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AIR DOMAIN TECHNOLOGY

UNMANNED AIR MOBILITY FOR THE AUSTRALIAN DEFENCE FORCE:

FUTURE PLATFORMS, PARTNERSHIPS AND CHALLENGES

Matt Hetherington

BEYOND THE FUTURE FORCE

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FOREWORD

It is my pleasure to present this paper for publication, the first in our Beyond the Future Force series. It is very heartening to have a senior leader like Group Captain Hetherington draw from his experience to think about possible futures for air power. Beyond the Future Force is intended to engage our readers and to challenge current models of contributing to the joint force, and this paper does exactly that.

I commend Group Captain Hetherington for his personal investment and contribution to the conversation on Unmanned Air Mobility for the ADF. As well as presenting myriad possible ways these systems could transform the way we work, he grapples with the obstacles to innovation. The paper presents a compelling argument that a 'step change' is necessary in the character of air mobility to most effectively response to our continually changing geostrategic landscape.

This paper is intended as a catalyst for collaboration. It will take investment in relationships between Services, Groups, academia and industry to realise the potential enhancements it describes. Group Captain Hetherington has painted a tangible vision of a possible future that has potential to inspire greater creativity a collaboration amongst air power practitioners across and beyond Defence.

Group Captain Jason Baldock
Director Air and Space Power Centre

ABOUT THE AUTHOR

GPCAPT Hetherington is currently the RAAF Liaison Officer to the US Pacific Air Forces. He joined the Air Force in 1992, studied at the Australian Defence Force Academy, and graduated from No. 98 Navigator Course in 1996.

Flying. He has flown 3000 hours in transport (C-130), bomber (F-111C) and training (MB326; HS-748, PC-9A, DHC-8) aircraft. Key roles included C-130H Special Operations Navigator, Air Mobility Operational Test and Evaluation Flight Commander, and Qualified Navigator Instructor where he was awarded an Air Commander Australia Commendation.

Operational Service. GPCAPT Hetherington has flown operational C-130 missions in Iraq, Afghanistan, East Timor, Bougainville, Solomon Islands; Indonesia, and PNG; and has commanded air lift units in the Middle East and Indonesia. His most recent role was Director Air Mobility Division, directing operations for all RAAF Air Mobility missions.

Command and Staff Roles. As Commanding Officer Air Mobility Training and Development Unit, he led the development and test of specialised air-transport methods. He has held staff roles in the office of Chief of Air Force, in Preparedness, and in Military Strategy contributing to the ADF's core strategic guidance documents. As exchange officer to USAF 613th Air Operations Centre, he was awarded the United States Meritorious Service Medal. He was a directing staff member and graduate of the Australian Command and Staff College, and holds Masters Degrees in Business and Arts (Strategy), both from UNSW.

Family. He is married to Alicia, and they have three children, Amélie, Tess and Matilda. He is a keen surfer, and proud 1964 EH-Holden and 1966 Ford-Mustang owner.

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1.

Introduction

Few sacred cows survive in a domain so heavily reliant on technology. Air power has benefitted from and wrestled with the churn of a century of technological innovation and advancement. The advent of new technologies continues to challenge oft-held truisms in air power. One such evolving technology in air power is the Unmanned Aerial System (UAS). This technology presents great opportunities for the Australian Defence Force (ADF). While the ADF has made some UAS progress in select roles, the Royal Australian Air Force (RAAF) is yet to adopt this technology across *all* of its air power contributions to military effects.

The Air Power Manual (Air and Space Power Centre [ASPC], 2022)[1] defines seven *air power contributions*: force generation, airbase operations, air command and control, counter air, air mobility, air intelligence and ISR (intelligence, surveillance and reconnaissance), and air strike. Some advanced allied countries already employ well-developed unmanned systems for air intelligence, ISR and air strike. These include the U.S. Air Force's (USAF) MQ-1 Predator, MQ-9 Reaper and RQ-4 Global Hawk. Even counter air – which incorporates the most sacred of cows, manned air combat – is on its way to developing unmanned systems; the RAAF has partnered with Boeing on the Loyal Wingman program (Davis, 2019c), now formally named the MQ-28A Ghost Bat (Dutton, 2022).

But what of air mobility? The ADF has not embraced real conversation about future ADF air mobility autonomy. Is manned air mobility also a sacred cow? A more likely reason for the stasis in future thinking on autonomous air mobility is the decades of highly reliable and proven operational success of manned systems underpinned by an (until now) effective air lift doctrine. There is thus a Clausewitzian parallel here: an

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[1] The Air Power Manual Seventh Edition (ASPC, 2022) released March 2022, uses the term air power *contributions* to replace the term air power *roles* used in the sixth edition.

enduring element of the *nature* of war is the need for mobility, but what confronts the RAAF today is a step change in the *character* of war, a technological opportunity for mobility that is too significant to ignore.

This paper identifies the lag in adoption of UAS in ADF air mobility and explores opportunities for future ADF employment of UAS in that contribution. In doing so, the paper aims to increase collective awareness of the potential for unmanned ADF air mobility and provide a broad reference source for military and commercial contributors to the ADF Force Structure enterprise. The paper first examines drivers, or indicators, for UAS adaptation. These drivers include Australia's strategic interests, regional military modernisation, safety and survivability, reducing costs and technology availability. The paper then presents and analyses specific opportunities for and examples of UAS development for each of the three core air mobility *activities*.[2] It does this by briefly discussing the current ADF fleet, then exploring some evolving unmanned air mobility technologies and concepts that the ADF might consider for the next generation air mobility fleet. Lastly, the paper raises some challenges that UAS air mobility development may face, to assist future research and exploration.

The evidence points to the need for an agile, cross-service (and cross-cultural), cross-industry approach to future air mobility force design, development and employment. The traditional bifurcated model of medium- to heavy-lift RAAF platforms and light- to medium-lift Army platforms may give way to a blended fleet of large and small manned and autonomous systems. A collective approach between joint force designers – with real collaboration across single service headquarters – is crucial for collaboration between the RAAF's fixed-wing air mobility community and the Army's rotary-wing community. Perhaps even more crucial is the need for collaboration with industry in this arena. Commercial industry plays a considerable role in the autonomous vehicle field, as do government and private research and development organisations. Cross-service leverage of existing and new partnerships is essential to harness opportunities for future autonomous ADF air mobility.

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[2] The Air Power Manual Seventh Edition (ASPC, 2022) describes three core air mobility activities: Air logistics support (ALS), Airborne operations (ABNOPS) and Air-to-air refuelling (AAR). Aeromedical evacuation (AME) is recognised as a subset of ALS.

2.

DRIVERS FOR UAS ADAPTATION IN AIR MOBILITY

2.1 The Need for an Asymmetric Response to Regional Military Modernisation

The 2020 Defence Strategic Update unambiguously states that military modernisation in the Indo-Pacific has accelerated faster than envisaged (Department of Defence, 2020a). Regional force modernisation has resulted in the development and deployment of new weapons that challenge Australia's military capability edge. Hellyer (2018, p. 21) purports that the West no longer has a monopoly on world-leading defence innovation and technology. China, for example, is making great advances in the quality and quantity of its military equipment. The modernisation delta between West and East continues to close, particularly in emergent military technologies such as hypersonics, quantum technologies and artificial intelligence.

The 2020 Force Structure Plan is explicit in its intent for autonomous systems to form part of Australia's future force to meet this rising challenge:

> Improved weapon systems, with longer range and greater survivability, will give Defence the capability to deter or defeat attacks as far from Australia as possible. New and existing aircraft will combine with remotely piloted and autonomous systems to provide increased lethality and survivability. An expansion of the air mobility fleet will improve Defence's ability to support and project our forces across Australia, the Indo-Pacific and further afield, when required. (Department of Defence, 2020b, pp. 49-50)

Leveraging technological opportunity is no longer a means to stay ahead – it is a necessity to keep up. It is easy to argue that the current ADF air mobility enterprise has highly effective conventional systems. However, if the 2020 Force Structure Plan's intent is not fully embraced, then ADF air mobility will lag behind competitors' and allies' asymmetric systems, putting at risk the effective and survivable force projection of Australian forces.

2.2 Australia's Strategic Interests

Hellyer (2018, p. 22) asserts the future force described in the 2016 Defence White Paper (Department of Defence, 2016) already lags behind the evolving strategic environment. Foreshadowing judgements of the 2020 Defence Strategic Update (Department of Defence, 2020a), Hellyer (2018) purports a greater deployment of emergent asymmetric capabilities might be more effective in certain circumstances than conventional systems in averting a major power projecting force against Australia.

At the regional level, one of Australia's key goals – near-region stability and security – has seen the ADF successfully conduct disaster relief, counterterrorism and capacity-building with less expensive, lower-tech mission systems. But as emergent technology costs come down, high-tech should indeed be considered for some of these 'lower-end' military roles (Davis 2019a; Davis 2019b). The government's Pacific Step-Up policy provides an opportunity to develop emergent technologies such as UAS to enhance ADF and partner nations' surveillance and aerial delivery capabilities for near-region humanitarian, disaster relief and stability operations. The 2020 Defence Strategic Update amplifies the complexity and uncertainty of the strategic environment and edifies the need for a more capable, agile and potent force that can respond to the full range of contingencies, including participation in major power conflict, grey zone operations and humanitarian relief (Department of Defence, 2020a). Air mobility, as always, will have a role to play across this spectrum; by extension, so too should autonomous systems, to enhance ADF force projection across that spectrum.

2.3 Safety and Survivability

In an interview with Stevens (2019), Mirragin Aerospace director Rob Sutton describes the substantial enhancement to safety that UAS bring to many applications. In the military context, one basic premise of unmanned systems is distancing the human from conventional threat envelopes. This important factor may sometimes be overshadowed by increasing negative focus on efficiency and cost; UAS have not delivered the anticipated (and probably overinflated) savings in manpower and costs. Employment of UAS for air mobility would reduce conventional crews' exposure to threat and potentially have increased mission survivability. This is especially true for small multi-vehicle swarming systems, which, compared to a single, large, manned aircraft, would saturate most conventional surface-to-air missile tracking systems seeking to shoot down conventional aircraft. Increased survivability and reduced crew risk enable operational commanders the flexibility to proceed with higher payoff missions that may otherwise be deemed excessively risky with conventional manned platforms.

