pilots average fewer than two sorties per week due to statutory budget caps, prompting recommendations for a 55% increase in flying-hour funding – an uplift that would require tens of billions of additional dollars each year (Gordon, 2025; Office of the Under Secretary of Defense, 2025; Venable & Baker, 2025).

Comparable pressures exist elsewhere: the RAAF's combat-pilot-skills categorisation scheme requires between 180 and 200 hours of flying per annum to remain current – in line with NATO guidance for fighter readiness, but meeting that benchmark depends heavily on platform availability, instructor bandwidth and operational tempo (Australian National Audit Office, 2012; Binnendijk et al., 2020). With frontline fighter costs reaching AUD 60–80k per hour and a Defence sustainment budget of AUD 4.5 billion, increasing live hours to match foreign recommendations would add AUD 2–3 billion annually to an already oversubscribed Defence budget (Ablong, 2025; Australian Government, 2025; Hellyer et al., 2025; Laird, 2025a). Under these conditions, additional frontline flying cannot be the primary mechanism for strengthening airmanship at scale.

As operational tempo potentially rises, new operational requirements are introduced due to new technology (which need to be trained for), and exercises & deployments absorb a larger share of available hours, air forces are increasingly forced to prioritise frontline aircraft for operations and high-end exercises rather than foundational training (Department of Defence, 2023). As Bridel et al. (2021) note, the cost of employing combat aircraft is now sufficiently high that routine training demand must be met elsewhere. This elevates the importance of the training platform and training ecosystem: modern air forces must generate airborne learning and cognitive development on aircraft and systems designed for affordability, repeatability and integration with synthetic environments, reserving frontline jets for the tasks only they can deliver (Calcagno, 2025).

Rather than chasing raw increases in frontline jet hours, the PBS-consistent lever is re-allocation: increase airborne exposure on lower-cost Phase-4 platforms while preserving scarce Hawk/AJT hours and pricing any Red Air requirement transparently. This is consonant with Australia's Pilot Training System and Hawk upgrade investments, which deliberately grew synthetic quality while protecting airborne hours for tasks only aerial and jet platforms can teach (Pittaway, 2019a, 2019b).

The implication is clear: the RAAF should increase airborne experience but optimise how it achieves this. More airborne experience should be delivered earlier on cost-effective platforms, while the Hawk 127 – and any future Advanced Jet Trainer – is preserved for the jet-only envelope. This approach aligns with Australia's integrated training investments and ensures that trainees enter OCU with deeper cognitive readiness, reducing remediation and allowing instructors to focus on high-end mission integration.

4. Turboprop training as a scalable, cognitively-aligned enabler

Since the late 1990s, the introduction of advanced, technology-rich aircraft has driven a fundamental shift in pilot training, compelling many air forces to reassess and modernise traditional training models (Heap, 2002; Peck, 2021). Modern training systems increasingly prioritise cognitive fidelity – the accuracy with which a training environment reproduces the mental demands of modern air operations – over pure replication of jet performance. High-performance turboprops equipped with embedded simulation and mission-system emulation provide training of just that cognitive fidelity; a scalable means of developing the information-management, decision-making and tactical competencies required for fifth-generation employment.

From performance fidelity to cognitive relevance. For decades, jet trainers were selected for their aerodynamic similarity to fighters: speed, altitude, G-loading, jet response (Bridel et al., 2021). But modern fighters like the F-35A are easier to fly and far harder to cognitively master (Lemons et al., 2018). The decisive training value now lies not in matching top-end performance but in shaping the pilot's ability to manage fused information, prioritise effects and make disciplined decisions under pressure (Dahm et al., 2025; Hubbard, 2023).

High-performance turboprops provide sufficient aerodynamic manoeuvrability for early tactical handling and competency maintenance, while freeing bandwidth to teach these cognitive and airmanship skills. Their integrated avionics and embedded training systems allow realistic mission-system development without incurring jet-level costs (Australian Defence Magazine, 2025; Hubbard, 2023; Lockheed Martin, n.d.; Mezzanotte, 2000).

Delivering mission-system and tactical representation. Modern turboprops use datalink modes, sensor-emulation suites and LVC connectivity to expose trainees to realistic tactical problems – timeline control, datalink management, simulated radar cueing, threat reactions, mutual support and comms discipline (Alenljung et al., 2025; Woltjer et al., 2024).

These tasks depend on cognitive alignment, which can be delivered through scaling down weapon ranges and time-of-flight to match the operational cadence a frontline pilot might experience, not raw speed, and can therefore be delivered earlier and more frequently.

International evidence. International training system trends support this shift from kinematic to cognitive realism. With OEMs and prime integrators increasingly delivering pilot training as an integrated ecosystem – aircraft, simulation, planning/debrief tools, and syllabus design – and with modern turboprop aircraft, equipped with embedded tactical mission systems, less than 10% of an air force's total training program now requires a true jet trainer, confined largely to the transonic and high-altitude flight regimes (Air Education and Training Command, 2024; Tusa, 2025).

