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SUMMER 2023
VOLUME 75 NO.4

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MANAGING EDITOR'S MESSAGE

I AM LEAVING the managing editor role with mixed emotions as I feel the modernised version of *Wings* is my baby and I believe it has matured successfully over the past four years. The new-look magazine was inspired by RAAFA Publications Managing Director, AVM (retd) Neil Smith and I have been blessed with a very competent production team and an enthusiastic group of copywriters. I can't thank them enough for making me look good. In particular, I would like to thank Sandy McPhie for her editorial experience and guidance, and her tolerance; and Katie Monin for her artistic skill and initiative. John Kindler and Bob Treloar have been stalwarts; Bob's book reviews and last flight contributions add a human touch to the magazine. Peter Ring for his insightful observations of the human condition in relation to management and leadership. I must also acknowledge Michael Nelmes for his knowledge, research tenacity and authorship. Unfortunately, Michael is also leaving the magazine as his responsibilities as curator of the Narromine Aviation Museum has crowded out his spare time. Michael Musumeci has accepted the historian role and Rob Amos will assume the managing editor role. I appreciate their commitment and wish them well as the magazine continues to gain traction. Thank you all for the experience.

Ron Haack, **Wings** *managing editor*

EDITORIAL DEADLINES

Wings welcomes submissions and letters to the editor. Please send submissions to: **managing.editor@wingsmagazine.org**, including your name and details. Submissions maybe edited for length and clarity. We cannot guarantee all material will be published.

EDITION	DEADLINE
Autumn 2024 (March)	20 January
Winter 2024 (June)	1 April

AIR FORCE ASSOCIATION

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WINGS SUMMER 2023 VOLUME 75/NO.4

A MESSAGE FROM THE MANAGING DIRECTOR

STARTING LIFE IN 1943 as a morale-boosting RAAF magazine for its 180,000 members, *Wings* was transferred to the Air Force Association (then known as the RAAF Association) in 1946. With many RAAFies joining the RAAF Association on demobilisation, the readership was largely unaltered, and the content remained focused on the activities of our post-war but very much downsized RAAF.

Not unexpectedly, *Wings* gradually became more inwardly focused on the RAAF Association and its members, drifting away from the active RAAF. However, some four and a half years ago, the Air Force Association decided to rejuvenate the magazine, concurrently rekindling its association with the RAAF and exposing the Association to the public.

Starting with the winter edition of 2019, the new-look *Wings* focused on high quality, both in print and editorial content, and a much broader range of aviation topics, from history to future technology. In its renewed format, *Wings* has presented itself not only as a members' magazine, but also a premium quality aviation journal.

We have seen *Wings* move closer to the RAAF than it has ever been post WWII. While RAAF members have *Air Force News* issued on a fortnightly basis, we have intentionally positioned *Wings* as the RAAF's de facto quarterly journal.

The renewed *Wings* would not have been possible without the dedication and knowledge of the managing editor, Wing Commander Ron Haack (retd). After sourcing and editing the past 18 editions and this summer edition, Ron is unfortunately hanging up his quill. He will remain with *Wings* in a supporting role, but this will be his last edition as managing editor. On behalf of the RAAFA Publications Board and our dedicated readers, I cannot thank him enough for his enormous contribution.

Neil Smith
Managing director, RAAFA Publications

LETTER TO THE EDITOR

TECNOLOGICAL LEAPS

I SERVED IN THE RAAF as an Engineering Officer and retired, after more than 40 years' service, as a Wing Commander.

I believe that back in the late 1970s/early 1980s, we thought we were doing something special when we bought the C-130H and AP3C flight simulators.

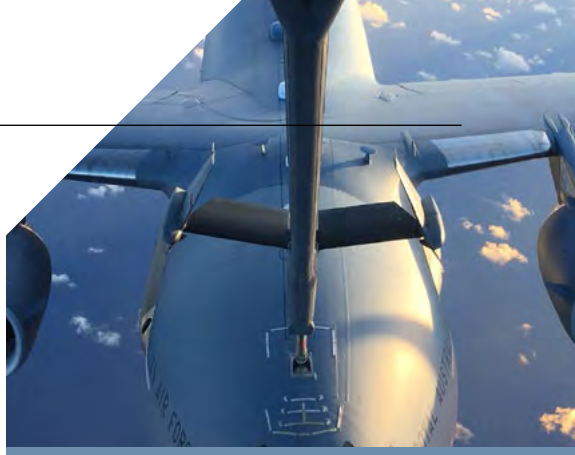
The introduction of a number of "new thingies" was very interesting, but none more so than the visual systems. While the Navy beat us in that regard for its Sea King simulator, we nonetheless felt privileged to be bringing that new technology into the RAAF.

I realise the visuals we introduced were fairly basic, but the article in the spring 2023 edition about the challenges of terrain simulation (A military metaverse) made me realise just how far technology has leapt in that relatively short period.

Fascinating read, thank you.

Bob Weight
(Ex PMA3A)
River Heads, Qld

The *Wings* team loves to hear from readers. Please send letters to: managing.editor@wingsmagazine.org, including your name and contact details. Letters may be edited for length and clarity.



ON THE COVER
A RAAF C-17A Globemaster III refuels from a US Air Force KC-10 Extender tanker aircraft from the 305th Air Mobility Wing during a trans-Pacific flight for Exercise Talisman Saber 17. Photo: Department of Defence.

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AIR FORCE ASSOCIATION

PRESIDENT'S DESK

I'VE BEEN ASKED OFTEN WHY WE celebrate the Battle of Britain when there were only 35 confirmed Australian's involved in the conflict. It's an easy question to answer. Most of the aviators took the initiative to join the fight and volunteered to take short service commissions in the RAF. Some had recreational flying experience. Others had only a few hours on type when they entered the fray.

They knew their lives were not likely to last four weeks, but they remained committed and engaged in the battle on a daily basis, sometimes several times each day. That is heroism in its truest form. Historians agree the Battle of Britain was one of the most decisive battles of World War II. Our lads will not be forgotten.

I felt honoured and humble to provide the occasional address at the Hobart Cenotaph as part of the Tasmania Division's commemoration of the Battle of Britain that took place over the weekend commencing 15 September.

AFA has a role to contribute to the Royal Commission into Defence and Veteran Suicide. Recently the commission sought a further 12-month extension. The government opposed it. The Association supported the DVA Ex-Service Organisation Round Table decision not to extend the inquiry. To do so would delay the implementation of the commission's accepted recommendations designed to assist veterans and their families.

Rumour suggested the government and Defence had not been fully cooperative in providing requested information. DVA has provided in excess of 250,000 pages of evidence. Defence would not want to be seen as hindering the inquiry. The government has information it may have withheld. I expect that would only be information classified as 'cabinet in confidence'.

I hope the government will reinstate the Office of the National Commissioner into Defence and Suicide Prevention that was previously held by Dr Bernadette Boss. That instrument of government could monitor the progress of accepted Royal Commission recommendations and investigate or drive other matters that would assist with suicide prevention.

The year 2023 is drawing to a close and I am pleased to say the Association's restructure has been fully implemented. The new AFA Ltd Board and the Federation Council have both agreed for the Association to focus on veteran and family support measures, mainly advocacy in the short term and veteran homeless recovery as a longer-term goal.

I hope you have a wonderful festive season. Stay safe.

Carl Schiller
National President

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To join the Association, visit ***raafa.org.au*** and follow the Membership link. For assistance, contact the Association by phone or email. See page 15 for the contact details.

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If you enjoyed our latest issue please consider a donation to help cover the cost of production and contribute to our work with military Veterans. Follow the Donate link at **wingsmagazine.org**

Wings is a product of the Air Force Association a charitable, ex-service organisation supporting military Veterans.

AIR FORCE ASSOCIATION

EDITED BY Bob Treloar

TALISMAN SABRE 23

EXERCISE TALISMAN SABRE 2023, the 10th and largest ever, was conducted across northern Australia from 22 July to 4 August, engaging more than 30,000 personnel from 13 countries.

Established in 2005, Talisman Sabre is a biennial large-scale military exercise orchestrated by Australia and the United States.

Talisman Sabre 23 involved land, sea and air operations, testing capabilities in diverse environments with a focus on real-world scenarios. Primary participants included the US Pacific Fleet, Marine Corps, Army, Air Force, and the ADF. Japan, Canada, New Zealand, UK, and European and regional forces also participated.

The air element of the exercise, conducted from Darwin, Tindal and Curtin bases, was planned to increase interoperability across the spectrum of air operations. Missions were designed to effect integration of RAAF and USAF assets, as well as aircraft from the USS *Ronald Regan* (CVN 76). Assets participating in the exercise included: USAF F-22 Raptor and KC-46 Pegasus aircraft alongside RAAF F-35A Lightning II, F/A-18F Super Hornet, E/A-18G Growler, KC-30A Multi-Role Tanker Transport and P-8A Poseidon.

For eight weeks before the exercise, 500 aviators from Combat Support Group pulled together a range of capabilities to activate bare base Curtin, Western Australia. A large convoy of combat support elements from around Australia deployed equipment and personnel to enable the base to support air operations.

No 44 Wing Deployable Defence Air Traffic Management and Control System (DDATMCS) Operations Cabin and Transportable Air Operations Tower (TAOT) were established at Curtin. The DDATMCS system includes an approach control cell, communications links and support equipment designed to operate from remote bases and austere airfields. The system provides airspace surveillance to about 100 nautical miles from the airfield and can be set up and packed down in 72 hours.

Source: Defence Connect

ABOVE DDATMCS Operations Cabin and TAOT. Photo: LACW Annika Smit.

First Black Hawks arrive

5th Aviation Regiment UH-60M Black Hawk.

THE FIRST TWO OF 40 UH-60M Black Hawk helicopters for the Army arrived at RAAF Base Richmond on 30 July via USAF C-17 and a third Black Hawk arrived on 4 August. The Black Hawks were acquired to replace the MRH-90 Taipan, grounded in September, and will be operated by the 5th Aviation Regiment, Oakey and the 6th Aviation Regiment at Holsworthy.

The Black Hawk is a proven and mature platform supported by a robust global supply chain. The decision to acquire Black Hawks followed an earlier decision in January 2021 to replace the Army's 22 Eurocopter Tiger armed reconnaissance helicopters with 29 Boeing AH-64E Apache Guardian attack helicopters.

Source: Australian Defence Magazine

US upgrades in THE TOP END

IN JULY, AN AUSMIN joint communique expressed an intent to rotate US Navy Maritime Patrol and Reconnaissance Aircraft in Australia, and continue to progress upgrades at RAAF Bases Darwin and Tindal, NT, with site surveys to scope additional upgrades at RAAF Base Scherger, Qld and Curtin, WA.

The US will construct a squadron operations facility, maintenance centre and additional tarmac space at RAAF Base Tindal. Aircraft parking space will be expanded to accommodate six B-52 bombers while the facility will support the conduct of strategic operations and run multiple 15-day training exercises for deployed B-52 squadrons throughout the year. The upgrade is expected to be completed in late 2026.

The US Squadron Operations facility is budgeted to cost US$26 million ($40 million while the aircraft parking apron will cost US$258 million ($366 million) and follows additional US expenditure of US$270 million ($415 million) to build 11 large aircraft fuel storage tanks near Darwin's main sea port.

Source: ABC News

ABOVE A USAF B-52 Stratofortress Bomber landing at RAAF Base Darwin. Photo: Department of Defence.

Radar missiles for RAAF

IN AUGUST, the government approved the acquisition of more than 60 Advanced, Anti-Radiation Guided Missile – Extended Range missiles from the US at a cost of $431 million. The missiles, designed to target radar systems, will be employed on the RAAF's Growler and Super Hornet aircraft and, in future, on the F-35A Lightning II.

The Defence Strategic Review emphasised the need for Australia to be able to hold an adversary at risk further from our shores, by developing the ADF's precision long-range strike ability.

Source: ADM

ABOVE An AGM-88 HARM Loaded on an F-4 Phantom. Photo: Wikipedia.

Japanese ALLIES

IN JULY, THE JAPAN AIR SELF-DEFENSE FORCE (JASDF) and the French Air and Space Force completed their first bilateral air force exercise to improve mutual operational procedures and promote closer military ties between the two nations. The French contingent comprised two Rafale fighters, supported by an A330 MRTT refuelling aircraft and an A400M tactical transport aircraft.

In the same month, the Chief of Staff of the Japan Maritime Self-Defense Force (JMSDF) announced plans to share information with the Italian Navy concerning F-35B Lightning II operations from the JMSDF's Izumo-class helicopter destroyers.

In September last year, the JASDF successfully conducted its first fighter aircraft drills in collaboration with the German Air Force and in January this year, engaged in a similar exercise with the Indian Air Force.

In August, the JASDF deployed four F-35As and an aerial tanker to Australia, while the RAAF deployed six F-35As, an aerial tanker and two separate transport aircraft to Japan. See page 8 for details.

Source: The Eurasian Times

LEFT Japanese F-15s fighters with a pair of French Rafale fighters.

Australian JAPANESE DEPLOYMENT

Japan Air Self-Defense Force F-35A Lightning IIs taxi through a water arch at RAAF Base Tindal. Photo: LACW Taylor Anderson.

FOUR JAPANESE AIR SELF-DEFENSE FORCE (JASDF) F-35As supported by an aerial tanker, three transport aircraft and 160 personnel, deployed to northern Australia last August. The deployment was conducted to enhance the JASDF's deployment capabilities with a view to conducting future rotational deployments to Australia and overseas joint exercises. Japan plans to acquire 105 F-35As and 42 F-35Bs; the latter to operate from the helicopter carriers JS *Izumo* and JS *Kaga*, which are being upgraded to support the aircraft.