2.4 Cost

Cost drivers influence the way militaries fight. As high technology systems such as the F-35A and the Royal Australian Navy's (RAN) future submarine occupy large swaths of the Defence budget, the cost of *simple* unmanned systems and their basic electronic technologies continues to fall (Hellyer, 2018). Thus, low-cost expendable systems may mitigate investment pressures while genuinely contributing capability. This is not to say that all UAS are inexpensive, but select simple systems might form part of an optimised future air lift force structure.

In November 2014, then–United States (US) Under Secretary of Defense for Acquisition, Technology and Logistics Frank Kendall asked the Defense Science Board to examine a radical idea: '*the use of large numbers of simple, low cost (i.e. "disposable") objects vs. small numbers of complex (multi-functional) objects*' (Sharre, 2015). This concept is starkly at odds with decades-long trends in defence acquisitions towards smaller numbers of ever-more expensive, exquisite assets. As costs have risen, the number of fighting platforms in the US inventory has steadily declined despite budget growth. For example, from 2001 to 2008, the USAF's base (non-war) budgets grew by 27% (adjusted for inflation). Yet the number of aircraft in the US military inventory decreased by 20%. Sharre (2015) asserts that Kendall is joined by a growing number of voices calling for a paradigm shift, from the few and exquisite to the numerous and cheap. He goes on to quote Hammes (2014): 'the future of warfare is the "small, many, and smart" over the few and exquisite'.

The Platform for Unmanned Cargo Aircraft (PUCA) advocates research and development of commercial cargo UAS. As a commercially focused group, cost savings is a driving factor for its advocacy of unmanned air cargo systems. It cites projected life-cycle savings in production, maintenance, crew salaries and fuel use, and purports unmanned cargo aircraft (UCA) will open up markets in regions where air transport has previously been uneconomical (Collins, 2017).

2.5 Technology Availability and Experience

The technology is here, now. There is a great body of development work by corporate and military elements to enhance UAS utility. As the multitude of UAS applications to everyday operations grow, demand across corporate and government sectors will increase. This will drive additional innovation and efficiencies and lower costs even further. An ADF UAS air mobility fleet need not (indeed, should not) be a first-of-type model. The depth of options for a capability selection could be fed by an already healthy selection from commercial off-the-shelf, military off-the-shelf and developmental UAS solutions. The 2020 Defence Strategic Update (Department of Defence, 2020a) devotes an entire chapter to industry and innovation – a clear indicator of the direction in which government intends ADF force development for disruptive technologies to proceed.

On leveraging existing experience and current Defence capabilities, the RAAF, ironically, must turn to its environmental partners: the Army, which has an existing and expanding fleet of UAS, and the RAN, with the UAS-operating

822X Squadron.[3] While the RAAF successfully operated Heron in the Middle East for a number of years and is building on an embryonic understanding of how to operate future MQ-4C Triton and MQ-28A Ghost Bat platforms, its sister services have demonstrated broader historical experience. The RAN, like the RAAF, operated the venerable Jindivik in the 1960s but sustained that UAS capability for decades longer (up until 1998), conserving organisational expertise. Today, the RAN has realised successful employment of modern UAS, including the enhanced (50 kg) payload S-100 UAS (Royal Australian Navy, 2022). The Army continues to build on substantial experience, developing and operating a range of UAS both domestically and in the overseas deployed environment.

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[3] While acknowledging the RAN's re-entry into UAS through the creation of 822X Squadron in Nowra, New South Wales, this paper's focus is on air mobility, which is predominantly the remit of the RAAF and Army.

3.

Evolving UAS Opportunities for Air Mobility

This section explores UAS options within each of the three core air mobility activities: Air logistics support (ALS), Airborne operations (ABNOPS) and Air-to-air refuelling (AAR) (ASPC, 2022). It briefly introduces current manned fleets and then explores evolving UAS technologies, concepts and systems that the ADF might consider in developing the next generation air mobility fleet for that particular activity.

3.1 Air Logistics Support (ALS)

In layman's terms, ALS is '*Aerial Delivery in a permissive environment*'. The Air Power Manual defines ALS as an air activity to deploy, distribute or recover personnel, materiel or forces in a permissive environment (ASPC, 2022). ALS missions may be inter- or intra-theatre, can use a traditional 'hub and spoke' logistics delivery model, and can use direct access to smaller and/or austere airfields.

Current RAAF ALS Fleet

The entire RAAF Air Mobility Group (AMG) fleet is capable of performing the ALS role. All AMG fleet platforms are manned aircraft: KC-30A Multi-Role Tanker Transport, C-17A Globemaster III, C-130J-30 Hercules, C-27J Spartan, B-737 Boeing Business Jet, Falcon 7X and B-300 King Air. The RAAF does not currently possess any unmanned ALS platforms. The following UAS opportunities do not imply the need for a complete replacement of manned systems; rather, they point to the benefits of a future force structure that blends manned and unmanned platforms and more closely integrates mission systems across the three services.

3.2 Evolving ALS UAS Opportunities

Notwithstanding the long history of science-fiction air transport concepts, autonomous air mobility remains an immature technology – a 'new frontier'. McNabb (2019) alludes to the massive future market potential for UAS air mobility and highlights the importance of capability and technology partnerships to realise this potential. The two core ALS roles of the RAAF and Army are cargo transport and personnel transport, highlighting the need to explore opportunities to partner with industry in realising the inherent ALS UAS opportunities.

Small to Medium Cargo

One of the leading applications in the small to medium cargo field is commercial small-package delivery. This has relevant applications for future ADF air mobility roles in competition, conflict and humanitarian resupply situations. Online distributors already employ autonomous airborne logistics systems. In the US, Amazon, Alphabet, UPS and Walmart have entered an increasingly competitive market employing UAS technology to deliver small cargo goods to customers by air. In Australia, the Civil Aviation Safety Authority continues to develop policy for drone operation and has approved a license for Google subsidiary package delivery company Wing Australia to deliver cargo under 1.5 kg via drone in parts of Canberra (Wing, 2019).

Figure 1. Wing Canberra cargo delivery UAS.
Source: Wing (2019).

Chinese delivery drone companies are competing for new markets in urban and regional areas and appear to have leapfrogged the original US companies like Amazon in some roles. While numerous companies operate small capacity rotary cargo drones, there has been limited global progress in large capacity cargo UAS, an area more akin to contemporary ADF air mobility methods. Numerous Chinese companies have larger capacity prototypes under development, with many claiming to have the largest cargo UAS. In the commercial space, this competitive quest for larger range and payload is mainly driven by economies of scale. In particular, larger drone deliveries to infrastructure-challenged rural and mountainous areas and over non-existent (or congested) roads can realise substantial logistics cost savings.

Unmannedcargo.org reports on Chinese companies' expanding cargo capacities, which still fall substantially short of contemporary manned cargo platforms. Retailer JD.com's delivery network in Shaanxi province, China, aims to cover a 300-kilometre radius and have multiple drone ports to support operations, with a fleet of various-sized UAS planned to carry an up to 1,000 kg payload. The 2018 Feihong-98 (FH-98) (adapted from the Shifei Y5B, a Chinese version of the Russian AN-2, in operation since 1957) was modified by the China Academy of Aerospace Electronics Technology for autonomous operation with a maximum payload of up to 1.5 tonnes (Zinan, 2018).

SF Express has test flown the AT200 (see Figure 2), a modified PAC P-750 XSTOL fixed-wing turboprop with a 1,500 kg payload capacity and flight range of 2,000 km. The Chinese company expects this unmanned cargo drone will reduce operational costs by 30% compared to traditional piloted aircraft. Aviation media sources assert this unmanned aircraft has military applications, with the capacity to deliver equipment from Hainan Island to the Paracel Islands in the contested South China Sea in under an hour (Chen, 2017). Even fully loaded, the AT200 can take off or land using a 200-metre runway and requires no standard airport facilities. It can operate on simply equipped airstrips or even earth slopes and grasslands, and so has the potential to be used in high-altitude and mountainous regions.

Figure 2. Chinese AT200 modified UAS cargo aircraft.

Source: UASVision (2017).

Large Capacity Cargo UAS

Commercial cargo UAS development is yet to reach capacities of the scale of current manned military platforms. The term 'Large Unmanned Cargo Aircraft' (LUCA) in current parlance is a misnomer. Varying sources cite 'LUCA' examples that carry a payload as small as 100 kg (Collins, 2017). The vast majority of commercial drones are vertical-lift rotary-wing platforms. There are physical limits to affordable rotary-wing solutions (although Russia has some remarkable manned exceptions), so some firms are simplifying their hardware design back to fixed-wing options. The Hungarian Black Swan, carrying a similar payload to the Chinese AT200 (1,500 kg), is another example of scalable fixed-wing technology that may provide scope for future very large scale cargo UAS. Others, like the US Sabrewing tested at Edwards Air Force Base, offer potential scalability in a tiltrotor turbofan configuration.

Truly large capacity future unmanned air lift may be as simple as upscaling smaller proven UAS, or automating present large capacity models (e.g., C-17 or AN-124). The USAF does not offer a great deal at the unclassified level on future autonomous heavy airlift design, though some unofficial military comments offer valid considerations about the environments and key attributes that may be necessary for the 'C-X' next generation military airlifter.

Conversely, future large unmanned air lift may require a complete rethink. Initiatives such as Californian start-up firm Natilus provide conceptual and experimental developments with impressive range and payload which aim to shape the future of commercial and military airlift. The annual Unmanned Cargo Aircraft Conference brings together manufacturers, operators, knowledge institutes, consultants, shippers and government organisations active in the present and future UCA field. Collins (2017) is an important reference source, providing a sound overview of the history, limited present developments and future prospects of LUCA.

Figure 3. Natilus future large autonomous drone concept.
Source: natilus.co.