International practice demonstrates that core cognitive and tactical competencies can be built on turboprop platforms before jet conversion. The Brazilian Air Force develops tactical leadership and weapons fundamentals on the A-29 (Wiltgen, 2017); the Swiss train future F/A-18 pilots entirely on the PC-21 (Fischer, 2018); and France's Phase 4 restructure shifted training from the Alpha Jet to PC-21 while preserving frontline jets for operational and conversion roles (CAE, 2020; Tanguy, 2021; Wolf, 2024). Several Middle East air forces have a turboprop training pipeline for Phases 1 through 4, and more European nations are adopting this methodology as they prioritise funding their warfighting capabilities and accelerate training (Dean, 2024).

Similarly, rather than defaulting to early jet utilisation, both the RAF – managing Hawk T2 availability challenges and expanding synthetic training under the UK Military Flight Training System (MFTS) 'Fast Jet Transformation' while considering Hawk-replacement options to optimise jet hours – and the Israeli Defence Forces – which employ a small-population, high-standard T-6A-to-M-346 LIFT model – illustrate that even forces retaining a jet phase still reinforce the logic and flexibility in increasing airborne volume and cognitive alignment earlier in the pipeline, without sacrificing readiness or safety (Ascent, 2025; Bate, 2025).

Implications for the RAAF training pipeline. A turboprop-heavy Phase 4 allows trainees to gain more airborne experience earlier and at lower cost, building cognitive and mission-system competence before reaching OCU. This reduces conversion bottlenecks and allows instructors to focus on integrated warfighting rather than remediation. By protecting the Advanced Jet Trainer for the jet-only envelope and using turboprops for scalable airborne training, the RAAF can increase throughput, improve readiness and preserve jet fleet life without compromising standards.

5. Balancing fidelity, cognitive demand and scalability

The central question in modern aircrew training is not whether realism should be preserved. Realism remains indispensable, but what type of realism is required at each stage of the training pipeline and at what cost? The evolution of air power has shifted the instructional centre of gravity from kinematic rehearsals towards cognitive readiness, mission-system fluency and decision-making under stress. As a result, training systems must balance three competing demands:

1. the need for sufficient performance fidelity to prepare aircrew for the operational environment;
2. the need for scalable airborne experience that develops airmanship, resilience and cognitive capacity; and
3. the imperative to deliver training outcomes within constrained sustainment budgets and finite jet-fleet lifecycles.

This section examines the trade-offs inherent in achieving these outcomes and outlines why a systematic reallocation of training tasks is required.

Redefining realism: kinematic fidelity vs cognitive relevance. Conventional thinking often equates 'realism' with aerodynamic performance or G-loading, suggesting that only a jet trainer can provide the authentic experience required for air combat training. While this perspective held weight in earlier generations of air power, when platform handling, performance margins and weapons delivery procedures dominated pilot workload, it is increasingly misaligned with the operational realities of fifth-generation employment. Modern combat platforms such as the F-35A demand far more from pilots in cognitive and information-centric domains (Dahm et al., 2025; Lemons et al., 2018). The decisive factors in mission success increasingly involve sensor management, fused-picture interpretation, prioritisation under ambiguity and efficient task-switching – competencies independent of transonic performance.

This evolution shifts the definition of realism from performance fidelity to cognitive fidelity. Training realism now depends on how effectively a system can reproduce information flows, task saturation, time compression and decision-making stress, rather than how closely it mimics a frontline aircraft's speed or altitude envelope (Hubbard, 2023; Self, 2025). High-performance turboprops – when equipped with modern avionics and embedded mission-relevant simulation – provide cognitively rich environments that allow trainees to practise these mental processes at lower cost and with higher repetition rates, without exceeding physiological or resource constraints.

The limits of low-fidelity platforms. If cost efficiency alone determined training design, one could theoretically imagine relying on piston aircraft or low-end simulation for a substantial portion of early training. Yet these platforms lack the performance envelope, systems architecture and mission-system integration required to develop higher-order competencies. They cannot replicate the time-compressed environments, visual demands, dynamic flight conditions or cognitive stressors needed to build the airmanship and tactical awareness of a future fast-jet pilot (Mezzanotte, 2000; Woltjer et al., 2024).

Piston and low-fidelity synthetic platforms remain valuable for foundational flying skills, but they cannot challenge trainees at the cognitive thresholds required by modern air operations. This limitation reinforces the need to employ a platform that, while less costly than a jet, provides sufficiently rich aerodynamic and mission-system context to build resilient decision-makers.

High-performance turboprops occupy this middle ground. They provide a wide and flexible performance envelope – adequate G-loading, manoeuvrability, speed and altitude – to support visual manoeuvring, formation, instrument, navigation, night and tactical flying (Fischer, 2018; Pittaway, 2019a). They also incorporate sophisticated avionics, embedded training systems, simulated sensors, electronic warfare cues and data-link architectures that mimic the cognitive environment of modern operations (Australian Defence Magazine, 2025; Lockheed Martin, n.d.).

Crucially, turboprops allow more airborne exposure, not less. By substantially reducing flying-hour costs relative to jets, turboprops allow trainees to fly more often, build experience faster, and develop deeper judgement and resilience – all without encroaching on the finite hours available for Hawk 127 or frontline jets (Bridel et al., 2021). This higher volume of airborne learning improves performance at Phase 4 and reduces the training load that must be absorbed at OCU.