Later in August, six Australian F-35As deployed to Japan for the first time as part of the bilateral Bushido Guardian air exercise, at Komatsu Air Base in western Honshu.

More than 150 Australian troops will travel to Japan in December for their first full participation in the Yama Sakura command-post exercise alongside US and Japanese forces.

Source: Japan Times, Stars and Stripes

First visit by USAF AC-130 Gunship

A USAF SPECIAL FORCES AC-130J GUNSHIP visited Australia for the first time in the lead up to Exercise Talisman Sabre 23. The AC-130J is armed with 30mm and 105mm cannons and can fire a plethora of smart munitions, including the GBU-39 Small Diameter Bomb, GBU-69 Small Glide Munition, AGM-114 Hellfire missiles, and AGM-176 Griffin missiles. AC-130 missions include close air support, air interdiction, and armed reconnaissance. They have seen action in Asia, Africa, South America, Europe and the Middle East.

Air Commandos from USAF Special Operations Command's 23rd Special Tactics Squadron took part in dry-fire rehearsals with US and Australian Combat Control teams on the ground.

Source: Business Insider

BELOW Two Australian Air Force PC-21s and a USAF AC-130J over the Newcastle region during Exercise Teak Action in July. Photo: LAC Samuel Miller.

Indonesia buys 24 F-15EX

DURING A VISIT BY Indonesia's Minister of Defense, Prabowo Subianto, to the United States, the Republic of Indonesia and Boeing finalised the sale of 24 F-15EX aircraft to Indonesia, subject to US government approval. A Memorandum of Understanding was signed on 21 August at the company's St. Louis facility following a tour of the F-15EX production line.

As a stop gap measure, the Indonesian Air Force purchased nine, single-seat Mirage 2000-5EDA aircraft and three, twin-seat Mirage 2000-5DDA aircraft.

Source: Defence News

ABOVE A F-15EX assigned to the 85th Test and Evaluation Squadron, Eglin Air Force Base. Photo: 2nd Lt. Mary Begy/USAF.

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ABOVE Aerial view of Cocos Island airfield.

Cocos Island airfield upgrade

DEFENCE PLANS TO upgrade the runway, airfield lighting and drainage of the Cocos (Keeling) Islands airstrip. Cocos Islands is an Australian external territory in the Indian Ocean, approximately 3,000km north-west of Perth, comprising two coral atolls made up of 27 smaller islands. It is considered essential as a forward base for Air Force airborne electronic warfare/ISR operations and the existing runway limits RAAF aircraft operational capabilities.

The upgrade project will also include a new wharf on West Island, with work is expected to commence in late 2023 and be completed by early 2026.

Source: Department of Defence

RAAF and TNI-AU

REFUELLING FIRST

IN AUGUST, A RAAF KC-30A MRTT refuelled Indonesian Air Force F-16 Fighting Falcon aircraft during a qualification and training program that involved 60 sorties and 189 boom contacts – a first for the two air forces.

Australia also completed KC-30A air-to-air refuelling qualification tests with Japan Air Self-Defense Force F-15J and F-15DJ Eagle fighters for the first time in March and April this year, completing 11 flights and 325 boom contacts.

Source: Defence Connect

ABOVE Pilot perspective from an Indonesian Air Force F-16 Fighting Falcon aircraft during an air-to-air refuelling training activity with a RAAF KC-30A MRTT from No 33 Squadron.

MARINES KILLED IN OSPREY CRASH

THREE US MARINES were killed and five were critically injured in August when an Osprey aircraft crashed in the Tiwi Islands, north of Darwin.

The Osprey is a tilt-rotor aircraft that takes off and lands vertically like a helicopter and transitions to a fixed-wing airplane configuration. It is used to transport troops and equipment in the battlefield environment. The aircraft's safety record has come under scrutiny in the wake of several, recent fatal accidents.

In June last year, five Marines were killed when their Osprey crashed near Glamis, California, and three months earlier an Osprey crashed during NATO exercises in Norway, killing four American service personnel. In 2017, an Osprey crashed in Syria, injuring two. That year, a crash in Australia also left three Marines dead. One of the deadliest Osprey crashes came in April 2000, when all 19 Marines on board were killed.

Source: Washington Post

USMC V-22 Osprey tilt rotor aircraft.

Fourth MQ-4C TRITON

THE AUSTRALIAN GOVERNMENT has announced plans to purchase a fourth MQ-4C Triton Remotely Piloted Aircraft System (RPAS) and a suite of anti-submarine warfare, maritime strike and intelligence collection enhancements for Australia's fleet of 14 Boeing P-8A Poseidon aircraft. The acquisition has an estimated combined value of more than $1.5 billion.

The Triton aircraft was selected to provide long-range, persistent surveillance across Australia's maritime region and will be based at RAAF Base Tindal. The first Triton is scheduled for delivery to Australia in 2024. An interim sustainment support contract with Northrop Grumman Australia, valued at $220 million, has been signed, to establish a strong maintenance workforce at RAAF Bases Tindal and Edinburgh for the Triton fleet.

The Triton has attained initial operational capability with the US Navy (USN) and commenced a deployment to Andersen Air Force Base, Guam, assisted by RAAF personnel embedded within the MQ-4C program. The USN has reduced its MQ-4C Triton surveillance program from a requirement for five orbits around the globe to three, reducing the number of Tritons from 68 aircraft to 27.

Source: Defence Connect

ABOVE Q-4C Triton. Photo: Northrop Grumman. Image has been manipulated.

A rendering of the MC-55A Peregrine. Photo: L3Harris.

MC-55A Peregrine progress

ON 23 JULY 2023, a Gulfstream MC-55A Peregrine destined for RAAF service flew into Greenville, Texas, for modification by L3 Harris. Still in primer paint coating, the aircraft is one of four Peregrines that will replace the electronic warfare variant AP-3C Orion at No 10 Squadron, RAAF Edinburgh.

The $2.5 billion acquisition of four modified Gulfstream G550s provides a new airborne electronic warfare capability that will be integrated into joint warfighting networks, providing a critical link between platforms, including the F-35A Lightning II, E-7A Wedgetail, EA-18G Growler, Navy's surface combatants, amphibious assault ships and ground forces.

Source: Scramble

Wedgetail to assist Ukraine

IN JULY, the government announced an Air Force E-7A Wedgetail aircraft would deploy to Germany in October for approximately six months. The deployment will comprise up to 100 crew and support personnel and will integrate with partner forces, including the US, to provide early warning in the event of threats from outside Ukraine against activities providing humanitarian and military assistance.

The E-7A will operate outside of Russian, Belarusian and Ukrainian airspace.

No 2 Squadron E-7A Wedgetail. Photo: CPL Craig Barrett.

AFA Ambassador HONOURED

RAAF VETERAN AND AMBASSADOR FOR THE AIR FORCE ASSOCIATION (AFA) Sharon Bown has been appointed a Member of the Order of Australia in recognition of her dedication and service to Australian veterans and their families.

Sharon's military journey is one of inspiring resilience. While serving as an aeromedical evacuation nurse in East Timor, she was involved in a devastating helicopter crash. Despite sustaining severe spinal injuries, a shattered jaw and aviation fuel burns, along with the long-term struggle with chronic pain and PTSD, Sharon fought her way back to active duty.

In subsequent roles, Sharon served as Aide-de-Camp to the Minister for Defence and commanded a surgical team in Afghanistan.

Moving beyond her military service, Sharon continues her advocacy work as a Member of the Council of the Australian War Memorial (AWM). She is also an Ambassador for Phoenix Australia, a member of the AWM Roll of Honour Committee and Vivian Bullwinkel Sculpture Committee and a Fellow of the Australian College of Nursing. She holds a Bachelor of Psychological Science, melding personal experience with academic understanding.

"Sharon Bown embodies the essence of resilience and courage. The award pays tribute not only to her professional achievements but also to her tireless efforts for the wellbeing of Australian veterans and their families," said AFA National President Carl Schiller.

"Her appointment to the Order of Australia is a well-deserved honour that serves as a testament to her exceptional life of service."

WGCDR Deanna Nott

BATTLE OF BRITAIN SERVICE

ON 16 SEPTEMBER 2023, Air Force Association – South Australia (AFA-SA) and RAAF Edinburgh co-hosted Adelaide's annual Battle of Britain Commemorative Service at the Air Force Memorial, Torrens Parade Ground.

More than 100 attendees, including dignitaries, serving members, veterans and friends, joined to commemorate those who became known as 'The Few' – the allied pilots, supported by ground crews, who fought in the skies over England in the air campaign that resulted in the first military defeat of Germany in World War II.

Her Excellency, Frances Adamson AC, Governor of South Australia attended in her Honorary Air Commodore role, sharing the day with WWII veterans Angas Hughes, Don Looker and Ray Merrill DFC.

In the keynote address, Commanding Officer No 1 Remote Sensor Unit, Wing Commander Peter Crookes told the story of South Australian Lou Hamilton, who joined the Royal Air Force (RAF) and was one of the eight South Australians to fly in the Battle of Britain. Remaining in the RAF after the war, he retired to Australia in 1961 only to die in a boating accident in 1977, aged 62, a tragic end for a veteran who had survived two operational tours, four flying tours and countless hours flying over ocean.

Five members of Wing Commander Hamilton's family travelled from Melbourne, Canberra and NSW for the service to honour their father and grandfather.

A wreath comprising images of the eight South Australians who flew in the Battle of Britain was at the base of the memorial.

ABOVE Members of WGCDR Lou Hamilton's family join with the Governor of South Australia in placing rosemary on the special Battle of Britain Wreath.

SHOAMP SERUM SAMPLES UPDATE

IN 2001, THE DEPARTMENT of Defence commissioned a Study of Health Outcomes in Aircraft Maintenance Personnel (SHOAMP) to investigate health outcomes in personnel who carried out fuel-tank repairs between 1975 and 1999 as part of the F- 111 Deseal/Reseal programs.

Some of those personnel volunteered to participate in the study and donated blood-serum samples for long-term storage, up to 50 years, to support the study over time.

To ensure continued long-term storage, and with the support of the SHOAMP Serum Management Committee (of which AFA is a member), serum samples have been moved from their original storage at QML Pathology to state-of- the-art bio-banking facilities at QIMR Berghofer Medical Research Institute in Brisbane.

The Australian Institute of Family Studies (AIFS) has been contracted to manage on-going storage of the data-linkage key which contains the information that allows a participant sample to be identified and withdrawn from storage.

Participant privacy continues to be a primary consideration. At no time has Defence or DVA received identifying participant information. As outlined in the original information provided to study participants, de-identified participant study data is held by the Australian Institute of Health and Welfare.

There is no impact on, or change to, SHOAMP Health Care Scheme entitlements.

Participants can withdraw consent for their sample to be used in further research by contacting the AIFS at shoamp-requests@aifs.gov.au or completing an online form at www.aifs.gov.au/shoamp-request.

For more information, see dva.gov.au/shoamp-storage-arrangements.

INNOVATORS AND ACES

IN RECOGNITION OF THE RAAF CENTENARY, AFA Victoria embarked on a project to record and acknowledge the notable characters active in the Division in the Association's formative years.

AFA-VIC's second president, Albert Edward (Bert) Chadwick, held the role in 1941-43 at the same time he was Director of RAAF recruiting and a member of the Melbourne Cricket Club committee. He faced a massive task with the RAAF to increase personnel numbers from 3,500 in 1939 to 180,000 plus by 1944. However, his commitment to the Association was strong. He had been instrumental in arranging a reunion dinner for AFC personnel in 1920 to welcome the Smith brothers after their record-breaking flight from England and that dinner became the genesis of the Australian Flying Corps Association (AFCA). By WWII, the AFCA had become the Air Force Association. Bert was Senior Vice President of the AFCA when the Association raised funds and presented the AFC memorial to Chief of Air Staff, AVM Dicky Williams, in 1938. The memorial stands at Point Cook opposite the new RAAF Memorial.

Bert was born on 15 November 1897 at Beechworth, Victoria. His father was a London-born chemist, his mother was a Beechworth local and his early education was at a single-teacher school in country Tungamah. When Bert was 12, the family moved to Carlton. Unfortunately, his father died soon after and Bert had to work to help support his mother and four siblings. He delivered papers, collected firewood around factories and eventually became an "apprentice helper". While working a 48-hour week, he attended night school and ultimately gained an apprenticeship in electrical engineering with Jack Duigan who had been the first to design, build and fly an aircraft in Australia. Duigan's interest in aviation led Bert to spend his spare time working with aircraft fabric.

In early 1916, Bert was enlisted in the 1st AIF as an aircraft mechanic and assigned to 1 SQN AFC. During the Sinai campaign, he was seconded to the Light Horse and Camel Corps where he met a "boot-faced Englishman" with "unusual qualities" – Lawrence of Arabia. By 1918, Bert was promoted to SGT, mentioned in despatches and awarded the Meritorious Service Medal.

Bert had never had time for sport until he was introduced to Australian rules football with 1SQN in the Sinai. He ended up captaining that team. When he returned to Melbourne, he played a few games for Prahran and then present himself to training at the Melbourne Football Club. By 1924, he was captain of the club and then captain/coach from 1925 to 1927, winning 42 of 58 games, including the 1926 premiership. He played 19 games for Victoria and won the 1927 interstate carnival as captain/coach.