Humanitarian Assistance

There is growing potential for autonomous cargo delivery for humanitarian assistance and disaster relief (HADR). The uncertain and volatile nature of HADR situations presents a complex mobility problem for established commercial logistics operations. 'Last mile distribution' in disaster-affected areas is particularly susceptible to this uncertainty, and an area where ADF air mobility could be enhanced by UAS employment. In the humanitarian context, last mile distribution is the final stage of a HADR chain, referring to the final leg of delivery of relief supplies – from Local Distribution Centres (LDCs) to the actual beneficiaries affected by disasters. The traditional ADF air mobility model for HADR has rarely been tasked for this final leg of the supply chain; instead, the RAAF's role often terminated with the offload of palletised cargo at an airfield (i.e., at the LDC, not to the final recipient). Augmentation with UAS could extend the air mobility effect to this final 'last mile' of the HADR supply chain.

Long-Range RPAS for HADR

'Last mile', short-range, small-payload cargo delivery is not the only area of UAS opportunity in HADR. Air power's natural reach signposts a logical thread to explore longer range, larger payload UAS for HADR. Tatham et al. (2017) analyse the HADR response to Cyclone Pam, which struck Vanuatu in

March 2015, to demonstrate how long-endurance remotely piloted aircraft systems (LE-RPAS) could have been used to support post-disaster needs assessment and subsequent response processes. They go on to analyse criteria for selection of a HADR LE-RPAS, review current LE-RPAS and consider the efficiency of two exemplar aircraft. Although proposed payloads are orders of magnitude smaller than current manned air mobility platforms, their paper provides sound considerations for future expansion within this role.

Tatham et al. (2017) cite just under 100 other studies directly related to UAS contribution to HADR, including a comprehensive American Red Cross and Measure (2015) study that includes an instructive matrix describing drone mission types in recorded HADR operations from 2011–2015.

A US-based Johns Hopkins research team has studied the efficacy and efficiency of UAS vaccine delivery in remote communities of the developing world. Haidari et al. (2016) identify critical criteria for this type of logistics supply chain method, including speed, reach and temperature control. These are all classic attributes serviced by specific air mobility capabilities, which could potentially be transitioned to unmanned systems.

Personnel Transport by UAS

The next evolution attracting the attention of commercial UAS entrepreneurs is personnel transport. In addition to commercial (taxi-style) applications, UAS personnel transport has other civil, humanitarian and military applications. For example, a American Red Cross and Measure (2015) report specially designed chambers on larger drones, such as the Kaman K-MAX (essentially a retrofitted helicopter), that can transport personnel as effectively as the space in small manned aircraft. This transport might be used for various scenarios, such as evacuation from disaster zones, an embassy under threat of being overrun by malign actors, or carriage of mission-essential or command personnel in and out of critical operational areas. These personnel capsules can also be suspended below heavy-lift drones.

Further studies by respected consultancies aimed at informing commercial and government ventures have yielded valuable insight into viability, challenges and technological opportunities for larger range and payload UAS for personnel transport. The NASA Aeronautics Research Mission Directorate's Advanced Air Mobility site contains a selection of studies addressing future UAS mobility opportunities for personnel and cargo. A paper commissioned by the US National Academies of Sciences, Engineering, and Medicine (2020) evaluates the potential benefits and challenges associated with this emerging industry. The paper provides recommendations to foster an environment focused on cementing the US' (purported) leading position in developing, deploying and embracing these new technologies. The paper presents a national US vision for advanced aerial mobility, market evolution, and safety and security management. Booz Allen Hamilton (2018) conducted an urban air mobility (UAM) market study for NASA. This comprehensive report focuses on commercial viability in three markets: airport air shuttle, urban air taxi and air ambulance. The former two (based on 1–5 passengers and 500–5,000 ft altitude systems) are apparently immediately viable proposals. Notwithstanding the promising outlook for these systems, present barriers, including legal/regulatory, certification, public perception, infrastructure and weather constraints, will reduce market potential in the near term. Such barriers are explored later in this paper.

Duvall et al. (2019) warily assert that wide availability of delivery drones is not expected for three to ten years, and it will be longer before passenger-transport drones are deployed at scale. But in capability development terms, this means planning and investing in the technology now. The RAAF should recognise this required lead time and consider immediate options for graduated development. To realise widescale near-future employment, Duvall et al. (2019) identify two critical areas of UAS infrastructure as priority for investment: (1) unmanned traffic-management infrastructure and (2) physical and supporting technology infrastructure (including vertiports/stops, package receiving and dispatch stations, and charging stations). The article highlights specific actions recommended for owners (build now), investors (buy now) and government decision-makers (engage, plan, fund and legislate now).

Austere Environments

Layton et al. (2019) highlight the increasing need for air logistics into and around Antarctica, while also recognising the enduring constraints and considerable opportunities the Antarctic environment imposes on aviation. There is real scope for expansion of UAS employment in Antarctica outside current reconnaissance and mapping tasks. As UAS cargo capacity expands, Australia could establish a viable UAS cargo resupply network, which could supplant the onerous and dangerous overland internal transport with an airborne intra-theatre 'last mile' transfer. This model would link inter- and intra-theatre transport to create an all-through RAAF aviation logistics model from an Australian mainland hub to the final remote Antarctic destination.

Figure 4. Concept for UAS employment in an austere environment. Source: Trendhunter.com.

In an Australian context, a sample scenario could involve modular cargo transported by RAAF C-17A from Hobart to the Wilkins Ice Runway; a RAAF Mobile Air Load Team would then separate and transfer the modular cargo onto multiple prepositioned (potentially C-17A-deployed) ADF cargo UAS;

the fleet of UAS would then concurrently depart for multiple destinations, delivering food and medical supplies to Casey, Davis and Mawson stations, another delivering ice core sample tubes to an inland high-altitude research site, and another rendezvousing on a smaller ice runway to resupply oil and spares to a helicopter conducting coastal wildlife surveys. This promising concept has the potential to substantially reduce the expenditure of time and resources and decrease the risk for Australian Antarctic Division crews.

Section Summary – Evolving Air Logistics Support (ALS) UAS Opportunities

In summary, ALS is the air mobility activity with the broadest range of applications – from small cargo delivery through to potential future heavy-lift platforms, from personnel transport to humanitarian assistance, in urban or austere environments. While there has been considerable research and development progress in the ALS role, RAAF ALS UAS development remains embryonic and presents many opportunities yet to be explored. The next section explores the more complex challenge of ABNOPS – air mobility operations in a contested environment.

3.3 Airborne Operations (ABNOPS)

The Air Power Manual defines ABNOPS as an air mobility activity conducted within an active theatre of operations to deliver or extract combat-ready forces and their logistic support (ASPC, 2022). This may be achieved by airdrop or airland from aircraft and can include delivery of special forces into enemy controlled or politically sensitive territories. In layman's terms, ABNOPS is '*aerial delivery in a contested environment*'. The primary discriminator from ALS is the presence of hostile threat to the aircraft. Thus, ABNOPS platforms are designed with self-protection systems to detect and mitigate threats to the system or mission.

Current RAAF ABNOPS Fleet

The RAAF's ABNOPS fleet is a subset of the ALS-capable fleet and predominantly comprises the C-17A, C-130J and C-27J. These aircraft have an array of self-protection systems. The RAAF does not currently possess an ABNOPS UAS capability.

The State of ADF UAS Development in the ABNOPS Role

The RAAF's air mobility force development enterprise should leverage experience from other ADF UAS operators and developers. While the RAAF has some operational experience with Heron and is developing expertise in MQ-4C Triton, the Army has an established and expanding fleet of multiple small UAS, including the Shadow, Wasp and Black Hornet within 20th Surveillance and Target Acquisition Regiment (20STA), and the RAN has established the 822X Squadron (Layton, 2018).

Current ADF UAS are predominantly employed to provide intelligence, surveillance, target acquisition and reconnaissance (ISTAR) support. To advance air mobility ABNOPS capability, there is much to be gained from cross-role partnerships. The RAAF air mobility community could engage Air Force's Directorate of Combat Capability and Surveillance and Response Group; tactical RAN and Army UAS units, and Army HQ aviation specialists. This would enable the air mobility enterprise to better understand Army's future plans for greater battlefield mobility. Army HQ identified the need for an autonomous battlefield lift capability in a Joint Capability Needs Statement (JCNS) for a medium-endurance, autonomous, Land Force Combat Service Support UAS. Its stated role will be to conduct autonomous delivery of mission-critical combat supplies from the forward-most CSS assets to personnel engaged in combat operations. These resupply activities will occur over a short distance within an environment that is typically hostile, complex and contested. The JCNS prescribed range, endurance and payload criteria intended to fill a gap for payloads less than those traditionally dispatched by RAAF platforms. In developing these evolving UAS, Army HQ has partnered with research teams in the Aerial Autonomous Systems group within the Defence Science and Technology Group (DSTG) and has collaborated with the U.S. Department of Defense on the Contested Urban Environment project. Army HQ has also created a collaborative sharepoint site on the Defence IT system.

There is the risk that future Army and RAAF UAS will remain on parallel, stove-piped development paths without concerted collaboration. The longstanding organisational and cultural divide separating Army's organic (rotary-wing) lift and Air Force's (fixed-wing) lift has bred a lack of comprehensive understanding and opportunity between two aviation communities that actually have a common goal – to provide air mobility support to the soldier. Improved cooperation across this gap will be critical for the successful development of a future ADF air mobility UAS capability. Both services' aviation communities should seek to align ways and means to achieve common ends.

One example of effective joint collaboration (albeit at the tactical level) is the Joint Precision Aerial Delivery System (JPADS). JPADS is a GPS-guided, air-dropped payload with a parachute guidance system 'steered' by a load-mounted computer flying the payload to a known GPS coordinate. The system has been employed operationally from RAAF air mobility aircraft and proven in training and capability demonstrations in conjunction with ADF Special Forces. Yet, despite its longevity as a trial capability, JPADS is yet to be fully accepted into ADF service. JPADS remains an orphan, lacking a capability manager to sponsor funding for full introduction into service and long-term sustainment.

3.4 Evolving ABNOPS UAS Opportunities

This section introduces a variety of potential future autonomous ABNOPS air mobility systems for RAAF consideration. Development has evolved from both military and commercial means, including some domestic but predominantly international sources. These various *last mile distribution systems* fit the range, endurance and payload criteria relevant to the ADF's operational needs. One of the primary benefits of these types of systems is asset protection. These systems reduce exposure of human operators and expensive platforms to surface-to-air and air-to-air threats. The systems introduced in the ALS section (such as those for HADR delivery) are also relevant to ABNOPS, where they can be upgraded to mitigate the effects of hostile threat systems designed to disrupt their mission.