International experience reinforces this logic. As discussed, the Swiss Air Force, the French Air and Space Force and the Brazilian Air Force all demonstrate that cognitive, procedural and foundational tactical skills can be developed effectively on turboprop platforms before jet conversion (Fischer, 2018; Wiltgen, 2017; Wolf, 2024). Peer systems with similar constraints diverge in platform mix but converge on cognitive fidelity earlier with protected jet-only envelopes (for example, RAF's synthetic uplift whilst reassessing Hawk T2 replacement; the IDFs' T-6A to M-346 LIFT model).

The jet-only envelope and the irreducible role of hawk. Despite their advantages, turboprops cannot replicate the jet-specific performance envelope required for certain training tasks. These include transonic acceleration, high-energy manoeuvring, high-altitude dynamic handling, and elements of weapons employment that require jet speed or aerodynamic characteristics (Mezzanotte, 2000). Additionally, some adversary air functions – particularly those requiring realistic kinematic threat representation, and increasingly electronic warfare simulation – must be delivered by jets or contracted high-performance aircraft (Australian Defence Magazine, 2025; Bridel et al., 2021).

Preserving the Hawk 127 for these tasks is essential not only for training effectiveness but also for resource management. Jet hours should be allocated to the training events that truly require jet performance and cannot be credibly or safely delivered on turboprop platforms. This disciplined allocation of tasks both protects Hawk life-of-type and ensures that trainees enter OCU with the cognitive foundation necessary to focus on advanced tactical and team-based training.

Airmanship and captaincy. The ability to lead, manage workload, make decisions under pressure and maintain situational awareness depend fundamentally on airborne experience. Even when delivered on lower-performance platforms, additional sorties contribute directly to the development of judgement, resilience, and leadership confidence (Self, 2025; Tornero-Aguilera et al., 2025).

This is particularly relevant for the RAAF, where OCU and AWIC are time-constrained and require trainees to arrive with robust foundational skills (Department of Defence, 2022a, 2022b; McLaughlin, 2024). When more airborne experience is delivered earlier and at lower cost, instructor time can be redistributed from remedial coaching to higher-end integration training, enhancing both throughput and quality.

The trade-off for the RAAF can therefore be expressed as follows:

- Too much emphasis on jet fidelity early leads to high costs, bottlenecks, reduced airborne volume, and sat-

uration of OCU and AWIC with foundational training tasks.
- Too much reliance on low-fidelity synthetic or piston training risks under-preparing aircrew for the cognitive and physiological realities of modern operations.
- A blended model – turboprop-heavy early, jet-protected later – offers the most coherent balance, enabling trainees to build cognitive, procedural and airmanship competence early, while reserving an AJT for the high-energy manoeuvre and jet-specific roles where its performance is indispensable.

The 'smart' allocation of tasks is therefore neither a compromise nor a cost-cutting measure; it is a training optimisation strategy grounded in operational, cognitive and economic realities (Zumwalt, 2015). It ensures the RAAF can produce aircrew who are not only ready for the jet environment but also prepared for the integrated, information-dense character of fourth-, fifth-, and next-generation air power.

6. Cognitive competency in modern air warfare

Modern air operations require aircrew who can perceive, decide and act effectively within information-dense, time-compressed and often degraded environments. This reality places cognitive competence – the capacity to manage attention, synthesise fused sensor inputs, prioritise tasks and retain judgement under stress – at the centre of training system design (Royal Air Force, 2025). While the lineage of pilot training still bears the imprint of the mass-production, time-based syllabi of the mid-twentieth century, fifth-generation employment and integrated multi-domain operations demand a transition to competency-based, data-enabled pathways that deliberately cultivate cognitive and team skills across a blended live-synthetic ecosystem (Greer, 1955; Lemons et al., 2018).

From time-in-seat to competency-based progression. Historical training constructs optimised for throughput – uniform hour counts, regimented events and linear phase progression – are increasingly mismatched to the cognitive demands of contemporary air power (Greer, 1955). Fifth-generation platforms such as the F-35A fuse multi-sensor data and present pilots with a rapidly updating tactical picture, shifting workload from physical control to information management and decision-making (Harrigian & Marosko, 2017; Lemons et al., 2018). In this context, competency-based training and assessment (CBTA/EBT) – which privileges demonstrated mastery over elapsed time – offers a more appropriate organising principle. Evidence from military and civil aviation shows that mapping syllabi to competency frameworks enables targeted remediation, reduced attrition and more efficient progression, provided instructor oversight remains the arbiter of readiness (Faske, 2025; Giddings, 2020; IATA, 2025; Paillard, 2025).

Competency-based progression is not a simple compression of hours; it is a deliberate reallocation of training effort toward the specific cognitive and behavioural outcomes that predict operational effectiveness. It requires clearly defined competencies (for example, information-management, prioritisation, autonomy under stress), observable performance indicators, and assessment gates applied consistently across live and synthetic modes (Dahm et al., 2025; Hubbard, 2023). In other words, effective fifth-generation training depends not just on using a tool that looks fifth-generation, but on identifying and training the right competencies within that tool – because applying an old syllabus to a new platform will not address the new cognitive and operational demands.