Bert was much more than a footballer. During the 1920s he worked for the British Imperial Oil Co (later Shell Australia) as an engineer before transferring to the commercial division. In 1935, he was appointed controller of sales with the Metropolitan Gas Co and when the Gas and Fuel Corporation was formed in 1951, he became assistant general manager and then general manager. Retiring in 1963, he became chairman of the corporation and also of the Overseas Telecommunications Commission from 1963 to 1968. He was chairman of Melbourne Football Club 1950-62 and served on the Melbourne Cricket Club (MCC) committee from 1941 to 1979, including as president from 1965 to 1979.

However, it is Bert's contribution to the war effort and veteran welfare that commands AFA-VIC's recognition. In 1940, he was appointed an Administrative Officer in the RAAF. In 1942, as GPCAPT Chadwick he was appointed Director of Recruiting based at the showgrounds and then the MCG. He was a vigorous advocate of mental and physical fitness, the "national importance" of football in maintaining morale, and the urgency of increasing the enlistment of women. At the end of the war, he was firm in his desire for an orderly demobilisation process and, notwithstanding his position on the MCC committee, he supported retention of RAAF Ransford until the demobilisation process calmly transferred to the Exhibition Buildings.

The MCG was handed back to the cricket club at the end of October, just in time for the cricket season. Bert's support for veterans continued as trustee and treasurer of the RAAF Women's Educational Fund and chairman of the RAAF Veterans Residence Trust.

He was appointed Companion of the Order of St Michael and St George (CMG) in 1967 and was knighted in that Order in 1974.

He married Thelma Marea Crawley in 1924. He died in October 1983 at his home in Toorak, Melbourne and was survived by his son and daughter.

John Clarkson

LEFT
Bert Chadwick.

BELOW
Bert second left in the back row, Sinai 1918.

RECOGNISING OUR CENTENARIANS

FIVE SOUTH AUSTRALIAN RAAF VETERANS who have recently become centenarians have been recognised by AFA-SA and RAAF Edinburgh.

In September, AFA-SA Vice President Robert Black and RAAF Edinburgh aviators joined Lyall Ellers and his family at his house on his 100th birthday for a morning tea. A birthday cake featuring the RAAF Badge provided a wonderful opportunity for Lyall to share stories of his service with the young aviators.

In October, AFA-SA joined with 460SQN veteran Howard Hendrick in celebrating his 100th birthday at the Loxton Show. Then AFA-SA celebrated 467SQN veteran Angas Hughes'100th birthday when he visited RAAF Edinburgh.

ABOVE RIGHT Howard Hendrick with Dr Black and GPCAPT Greg Weller.

RIGHT Lyall Ellers with Dr Black, RAAF Edinburgh aviators and his son Grant Ellers.

ABOVE Angus Hughes at RAAF Base Edinburgh.

LOXTON ANSON CRASH ANNIVERSARY

ON 24 SEPTEMBER 2023, AFA-SA, RAAF EDINBURGH and the Loxton community commemorated the 80th anniversary of the loss of four aviators in an Avro Anson crash near Loxton. Avro Anson W2481 of No 2 Air Navigation School based at Nhill, Victoria was on a night navigational training flight when it crashed, killing the crew, FLGOFF Lawrence Flynn (Pilot), PLTOFF Albert Rapp (Observer/ Navigator), SGT Ronald Obst (Wireless Operator Air Gunner) and SGT John Bowman (Observer). They were aged between 19 and 30. Several had connections to the Loxton community.

The service was held at a memorial featuring an Avro Anso aircraft sculpture with the registration number W2481, unveiled by the Loxton community in 2019. AFA-SA Secretary Dr Warwick Raymont spoke and Acting President Lawrence Ng laid a wreath. The Ode was recited by 99-year-old Howard Hendrick DFC OAM, a local Bomber Command veteran.

ABOVE Lawrence Ng pays his respects after laying a wreath at the Loxton Avron Anson.

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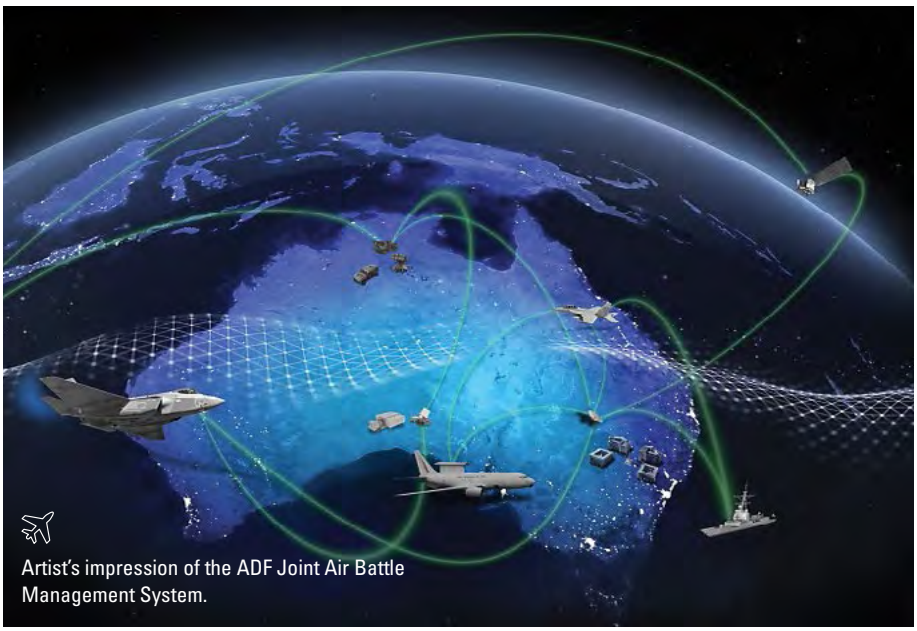
EDITED BY John Kindler

AIR 6500 PHASE 1 WINNER



Artist's impression of the ADF Joint Air Battle Management System.

LOCKHEED MARTIN (LM) has been awarded the Project Air 6500 Phase 1 contract to provide the ADF with a Joint Air Battle Management System (JABMS) at the core of the ADF's future Integrated Air and Missile Defence capability. The management system is expected to provide a sovereign capability designed to improve situational awareness and coordinate defence against air and missile threats while remaining interoperable with allied partners.

More than 130 Australian small to medium enterprises employing more than 200 Australian staff will be employed by LM to develop the capability. LM has also invested $10 million to upgrade its Endeavour Centre to engage, explore, test, design and problem-solve with the ADF and industry.

The Federal Government committed $765 million to deliver the JAMBS as a second tranche of what is expected to be a multibillion-dollar program. It is also accelerating the ADF's medium-range ground-based air defence capability and strategy for layered, integrated air missile defence capability. Options are currently being developed with several companies for consideration.

Source: Defence Connect

Wedgetail contract extension

BAE SYSTEMS AUSTRALIA will continue to sustain the E-7A Wedgetail Electronic Support Measures (ESM) and Electronic Warfare Self-Protection (EWSP) systems for Boeing Defence Australia under Wedgetail's Airborne Early Warning & Control program, in the latest two-year agreement.

BAE has been providing sustainment support for the Wedgetail fleet since its introduction into service in 2011 and will continue to provide engineering, field services, supply, maintenance and management support for the ESM and EWSP systems on the RAAF's fleet of six E-7A Wedgetail aircraft.

LEFT
E-7A Wedgetail in an aircraft shelter at RAAF Base Tindal.

Artist's impression of an orbiting Skykraft satellite.

Air Traffic CONTROL VIA SATELLITE

VOICE COMMUNICATION BETWEEN aircraft and air traffic control agencies (ATC) via satellite is a step closer after Canberra-based Skykraft conducted a trial of the technology. The trial was carried out after the company launched a series of satellites, with plans to grow the constellation to 200.

The test used the very high frequency (VHF) band traditionally employed by ATC, which currently can only be accessed by aircraft in range of a ground-based transceiver.

Skykraft believes its technology will fill in communication blackspots, improve safety and reduce fuel costs by allowing aircraft to dynamically plan more efficient routes.

Skykraft began in 2017 as a spin-off from the space capability incubator UNSW Canberra Space. It now exists within the framework of UNSW Launch and has a dedicated manufacturing facility within the Canberra campus.

Source: Space Connect

An Australian Army CH-47 in the field.

SitaWare secures Army contract

THE ADF CAPABILITY ACQUISITION & SUSTAINMENT GROUP (CASG) has announced Systematic's SitaWare software as the sole-source winner for the Army's new digital command and control battle management system. The SitaWare suite offers C4 (command, control, communications, computers) intelligence, surveillance and reconnaissance battle management solutions across the battlespace – land, sea, air or in the joint domain.

The decision follows the first pass approval, in mid-July, of LAND 200 Phase 3 Battlefield Command Systems project designed to improve the security and performance of Defence's tactical communications network and battle management systems.

Defence said the new battlefield command and control system "will increase the speed and quality of decision-making, essential to success in military operations and also improve communication and coordination within Army and between the joint elements of the ADF".

Source: Defence Connect

Aerospace Propulsions Centre of Expertise

ADF'S CAPABILITY ACQUISITION AND SUSTAINMENT GROUP has signed a three-year contract with Australian-owned and operated Capagility to establish an Aerospace Propulsions Centre of Expertise (APCoE) and provide expert advice to the ADF about military aircraft engine management.

Air Commodore Steve Pesce, director-general airlift and tanker systems, said the centre would benefit from the advice of Capagility's four experts on managing and sustaining engines fitted to ADF aircraft. "Advice from Capagility has already saved the Commonwealth significant expenditure and we expect that trend to continue once the APCoE is up and running," he said.

Source: Defence Connect

ABOVE AIRCDRE Steve Pesce and Capagility managing director Steve Green sign the APCoE contract.
Photo: Private Nicholas Marquis.

New testing team for ADF

KBR AND QINETIQ HAVE signed a teaming agreement to deliver test and evaluation services for the ADF. QinetiQ is a test and evaluation partner to the UK Ministry of Defence and Australian Government. KBR is a specialist test, trial and training agent for the US Department of Defence. Under the agreement they will share skills and experience to build on both companies' respective test and evaluation solutions, drawing on both global and local capabilities.

A RAAF F-35 Lightning II.

Regional hub for F-35 SUSTAINMENT

AUSTRALIA'S FIRST DEDICATED COATING FACILITY, designed to apply a specialised paint to the F-35A to preserve the aircraft's stealth attributes will be established in partnership with BAE Systems Australia at Williamtown, NSW. The design for the $100 million facility is due to be finalised by the end of the year, with construction expected to start mid-2024.

To date, only Australian F-35As have undergone maintenance by BAE Systems at Newcastle Airport. The new coating facility will support the maintenance of other F-35A fleets operating in the Indo-Pacific, transforming Newcastle Airport into a future regional hub.

MR simulator wins innovation award

MIXED REALITY SIMULATOR BLUEROOM, created by Australian company Real Response, won the most Innovative Project Award for 2023 at the Simulation Australia Awards in Adelaide.

The BlueRoom simulator uses mixed reality (MR) technology with the Varjo XR3 headset to provide an interactive platform to train medical practitioners. MR allows users to engage with the virtual realm using their own hands and physical movements, mirroring real-world interactions.

BlueRoom was created by medical professionals and software developers with support from the Defence Innovation Hub. It has since been further developed for use by the RAAF and is now enabling ADF medics to practice using equipment and navigating medical scenarios within a virtual environment.

SLINGERS BOUND FOR UKRAINE

THREE "SLINGER" LIGHT-WEIGHT 30MM COUNTER DRONE CANNON SYSTEMS made by Canberra-based Electro Optic Systems (EOS) are being sent to Ukraine as part of a US security assistance package. Each Slinger contains a radar and a slaved 30mm stabilised cannon able to track and engage a target at more than 800m. The cannon is capable of firing proximity-fused and hi-explosive or armour-piercing ammunition. The Ukraine version will be used in coordination with Northrop Grumman's M-ACE (mobile- acquisition, cueing and effector) system. The weapon system can be mounted on a heavy 4x4 and configured as an unmanned autonomous vehicle.

The Australian-designed and developed counter-drone system was officially launched in May. It is the second EOS related counter-drone system in operation on the ground in Ukraine after EOS provided AS-65 Remote Weapon System gimbals for the L3Harris "Vampire" portable rocket kit.

Source: Defence Connect

EOS "Slinger" counter drone weapons system. Photo: EOS.

"Silent and deadly" laser

ELECTRO OPTIC SYSTEMS (EOS) demonstrated a "silent and deadly" directed-energy laser system during a live-fire demonstration at Klondyke Range Complex in Western NSW in August.

The company's Titanis water-cooled, 34-kilowatt (latent energy) laser directed-energy system was successfully fired against unmanned aerial vehicles and 8mm-thick steel plates at a distance of about one kilometre. The system operates out of a 20-foot container testbed.

Matthew Jones, EOS executive vice-president defence systems, said the system is designed for counter drone operations, but can be scaled up or down for a range of applications, including potentially against high-speed missiles and hypersonic threats.

Directed energy has a range of applications from low-power systems for counter sensor operations to very high-powered systems which can deliver counter ballistic missile, counter hypersonic, and even counter space effects.

Jones said the company had not confirmed any contracts for the directed-energy system and was about 12 months away from a soldier-proof deployable battlefield system.

Source: Defence Connect

ABOVE EOS Titanis directed-energy weapon.

F414 ENGINE TEST CELLS UPGRADE

TAE Aerospace CEO Andrew Sanderson and Valerie Lawson at the contract signing.

TAE AEROSPACE AND THE RAAF AIR COMBAT and Electronic Attack Systems Program Office (ACEASPO) have signed a contract for the upgrade of the General Electric F414 engine test cells at RAAF Bases Amberley and Williamtown. The test cells are used for functional testing and fault-finding (or troubleshooting) of the RAAF's fleets of Super Hornet and Growler aircraft F414 Engines.