Swarming Air Mobility

Traditional air logistics resupply is based on single or multiple manned aircraft dispatching a fixed load to a predetermined destination. In-flight re-tasking provides flexibility to adjust destination but will not change the aircraft's cargo should a commander require variation to a requested load (e.g., more bullets, less rations). Enter distributed swarming air mobility operations. Swarming operations would allow a tactical commander even more flexibility to separate and distribute loads onto multiple complex concurrent objectives. It would transform a basic air logistics system into one that could combine the accuracy and volume of a JPADS-like system with a networked system of multiple, reliable concurrent deliveries, as effectively as DHL, Linfox, Amazon or Australia Post. A land commander whose bid for air lift is rejected on the basis of priority or suboptimal aircraft utilisation would benefit greatly from a flexible, scalable swarm drone system that can transport multiple sub-elements of equipment or people.

Existing concepts for swarming UAS in support of ISR and air combat provide a sound basis to explore opportunities for unmanned swarming air mobility UAS. The following examples demonstrate initiatives in this field relevant for air mobility consideration. These concepts have, at their core, enhanced flexibility for the tactical commander on the ground.

Thornton and Gallasch (2018) highlight the range of opportunities, potential benefits and challenges of swarming UAS logistics delivery. Key benefits include scalability, flexibility and redundancy compared to a single-load delivery system. A reduction in operating costs is feasible as a single operator controls a large number of platforms. The distributed nature of delivery means failure of a small number of individual platforms has a much-reduced effect on the overall quantity supplied. Faster decision-making is another potential benefit, where algorithms can determine optimum distribution for different sub-loads as determined by evolving customer needs. There is also greater scope for continuity of operations, with sustained or repeated UAS operations beyond that of human endurance. Further, a mass of individual platforms can be used to disguise critical loads and decoy threat systems. Platforms can also be employed as multi-role systems, for example, conducting ISR while delivering loads. Stated vulnerabilities or challenges include control link jamming and spoofing, counter-drone systems, assured navigation (internal vs external), intra-swarm avoidance, detection or signature management, command and control, and networking.

Thornton and Gallasch (2018) introduce a number of specific examples of leading-edge developments for swarming, last mile logistics. In the United Kingdom (UK), two defence-focused technology companies (2iC and Blue Bear) have collaborated on a proposal to develop an *Autonomous Last Mile Logistics System* for the UK Ministry of Defence. The proposed system integrates 2iC's adaptive logistics control system (the Autonomous Vehicle Service) with Blue Bear's scalable UAS transport system (the Unmanned Vehicle Environment). This well-thought-out concept focuses on responsive and flexible delivery of battlefield supplies in a volatile demand environment (see Figure 5). The designers have applied considerable rigour in understanding the nuanced challenges from both a logistics perspective and a UAS operator's perspective in designing a system that is purpose built for hostile environment resupply. Design features include optimised route design based on all sensed factors, including threat, weather, terrain, intelligence, load and timing; dynamic re-tasking, including autonomous rerouting in response to a forward commander's demand transmission; live feedback to soldiers on resupply status; autonomous swarm or single-platform delivery; and autonomous reorganisation to optimise remaining loads if some of the formation is lost. This 2iC and Blue Bear system is highly applicable to Army and RAAF battlefield resupply, which has implications for a more optimised reapportionment of high-demand aviation assets.

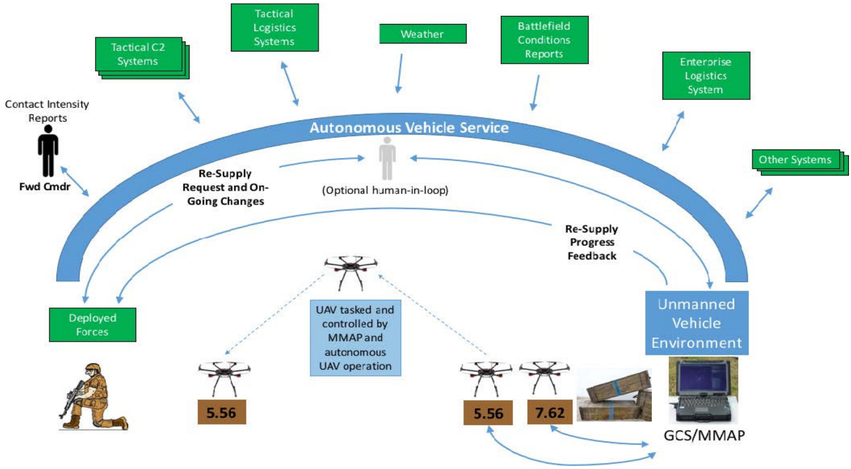

Figure 5. Autonomous Last Mile Logistics System designed by 2iC and Blue Bear for the UK Ministry of Defence.
Source: 2iC (2017).

In the US, the Defense Advanced Research Projects Agency (DARPA) has funded several companies under its ICARUS (Inbound, Controlled, Air-Releasable, Unrecoverable Systems) program to create cost-effective, disposable drones designed to deliver a load without the need for vehicle recovery. Ackerman (2017) reports that one of these companies, Otherlab, developed a one-metre glider made almost entirely of cardboard and packing tape, with some simple guidance and steering electronics. The ASAPRA (Aerial Platform Supporting Autonomous Resupply/Actions) is a flat-pack design allowing efficient storage and carriage and a 30-minute assembly. Designed to be released as huge swarms (see Figure 6) carrying a 1 kg payload each, Otherlab claims these units can glide up to 150 km and arrive with an accuracy of 10 metres. The applicability to the ADF is the inherent design for these units to be dispatched via a large transport platform such as the C-17, C-130 or Chinook. With a glide range greater than conventional parachute-steered loads, the release point by the manned platform can be retained further from the required landing point and potential hostile threats. For higher risk, special or covert missions, DARPA is also funding a separate Otherlab program called

Vanishing Programmable Resources (VAPR) to develop electronics capable of ‘physically disappearing in a controlled, triggerable manner’ (Lobner, 2017).

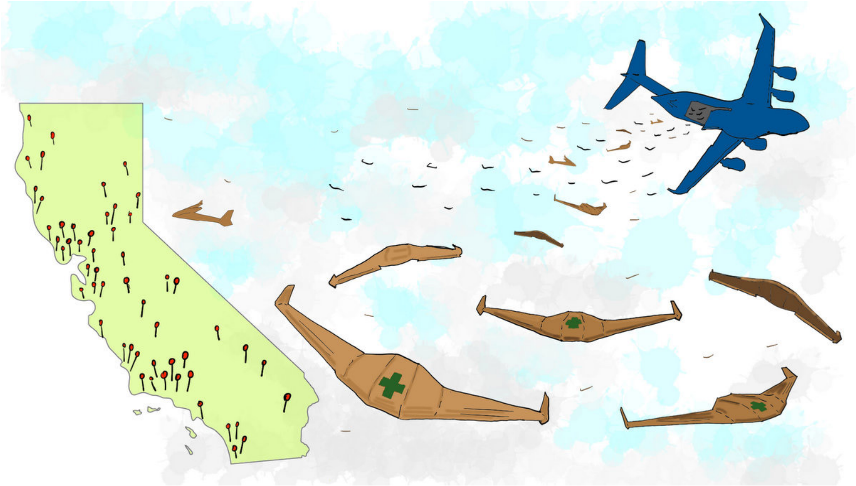

Figure 6. The US DARPA-sponsored Aerial Platform Supporting Autonomous Resupply/Actions (ASPARA) Aerial Delivery System.
Source: Ackerman (2017).

Another US company, California-based Logistic Gliders Inc., has tested a very low cost disposable glider for the U.S. Marines. Surprisingly, this concept is not unlike that applied by Germany and Britain in the Second World War. The unmanned TACAD (TACtical Air Delivery) glider is a very simple plywood cargo glider that can fly up to 100 km to deliver up to 700 kg with high accuracy, and then be abandoned if required (Ackerman, 2019). The system can land as a belly-down glider or via a late-release parachute deployment. Simple electronics include a hobby-grade GPS and autopilot system, or remote control, with a few basic servo motors for steering. Total production cost for the TACAD glider might be lower than US$2,000. The TACAD offers similar capacity to some small- to mid-weight conventional airdrop loads, but with a greater reach from dispatch and a disposable guidance system cheaper than

JPADS. Again, release from a larger cargo aircraft by airdrop at considerable stand-off provides reduced risk to mission and risk to force.

Figure 7. Logistic Gliders Inc. very low cost TACAD (TACtical Air Delivery) glider.
Source: Ackerman (2019).

UAS for Complex HADR: Threat Mitigation for Humanitarian Assistance

The first part of this paper introduced the benefits of UAS in a benign (ALS) HADR environment. However, HADR is also often necessary in a complex hostile threat (ABNOPS) environment. In 2014, USAF C-17 pilot Mark Jacobsen initiated a grassroots UAS initiative, the Syrian Airlift Project, aimed at delivering cross-border food and medicine to civilians in Syria (Jacobsen, 2016). While the project eventually folded due to lack of funding, the applicability of this particular project to Australian military airlift is clearly apparent. This project focused on tactical delivery to Syrian refugees with elevated mission assurance through threat mitigation (Gibbons-Neff, 2014). The developer's 'swarming airlift' concept was based on multiple fixed-wing UAS with a 1–2 kg payload plus some basic threat mitigators, including autopilot, low-cost GPS guidance, night flight and concurrent launch to multiple destinations. The concept also included mission planning software for multiple simultaneous flights. The founder asserted that the benefits of this system included its low cost, rapid unit replacement and elimination of the threat to conventional transport platforms:

> Our intent *was to push humanitarian aid through contested airspace. My team's cargo drones cost about $700 in parts, flew at 35 miles per hour, and could autonomously airdrop 2-pound payloads at 80-mile range (or 4 pounds at 40 mile range), usually hitting within 15 to 50 feet of the intended coordinates. Thanks to highly customizable autopilot software, it was trivial to turn off all data links, which rendered the drones immune to some electronic countermeasures. If the GPS was jammed, the drones could continue flight with at least some accuracy using a magnetic compass. We wrote software that generated semi-randomized flight plans to enhance swarm survivability.* (Jacobsen, 2016)

Australian ABNOPS UAS Initiatives

At the Australian DSTG, Ivanova et al. (2016) report an Australian/US research and development request for a detailed look at UAS technologies and their applicability to ADF mobility roles. The study identifies UAS logistics as one of four top technologies of interest for Army CSS. Its focus is last mile logistics UAS for delivery of critical material to isolated and contested areas, to dispersed units and for enhanced battle casualty care. The paper provides a detailed analysis of current UAS examples, challenges, opportunities and potential applications. It discusses examples of existing small, medium and large UAS predominantly used for ISR that could be converted or re-roled for air logistics missions. The paper also presents a detailed battlefield resupply case scenario for last mile combat logistics resupply. It is noteworthy that there is no recorded consultation with RAAF air mobility subject matter experts in this case study, evidencing that existing service rivalries are leading to a loss of coordination and progress between the RAAF and Army.