Blending modalities to shape cognitive load. Cognitive readiness is best developed in a scaffolded blend of modes. High-fidelity simulators and ground-based LVC environments can introduce complex mission problems, rehearsals and multi-platform integration at low risk and cost, while enabling instructors to pause, replay and reinforce decision frameworks (Alenljung et al., 2025; Woltjer et al., 2024). Yet the physiological component – G-onset, vestibular challenges, thermal stress, sustained visual attention and the psychology of real consequence – cannot be fully replicated on the ground (Self, 2025; Tornero-Aguilera et al., 2025). Airborne LVC adds further realism but still depends on a live aircraft to host synthetic entities and stimulate real-time decision-making under load (Laird, 2025b).

Designing sequences that gradually increase cognitive and physiological load – from procedural and systems-management tasks in simulators to airborne LVC vignettes and live multi-ship sorties – improves transfer to operational conversion. This approach supports earlier and more frequent airborne exposure on cost-effective platforms, reserving jet hours for the irreducible manoeuvre and envelope-specific tasks (Pittaway, 2019a; Woltjer et al., 2024).

Training data, instrumentation and AI/ML-enabled insights. Modern training ecosystems produce rich data flows – from aircraft mission systems, simulator logs, planning and debrief tools, and (where appropriate) biometrics. When responsibly integrated and governed, these data enable granular performance analytics and early-warning indicators for attrition risk, complementing instructor judgement rather than replacing it (Faske, 2025; Giddings, 2020). Studies linking eye-tracking metrics (for example, pupil dilation and fixation patterns), electroencephalogram (EEG) parameters, and heart-rate variability to cognitive workload suggest objective correlates of high-demand states that can guide coaching and scenario design (Carlsen et al., 2024; Hebbar et al., 2021).

Artificial intelligence (AI) and machine-learning (ML) methods have been shown to predict training performance and inform personalised interventions, especially when combined with transparent feature sets and human-in-the-loop validation (Faske, 2025; Giddings, 2020). The practical value is twofold: triage (identifying where a trainee needs targeted practice) and design (refining scenarios to elicit the desired cognitive behaviours). Crucially, data-driven insights must be embedded within the instructional workflow – mission planning, event execution, structured debrief – not treated as a post-hoc analytics exercise (IATA, 2025; Paillard, 2025).

Assessment and assurance. Competency-based systems require clear assessments aligned to operationally rel-

evant behaviours. For Phase 4 and pre-OCU stages, these assessments should include observable indicators of:

1. information-management and prioritisation under time pressure;
2. communication discipline and crew/flight coordination;
3. autonomy and judgement in ambiguous situations; and
4. recoverability from error through sound threat- and risk-management (Hubbard, 2023; IATA, 2025).

These assessments must be applied consistently across simulators and aircraft, and they should trigger adaptive syllabus paths – for instance, adding repetitions in sensor-fusion tasks or mission-lead planning before progressing to more complex vignettes (Faske, 2025; Paillard, 2025). Assurance is achieved not through rigid hour minimums but through triangulation of instructor observation, objective data and demonstrated performance in increasingly complex conditions (Giddings, 2020; Woltjer et al., 2024).

Team cognition: instructor-led, collective competencies. Some of the most consequential skills – mission planning, integrated execution, multi-ship mutual support, and rigorous debrief – are inherently collective and instructor-intensive. These cannot be reduced to individual simulator tasks; they require multi-platform, multi-role interactions and experienced instructors who can orchestrate and assess team performance under realistic conditions (Department of Defence, 2022a, 2022b). The RAAF's Air Warfare Instructor Course (AWIC), culminating in the Diamond Shield/Spear/Storm exercises, is illustrative: it compresses complex air-power problems into demanding, adversarial scenarios to develop instructors who can lead integrated operations (Campbell, 2024; Hartigan, 2024; Magee, 2024; McLaughlin, 2024).

A modern training system should therefore protect OCU and AWIC bandwidth for these group-level competencies. The route to doing so is not to 'synthetically teach' AWIC content earlier, but to download prerequisite cognitive and mission-system skills into earlier phases (on cost-effective platforms) so that OCU/AWIC can remain focused on the integrated war-fighting tasks for which they are uniquely suited (Laird, 2025b; Woltjer et al., 2024).

Implications for the RAAF system design. For the RAAF, a competency- and data-driven approach complements current programmatic directions. AIR5428 already integrates aircraft, simulation, courseware and debrief tools, while the Future Air Mission Training System (F-AMTS) extends this logic to mission aircrew and controllers – creating the system connectivity required for evidence-based coaching and adaptive progression (Australian Defence Magazine, 2025; Gigliotti, 2025; Lockheed Martin, n.d.; Pittaway, 2019a).

Within this ecosystem, Phase 4 should:

- define cognitive competency assessments for both live and synthetic training events to capture relevant indicators;
- use high-performance turboprops with embedded simulation/LVC to deliver early airborne exposure and cognitive scaffolding at scale;
- ring-fence Hawk/AJT hours for the jet-only envelope (transonic/high-energy manoeuvre, specific weapons-related work-ups, selected Red Air roles); and
- standardise planning–execution–debrief practices that mirror OCU/AWIC expectations.

The outcome is a training pipeline that intentionally builds cognitive competence where it is most efficiently acquired, concentrates collective training where it is most effectively taught, and uses data to ensure that standards are preserved and demonstrable across cohorts (Faske, 2025; Giddings, 2020).