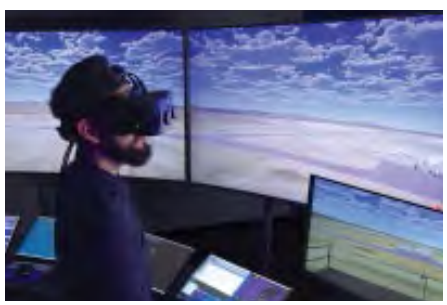
The contract involves an upgrade of the F414 test cell Control and Data Acquisition System to ensure F414 test functionality and performance with improved reliability and supportability. Director Enabling Services ACEASPO, Valerie Lawson said: "The current F414 engine test system has served us well for over a decade. TAE's comprehensive system upgrades will now ensure that these critical engine test facilities remain reliable and sustainable to support our air combat capabilities well into the next decade."

Adacel joins

TEAM AUSTRINGER

AIR SPACE SAFETY COMPANY ADACEL has joined the CAE Australia-led Team AUStringer in response to the Commonwealth of Australia's Project Air 5428 Phase 3, for RAAF's Future Air Mission Training System (F-AMTS).

Adacel will support CAE in the provision of training solutions and services to deliver Air Traffic Control (ATC) training integrated within the F-AMTS located at RAAF Base East Sale, Victoria. ATC candidates and postgraduate students represent a significant number of mission aviators trained in Australia.



ABOVE Artist's impression of a Future Air Mission Training System Station.

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Contenders for USN Super Hornet replacement

IN A MAJOR STEP FORWARD for the secretive F/A-XX program to replace its fleet of Boeing F/A-18E/F Super Hornet aircraft, the US Navy (USN) has confirmed that Boeing, Lockheed Martin and Northrop Grumman are actively competing to deliver the potentially multi-billion contract.

The USN has also confirmed that General Electric Aerospace and Pratt & Whitney are competing to deliver the engine for a proposed next-generation fighter fleet that will differ from the USAF's Raptor-replacing Next Generation Air Dominance (NGAD) program. Both engine competitors are also competing for the NGAD program, while Northrop Grumman confirmed in June that it was not competing for the NGAD program.

Unpacking the future of the program and the capability expected to be delivered, a USN spokesperson said the USN had "identified operational reach, capacity, long-range kill chains, autonomy and next-generation survivability as key enablers in the Air Wing of the Future and supporting family of systems".

ABOVE Artist's impression of apotential F/A-XX fighter.

DIGITAL FLEET MANAGEMENT FOR RAAF

THE ADF HAS DEPLOYED A DELPHI-BASED DIGITAL FLEET MANAGEMENT SYSTEM to help fleet planners make agile and responsive decisions. Delphi is part of the Jericho Disruption Innovation Program for collaborative design, development and rapid prototyping within the RAAF.

Wing Commander Mike Moroney, who leads the Jericho team developing Delphi at Air Force Headquarters in Canberra, said the program is already paying dividends on the ground. WGCDR Moroney said the agile approach pioneered through Delphi can be scaled across Air Force so aviators have software that is fit-for-purpose, and the latest technology can be delivered right into their hands.

Through a long-term collaboration with Defence Science and Technology Group researchers, Delphi is incorporating cutting-edge science to help fleet planners make decisions to respond to the changing needs of their fleet. The program is also illustrating how rapidly evolving technology such as AI enhances Air Force capability.

Source: Defence Connect

ABOVE A RAAF P-8A Poseidon at Daniel K. Inouye International Airport, Hawaii during Exercise Rim of the Pacific 2022. Photo: LSIS Daniel Goodman.

Canada upgrades its MRTT fleet

THE CANADIAN GOVERNMENT has awarded Airbus Defence and Space a CA$3 billion contract for four newly built Airbus A330 multi-role tanker transport (MRTT) aircraft and the conversion of five used A330-200s.

Known as the Strategic Tanker Transport Capability, the new fleet of aircraft will replace the ageing CC-150 Polaris (A310 MRTT) operated by the Royal Canadian Air Force (RCAF).

The existing A310 fleet is used to perform air-to-air refuelling operations, military airlift, medical evacuations and strategic transport of Canadian government officials.

The new A330-200s will be assembled at the A330 aircraft final assembly line in Toulouse, France, prior to their scheduled entry to conversion at A330 MRTT facilities in Getafe, Spain in mid-2025. The first MRTT will be delivered to the RCAF in 2027.

As of March 2020, a total of 60 MRTT aircraft had been ordered by launch-customer Australia (designated KC-30A), France, NATO, Saudi Arabia, Singapore, South Korea, the United Arab Emirates and the UK.

Artist's impression of an A330 MRTT in RCAF livery.

Planning FOR WOOMERA REDEVELOPMENT

AUSTRALIAN INTEGRATED SERVICES COMPANY DOWNER EDI LTD will deliver the planning phase of the ADF's proposed Woomera redevelopment program. Under the contract, Downer and joint venture partner CPB Contractors will commence design development for the estimated $500 to $700 million project that will form the basis of Defence's submission for government approval.

Pending approval and successful negotiations with the Downer-CPB joint venture for the delivery phase, the project will deliver buildings, services and infrastructure works to meet the objectives of the Defence Strategic Review.

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STAYING ALOFT

WORDS Michael Nelmes

THIS YEAR MARKS THE CENTENARY OF IN-FLIGHT REFUELLING, A FORCE MULTIPLIER FEW MODERN AIR FORCES CAN DO WITHOUT.

BELOW LEFT
Two RAAF F/A-18 Hornets fly in refuelling formation with a KC-30A Multi Role Tanker Transport during an Australian Defence Force showcase rehearsal in preparation for the Australian International Airshow, 2019. Photo: CPL David Said.

BELOW
The world's first air-to-air refuelling, 27 June 1923. The upper de Haviland DH-4B dangled a fuel hose to be connected by a crewman in the lower DH-4B, transferring 284 litres.

IN 1919 ALCOCK & BROWN made their famous 3,000km crossing of the North Atlantic Ocean. The feat required fitting extra fuel tanks to their Vickers Vimy biplane, nearly doubling its usual range. Such long-distance flights got people thinking. Was there a way an aircraft could take on fuel without having to land? Just a few years later, the first in-flight or air-to-air refuelling (AAR) experiments were carried out in America.

The 1920s saw some great leaps forward in aviation. In America, the centre of innovation was the US Army Air Corps' (USAAC) research and development unit at Dayton, Ohio (home of the Wright Brothers). In 1922, chief test pilot John McCready set a world endurance record of more than 35 hours in a Fokker T-2 while circling over San Diego, California. But the USAAC wanted still greater endurance.

The following year at San Diego's Rockwell Field, the world's first in-flight refuelling system transferred fuel by hose between two US-built Airco DH-4B biplane bombers. That success was followed by a record 37-hour flight requiring 16 in-flight refuellings. A non-stop north-to-south flight across the USA with three in-flight refuellings followed.

Those accomplishments preceded the first round-the-world flight, in 1924, using four Douglas World Cruiser biplanes, but in-flight refuelling and the associated logistics were not sufficiently developed, so caches of fuel were stationed along the route.

Then in 1929, an Atlantic Fokker C-2 named *Question Mark*, similar to Charles Kingsford Smith's *Southern Cross*, made a record endurance flight of more than six days over Los Angeles. Commanded by MAJ Carl Spaatz (future Chief of Staff of the USAF), it was refuelled by a pair of Douglas C-1 biplane tankers taking turns, lowering their hoses through an aperture in the Fokker's roof. The following year, the Hunter brothers spent no less than 23 days over Chicago with two Stinson SM-1 Detroiters, one as refueller and the other as receiver.

BRITISH DEVELOPMENTS

While America led the way with in-flight refuelling in the 1920s, Europe and Britain were not far behind. Following a flight of 60 hours with in-flight refuelling in Belgium in 1928, the Royal Aircraft Establishment at Farnborough, UK, began experimenting in 1930 using biplane bombers. Rather than increasing range, the aim was to lighten take-off weights by carrying less fuel, thus allowing greater payloads to be carried.

RIGHT
A KB-29M (upper) refuelling B-50A *Lucky Lady* with the Cobham looped-hose system during the first non-stop round-the-world flight. Photo: USAF.

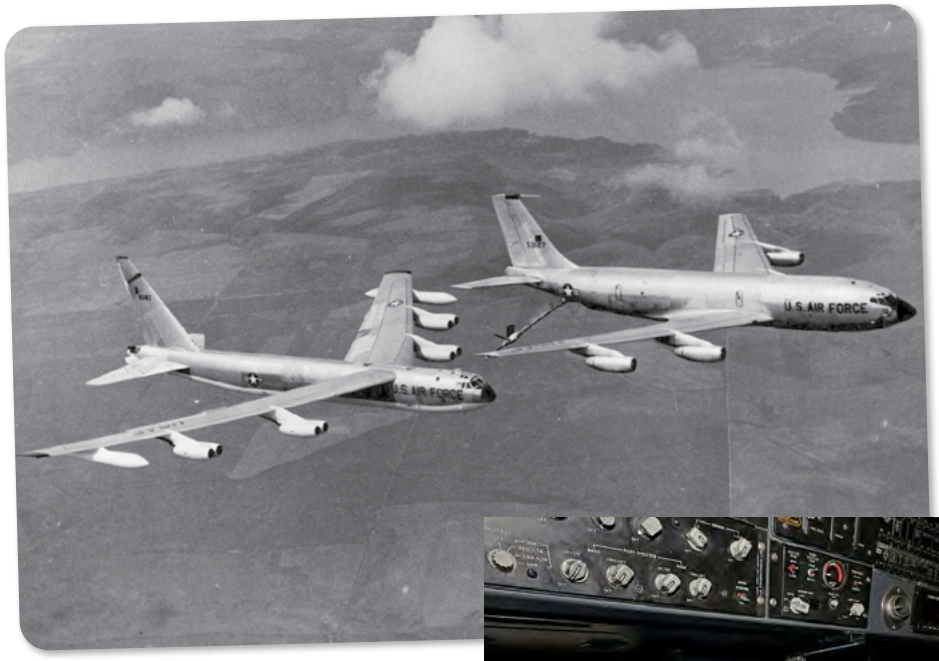
In 1934, FLTLT Richard Atcherly, Royal Air Force (RAF), aware of the American experiments over the previous decade, invented and patented his looped-hose system in which both tanker and receiver trailed cables with grappling hooks on the ends. The tanker would fly across the receiver cable to affect a hook up and once engaged a receiver crewman reeled in the cables and the tanker's 90m fuel hose. Once connected, the tanker climbed above to achieve gravity-fed fuel transfer. Once refuelling was complete, the crewman disconnected the hose and the tanker reeled it in, then turned away to break a weak link in the cable connection.

Sir Alan Cobham, the British pioneer of long-distance survey flights in the 1920s, further developed Atcheley's looped hose system. The Cobham system employed a mechanism to fire a projectile to lay the receiver line across the tankers' trailing cable and once the hooks engaged, a receiver crewman would reel in the line and refuelling hose and initiate fuel transfer. An alternative method, in which a metal hook was fired from a gun to engage the receiving aircraft was, understandably, abandoned.

Cobham and his crew made a non-stop proving flight from England to India in an Airspeed single-engine monoplane. The 8,000km two-day journey required four in-flight refuellings. The company that Cobham created in 1934, Flight Refueling Ltd (FRL), led the way worldwide and later became the aerospace company Cobham Ltd, which still develops aerospace innovations.

In America, greater and greater flight endurance records were made. In 1935, brothers Al and Fred Key kept their Curtiss Robin aloft for more than 27 days using a spill-free valve on the end of the fuel hose from a tanker, greatly improving safety. Food and water were also lowered by rope to the pilots. In 1958-59, refuelled flight endurance more than doubled when a Cessna 172 was kept in the air by two pilots for just under 65 days, using ground-to-air refuelling from a moving truck rather than air-to-air.

By 1939, Cobham's method had been refined sufficiently to be used on a regular Imperial Airways trans-Atlantic airmail and passenger service. Four Short Empire flying boats were fitted with a looped-hose system: a long fuel hose from the tanker looped behind it to engage with



a receptacle beneath the receiver tail. Adoption of the AAR procedure together with extra fuel tanks enabled the Empires to lift off at well below maximum weight, and then take on 4,500L of fuel once airborne, giving the Empire a 4,000km range. Sixteen Atlantic crossings were made before war intervened.

WORLD WAR II

Although no operational in-flight refuelling was deemed necessary or practical during the war, some interesting proposals were made and experimental flights were conducted by the USAAC. Ideas included: launching bombing raids against Japan from Midway Island using B-17 bombers and B-24 converted tankers; B-24 bombers using US Navy seaplane tankers; and even B-17s towing their own tankers in the form of fuel-laden gliders. A variation of the looped-hose method was successfully tested in 1943 at Eglin Field, Florida.

When the very long-range B-29 Superfortress first bombed Japan from Chinese bases, proposals were made for in-flight refuelling from B-24 tankers. However, once the B-29 began operating from captured islands closer to Japan, its 26,000l fuel capacity proved adequate.

Then there was the question of fighters with the range to escort bombers to distant targets. One experiment involved a B-24 tanker dangling an external fuel tank on a cable for attachment, in flight, to a P-38 fighter. However, with the difficulties encountered, and the advent of the P-82 Twin Mustang long-range escort fighter, such experiments were abandoned. Indeed, after the war, a P-82 using external fuel tanks set an unrefuelled fighter distance record of over 8,000km, from Hawaii to New York.