DSTG has also engaged Australian Defence technology company DefendTex in collaborative research to develop, test and demonstrate machine learning algorithms for use on DefendTex UAS that enable guidance to be issued to facilitate coordinated formation flying (DSTG, 2018). DSTG also sponsors the annual Australian UAV Challenge. The stated goal of the UAV Challenge is to demonstrate the utility of UAVs for civilian applications, particularly those that will save the lives of people in the future, by harnessing the ingenuity and passion of aero modelers, university students and high school students around the world to develop novel, cost-effective and resilient autonomous solutions. The 2020 competition themes of airborne delivery and medical rescue are highly relevant to the RAAF. Although postponed due to COVID-19, this forum will offer excellent development opportunities once resumed.

Defence-led initiatives to encourage homegrown development include the annual Defence Entrepreneurs Forum (DEFAUS), conceived in 2016 as a vehicle for junior leaders to pitch proposed innovation for future investment. The pitch by 2018 DEFAUS winner, Captain Jacob Choi (Army Headquarters), was 'LOGBOTS: Unmanned Logistics Vehicle Swarms' (Choi, 2018). Choi asserts that an integrated, swarming logistic system will enable dependencies down to the section level to be continuously resupplied by small, unmanned vehicles capable of moving, hiding and caching independently throughout the battlespace, without exposing manned logistic nodes to enemy targeting.

Tactical Personnel Transport

This section's focus thus far has predominantly centred on *cargo* delivery. The other fundamental part of the ABNOPS mission is *personnel* delivery. This is generally achieved through either landing and offload (airland) or insertion by parachute. Future autonomous systems may leverage commercial models discussed earlier in the ALS discussion; however, the addition of the threat environment makes personnel insertion more complicated and riskier. Although the appetite for such a mission may be low, that has not prevented some research and development of a potential future system.

Futurists and political scientists assert that military application of China's passenger drone – the EHang 184 (see Figure 8) – is not a far-flung concept (Lin & Singer, 2016). Peck (2016) asks, 'will China's new passenger drone carry soldiers into battle?' Peck presents developments in Chinese single-seat autonomous lift vehicles, including the EHang 184, asserting that the transition from civil to military application of these vehicles will be relatively easy and quick. The EHang 184 is capable of carrying a 220 lb passenger (soldier?) at 60 km/h for up to 23 minutes. When paired through manned–unmanned teaming (similar to, for example, the Loyal Wingman concept), this system of multiple linked platforms could be capable of deploying a section of soldiers in fighting order to a precise location of tactical advantage selected and controlled by the mission commander.

Figure 8. The EHang 184, China's claimed 'world's first passenger drone'.
Source: Peck (2016).

Further, the US Kaman K-MAX is a cargo-carrying drone helicopter that can fly autonomously and has been used to resupply U.S. Marine outposts in Afghanistan (Parsons, 2019). Variants of this design could carry both cargo and passengers. Again, teaming multiplies this mobility effect for cargo or personnel dispatch. These personnel transport systems examples might only find utility for small-scale operations. However, they present a genuine consideration for the insertion of small teams on high-risk, high-payoff missions, instead of conventional, large-signature, manned, rotary- or fixed-wing platforms that may compromise a mission. This function is certainly one that RAAF air mobility force developers may wish to explore.

Section Summary – Evolving Airborne Operations (ABNOPS) UAS Opportunities

Air operations in a contested environment add complexity, risk to mission and risk to force. The application of unmanned systems in the contested (ABNOPS) environment can mitigate some risk to air mobility operations. The range of unmanned systems and methods presented in this section offer real potential for cost-effective application in the Australian context. These include swarms of autonomous small-packet payloads delivered by conventional platforms; last mile autonomous battlefield resupply systems; unmanned tactical personnel transport of small teams; and ingenious, low-risk, low-cost HADR delivery systems.

3.5 Air-to-Air Refuelling (AAR)

The Air Power Manual defines AAR as the refuelling of an aircraft by another while both are in flight (ASPC, 2022). A key enabler of force projection, AAR can augment a number of other air power contributions by enhancing the range, endurance and payload of receiver aircraft. Dedicated force protection for both refueller and receiver aircraft may be necessary based on threat.

Current RAAF AAR Fleet

The RAAF's only purpose-built AAR aircraft is the KC-30A. Other select non-AMG platforms (F/A-18F) can buddy-refuel from like aircraft, but this substantially reduces the provider's mission effectiveness. The RAAF does not currently possess an autonomous AAR capability.

3.6 Evolving AAR UAS Opportunities

The RAAF has explored the scope for autonomy in subsystems of the AAR mission. In a 2018 trial, Airbus and the RAAF collaborated to successfully demonstrate the first Automatic Air-to-Air Refuelling (A3R) boom contact with a large receiver aircraft (Airbus A310 to RAAF KC-30A [A330]; Daly, 2018; Szondy, 2018). The system, hosted on the delivering aircraft, requires no additional equipment in the receiver aircraft. The A3R uses imaging technology to detect the position of the receiver and its receptacle (see Figure 9). After initial manual approach, the Air Refuelling Officer can activate the automated system, whereby a fully automated flight control system flies and maintains the boom alignment with the receiver's receptacle. This automatic refuelling technology aims to reduce the risk associated with AAR operations, minimise contact time, improve operational efficiency and reduce operator workload. The ultimate goal of Airbus' ongoing multinational A3R trials is the incorporation of the A3R system onto its customers' A330 Multi-Role Tanker Transport aircraft to *deliver* fuel.

Automation of AAR subsystems is just part of the way towards what some concept developers anticipate is the future of AAR: UAS AAR. AAR is a crucial force multiplier across the range of air power roles. As the technology in receiver aircraft (stealth, range, autonomy) advances, a commensurate advancement in AAR as part of a fifth-generation package is completely reasonable, if not essential (Evans, 2017). Unmanned AAR platforms should factor into RAAF future force structure consideration.

Figure 9. Detection of receiver aircraft in Airbus' fully automated A3R system.
Source: Airbus (2020)**.**

The Boeing MQ-25 is a leading example of evolving AAR capability (Harper, 2022). The MQ-25 is designed to provide the U.S. Navy with a carrier-based AAR refuelling capability. It will expand the potency of the Carrier Air Wings' air combat capability by extending the range of deployed F/A-18F Super Hornet, EA-18G Growler and F-35C aircraft. The MQ-25 conducted its first successful test flight in September 2019, completing a US Federal Aviation Administration–certified two-hour mission on a programmed land-based flight route. The U.S. Navy aims to declare Initial Operational Capability for this carrier-based AAR UAS in 2024. Although a carrier-based system is not directly comparable to ADF force structure, the technology and procedures associated with the U.S. Navy's MQ-25 AAR program are highly relevant to a future unmanned RAAF (and potentially amphibious) AAR capability. This future AAR capability might be a swarm of distributed buddy MQ-25 AAR platforms, or an advanced wide-body unmanned aircraft system incorporating both autonomy and stealth.

Should the RAAF progress down the wide-body AAR path, it should observe development of the USAF KC-Z program. Trevithick (2019) analyses the challenges and opportunities for the USAF's next generation tanker, which is yet to be determined. A number of critical trade-offs will shape the final design of the KC-Z. First, the efficacy of low observability, or stealth, is an important factor for a tanker that is refuelling a stealth receiver in a hostile, fifth-generation radar environment. Second, the decision between a single wide-body tanker versus a distributed, multiple small-tanker system is needed. Third, the choice of manned versus unmanned, or a combination for both, for receiver and refueller. An entirely autonomous system (receiver and refueller) would not be without its challenges, such as complex rendezvous and connection logic, system communication assurance and physical contact risks on delicate stealth surfaces.

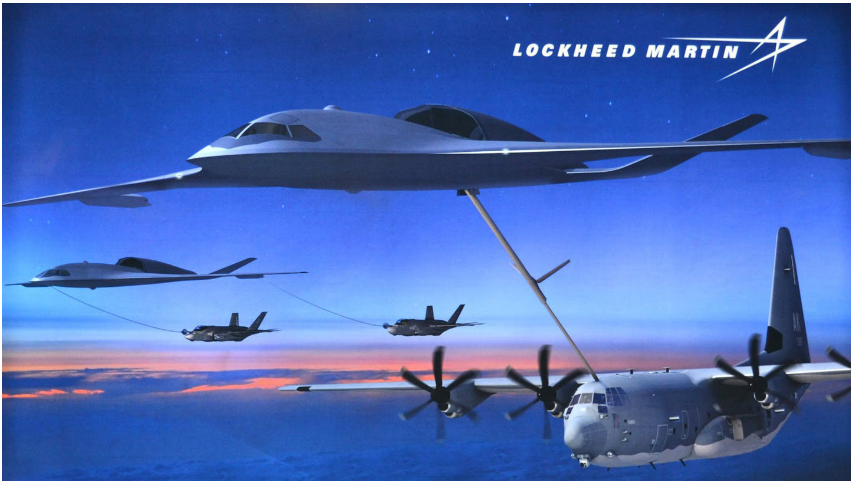

Figure 10. Lockheed Martin's future AAR system concept.
Source: Trevithick (2018).