7. Training cost optimisation: method, scope and sensitivities

Sustainable improvement in aircrew generation requires a cost framework that reflects how training outcomes are actually produced. Flying-hour rates alone are insufficient: meaningful comparisons must incorporate platform mix and fleet size, synthetic utilisation, instructor effort, OCU time-in-training, Red Air provision and the life-of-type consumption of fast-jet fleets.

To keep the model tractable, this section acknowledges all cost drivers but focuses primarily on airborne platforms, then applies a PBS-anchored method to compare Phase 4 (LIFT) options on a like-for-like basis and to derive defensible cost-per-graduate, total normalised time per graduate and throughput-adjusted results for the RAAF.

The analysis spans Phases 1–4 through to OCU because Phase 4 design directly influences OCU duration, instructor load and the draw on scarce fast-jet hours. Within this scope, we define the option boundaries, core cost components, data sources and sensitivities. The endpoint is the production of a 'D-Category' F-35A or F/A-18F pilot at OCU completion.

The training models are presented *ceteris paribus* for procurement; any future changes to turboprop or AJT fleet sizes would require re-modelling. **Figure 1** shows the normalised training time per graduate for the training models from Phase 1 to OCU. The current training model (**Baseline model**) reflects the existing ADF Pilot Training System, covering Phase 1 through OCU, using an AJT for Phase 4 and LIFT.

The **Hybrid model** retains a turboprop-heavy Phase 4 and lengthens OCU for assurance. Some 90% of LIFT is flown on a high-performance turboprop, with 10% allocated to a modern AJT. OCU expands by 20% to absorb elements not fully downloaded. The **Optimised mode**l also emphasises turboprop delivery but pairs it with a reduced OCU. A total 125% of baseline LIFT is flown on the turboprop (including additional operationally relevant sorties), 25% on an AJT, and OCU is reduced by 25% by safely downloading suitable elements into Phase 4. The last training model considers a pure **Turboprop substitute model** that replaces the Hawk 127 with an advanced turboprop while

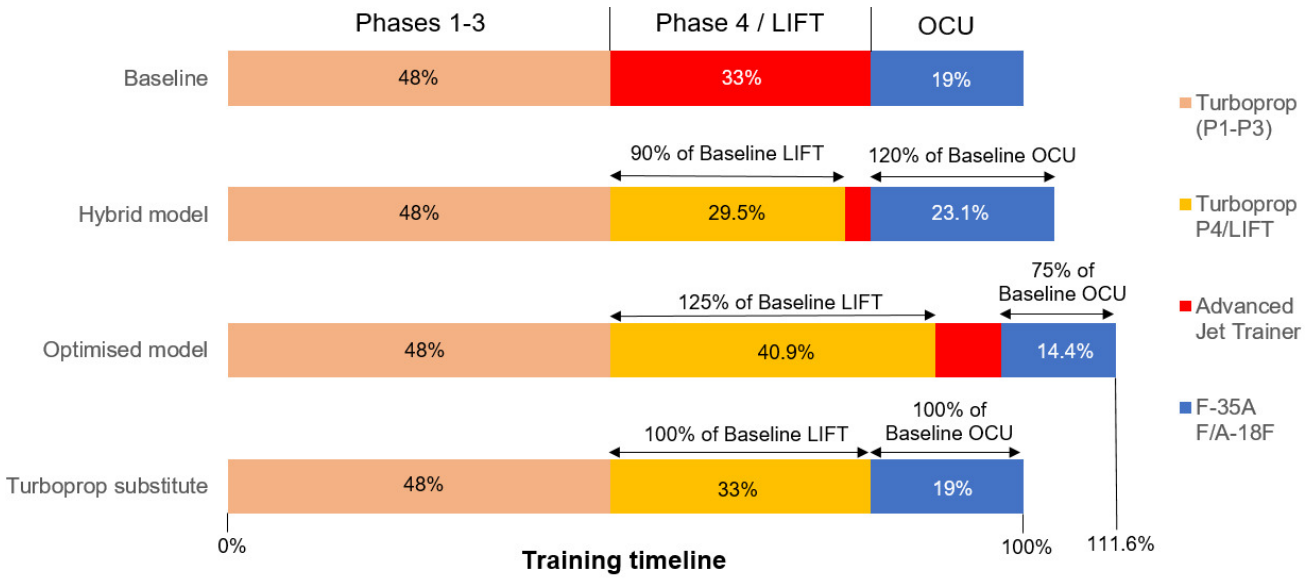

Figure 1. Different training models considered in the study as a function of training timeline.

holding other variables constant, serving as a counterfactual.

The extended durations visible in Figure 1 reflect the longer OCU period for the Hybrid model and the larger Phase 4 volume for Optimised model. The combined increase across Phase 4 and OCU represents an 11.6% net training-time rise, which capability managers must balance against system benefit.

To calculate for the cost-per-graduate, we use the relative cost per hour for different platforms used in training as shown in Figure 2. All financial baselines and rate bands are anchored to the Defence PBS and extant program documentation (Australian Government, 2025), with open-source estimates used conservatively where necessary (Blenkin, 2023; Durrant, 2018; Luke Air Force Base, 2017). Relative costs are normalised with cost per hour for turboprop. Multiplying the relative cost per hour to the normalised time-per-graduate in Figure 1 could account for the relative cost-per-graduate for the different training models.