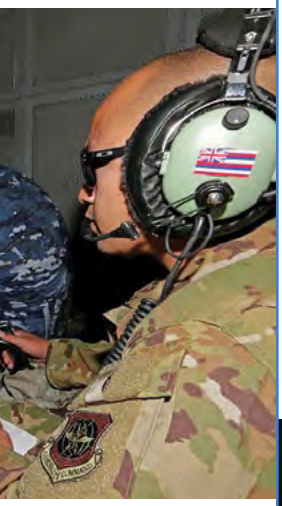
Meanwhile a game-changing FRL innovation, the hose-and-drogue system, was trialled. A trailing fuel hose fitted with a funnel-shaped drogue, perforated to reduce drag, could be engaged by a forward-facing probe on the receiving aircraft.

POST-WAR

The US Cold War posture required Strategic Air Command (SAC) B-47 Stratojet bombers to strike targets anywhere in the Soviet Union. US manufacturing rights were obtained for the FRL looped-hose refuelling system, and B-29 Superfortresses were converted to KB-29 tankers. A trial was staged in

LEFT
A USAF Strategic Air Command KC-135 tanker refuelling a B-52D during the Cold War. Photo: USAF.

BELOW LEFT
A US Air Force KC-10A boom operator deploys a hose-and-drogue to refuel a US F/A-18E Super Hornet. A RAAF imagery specialist videos the operation during a sortie out of Brisbane on Exercise Talisman Sabre 2019. Photo: Department of Defence.



1949, the first non-stop round-the-world flight, accomplished by a Texas-based B-50 Superfortress (refined B-29) refuelled by KB-29s deployed along the route. The 94-hour flight covered nearly 38,000km.

That flight proved system viability for routine AAR, although the grapple-line and looped-hose technique was already being replaced by hose-and-drogue. SAC Air Refuelling Wings were formed, and combat-tested in 1950-53, during the Korean War. KB-29 tankers refuelled F-84 fighter-bombers, a probe in the F-84's wingtip fuel tank engaging with the tanker's drogue.

In 1949, the RAF used a Lancaster tanker to refuel a Meteor fighter 10 times in one flight, using the probe-and-drogue system. In America, ideas for giving fighters greater range without in-flight refuelling were trialled. FICON (Fighter Conveyor) involved a B-36 bomber carrying its own F-84 escort fighter beneath it, on a 'trapeze'. A prototype 'parasite' jet fighter small enough to fit into the B-36 bomb bay was also produced. In another trial, a pair of F-84s was attached to a bomber's wingtips (Project Tip-Tow). However, the inherent danger in docking aircraft in flight forced those projects to be abandoned. By 1950, in-flight refuelling had improved to the point that fighters routinely flew across the Atlantic.

As the drogue system only allowed a fuel transfer rate of 400L per minute, Boeing developed a rigid tail-mounted 'flying boom' for the KB-29, allowing a larger diameter fuel pipe for faster fuel transfer. It required a boom operator, lying in the tail turret, to visually 'fly' the telescoping boom to the receiving aircraft's receptacle. Flying the boom accurately was accomplished with 'ruddervator' control surfaces. Boeing incorporated the boom in the KC-97 (a tanker version of the C-97 Stratofreighter), the world's first factory-built, rather than converted, in-flight tanker. Today, both rigid-boom and hose-and-drogue systems have been adopted by air forces around the world.

With the introduction of the eight jet-engine B-52 Stratofortress bomber in 1955, the slower and lower-flying piston-engine KC-97 tanker became obsolete. Its replacements included the KC-130 tanker version of the Hercules transport (still in use after 60 years, now as the J model variant) and the Boeing KC-135

Boom operator's view of a B-2 Spirit bomber refuelling from a KC-135 Stratotanker, during deployment to Guam. Photo: USAF.

Stratotanker (developed alongside the B707, with more than 800 in US service since 1957). The latter is only now being replaced by the Boeing KC-46 Pegasus, adapted from the B767 airliner. In 1957, the round-the-world non-stop record time, set in 1949 by a piston-engine B-50, was more than halved by a trio of B-52s and KC-97 tankers.

1960S TO PRESENT

After Korea, the Vietnam War was the next conflict to feature regular in-flight refuelling. Since then, it has been used to facilitate bombing raids of unprecedented range. In the seven Black Buck operations during the 1982 Falklands War, a trio of RAF Vulcan bombers attacked the Argentine-held airfield at Port Stanley, a 12,000km round trip from their base on Ascension Island. The operations required no less than 11 Victor tankers providing hose-and-drogue refuelling.

In 1991, Operation Desert Storm began with an even longer mission. Seven US-based B-52G Stratofortresses made a cruise missile strike against power stations and communications centres in Iraq, the 22,500km round trip lasting 35 hours and each requiring six or more AARs by KC-10 (converted DC-10 airliner) and KC-135 tankers. In 1999, when the B-2 Spirit bomber made its combat debut in the Kosovo War, even its 11,000km range required extension by in-flight refuelling. US-based B-2s also flew missions against Afghanistan from 2001, Iraq from 2003, and Libya in 2011 and 2017, the latter requiring four refuellings for each flight.

The SR-71 spyplane, with a supersonic duration of only 90 minutes, required in-flight refuelling for all its missions. Its JP-7 fuel necessitated a special version of the KC-135 tanker, the Q model. The SR-71 had a fuel capacity of 46,000L, which leaked until Mach-3 flight had heated the airframe sufficiently to expand its skin panels to close the gaps.

The USSR and its allies initially used converted bombers for in-flight refuelling. Then, in the late 1980s, the Ilyushin Il-78, a development of the Il-76 strategic transport, was introduced. It was capable of transferring up to 2,200L of fuel per minute. China currently flies a home-grown tanker-transport designated YY-20, a C-17 lookalike that uses three hose-and-drogue pods.

FORCE MULTIPLIER

In 1958, the Commonwealth Aircraft Corporation considered in-flight refuelling for the Sabre fighter. After exploring possible tanker options such as the Canberra bomber or even a 'buddy' Sabre, the idea was discarded. In 1970, with the impending delivery of F-111Cs that incorporated an in-flight refuelling receptacle, RAAF tanker options were again examined with the aim of increasing the tactical flexibility, payload, and endurance of the F-111.

The aircraft in mind was the Boeing 707 tanker transport. As events transpired, the transports were not acquired until Qantas provided four B707-338Cs during 1979-83, and not converted to tankers until 1991-92, when they were delivered to 33 Squadron. Until then, in-flight refuelling of RAAF F-111s and F/A-18s was by USAF KC-135 tanker. Once modified, the RAAF B707 tanker could refuel two F/A-18s simultaneously, and up to six per mission.

BELOW
RAAF F/A-18 Hornets refuelling from the drogue of a RAAF Boeing 707 tanker transport during Exercise Pitch Black 2008. Photo: Department of Defence.

TOP RIGHT
Russian Ilyushin Il-78 tanker with drogue deployed ahead of a Tu-95MS (Bear) over Moscow, 2009.

RIGHT
A Boeing MQ-25 Stingray drone refuels an an F-35. Photo: Boeing.

RAAF tankers also refuelled fighters of foreign air forces.

With changes in RAAF structure during 1997/98, No 486 (Maintenance) Squadron's B707 Maintenance Flight was reassigned to 33SQN, and the squadron joined No 84 Wing of Air Lift Group. For three months in 1998, the squadron deployed a pair of B707s to Kuwait supporting Operation Southern Watch, enforcing a UN-sanctioned post-Gulf War no-fly zone over southern Iraq.

The B707's next deployment was to the war in Afghanistan in 2002, supporting Operation Slipper to oust the Taliban regime. No 84 Wing maintained a detachment of two aircraft at Manas in Kyrgystan. The contribution of hose-and-drogue refuelling capability was invaluable, as some 350 coalition fighter aircraft – US Navy and Marine Corps F/A-18s, French Mirage 2000s and others – were incompatible with the USAF fleet of boom-equipped tankers. The 84 Wing Detachment was awarded a Meritorious Unit Citation for outstanding service.

During Operation Iraqi Freedom from 2003, RAAF F/A-18s used in-flight refuelling in a war theatre for the first time. Their initial missions were escorting coalition Airbourne Early Warning and Control and tanker aircraft, while later in the campaign, RAAF Hornets were assigned ground attack missions.

By 2008, the ageing B707s were withdrawn from service and sold to the American company Omega Air.

MRTT REVOLUTION

The boom-versus-drogue deficiency was resolved with the B707's replacement, the KC-30A Multi-Role Tanker Transport (MRTT), which features a fuselage centre-line flying boom and underwing pods containing a hose and reel mechanism for probe and drogue refuelling. The fly-by-wire boom telescopes out 17m and is 'flown' by the on-board air refuelling operator, monitoring the operation remotely on-screen, to engage with the receiving aircraft's Universal Aerial Refuelling Receptacle Slipway Installation.

Chosen in 2004 under Project AIR 5402, the MRTT is a conversion of the Airbus A330-220 airliner and, like the B707, doubles as a transport for passengers and freight. The RAAF was the first customer for the type, which was converted by the Military Transport Division of European Aeronautic Defence and Space Company and Qantas Defence Services, Brisbane. Seven KC-30As, including two converted ex-Qantas airliners, were acquired during 2011-2019. The role was assigned to Air Mobility Group and the aircraft are operated by 33SQN at RAAF Base Amberley. The MRTT can itself be refuelled from another boom equipped tanker.

Project AIR 6000 identified the need for the RAAF F-35A to achieve an AAR receiver clearance with the RAAF KC-30A tanker prior to the planned ferry flights from the USA to Australia in 2018. The Joint Project Office secured a slot in the USAF's F-35A Flight Test Schedule, from October to December 2015, to undertake the KC-30A/F-35A receiver tests in support of the formal receiver clearance process that was managed under a combined USAF/RAAF framework. Air Warfare Centre and 86 Wing were subsequently tasked in late 2015 to support a US Department of Defense-led effort – the Coalition Aerial Refuelling Initiative Program – that has continued through to today and has included a variety of USAF boom-receiver aircraft: F-16C/D, C-17A, B-1B, A-10C, B-52H, F-22, B-2 and RC-135. More recently, Indonesian Air Force F-16 Fighting Falcons and Japan Air Self-Defense Force F-15J and F-15DJ aircraft qualified to refuel from the RAAF KC-30A MRTT.

The MRTT's first operational deployment was to the war in Iraq and Syria during 2014-2020. The aircraft delivered fuel to a range of coalition aircraft and RAAF E-7A Wedgetails, F/A-18A Hornets and F/A-18F Super Hornets in some 1,440 missions. The MRTT can refuel most RAAF aircraft. Operations supported have ranged from the Middle East to the Pacific and Antarctica. Since Australia's acquisition of the aircraft, more than half a dozen nations have opted to purchase the MRTT.

Like many other roles, in-flight refuelling is set to be accomplished by both manned and unmanned aircraft. In 2021, a Boeing MQ-25 Stingray drone successfully refuelled F/A-18E and F-35 fighters for the US Navy's Carrier-Based Aerial-Refuelling System program.

Scan the QR code for a one-minute video showing in-flight refuelling training with a pair of RAAF KC-30A aircraft. For a history of US Air Force in-flight refuelling, download the book Air Refueling: Without tankers we cannot… *(Office of History Air Mobility Command, 2009) at amc.af.mil/Portals/12/documents/AFD-131018-046.pdf*

A HIGHLY CONNECTED FORCE

FOLLOWING THE DEFENCE STRATEGIC REVIEW, **GREGOR FERGUSON** TAKES A LOOK AT AUSTRALIA'S MILITARY AEROSPACE INDUSTRY AND WHERE IT IS HEADED NEXT.

Three RAAF F-35A Lightning II aircraft. Photo: LAC Samuel Miller.

THE RAAF HAS JUST STARTED its second century of service to the nation. In its lifetime it has gone from experimenting gingerly with Bristol Boxkite biplanes at Point Cook to fielding one of the world's first fifth-generation air forces.

An air force needs aircraft because it fights in and aims to dominate the air domain and suppress surface movements from the air. But aircraft and weapons aren't enough anymore. An air force's competitive advantage today is measured in its ability to create a portfolio of capabilities that adds up to – and even exceeds – the sum of its parts.

Aircraft and weapons are just parts of that portfolio, and that's one of the messages in this year's Defence Strategic Review (DSR).

That term fifth generation isn't widely understood. It means the RAAF is a highly connected force, not just one that's equipped with stealthy fighters, but part of an increasingly integrated and connected national security organisation designed to deliver lethal force – the Australian Defence Force (ADF).

The RAAF's connectivity links its assets with each other and with those of the Royal Australian Navy (RAN), Australian Army and every coalition partner our nation choses to operate with. To provide a fictitious example, the Jindalee over the horizon radar (JORN), which is a RAAF asset, might detect a contact a couple of thousand kilometres offshore; a RAN ship could localise it using its own SPY-1 or CEAFAR radar; target information could be fed via satellite to an orbiting Wedgetail airborne early warning and control (AEW&C) aircraft for onward transmission to an F-35; and the F-35 could take whatever action the situation demands.

If fitted with an anti-ship weapon, the F-35 could prosecute the target itself; or the targeting information could be fed to a P-8A Poseidon armed with the Harpoon or Long-Range Anti-Ship Missile. If necessary, the F-35 could even share the targeting information with an Army ground-based HiMARS missile launcher that might be better placed to engage the target.