Section Summary – Evolving Air-to-Air Refuelling (AAR) UAS Opportunities

The evolving counter air threat from potential adversaries has, in recent years, extended the range at which large aircraft, including AAR platforms, are held at risk. As with autonomous ABNOPS initiatives, evolving autonomous AAR systems create real opportunities to reduce risk to mission and risk to force for high-value AAR assets. These opportunities span AAR subsystems that ADF force developers should consider for future force structure. These include the KC-30 boom; small autonomous systems, such as the MQ-25; through to large next generation platforms, including the US KC-Z, that may or may not follow the autonomous path.

3.7 Aeromedical Evacuation (AME)

An aeromedical evacuation (AME) is an air activity conducted to transport ill or injured personnel under medical supervision to appropriate medical treatment facilities (ASPC, 2022).[4] AME capabilities make it possible for personnel to receive critical care from the point where they embark, thereby providing more than just a transport capability.

Current RAAF AME Fleet

The RAAF AME mission can be carried out by all aircraft that conduct the ALS role; however, specialist AME configurations are tailored to the C-17A, C-130J and C-27J. The RAAF does not possess an autonomous AME extraction or resupply capability.

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[4] The Air Power Manual Seventh Edition (ASPC, 2022) categorises AME as a subset of ALS.

3.8 Evolving Aeromedical Evacuation (AME) UAS Opportunities

The earlier discussion on UAS personnel transport to *insert* soldiers into the battlefield is equally applicable to their *extraction*, whether as a planned tactical manoeuvre or for medical evacuation. There are numerous evolving initiatives under development for patient transport. These systems have considerably more complex requirements than a simple cargo or basic passenger UAS. However, there is real scope for the RAAF and Army to assess the cost and mission effectiveness of a future unmanned AME system against the cost of the current tactical (intra-theatre) AME capability provided by manned rotary-wing and the small to medium C-27J and C-130J fixed-wing airlift fleet.

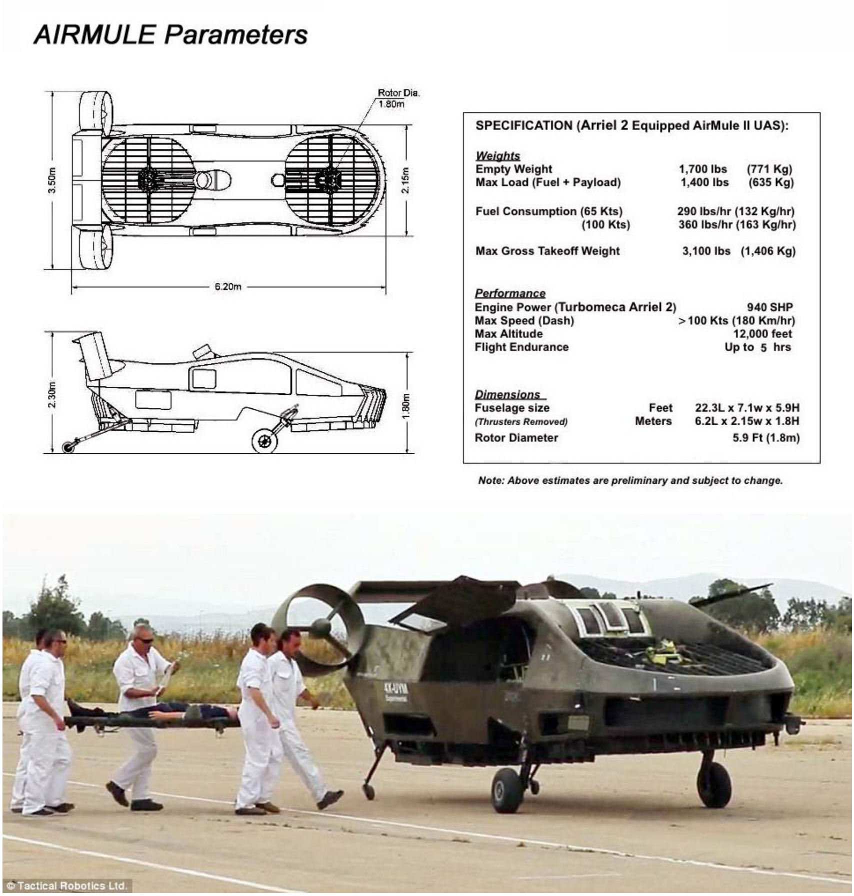
The ADF should look to the US military in particular as it leverages both military and civilian experience to assess next generation AME systems. Stanzione et al. (2018) estimate that US Air Mobility Command Aeromedical Evacuation forces support approximately 20,000 combined fixed- and rotary-wing airlift movements annually, while civilian Helicopter Air Ambulance Operations account for the transport of over 500,000 patients annually. Stanzione et al. importantly highlight technology advances and new design considerations specifically relevant to the operational challenges of AME. Beebe and Gilbert (2010) highlight the anticipated advantages of fielding unmanned systems in complex casualty evacuation (casevac) situations. These advantages include: (1) increased tactical and operational flexibility for tactical commanders; (2) mission execution in conditions manned platforms cannot (or should not) operate, such as contaminated or poor visibility environments; and (3) increased force protection for critical medical first responders and force multiplication for scarce medical evacuation systems. Early development examples include the Boeing Little Bird UAS trial to deliver supplies (water and food) and evacuate a casualty (weighted mannequin), carried in an outboard cargo pod. That 2009 trial validated both the unmanned resupply and casevac concepts but, unsurprisingly, cited the need for technical improvement and further experimentation on tactics, techniques and procedures (Beebe & Gilbert, 2010).

In a later work, Beebe et al. (2013) edify the continued focus that militaries (particularly the U.S. Marine Corps and U.S. Army) are placing on this future capability and the considerable gains to date. Yet, Beebe also highlights the significant technical and non-technical issues that must be addressed before a viable unmanned AME capability can be fielded.

The substantial civilian advances in this field, both domestically and abroad, and following examples may provide leading solutions for the ADF's future AME capability. A discussion between Phil Tarrant (Defence Connect) and Rob Sutton (Mirragin Aerospace) describes Australian technology and research firms' leading role in the development of a wide range of UAS applications, including medical evacuation systems (Stevens, 2019).

Booz Allen Hamilton (2018) assesses the commercial viability of an air ambulance capability (5–8 persons on board) market served by eVTOL (electric vertical take-off and landing) aircraft. The study concludes that, presently, the model is not viable for commercial markets due to technology constraints, including battery capability; however, it suggests that use of *hybrid* VTOL aircraft could make the market viable.

Israeli subsidiary firm Tactical Robotics has developed the Cormorant (formerly AirMule), a compact, single-engine, two-seat, vertical take-off and landing UAS (see Figure 11). The Cormorant's innovative internal lift rotors enable flight inside obstructed (e.g., mountainous, wooded or urban) terrain where helicopters are unable to operate. The company claims Cormorant's manoeuvrability, small visual footprint, low noise, and reduced radar and IR signatures offer a stealth advantage that enhances effectiveness and survivability in complex environments compared to conventional casevac systems.



SPECIFICATION (Arriel 2 Equipped AirMule II UAS):

Weights		
Empty Weight	1,700 lbs	(771 Kg)
Max Load (Fuel + Payload)	1,400 lbs	(635 Kg)
Fuel Consumption (65 Kts)	290 lbs/hr	(132 Kg/hr)
(100 Kts)	360 lbs/hr	(163 Kg/hr)
Max Gross Takeoff Weight	3,100 lbs	(1,406 Kg)
Performance		
Engine Power (Turbomeca Arriel 2)		940 SHP
Max Speed (Dash)		>100 Kts (180 Km/hr)
Max Altitude		12,000 feet
Flight Endurance		Up to 5 hrs
Dimensions		
Fuselage size	Feet	22.3L x 7.1w x 5.9H
(Thrusters Removed)	Meters	6.2L x 2.15w x 1.8H
Rotor Diameter		5.9 Ft (1.8m)

Note: Above estimates are preliminary and subject to change.

Figure 11. Cormorant (formerly AirMule) casevac UAS. Top: Specifications. Bottom: Demonstration for emergency casualty evacuation.

Source: Tactical Robotics.

3.9 Supporting Missions –
Enabling UAS Air Power Applications with an Air Mobility Effect

While this paper's focus is predominantly platform based, it is important to recognise the contribution – and real potential – of autonomy in supporting roles. There exists a wide range of autonomous systems that are not purpose built for air mobility tasks or exclusive to a single type of air power contribution but contribute in some way to producing an air mobility effect. Some of these are modular, reconfigurable or simply flexible systems that can support multiple joint warfighting functions. These systems provide cause for consideration as part of an increasingly multi-role air power capability solution of the future and are thus worthy of future development for their potential as Defence-wide aviation enhancements. This section introduces some examples for consideration.

Force Protection, Force Generation and Sustainment

Airbase protection is a crucial force protection mission that relies on sound situational awareness. There is a range of UAS already fielded that would be capable of providing airbase perimeter patrols and augmenting rapid airbase security forces response. Airbase logistics, a crucial sustainment mission, could employ simple unmanned aerial or ground cargo systems to transport basic logistics, maintenance supplies and tools onto and around large airbases. Another example is the use of UAS for large aircraft maintenance inspections. Air Force News reported on Number 36 Squadron's trial of the Phantom UAS to conduct in-hangar assessments of hard-to-access locations on the C-17A Globemaster aircraft, including the tail section, which sits nearly 17 metres above ground. This system delivers workplace safety, time saving and quality management benefits and is a fine example of cross-service collaboration, leveraging 20th Surveillance and Target Acquisition Regiment's experience with the Phantom UAS. A civil company, MRO Drone, offers a similar commercial service that employs the RAPID (Remote Automated Plane Inspection and Dissemination) system. RAPID combines UAS flight control, automation and sensor technologies with innovative 3D visualisation and damage localisation tools and computers that allow aircraft operators the ability to capture, review, assess and disseminate aircraft damage information across an airline maintenance, logistics and reporting system.