Figure 3 summarises the cost results. The Hybrid model yields cost savings of 11.5% (F-35A) and 6.9% (F/A-18F), while the Optimised model delivers the largest gains: 28.3% (F-35A) and 27.8% (F/A-18F), enabled by high turboprop utilisation, a controlled AJT share and reduced OCU time. The pure turboprop substitute still reduces costs: 25% (F-35A) and 21.2% (F/A-18F) but does not balance cost and readiness as effectively as the blended options.

Overall, high-performance turboprops can deliver most of the training value traditionally associated with jets, at far lower cost and with only modest additional time per graduate. This reduces expenditure, increases throughput, and preserves readiness.

To clarify our logic:

- The Baseline model reflects 2025 curricula across Phases 1–3+, Phase 4 on Hawk 127 with current synthetic ratios, and current OCU durations; Red Air is embedded in PBS sustainment.
- The Hybrid model shifts 90% of Phase 4 to an advanced turboprop, retains 10% AJT and increases OCU by 20%.
- The Optimised model grows Phase 4 volume to 150% of Baseline (125% turboprop, 25% AJT) and reduces OCU by 25% by safely downloading suitable components.
- The Turboprop substitute model directly replaces Hawk 127 to illustrate the delta from Baseline.

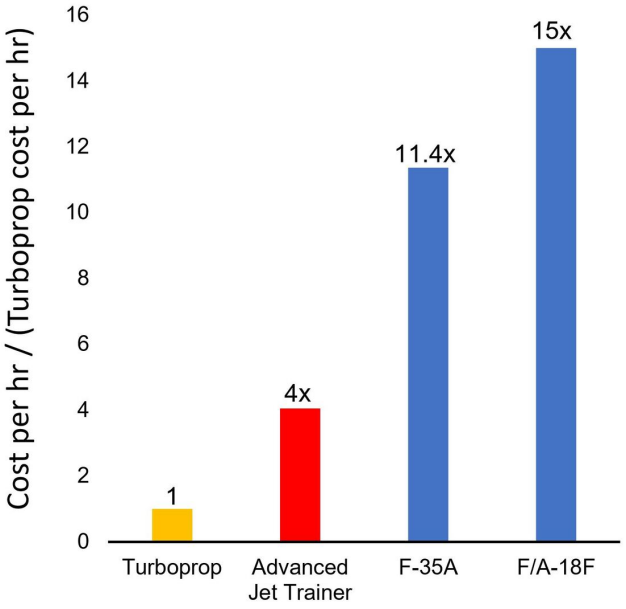

Figure 2. Relative training costs per hour relative to Turboprop for the different platforms used in training.

Three consistent patterns emerge:

1. The Hybrid model reduces cost with modest syllabus change. Moving 90% of Phase 4 to the turboprop and

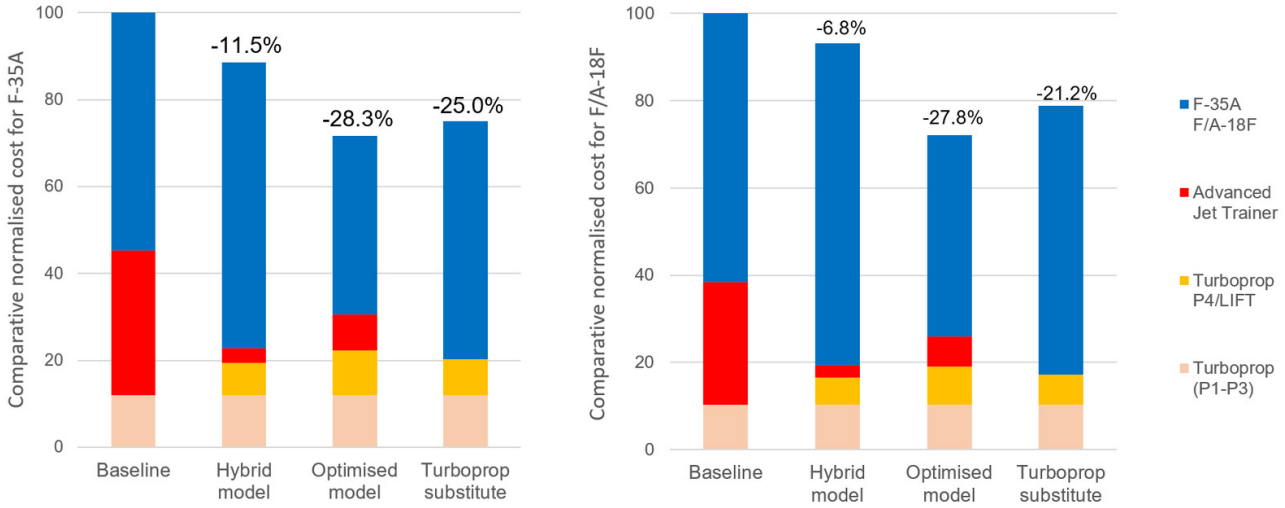

Figure 3. Cost analysis for the different training models for F-35A (left) and F/A-18F (right) conversion.

retaining 10% AJT, while conservatively increasing OCU by 20%, lowers CPG by 11.5% (F-35A) and 6.8% (F/A-18F). TPG rises by only 3.9%. This reflects the strong leverage of transferring airborne hours from jets to a lower-cost platform with embedded mission systems and LVC, while preserving key jet-only effects in AJT and OCU. Hybrid is therefore a low-risk, cost-reducing interim state.