The F-35, P-8A and Wedgetail would be sustained on station by a KC-30 tanker and the whole thing would be coordinated by an Air Commander, probably using the Joint Air Battle Management System (JABMS), just ordered under Project AIR6500 Ph.1. The HiMARS launcher might get delivered to its operating site by a C-130 or C-17 airlift aircraft which could also download and share the necessary targeting information with the launcher. In true 'shot and scoot' style, that same airlifter would whisk the HiMARS launcher away after it had fired its weapons.

Indeed, if the RAAF were to acquire Lockheed Martin's 'Rapid Dragon' system – which the US Air Force has already trialled successfully – we could see palletised, air-launched Joint Air to Surface Standoff missiles dropped out of the back of C-130s or C-17s to prosecute surface threats.

The assets that make all this possible are mostly airborne or owned by the RAAF, and they've been the subject of major capability acquisition campaigns for the past 20 years.

Australia has used its purchasing power and unique access to the US arsenal to build an air defence and strike force that's capable of self-deploying and sustaining itself and the other two services across global distances, as it has done with conspicuous success in the Middle East over the past few years. One of the things making that possible is the nation's portfolio of outstanding ground-based situational awareness (SA) and command, control and communications (C3) systems, including mobile elements.

Australia has succeeded in creating a fifth-generation Air Force for a number of reasons:

- We've made good use of our purchasing power
- We have privileged access to the US inventory of aircraft, missiles and surveillance resources
- Robust C3 and SA organisation and doctrine
- Connectivity
- A workforce that is able to operate and sustain state of the art assets
- An ADF leadership that understands the value of connectivity, SA and lethality at range, right across the force.

We have been able to buy equipment that gives us interoperability with our most important ally. And, as the launch customer, we've contributed to the development and manufacture of world-leading fighter, AEW&C and air-to-air refuelling aircraft.

Defence purchases over the past decade or so have meant Australia has one of the youngest fleets of combat, intelligence, surveillance and reconnaissance (ISR), and transport aircraft in the world. Few air forces achieve the combination of modern air power with relatively young assets.

Mostly we've bought stuff off the shelf in a very deliberate, even slow, process. On occasions we've developed a sovereign capability such as JORN, or the Wakulda (formerly Vigilare) air defence surveillance network, or the new JABMS that will replace it.

But when it comes to replacing major platforms such as our Super Hornets, Lightning IIs, Wedgetails and tankers,

AIR6500 will connect assets across air, land, sea, cyber and space for enhanced defence against potential threats to national security. Graphic: LM.

will we carry on buying off the shelf or will we seek to become more closely involved in designing and building their successors? That's a good, post-DSR question.

It's government policy that Australia will develop a resilient, robust and sustainable defence industry. If we're going to spend serious amounts of money equipping our armed forces, then that expenditure is a good mechanism for kickstarting and growing the industry we seek.

We certainly have the research and industry capability to play a significant role in developing the next generation of air power and we can become a second source of finished product as well. Indeed, we're looking at achieving exactly that with Defence's planned Guided Weapons and Explosive Ordnance (GWEO) Enterprise. It's up to Defence to back local capability, and the market dynamics in this third decade of the 21st century would seem to favour such a thing. The GWEO example suggests our evolution as a supplemental resource could become a reality.

Since the last major combat platform acquisition (the F-35 Lightning II) three things have happened. Firstly, the rise of China and Russia, creating a new strategic threat and forcing us to enhance our capability quickly. That has led to the next two: AUKUS, the Australia-UK-US agreement, which is as much about co-developing and fielding quickly advanced technology as it is about nuclear-powered submarines; and the DSR, which is partly about enhancing capability and achieving speed to capability, and foreshadows significant changes in the acquisition system.

Those decisions are forcing our capability development and acquisition system to do three things it hasn't had to do since World War II: react much quicker to unexpected threats; innovate to overcome emerging threats by developing asymmetric capabilities; and promote innovations into frontline service quickly.

Defence is being forced to think differently. Nowadays, the ADF talks less about specific assets and more about asymmetry and emergent technologies and capabilities such as:

- AI and autonomy
- Space
- Advanced cyber
- Hypersonics and counter-hypersonics
- Electronic warfare (EW)
- Quantum technologies
- Undersea capabilities
- Long-range strike
- Growing and retaining a highly skilled defence workforce.

Those considerations all demand a lot of concentrated research and development (R&D) and some rapid commercialisation – and collaboration. No country can develop a fifth-generation fighting force, still less the forthcoming sixth-generation fighting force, on its own. Our allies – especially our AUKUS partners – will need to conduct joint R&D with us and, in the author's view, undertake joint acquisition so we operate similar equipment that's affordable due to the economies of scale.

For a glimpse of the future, look at the current war in Ukraine and the recent attack by Hamas on Israel. When Russia first attacked last year, it sent conventional combat equipment into Ukraine, with appalling results. Its command and control, logistics and man management were unbelievably bad. Ukraine was able to hold on and fight back with growing success.

Now, 18 months on, everybody who matters to us has learnt lessons from that conflict – including Hamas. While traditional platforms and sheer mass still matter, we're also looking at a new generation of capability: long-range rocket artillery; cluster munitions; lots and lots of Unmanned Aerial Systems (UASs), both for ISR and direct attack; EW to degrade an enemy's C3 capabilities and to ward off manned and unmanned aircraft and missiles; lots of diversity of supply, which the Ukrainians seems to have taken in its stride; and asymmetric effects. Those changes have been effected in just 18 months.

The expenditure rates of UAS's, conventional and smart munitions and missiles is sobering. Ukraine has expended seven years-worth of Javelin anti-tank missile production in about 18 months. By one estimate, it needs 250,000 155mm artillery shells a month, about four times the combined European and US production capacity before the war broke out. And it is estimated to be losing about 10,000 UASs every month.

The lessons for onlookers like us are significant. We need to develop and field:

- The ability to respond rapidly to contingencies
- The ability to identify and then attack an adversary's centres of gravity – financial, moral, societal, operational and technical
- The ability to identify and then defend our own centres of gravity
- Asymmetry – cardboard drones, paragliders, Rapid Dragon and…?
- An integrated air and missile defence system

- Lots of autonomous systems in every domain
- Longer-range weapons and munitions – and lots of them
- Electronic warfare
- A strong and effective cyber capability
- A strong and effective sustainment and logistics systems
- A strong and effective training pipeline
- A strong and effective medical system.

Australia also needs advanced R&D, rapid commercialisation, mass production and, increasingly, international collaboration to manage short-term shifts in threat outlook. The focus should be on 'speed to capability'. Long-term shifts will take longer to understand and assimilate, requiring even more advanced R&D.

It's notable that the US Department of Defence has just created the Replicator Initiative, headed by the Deputy Secretary of Defence, Kathleen Hicks. It aims, among other things, to deliver mass: building attritable autonomous systems by the multiple thousand across all domains within the next 18 to 24 months. While the US will still need platforms that are large, exquisite, expensive and few, such as aircraft carriers, the Replicator will galvanise progress in the acquisition of platforms that are small, smart, cheap and numerous.

Interestingly, the first project by Australia's new Advanced Strategic Capabilities Accelerator (ASCA), another post-DSR initiative, aims to achieve something similar.

THE SIXTH GENERATION

A fifth-generation Air Force is manned, stealthy, connected and employs a bit of AI. The RAAF is there already.

In the short-term, we're looking at mastering robotics, autonomous systems and artificial intelligence technology and acquiring lots of different autonomous and unmanned systems – in the air, on land, at sea and underwater. Our priorities will be weapons and UASs and everything that goes with them, including the use of space-enabled targeting, ISR, SA and communications technologies. We'll increasingly see UASs used for resupply – the US Marine Corps has already explored that in live theatres such as Afghanistan.

The integration of those capabilities into the force will necessarily be a bit looser because we won't have the time to integrate them fully – at least, at first.

Our short-term technology horizon might be as little as a couple of years, which means our acquisition and contracting mechanisms need to move at the speed of relevance. And anything that can't deliver within that timeframe should be discarded, in my view, unless it offers an unbeatable advantage in the medium and long terms.

ABOVE LEFT RAAF's first MQ-4C Triton UAV on its maiden flight.

ABOVE Air Warfare Engineering Squadron Avionics Design Engineers working on the Loyal Wingman telemetry data recording system at RAAF Base Edinburgh. Photo: SGT Bill Solomou.

TOP No 77 Squadron armament technicians prepare to load a Joint Air to Surface Standoff Missile onto an F/A-18 aircraft at Woomera, SA. Photo: LAC Scott Woodward.

In the long term, beyond 2031, we're looking at sixth-generation air systems, but we don't really know yet what that will look like. Sixth-generation air systems may include:

- Stealthy, optionally manned aircraft
- SR and SA tools, both airborne, space-based and surface-based
- Semi-stealthy Loyal Wingman UASs such as the Boeing MQ-28A Ghost Bat
- Smaller UASs for ISR and, in loitering munition form, for direct attack
- Autonomous technology
- Longer-range weapons, both air-air and air-surface
- Directed energy weapons
- Lots of virtuality
- New propulsion technologies
- Affordability.

Note the word system; acquisition is not just about buying a Super Hornet or Lightning II replacement. It's about acquiring an integrated air combat system that's suited to our circumstances and budget. It might be all or part of a partner nation's sixth-generation system. And we have a choice of partners. The USAF and USN are developing separate Next Generation Air Dominance systems – the USN program is also known as F/A-XX. France, Germany and Spain are developing the Future Combat Air System and the UK, Japan and Italy are developing the Global Combat Air System (Project Tempest).

It's not really possible to map air power development over the next generation or so in detail, partly because new technologies and threats are classified, and partly because they may also emerge at very short notice.

The medium term, from 2026-2030, in my view is the convergence zone. In Australia's air domain the DSR and AUKUS Pillar 2 suggest we'll see the following short and medium-term capabilities emerge:

- An enhanced, integrated targeting capability
- An enhanced, long-range strike capability in all domains
- A fully enabled, integrated amphibious-capable combined-arms land system
- Enhanced, all-domain, maritime capabilities for sea denial operations and localised sea control
- A networked, expeditionary air operations capability
- An enhanced, all-domain, integrated air and missile defence capability
- A joint, expeditionary theatre logistics system with strategic depth and mobility
- A theatre command and control framework that enables an enhanced Integrated Force
- Quantum technologies
- RAS-AI – robotics, autonomy and AI
- Advanced cyber capabilities
- Hypersonic and counter-hypersonic capabilities
- Pervasive EW.

We can distil two things from that realisation. Firstly, we'll need lots of R&D and industry capacity. Secondly, cyber security will be ubiquitous; there's nothing we plan to do that isn't impacted by the cyber threat.

Interestingly, with the possible exceptions of aircraft propulsion and some aspects of ISR, Australia is not disadvantaged in any of the disciplines identified. We already have a research and industry base that can

ABOVE Two US Army HIMARS launcher vehicle drive off a RAAF C-17A Globemaster aircraft at RAAF Base Peace, WA, demonstrating the rapid deployment capability of the long-range precision rocket system. Photo: CPL Nakia Chapman.

RIGHT An ATM-84J Harpoon released from a P-8A Poseidon aircraft during RIMPAC 2018.

rise to the challenges, both by itself and in partnerships.

The aerospace community must embrace non-traditional aerospace disciplines because they're now an integral part of the aerospace ecosystem. The range of skills and competencies the industry needs to master isn't declining. As well as the things we had to be expert at in the fifth generation, we now also need to be expert in AI, mission computing and cyber security. The sheer complexity of what we're doing is compounding with the range and depth of new disciplines we need to master.

In Australia, we have the academic smarts to play a leading role in that more complex environment and to collaborate with research partners in the USA and elsewhere. But we must learn how to commercialise our intellectual property quickly so that our industry base can collaborate properly with partners instead of merely adding sub-contractor support or building to print services. That's a role for the Defence Science and Technology Group and ASCA. Both agencies are intended to enable our research and industry sectors to focus on advanced and asymmetric capabilities.

ASCA has taken over from the former Defence Innovation Hub and Next Generation Technologies Fund. Its role is to drive defence innovation and deliver operational capability quickly. It won't do anything that's not defined as a problem or challenge by one of Defence's capability managers, and which doesn't therefore have a direct route to acquisition and frontline service.

The aim is two-fold: to get what is called minimum viable capability (MVC) into service, and quickly, knowing that subsequent iterations will develop the product to concept boundaries. The Spitfire and Hurricane from WWII present an analogy of the concept. Both aircraft made their maiden flights in the late-1930s. The initial versions of each were quite inferior to the versions that fought in the Battle of Britain in 1940. Both were delivered as MVCs and their designs underwent a series of upgrades and enhancements in the light of operational experience and industrial development as time passed. The RAF didn't wait for some 'perfect' version of either – if they had, the UK would have lost the battle. In fact, the Spitfire might have missed the entire war.

Boeing Australia's Loyal Wingman, Ghost Bat.
Photo: CPL Craig Barr

The history of air power shows that successful air campaigns are team victories. They are won by aircraft and weapons in combination with: superior C3 and SA systems; a manufacturing and sustainment system that produces aircraft and updates quickly, repairs them quickly and ensures they stay airworthy; an acquisition system that responds rapidly to customer needs; and the expertise and experience of men and women in the services and industry who know, sometimes intuitively, sometimes based on data, what really matters and what can be ignored.

The start of any future war Australia engages in will be a 'come as you are' conflict. At the outbreak we'll be fighting with whatever platforms the ADF has in service at that time. It can take years to build new platforms and weapons and it's unlikely our allies will have spare equipment or capacity to provide us with additional equipment in the short term – their own needs will take priority. But whether we're on our own or part of a coalition our objective must be to win, on our terms. The first step towards that is ensuring we aren't defeated in the early stages.