Command and Control (C2)

Behind the multitude of platform-centric missions is the crucial command and control function; in the RAAF air mobility case, this is conducted by AMG's Air Mobility Control Centre (AMCC). As with airborne platforms, AMCC has relied on traditional manned execution methods. AMCC employs some basic software programs to facilitate situation awareness, scheduling and command and control. However, these substantially disparate systems rely heavily on human-in-the-loop for usable outcomes. One particularly resource-intensive function is aircraft re-tasking due to mission amendment or cancellation. This task involves rearrangement of a multitude of complex, interrelated and causal aspects of a mission. This function could be substantially enhanced through the employment of human–machine teaming artificial intelligence to analyse all possible mission aspect combinations, derive an optimal course of action for re-tasking aircraft and redistributing planned cargo from the cancelled or amended mission. Coupled with a distributed swarming fleet, the system could act dynamically to re-task planned or airborne platforms to optimise cargo distribution.

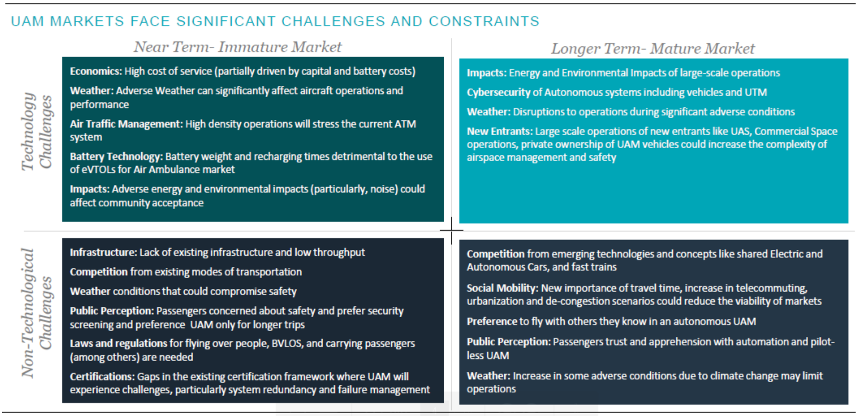
4.

CHALLENGES AND CONSTRAINTS

This paper has presented a breadth of applications for UAS in the military air mobility space. Significantly, it has drawn from a range of evolving civilian models and expertise. In certain areas of technology, commercial ventures with large budgets can outpace military development. As smaller inexpensive technologies become more accessible to both the everyday and corporate developer, the sheer mass of start-up companies can mean that new lessons (and barriers) are learned quickly and can be applied iteratively as the market drives further innovation (or vacillates). There is thus already a significant body of work publishing known challenges, constraints and lessons for UAS development and employment, with notable seminal sources including Collins (2021) and recent RAND studies.

Booz Allen Hamilton (2018) explores market size and barriers for three potential UAM markets (airport shuttle, air taxi and air ambulance) in the US. The report provides a comprehensive analysis of constraints associated with establishing a viable UAM system. These constraints can mostly be translated to an Australian perspective, whether military or commercial, and are summarised in Figure 12.

While the constraints are generic to most UAS applications, some are more pertinent to air mobility. A selection of these is explored in the following paragraphs. These lessons, plus those already learned through ADF experience to date, will be valuable for the developers of next generation air mobility UAS. Booz Allen Hamilton (2018) notes that some of these constraints can potentially be addressed through ongoing intragovernmental partnerships (e.g., NASA–FAA), government and industry collaboration, strong industry commitment, and existing legal and regulatory enablers. Again, while that study focuses on commercial UAS development, it highlights the leverage the military can gain through partnerships with government and industry.



UAM MARKETS FACE SIGNIFICANT CHALLENGES AND CONSTRAINTS

	Near Term- Immature Market	*Longer Term- Mature Market*
Technology Challenges	**Economics:** High cost of service (partially driven by capital and battery costs) **Weather:** Adverse Weather can significantly affect aircraft operations and performance **Air Traffic Management:** High density operations will stress the current ATM system **Battery Technology:** Battery weight and recharging times detrimental to the use of eVTOLs for Air Ambulance market **Impacts:** Adverse energy and environmental impacts (particularly, noise) could affect community acceptance	**Impacts:** Energy and Environmental Impacts of large-scale operations **Cybersecurity** of Autonomous systems including vehicles and UTM **Weather:** Disruptions to operations during significant adverse conditions **New Entrants:** Large scale operations of new entrants like UAS, Commercial Space operations, private ownership of UAM vehicles could increase the complexity of airspace management and safety
Non-Technological Challenges	**Infrastructure:** Lack of existing infrastructure and low throughput **Competition** from existing modes of transportation **Weather** conditions that could compromise safety **Public Perception:** Passengers concerned about safety and prefer security screening and preference UAM only for longer trips **Laws and regulations** for flying over people, BVLOS, and carrying passengers (among others) are needed **Certifications:** Gaps in the existing certification framework where UAM will experience challenges, particularly system redundancy and failure management	**Competition** from emerging technologies and concepts like shared Electric and Autonomous Cars, and fast trains **Social Mobility:** New importance of travel time, increase in telecommuting, urbanization and de-congestion scenarios could reduce the viability of markets **Preference** to fly with others they know in an autonomous UAM **Public Perception:** Passengers trust and apprehension with automation and pilot-less UAM **Weather:** Increase in some adverse conditions due to climate change may limit operations

Figure 12. Constraints affecting urban air mobility viability. Source: Booz Allen Hamilton (2018).

4.1 Legal and Regulatory Barriers

Assured autonomy remains a challenging problem for UAM. Critical legal, regulatory and certification challenges must be addressed to bring urban air transportation to the market, as the current regulatory structure does not fully allow for these activities. Current legal frameworks for UAM do not address issues related to operations over people, beyond visual line of sight, commercial operations carrying cargo or people, and airworthiness certifications. One such consideration is the challenge in determining which existing airworthiness certification standards apply, or whether existing certification standards should be amended, given that traditionally standards have been developed for manned flights requiring strict system redundancy and failure management processes. Tatham et al. (2017) cite the high potential for LE-RPAS to successfully provide air logistic support in a disaster relief situation; however, they highlight a number of important hurdles to be overcome before the LE-RPAS concept can be operationalised. Key among these are the development of an air traffic control regime that supports (rather than constrains) RPAS use and the mechanisms (both process and people related) that translate the data from the RPAS into usable and certifiable information to underpin safe operation and timely and effective decision-making.

4.2 Societal Barriers

Booz Allen Hamilton (2018) applies a useful five-element framework for addressing societal (public perception) concerns: spatial, distance, temporal, economic, physiological and social. These are relevant to varying extents to military operations. Within these elements, the largest societal barriers identified at present are trust of automation, cost, personal security, safety and privacy. These factors would be unlikely to present substantial risk to uptake in the military context. However, societal mistrust of *military* UAS operations is a reality. This ranges from scepticism of government surveillance operations in urban areas through to challenges to the ethical validity of UAS use in war-torn areas (Stelzer, 2015). Even USAF pilot Mark Jacobsen's humanitarian Syrian Airlift Project faced opposition; Jacobson states, 'The whole idea of using drones in conflict zones has been controversial because of their legacy as weapons [or of UAS falling into the hands of the enemy]. … There's a lot of scepticism and distrust among aid organizations'. That scepticism is not limited to aid organisations or even to conflict zones. From the Middle East to California, there is ongoing debate about drone surveillance and safety (Stelzer, 2015).

4.3 Weather/Atmospheric Barriers

Weather (including visibility, temperature and winds) can influence components of UAM, creating a variety of potential barriers. The following impacts are noteworthy: impacts to operations through a reduction or cessation of missions due to safety risk; impacts to service supply because weather conditions may extend time, distance or reduce battery life; impacts to passenger comfort, not unlike manned platforms; impacts to community acceptance, such as passenger apprehension towards flying in certain conditions; impacts to infrastructure, including the viability of 'vertiports'; and impacts to traffic management due to disrupted flow patterns resulting from inflexible unmanned flight paths.

4.4 Load Concentration

The following operational counterarguments against battlefield air mobility autonomy should be addressed before a decision is made on the scope and scale of a future air mobility UAS. A number of these cite the benefits of conventional, large-scale, single platforms over autonomous distributed systems. Sufficient concentration of force might not be achievable through 'distributed delivery', particularly when a military contingent requires heavy cargo such as tanks or vehicles delivered as a core part of a ready-to-fight force. Delivery of cargo by individual small platforms is potentially more expensive and time consuming to prepare for carriage than single conventional platforms. After delivery, assembly may be required for components delivered in a distributed fashion. This may be unsuitable for the operational commander. Further, some systems may simply be too large for carriage by distributed UAS.

Another case against UAS is the fact that other, simpler systems are already fielded. The JPADS can airdrop large loads from cargo aircraft using GPS guidance of a steerable parachute. Simple multi-channel programming enables multiple separate loads dispatched from the same large cargo aircraft to fly to multiple separate coordinates. In this way, a single aircraft can deliver the effect that a swarm of potentially lower capacity and higher complexity UAS would be required to achieve.

Thornton and Gallasch (2018) also highlight some downsides of UAS swarms. One is a need for sensing in three-dimensional space, though there are fewer obstacles to avoid in the sky. Another is that UAS swarms, if flying in open skies, may reveal troop locations and/or be actively targeted by countermeasures. Again, payload capacity is raised as an issue, though the use of scalable swarms can somewhat mitigate this as supplies can be distributed across multiple platforms.

4.5 Susceptibility to Cyber Interference

UAS suffer conventional vulnerabilities that endure today. Hartmann and Steup (2013) stress the risk in presuming that UAS will ensure autonomous and reliable service at all times. Given the ISR focus of UAS at the time, the paper notes that the quantity and type of information carried on UAS make them an extremely valuable target for espionage, theft, manipulation and attacks. It raises the need – still valid today – for a methodical analysis of UAS' technical vulnerabilities, including communication systems, storage media, sensor systems and fault-handling mechanisms. Krishna and Murphy's (2017) analysis edifies earlier concerns about UAS vulnerabilities. Their research highlights particular trends in attack vector and target system elements for actual recorded cyberattacks on UAS. The paper reports attack vectors were by direct physical and remote means. Specific system elements targeted included GPS (jamming and spoofing), control communications stream (including authentication and other vulnerabilities) and data communications stream (intercepting the data feed and substitution of a video feed, also known as 'video replay' attack). These vulnerabilities are not restricted to ISR UAS and thus have implications for the need to protect all types of UAS, including unmanned air mobility systems.