2. The Optimised model produces the largest savings but depends on real OCU reductions. With ~125% turboprop volume, 25% AJT share and a 25% OCU reduction, CPG falls by 28.3% (F-35A) and 27.8% (F/A-18F), with TPG rising by 11.6%. These gains occur only if OCU reductions are genuine and if Red Air is properly planned and priced. Without effective OCU downloading, Optimised regresses towards Hybrid while adding complexity. It therefore requires performance-based gating.

   Further balancing can produce deeper savings: for example, +150% turboprop, 15% AJT and a 50% OCU reduction with heavier synthetic emphasis yields >40% CPG reduction with <10% TPG increase.
3. The pure Turboprop substitute model is beneficial but inferior to blended models. Replacing Hawk 127 entirely with a turboprop reduces CPG by 25% (F-35A) and 21.2% (F/A-18F) with unchanged TPG but does not match Hybrid or Optimised in balancing cost and readiness.

Across all scenarios, the dominant sensitivities are fast-jet flying-hour rate variance, actual OCU time-in-training achieved, and the live-synthetic balance. These shape the magnitude of savings but not the ranking: Hybrid consistently outperforms Baseline and Optimised outperforms Hybrid when OCU downloading is achieved.

Hybrid is the rational starting point: cost-reducing, throughput-enhancing and low-risk. Optimised is the aspirational end state: offering the greatest savings and throughput but dependent on demonstrable performance in OCU and synthetic integration. A pure turboprop model is not competitive because it removes the AJT component that preserves readiness at acceptable cost.

Fundamentally, sustainable improvement in aircrew generation requires cost modelling aligned to how capability is actually produced. Re-shaping Phase 4 around the lowest-cost platform mix that still preserves fast-jet-ready competencies – and treating OCU as a system-wide resource – consistently yields superior outcomes. Within that logic, Hybrid delivers a low-transition path to ~10% savings, while Optimised provides a gated path to ~28% savings. Both outperform the Baseline on a PBS-anchored, like-for-like basis, validating the central argument for Phase 4 reform.

8. Recommendations and Implementation Pathways

The analysis demonstrates that the RAAF can increase throughput, reduce cost-per-graduate and safeguard fifth-generation standards by reallocating cognitively rich but non-jet-dependent Phase 4 tasks to a high-performance turboprop, while preserving Hawk or AJT hours for the small set of training events that genuinely require jet performance. Achieving this requires a simple, disciplined and evidence-based implementation pathway that aligns training design with how capability is actually produced.

The core design logic rests on three interlocking principles. First, the jet-only envelope must remain protected so that transonic manoeuvre, weapons-related work-ups and defined Red Air roles continue to be delivered on platforms capable of safely and credibly teaching them. Second, cognitive readiness must be developed earlier and at scale using high-performance turboprops equipped with mission-system emulation and LVC, which allow trainees to rehearse decision-making, information-management and tactical execution far more frequently and at much lower cost. Third, Phase 4 must be fully integrated into the broader aircrew training ecosystem so that planning, execution and debrief cycles – and the data that support them – are consistent across live and synthetic modes.

The first step in implementation is the trialling and/or re-authoring of Phase 4 into a Hybrid model that shifts roughly 90% of cognitive and mission-system events to the turboprop while retaining about 10% of the syllabus on the Hawk or AJT for jet-dependent tasks. The event-allocation logic is straightforward: cognitive events shift to turboprop; kinematic or weapons-specific events remain on jet. Each competency block should progress from simulator to airborne LVC to live multi-ship, ensuring trainees arrive at OCU with strong cognitive foundations rather than requiring remediation. Given the mixed RAAF fast-jet fleet, a control-and-variable approach – using the F-35A stream as a stable baseline and the F/A-18F stream as the variable pathway – would enable comparative evaluation of the Hybrid model.

Successful reform depends on establishing a small, stable fourth- and fifth-generation instructor cadre responsible for re-authoring the syllabus, defining competency gates and standardising assessment across all modalities. These gates, covering information-management, prioritisation, communications discipline, decision-making under ambiguity and recoverability from error, form the contract between Phase 4 and OCU. When consistently met, they allow OCU to concentrate on high-end, collective mission integration rather than re-teaching foundational skills.

AIR5428 and F-AMTS already provide a baseline for integrated training. The next step is to scale their use so that Phase 4 routinely captures simple, high-value data such as timelines, cognitive load, and capacity signals such as task-switching indicators. These should be provided to instructors as usable insights that support adaptive coaching and early remediation, rather than as complex dashboards. This data-enabled approach preserves standards without relying on fixed hour counts.

Red Air must be treated as a planned and priced resource rather than absorbed incidentally through Hawk utilisation. Hawk (and future AJT) hours should be reserved exclusively for the jet-only subset of Red Air events, with additional vignettes delivered by contracted adversary providers at predictable points in the training year. This ensures Hawk life-of-type remains protected and removes unplanned demand from the system.