So, our advantage will lie in having enough of what we need to begin with: developing mass, both real and virtual, manned and unmanned. We need to be able to keep those assets operating and we need to be able to enhance their operational capability quickly in response to suddenly emerging threats or opportunities.

Our innovation, capability-development and acquisition systems must also become part of our competitive advantage. And so must our workforce, because none of that posture happens without a trained and experienced workforce to animate our capabilities.

What does that all mean for Australian air power? It means three things: research excellence; industry excellence; and people. They're all inter-related and the terms that connect them are knowledge, experience and professionalism. Those attributes have been the hallmarks of the RAAF for more than a century.

An edited version of a paper Gregor Ferguson delivered to the Royal Aeronautical Society – Australian Division's symposium Celebrating Aerospace Downunder in Canberra, October 2023.

RESILIENT COMMUNICATIONS

DEFENCE PARTNER VOCUS IS PRIMED TO PROVIDE CRITICAL CONNECTIVITY FOR THE FIFTH-GENERATION RAAF.

LIKE MOST ORGANISATIONS TODAY, the RAAF does not want its communications capabilities tied solely to fixed networks. Instead, it wants high-bandwidth connections wherever its assets are deployed, whether it be at a major Australian base, a bare base in the north or a foreign location.

That need, as much as the RAAF's status as one of the first (and still one of the few) air forces to have achieved genuine fifth-generation status, is creating demand for new communications bearers and bandwidth.

Understanding that need has presented major opportunities for Vocus, an Australian-owned company that specialises in terrestrial and satellite communications.

"Every capability that Defence replaces demands more communications capacity," says Sydney-based Vocus' Head of Defence Business Development, Peter Humphreys.

Vocus is investing nearly $1 billion in expanding its 26,000km fibre optic network connecting all of Australia's mainland capitals and most regional centres. It also owns a cable system that connects Australia to Christmas Island and Singapore and has onward connectivity to Jakarta. Notably, it has recently completed Darwin's first direct international fibre optic connection to Asia.

The ADF need for resilient communications links, and more of them, was endorsed in April by the Defence Strategic Review which also called for major upgrades of Australia's network of northern bases. The RAAF's communication needs are high bandwidth – its assets can generate terabytes of data in one exposure – and low latency – command and control and safety systems work best when packets of data flow back and forth rapidly. Increasingly, a connected generation of soldiers, sailors and aviators also expect to have robust internet links for personal use, regardless of where they are.

Vocus is a long-term partner to the Department of Defence and global Defence prime contractors and operates under Information Security Manual accreditation and Defence Industry Security Partner certified protocols and procedures.

Equally important, Vocus also offers next-generation fibre-like satellite communications (SATCOM) through Starlink's low-earth orbit (LEO) communications satellite constellation. That constellation of more than 4,000 satellites orbiting at about 550km enables high-bandwidth and low-latency wireless communications wherever a customer has a terminal. As Starlink satellites are in a low orbit, latency (the time it takes for a packet of data to transit out and back to Earth) is significantly lower, about 50 milliseconds versus 600-plus milliseconds on a geostationary orbit (GEO) satellite.

There has been an insatiable demand for Vocus' low-latency LEO SATCOM by commercial and other government customers, demonstrating a real desire for broadband in the remotest parts of Australia. Likewise, defence forces all over the world are looking at LEO satellite connectivity to provide fibre-like connectivity to their forces and bases.

The reason Vocus chose to use LEO satellites for wireless communication is its fibre-like performance. With fibre, the latency is essentially the speed of light travelling over a length of optical fibre and is therefore negligible on a domestic route.

LEFT 60 Starlink satellites stacked together before deployment in 2019.

With LEO satellites orbiting much closer to earth than GEO satellites, the latency of a LEO SATCOM link is similar to a fibre optic cable connection.

Latency matters because in the process of passing intelligence, surveillance and reconnaissance, targeting data or approval to engage a target, milliseconds can count. A communications satellite in GEO at an altitude of about 36,000km has a latency of about 600 milliseconds – more than half a second. A LEO satellite link has a much lower latency of about 50 milliseconds, which is critical when handling highly automated, time-sensitive data processing tasks. That low latency also enables things like networked simulation, meaning that defence force units distributed across the country can train more effectively with each other, says Humphreys.

Vocus has built 16 satellite ground stations on behalf of LEO satellite operators with more in progress, making it by far the largest provider of LEO ground station infrastructure in the country. Vocus also offers Starlink's own proprietary terminals which have unique antennas and signal waveforms that connect a fixed, temporary or mobile site with the Starlink constellation, enabling communications between suitably equipped nodes right across the world.

Vocus is a founding shareholder in another Australian startup business, Sydney-based satellite ground station company Quasar Satellite Technologies. In March, Quasar won a $5.3 million Defence Innovation Hub contract to develop a multi-beam phased array ground station that can support 100 SATCOM links simultaneously in different orbital bands using a single antenna.

At present, most SATCOM ground station antennas allow only one link at a time with a single satellite, but Quasar's solution enables connectivity with multiple satellites, and different types, rather than being paired with a single satellite type. The advantage of the ground-station-as-a-service solution is the ability to access, on-demand, more payloads from more constellations.

Vocus' intention is to make Quasar the ground station provider of choice, says Humphreys.

"Vocus is working to introduce different LEO satellite constellations and industry-first ground station technology into our network to provide maximum diversity for critical connections," he says.

"For our defence customers, we know how important it is to provide diverse network designs that incorporate multiple providers and paths, providing protection against a single point of failure."

Gregor Ferguson

BIRDS-EYE BOOST

FOR LITTORAL OPERATIONS

A QUICK, IN-DEPTH SCAN WILL GIVE NAVY FLEET COMMANDERS AN ACCURATE VIEW OF APPROACHING SEABEDS AND HINTERLANDS.

ABOVE Dr Winter (second from left) and Jacob Houweling (third from left) with RAN 822X Squadron collaborators aboard HMAS *Adelaide* during Exercise Sea Raider 2023.

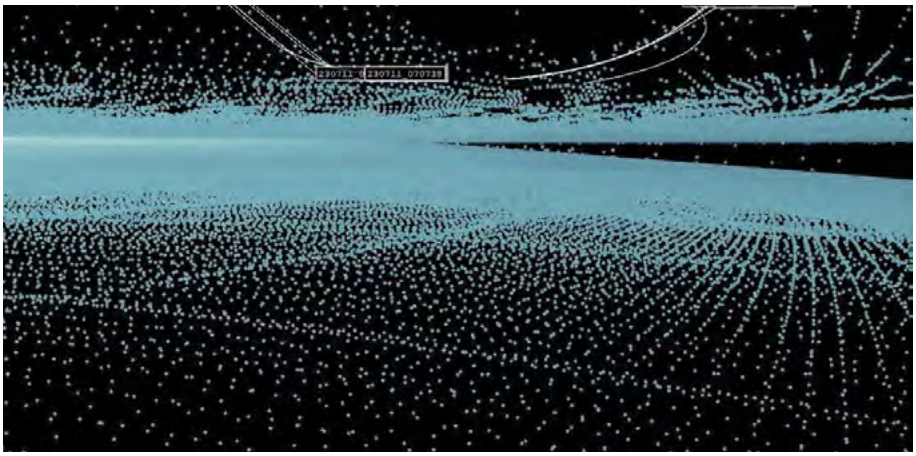
NAVAL OPERATIONS IN AND AROUND THE NEAR SHORE ZONE, referred to as littoral operations, are complicated and dangerous, particularly for defence forces supporting landing and onshore combat operations.

Earlier this year, a team from Defence's Defence Science and Technology Group (DSTG) successfully demonstrated a unique capability that will support missions in littoral environments, giving fleet commanders an accurate view of approaching seabeds and hinterlands. The Defence scientists have integrated a laser-based bathymetric (seabed topography) sensor into the Royal Australian Navy's S-100 uncrewed aerial system (UAS). The modified S-100 UAS lifted off from HMAS *Adelaide*'s landing helicopter dock during Defence's Exercise Sea Raider 2023, flying sorties to measure features of the surrounding North Queensland seabed and hinterland in great detail.

DSTG team leader Anthony Quach reported that his team demonstrated the successful integration of the Riegl VQ480-G Topo-Bathymteric laser-based light detection and ranging (LIDAR) system with a DSTG UAS at Defence's Autonomous Warrior event in 2022. Then in early 2023, the team completed successful flight tests of the LIDAR with the S-100.

Typical operations a UAS/LIDAR sensor capability would support include:

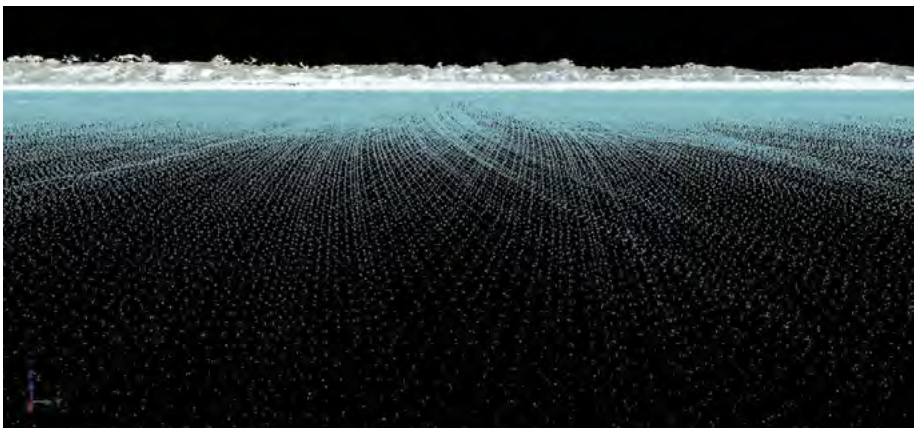
- mine countermeasure operations in shallow depths
- accurate rapid environmental assessment between the hinterland and shallow waters including terrain and seabed characterisation and bathymetry



ABOVE An underwater viewpoint: a LIDAR point cloud generated by the team during Exercise Sea Raider 2023 showing the water surface and seabed.

ABOVE RIGHT Detail from a LIDAR point cloud showing a submerged rock in the bay.

RIGHT A LIDAR point cloud showing the water surface approaching the Bowen coastline, Qld.



- amphibious operations between the hinterland and surf zone including beach profile, object detection and battlespace characterisation.

The system could also support humanitarian assistance and disaster relief operations.

HOW DOES IT WORK?

The Riegl LIDAR system is designed for high-resolution, low-altitude airborne survey, and is light and small enough to be carried by a small to medium UAS such as the S-100. The Riegl LIDAR uses a laser which produces intense pulses of green light that are effective in penetrating a water column. The laser pulses are distributed in an elliptical pattern beneath the aircraft. The accurate measurement of both LIDAR position and orientation (via embedded inertial navigation systems and satellite-based navigation systems) as well as the time-of-flight for the laser pulse return, produces a point cloud accurately representing the surveyed area, both above and below the water.

The Austrian-built Schiebel S-100 is a remotely-piloted aircraft operated by the Navy's 822X Squadron. The S-100, a vertical take-off and landing UAS, is made of titanium and carbon fibre materials, and is designed to carry multiple payloads simultaneously for up to six hours.

822X Squadron's mission is to conduct experimentation and evaluation activities with contemporary UAS and advanced payloads to develop operational knowledge and experience, develop regulations and procedures supporting safe UAS operations, and to assess UAS capability options that support integrated warfare outcomes for Australia's Future Fleet.

TIGHT TIMEFRAME

During Exercise Sea Raider, DSTG team members Dr Robert Winter and Jacob Houweling spent several days testing their system aboard HMAS *Adelaide*. The team praised the support from Navy's 822X SQN, which assisted in setting up the payload and providing test flights over many days at Jervis Bay airfield.

"Getting the chance to do a trial during a busy exercise is a real privilege," says Dr Winter. "Over a number of days the embarked 822X SQN flew S-100 sorties over beach zones with our LIDAR aboard, collecting shallow-water bathymetry data, as well as beach and back-of-beach topography. The S-100 allowed us to collect data from much higher altitudes and at much longer ranges than we had done previously, allowing us to test the operational limits of the LIDAR and evaluate performance in a representative combat setting."

Quach says a focused future mission requirement combined with real-world testing has led to a great demonstration of how DSTG can potentially accelerate a capability into service within a constrained timeframe. "Working as a team with ADF colleagues, we have been able to successfully integrate, test, evaluate and optimise a commercially available optical sensor mounted on a Defence UAS to support future operation," he says. "The successful demonstration during Exercise Sea Raider 2023 has been a great achievement for both DSTG and Defence as a whole."

This DSTG research supports Defence Project SEA1905 Phase 1 (Maritime Mine Countermeasures and Military Survey), which is a major investment by the Navy in a robotics, autonomous systems and artificial intelligence capability.

F/A-18F SUPER HORNET
B-52H STRATOFORTRESS

WINGS VOLUME 75 NO.4

A USAF B-52H Stratofortress and RAAF F/A-18F Super Hornet flying over the Northern Territory during Exercise Talisman Sabre 23. Photo: Department of Defence.

OUT OF THE BOX

AN AUSTRALIAN LONG-RANGE, HYDROGEN-POWERED VERTICAL TAKE-OFF AND LANDING AIRCRAFT IS SET TO REVOLUTIONISE PASSENGER AND CARGO TRANSPORT.