4.6 Capacity

When considering the application for UAS in the contemporary military air mobility context, large capacity UAS platforms are the exception to the current generation of air mobility UAS. As previously noted, some so-called 'large drones' or LUCA barely exceed 100 kg in carrying capacity. At the time of writing, the AT200 is China's (declared) heaviest cargo unmanned aerial vehicle and reported as one of the largest globally since its maiden flight in Shaanxi province, China, in 2017. The issue of limited capacity is a substantial constraint in the selection of the next generation of military air mobility platforms. As discussed earlier, this aspect of UAS development is a niche field and thus an information gap in an area highly applicable to military air mobility operations. The highly successful advent of wide-body air mobility platforms with global reach and tactical access (most notably, the C-17A) is the result of a century of evolution to optimise speed, range and payload. Conversely, new concepts, including smaller scale, swarming mobility systems, challenge the long-held paradigm that bigger, faster and farther in a single platform provides the optimum solution. Further experimentation, analysis and comparison are required.

5.

WHERE TO FROM HERE FOR AUSTRALIAN AIR MOBILITY?

The aforementioned hurdles to UAS employment should be acknowledged and addressed, not accepted as insoluble barriers. They are all valid; some are more difficult, but none are likely to be insurmountable. In numerous contemporary airlift cases, bigger may be better, but not always. In some circumstances, single is more efficient but may not always be effective. As technology evolves, a mixed fleet of air mobility options – some wide body, some small to medium swarming systems – might provide the best flexibility for the operational commander. Technology, economic opportunity, commercial and government cooperation, and military necessity are all powerful drivers that, when adopted or accepted as essential in the right circumstance, could yield substantial progress in unmanned air mobility, even within this decade.

5.1 Partnerships

The 2020 Defence Strategic Update (Department of Defence, 2020a) recognises the centrality of partnerships in innovation for the success of future technological systems. It promises a more comprehensive, coherent and agile innovation system that links Defence's capability plans with industry policy initiatives, innovation, science and technology. The Australian Government has committed around A$3 billion of capability investment across Defence innovation, science and technology over the next decade, including the Next Generation Technologies Fund, the Defence Innovation Hub and the new Defence Capability Acceleration Fund. Australian military expertise in unmanned systems is but a tiny subset of the global enterprise working towards effective and widescale employment of unmanned systems. These government commitments are the green-light for substantial – not peripheral – investment in game-changing autonomous technology.

But the RAAF alone does not possess sufficient resources or expertise to develop an effective future autonomous air mobility capability. The ADF UAS initiatives that succeed will be those that leverage funding to foster successful collaboration in all aspects of a system's life cycle and across organisational boundaries. For the future MQ-4C Triton, the RAAF should leverage its recent MQ-28A Ghost Bat experience, but also learn from its sister services and allies' in the importance of partnering to develop UAS capabilities. AMG could also take lessons from flailing attempts to establish JPADS as a fully supported system.

The RAAF's Jericho Disruptive Innovation and Jericho 21 Enterprise are effective means of access to a range of non-traditional partnerships for technology development, through which connections can be established and collaborations initiated with large and small enterprises. These could include DARPA, NASA, DSTG (particularly its Aerial Autonomous Systems group) and other government-sponsored research and development agencies. Partnering could also be established with local and international logistics companies such as TOLL, FedEx, UPS, Amazon and Google, or counterpart public companies such as postal services. Trusted Defence industry is of course an essential source of partnership. Boeing is working very closely with the RAAF on the development of the Loyal Wingman and has direct experience with MQ-25 AAR; Northrop Grumman and the U.S. Navy are key actors with Triton; and Lockheed Martin's Advanced Development Programs division, also known as Skunk Works, has developed future AAR and air lift options for the US military.

Small capital companies are also valuable sources for collaboration. South Australia–based Airspeeder aims to drive innovation in future electric air mobility through an eVTOL electric air vehicle racing series. With an initial focus on improving speed, agility and safety through competitive aerial sport, the company aims to develop performance UAM technology in Australia through partnerships across a breadth of air operations innovators, including Defence.

Figure 13. UAS air racing vehicle.
Source: Airspeeder.

Lastly, collaborative forums are an important and rich source of wide-ranging access to potential suitors. These forums attract organisations offering new technology and others looking to partner on like-minded programs. Often sponsored by well-funded agencies (including governments), these forums, including the following examples, should be regarded by the RAAF as an essential means of leveraging our government's intent and funding for Defence innovation.

The Platform for Unmanned Cargo Aircraft (PUCA) aims to facilitate the development of UCA and let its members play a meaningful and profitable role in this development. PUCA aims to capitalise on the strengths of its members: logistics, systems integration, sensors and development of subsystems. Key activities include identification of, and discourse on, possible configurations and applications of UCA; research project sponsorship; and organisational management of research and development activities.

The annual Unmanned Cargo Aircraft Conference aims to bring together manufacturers, operators, knowledge institutes, consultants, shippers and government organisations active in the upcoming field of UCA. The 2021 conference topics included UCA business models, UCA configurations (large/medium, last mile delivery, urban space delivery, medical supply drones), regulatory/legal issues, UCA contribution to economic and social development, market analysis, air traffic management/UAS traffic management and integration of systems/technologies.

The USAF launched an expansive and high-profile program to enhance UAS air mobility innovation. The Agility Prime program is a non-traditional investment program seeking to accelerate the commercial market and safety and security standards for advanced air mobility vehicles by bringing together industry, investor and government communities. The focus is on exploring potential commercial products being developed in the emerging eVTOL/UAM market for disaster response, humanitarian aid and logistics missions. The program also includes a rapid innovation contracting mechanism, 'Race to Certification' series, to drive government procurement of operational capability by 2023. The program was launched in April 2020, comprising a large virtual gathering of 95 speakers with recorded sessions and a virtual tradeshow. Support for this initiative sits at the highest level of the USAF; the program launch was hosted by the Secretary, Chief of Staff and Assistant Secretary (Acquisition, Technology and Logistics) of the USAF, leading a range of speakers, including Commander USAF Air Mobility Command, senators and NASA, FAA and Federal Transportation executives. This is a strikingly agile USAF initiative that a small force such as the RAAF should lean substantially into, with potentially excellent outcomes. Through US Government sponsorship and testing resources, Agility Prime is able to draw on small business technology innovation in the evolving market in areas highly relevant to USAF and, by extension, RAAF air mobility operations.

6.

CONCLUSION

Manned air mobility is not a sacred cow. Rather, the reason ADF mobility platforms have employed broadly the same methods for the past 100 years is because these methods have been highly effective, and because the technology at the time did the job. The can-do attitude of air mobility teams in 'just getting on with the job with what we've got' is a mantra that has likely stifled initiative for step-change evolution of air mobility technology. The RAAF simply has not had sufficient powerful drivers for change, be they external adversity or internal pressure. However, more recent strategic environmental trends coupled with a rapidly evolving technological landscape emphasise the need and opportunity for adoption of autonomous air mobility.

The timing for that step change is now. After a long absence post Jindivik, the small slice of UAS experience in Heron was a good reset for the RAAF, and the MQ-4C Triton and MQ-28A Ghost Bat will be with us in short order. Clearly however, the current focus is still on air strike and ISR. Current ADF thinking on future autonomous air mobility systems must expand. The small air mobility initiatives with maintenance drones at Number 36 SQN and autonomous KC-30 AAR booms are encouraging but strategically insignificant. There exists both scope and available technology for adoption of unmanned technologies to significantly enhance air mobility options.

ALS opportunities start with the most developed UAS – small capacity cargo systems. The evolving applications of personnel transport are highly relevant for ALS, as is the use of UAS for HADR and in austere environments such as Antarctica. The area of ALS development is potentially the most relevant to the RAAF, but the most immature area globally is large capacity UAS. ABNOPS applications also abound, offering a range of unique threat mitigation measures. The RAAF should explore opportunities in swarming

UAS; manned–unmanned teaming; expendable, lightweight, guided UAS; end-to-end battlefield logistics resupply systems; and tactical personnel transport. RAAF AAR has made a small step towards autonomy, partnering with Airbus on the A3R automated boom refuelling system. More substantial gains will be realised through the development and adoption of unmanned refueller platforms, such as the U.S. Navy's MQ-25, and partnering with the USAF on its future KC-Z program. AME will leverage gains already made in UAS passenger transport but must account for the unique environmental and clinical requirements of patient transport. Lastly, autonomy is not limited solely to flying platforms. Human–machine teaming in the application of command and control will be a critical element of any future mobility UAS.

The challenges facing development of an autonomous air mobility capability are considerable. Force designers will need to address regulatory, legal, infrastructure, cost, weather, societal, capacity and hostile cyber interference constraints. These constraints are not insurmountable but require a well-integrated and collaborative approach to draw expertise across each of these disparate fields.

Partnership and collaboration are key to success in evolving technologies. The RAAF must leverage the relative maturity of cooperative nations, industry, research partners and forums to develop concepts for employment and subsequently investigate and acquire autonomous solutions for all three air mobility activities. Potential partners and forums include Jericho Disruptive Innovation, Jericho 21 Enterprise, the Air Warfare Centre, DSTG, NASA's Aeronautics Research Mission Directorate, USAF's Agility Prime, Army and RAN's UAS enterprise, and international UAS forums such as PUCA.

This period of strategic ambiguity, overlaid by the advent of disruptive technology, has seen a rise in competitive technologies that challenge the efficacy of contemporary systems. With the massive expansion in civil and military UAS development, now is the right time for the ADF to seriously consider the opportunities that unmanned air mobility can offer and the costs that ignoring it may impose.

Source: alternathistory.com.

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This paper identifies the lag in adoption of unmanned aerial systems (UAS) in ADF air mobility and explores opportunities for future employment of UAS in that field. Its aim is to increase collective awareness of the potential for unmanned air mobility and provide a broad reference source for military and commercial contributors to the ADF Force Structure enterprise. The first part discusses the drivers of UAS adaptation, including Australia's strategic interests, regional military modernisation, safety, survivability, cost and technology availability. The second part presents a collection of specific opportunities and examples for UAS development within each of the three core air mobility activities. The final part highlights potential challenges that air mobility UAS development may face and concludes with a discussion on the importance of partnerships in realising an Australian unmanned air mobility capability.

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