Every stage of implementation must remain inside the PBS-aligned sustainment envelope. Hybrid achieves immediate cost-per-graduate reductions by shifting volume to lower-cost platforms. Any transition to an Optimised model should follow only after demonstrated reductions in OCU time-in-training and evidence of predictable, appropriately priced Red Air demand. No savings should be credited until they are proven.

A small Training System Board should oversee rollout, maintaining a configuration-controlled data pack that captures syllabus design, usage assumptions, Red Air planning and device logs. After two Hybrid cohorts, the Board should convene a Gate-2 review to determine whether progression to the Optimised model is justified. Progression should occur only when evidence demonstrates improved graduation rates and throughput, reduced OCU duration, lower instructor remediation load, increased pre-OCU airborne experience, reliable delivery of Red Air without unplanned Hawk draw, and cost-per-graduate improvements within expected bands. If these conditions are not met, Hybrid becomes the steady-state model while refinements continue.

The transition can be executed in a deliberate two-year cycle. During the first three months, the instructor cadre is established, the syllabus is re-authored and baseline data are set. Hybrid Cohort A runs from months 4 to 12, followed by a mid-cycle review. Hybrid Cohort B runs from months 13 to 21, during which preliminary OCU analysis informs the Gate-2 decision at months 22 to 24. Only if measurable benefits are observed should transition to the Optimised model proceed.

Risk is minimised through strict protection of the jet-only envelope, the use of competency gates, two-cohort validation, planned rather than incidental Red Air, sequencing aligned to AIR5428 and F-AMTS capacity, and maintaining instructor cadre stability. This disciplined pathway ties reform to evidence and reinforces the broader trajectory Defence is already pursuing – aircrew training at a systems level, integrated synthetics and a renewed emphasis on the human dimension of fifth-generation capability.

9. Conclusions

The effectiveness of contemporary Australian air power rests not only on advanced platforms but on a training system that can produce aircrew ready for fifth-generation operations. The evidence shows that the centre of gravity in pilot training has shifted from kinematic fidelity to cognitive fidelity – the ability to manage fused information, prioritise under ambiguity and operate effectively in complex, often degraded environments (Dahm et al., 2025; Hubbard, 2023; Lemons et al., 2018). Defence's recent investments demonstrate an institutional shift toward this integrated, competency-based approach (Australian Defence Magazine, 2025; Lancaster, 2024; Lim, 2025; Lockheed Martin, n.d.).

Within this environment, the paper has made a RAAF-specific, evidence-based case for modernising Phase 4 by reallocating cognitively rich but non-jet-dependent tasks to a high-performance turboprop with mission-system emulation and LVC, while preserving the Lead-in Fighter Trainer for transonic manoeuvre, weapons-related events, and defined Red Air roles. This is not a platform-replacement argument; it is a training-effect argument, aimed at increasing early airborne exposure, improving cognitive readiness, reducing cost-per-graduate, and protecting scarce jet hours for the operational and training tasks that require them most (Australian Government, 2025; Bridel et al., 2021).

To ensure that decisions remain grounded in evidence rather than assumptions, the paper introduced a PBS-anchored cost method that accounts for flying-hour sustainment, fleet effects, synthetic utilisation, instructor effort, Red Air provision and OCU time-in-training. These inputs are presented as sensitivity bands, not false-precision point estimates, providing a transparent framework for evaluating alternative training designs (Australian Government, 2024a, 2024b, 2025; Department of Defence, 2023).

Recognising the realities of system transition, the paper recommends a gated pathway: adopt a Hybrid model for two cohorts, instrument outcomes using AIR5428/F-AMTS data, and progress to an Optimised model only when performance criteria are met – higher throughput, reduced OCU time-in-training, improved instructor utilisation, predictable Red Air demand and measurable cost-per-graduate reductions (Australian Defence Magazine, 2025; Lockheed Martin, n.d.; Pittaway, 2019a).

The broader implication is that training realism must be re-defined. In early and mid-pipeline phases, realism is primarily cognitive; in late stages it is jet-kinematic and collective, centred on instructor-led integration at OCU and AWIC (Hubbard, 2023; Self, 2025; Woltjer et al., 2024). High-performance turboprops and synthetic environments therefore become force multipliers, expanding airborne learning volume and sharpening mission-system fluency, while Hawk hours are conserved for the irreducible jet envelope. This approach aligns with international practices, including Switzerland, Brazil and France's restructuring, while remaining tailored to Australian force-structure, cost, and sustainment realities (Fischer, 2018; Wiltgen, 2017; Wolf, 2024).

Finally, the argument re-centres the human dimension of fifth-generation air power. No platform can compensate for aircrew who cannot think clearly, integrate effects across domains, manage ambiguity or lead teams under pressure. A training system that builds cognitive capacity early, preserves scarce jet and instructor resources for the tasks only they can teach, and measures what matters will better prepare Australian aviators for the operational realities of the coming decades. In short, by flying more, and flying smart, within an integrated, data-connected ecosystem, the RAAF can increase throughput, protect standards, and deliver the cognitively ready aircrew demanded by modern and future air warfare.

Submitted: October 31, 2025 AEDT. Accepted: January 23, 2026 AEDT.

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