IT'S HARD TO IMAGINE HOW A TEST FLIGHT CONDUCTED IN 1894 would have much relevance in the modern aviation age, but Lawrence Hargraves' successful launch of a tandem box kite proved that a vehicle heavier than air could fly. Hargraves' historic flight to a height of 16 feet captured the imagination, and the design went on to be used in meteorological kites and gliders before adoption by the Wright Brothers.

Now AMSL Aero, based in Bankstown, NSW, is building a craft based on the box-wing configuration. Motivation to start the company came from a chance meeting CEO Andrew Moore had with an Army LtCol in 2017. The Army required a runway-independent autonomous casualty evacuation (casevac) aircraft to enable rapid troop evacuation from remote places.

Moore had been fascinated with aircraft since school. His father was a Grumman Tracker pilot in the Royal Australian Navy, and Moore started sketching designs for potential aircraft at a young age. His passion took him to the Navy, where he studied Aerospace Engineering and progressed to designing helicopters.

Initial ideas for the casevac solution were based on a novel tilt-wing concept within a box-wing or Prandtl-plane type configuration. Knowledge of those concepts was applied to several versions before settling on the current Vertiia design.

With modern analysis tools, Moore and his team, with support from the University of Sydney, optimised the box-wing principle for a vertical take-off and landing aircraft, achieving a high lift-to-drag ratio with a corresponding short wingspan. Drag reduction effectively translates to increased lift for a given power, reducing the fuel/weight ratio and thus fuel consumption.

INNOVATIVE DESIGN

Vertiia's box-wing design has the fore-plane and tail-plane tips connected in a continuous loop, a configuration that reduces induced drag (the drag caused by the wing tip vortices that trail all aircraft). The box-wing configuration provides a light, aerodynamically efficient structure, reducing energy and power requirements. Operating cost is expected to be about a quarter that of a similar weight helicopter.

Vertiia has eight electrically powered rotors, four on the front wing and four on the rear. All motors rotate from vertical in the hover mode to horizontal for cruise flight. Two independent electrical buses connected to multiple power supplies feed each motor. A digital flight control system manages differential thrust, motor lift and controls surface deflection to precisely achieve the desired flight profile, hover or cruise.

Aircraft weight is optimised using carbon fibre-reinforced plastic and aluminium, providing a strong and low-maintenance structure.

One of the critical AMSL objectives was to build a craft competitive with a light aircraft in range performance and, ideally, superior to a conventional helicopter.

Vertiia.

ABOVE RIGHT
AMSL Aero CEO Andrew Moore.

Vertiia's electric motors are energised by battery and sustained in-flight by an auxiliary power unit that recharges the batteries from hydrogen fuel cells. Hydrogen, as a gas, has a low volumetric density but a very high energy density and filling up with compressed hydrogen is as simple and quick as filling an aircraft with jet fuel and much quicker than charging a battery-only configured vehicle on the ground. Hydrogen fuel cells provide clean energy through an electrochemical reaction that converts hydrogen gas into electricity.

Gaseous hydrogen is stored under pressure in lightweight tanks constructed mainly of composite material, installed in the boom each side of the fuselage that form the box-wing configuration. The amount of hydrogen gas required for the specified range adds 20-30kg to the overall aircraft weight and the box-wing design offers spare volume for additional tanks to increase range if required in the future.

In its current configuration, Vertiia can travel up to 1,000km at a cruising speed of 300kph, performance far superior to air taxis of similar size.

KEY MARKETS

Vertiia will be certified for civil applications to carry four people plus a pilot and has been designed for easy loading and unloading of casevac passengers and aeromedical patients, cargo and equipment. It current payload capacity of 500kg will be increased to 700kg in a military version and that vehicle will incorporate a high degree of autonomy to support remote operations.

Reduced on-ground time is one of Vertiia's key attributes; the ability to land directly within a hospital precinct is particularly beneficial for casevac operations. Similarly, in the general passenger transport role, Vertiia will eliminate most airport wait time and move passengers to their destination more directly.

The same flexibility can apply to cargo operations as shipments can be collected directly from the manufacturer or depot and transported swiftly to destination without intermediate handling. Courier work is likely to be a key market.

DEVELOPMENT PROGRAM

AMSL has joined forces with organisations that provide expertise and added value to the development program. The University of Sydney continues to provide support. Mission Systems has been collaborating with AMSL since its inception, the same year as AMSL (2017), and provides autonomous system development along with sensing and perception using simple AI.

A full-size Vertiia prototype made over 40 flights in regional NSW in early 2023. Those flights validated the concept, demonstrated the vehicle's handling qualities and captured data for flight control algorithm analysis and refinement. Test flights also validated the weight advantage of the box-wing design.

"Vertiia is more straightforward to fly than a helicopter and most fixed-wing aircraft," says Moore. "To the pilot, it's like flying a large drone where you manage the aircraft rather than manipulate through stick and rudder control. Furthermore, our test pilots estimate that you could take a fixed-wing pilot and convert them onto Vertiia in less than five hours."

While Vertiia is a zero-emissions aircraft, AMSL is developing an Army variant that uses sustainable aviation fuels. Further prototypes are in construction for a casevac demonstration along with a version to develop the hydrogen propulsion system. The next landmark is to gain CASA certification, ideally by 2026.

Originally designed with a long range for the Australian environment, Vertiia can be tailored to operate in many different roles and has the potential to be exported all over the world.

Christopher Rees

AMDA FOUNDATION INNOVATION AWARDS

THE CONVENTIONAL WISDOM IS THAT AUSTRALIA doesn't innovate and can't manufacture anything complex, high quality or affordable. This year's AMDA Foundation Innovation Awards, now in their 10th year, continue to disprove that.

"Australian companies and individuals are showing themselves the equal of any in the world in creating technologies and ideas that solve real-world problems," said Justin Giddings, Chief Executive of AMDA Foundation Limited, which organised Indo Pacific 2023.

For only the third time in the history of the awards, and the first time at Indo Pacific, only two Australian innovators were named winners of the prestigious Indo Pacific 2023 Innovation Awards instead of the usual three. The Indo Pacific 2023 National and SME Innovation Awards both went to Sydney-based Hypersonix Launch Systems for its world-leading work developing a 3D-printed hypersonic vehicle and hydrogen-powered SPARTAN scramjet propulsion system. The Hypersonix DART AE has been selected by the Pentagon's Defense Innovation Unit for the Hypersonic High-Cadence Airborne Testing program.

The panel of eight judges, led by Tony Quick, agreed Hypersonix's entry was significantly better than its rivals in both categories.

The Young Innovator Award was presented to Rhys Centin, an engineer from Melbourne-based Thornton Tomasetti, for his work on two projects: explosive ordnance blast modelling for the Royal Australian Navy; and shock-testing naval equipment weighing more than one tonne using Australia's only JASSO shock-testing machine.

The prize for the SME and Young Innovator Awards are worth $50,000 each.

"The Indo Pacific 2023 Innovation Awards provide a meaningful, financial incentive for small business and individuals to help them develop their innovations, and visibility to potential customers and partners to get them noticed," said Giddings. "The result is commercialisation of products and services that strengthen both our industry and their customers, in particular the Royal Australian Navy."

In addition, three award contenders were given a high commendation, two in the SME category – Advanced Navigation (NSW) and AMOG (Victoria), and young innovator Joshua Cribb, Electro Nautic (WA).

Although the awards are funded and judged by the AMDA Foundation, their aims are aligned with those of Pillar 2 of the tripartite AUKUS agreement and the Advanced Strategic Capability Accelerator (ASCA) program, which was established following a Defence Strategic Review recommendation and designed to facilitate innovation and the rapid fielding of new technologies.

"It is great to see that this year's Innovation Award winners embody the values of the Advanced Strategic Capabilities Accelerator, in that they are striving to accelerate development and transition of capability for the ADF through innovation," said Head of ASCA, Professor Emily Hilder, who presented the awards.

The awards were first presented at Avalon 2013, an event run by the AMDA Foundation. Since then, the foundation has presented SME and Young Innovator Awards worth $685,000, including this year's awards.

Gregor Ferguson is part-time Innovation Coordinator, AMDA Foundation Limited

ABOVE Young Innovator Award winner Rhys Centin.

BELOW Concept image of the Hypersonix DART. Image: Hypersonix Launch Systems.

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EDITED BY Bob Treloar

140 NEW PILOTS FOR JETSTAR

IN WHAT THE LOW-COST carrier says is one of its biggest-ever pilot intakes, Jetstar is on track to hire more than 140 extra pilots by the end of the year. The recruitment will support new routes, including Sydney to Rarotonga, Brisbane to Seoul and Melbourne to Fiji, as well as its push to improve reliability. The airline is also looking to employ up to an additional 700 cabin staff by year's end.

In April, the Bureau of Infrastructure and Transport Research Economics data showed Jetstar to be "considerably worse" than other airlines for cancellations. Jetstar recorded an 8.1 percent cancellation rate in April 2023 compared to an industry average of 3.9 percent.

In May, Jetstar announced overhauls to check-in and bag-drop procedures along with boarding deadlines in an effort to improve on-time performance.

AirJapan aircraft livery.

AIRJAPAN TAKES OFF

AIRJAPAN, the new airline brand of parent company All Nippon Airways, has announced it will commence operations on 9 February 2024. AirJapan will operate a Boeing 787-8 fleet under an entirely new brand identity and hybrid business model combining elements of contemporary full-service and low-cost airlines.

Source: Aerotime

UK STREAMLINES SPACE LAUNCHES

THE UK'S CIVIL AVIATION AUTHORITY (CAA) will streamline its licensing procedures for space launches, following complaints following a failed Virgin launch attempt from a Boeing 747 aircraft based at Spaceport Cornwall. Although the January failure was due to an onboard anomaly with the Virgin LauncherOne rocket, the original November 2022 launch date had been postponed due to CAA licencing delays.

Virgin Orbit's next launch will occur from the Mojave Air and Space Port in California for a commercial customer.

Source: SpaceRef

LEFT Virgin Orbit and Boeing 747 aircraft.

DRONE ID

PACIFIC AEROSPACE CONSULTING has partnered with US-based Pierce Aerospace to introduce Remote ID drone technology to Australia and New Zealand.

Remote ID ensures information about drones in flight, such as identity, location and altitude, are passed on to an airspace control station – and if needed to other airspace agencies – when a drone appears to be flying in an unsafe manner or is making an unauthorised airspace excursion.

Source: Consultancy.com.au

ABOVE A drone in flight. Photo: Pacific Aerospace Consulting.

BOEING STRENGTHENS INDONESIAN TIES

INDONESIA'S DIRECTORATE GENERAL OF CIVIL AVIATION and Boeing have entered into a comprehensive Memorandum of Understanding (MoU) to foster economic and technological growth in the Indonesian aviation sector. The MoU addresses supply-chain management, human resources, technological innovation, and aircraft maintenance. It builds upon a 75-year cooperative relationship between Boeing and Indonesia, underscoring a commitment to aviation safety, service quality, air-navigation services and personnel training.

Source: Investing.com

AIR NIUGINI FLEET MODERNISATION

AIR NIUGINI, the national carrier of Papua New Guinea, has ordered six of the latest generation of A220-100s as well as three A220-300s from the manufacturer, Airbus, and another two A220-100s from third party lessors under its fleet modernisation program.

The Air Niugini order was formally announced on 1 November 2023 in Port Moresby at a special event involving Gary Seddon, Acting Chief Executive Officer Air Niugini and Anand Stanley, President Airbus Asia-Pacific, in the presence of Papua New Guinea's Prime Minister James Marape and Minister for State Enterprises William Duma.

As the most modern airliner in its class, the A220 combines the longest range, lower fuel consumption and widest cabin in the 100-150 seat category. Fleet modernisation will deliver additional capacity and greater reliability across domestic networks, and also to new destinations across the Asia-Pacific region.

Source: Airbus

NO-FLY ZONE ENCROACHMENT

AN AIRSERVICES AUSTRALIA report revealed that in the year to June, 40,000 drone flights were detected in the no-fly zone at Sydney airport – more than 100 drones a day – up 22 percent on the previous 12 months. Over 5,000 individual drones were detected, but the data did not distinguish between approved and illegal operations. No-fly zones refer to the area within 5.5km of airport runways. Adelaide Airport had 17,000 detections in the no-fly zone, while Brisbane Airport had more than 15,000.

Source: Australian Financial Review

Drone pilot Matt Sturdy in the field with a Carbonix Volanti drone.

LONG-DISTANCE SURVEILLANCE

AUSTRALIAN DRONE MANUFACTURER CARBONIX has partnered with global drone operator Skyports Drone Services to develop beyond visual line of sight operations across the country using long-range vertical take-off and landing drone.

In the first phase of the partnership, a specialist international drone pilot was imbedded within the Australian company that conducts regular data acquisition missions supporting energy infrastructure and mining projects, with a long-term objective of developing operational capabilities. The long-distance surveillance capability was projected to be online by October.

ELECTRIC COMMUTER AIRCRAFT

TWO UNIVERSITY OF NSW researchers, in collaboration with industry partners, have been awarded $3 million from the Federal Government's Cooperative Research Centre Projects (CRC-P) program as part of a $12.8 million project to flight test and certify a turboprop aircraft conversion to electric propulsion for regional commuter services.

CRC-P program concept.

HYDROGEN-FUELLED FLIGHTS

IN SEPTEMBER, Cranfield Aerospace Solutions (CAeS), innovators in hydrogen-electric fuel cell propulsion technology, announced a three-party agreement with MONTE Aircraft Leasing and air-charter company Torres Strait Air to convert up to 10 Britten-Norman Islander aircraft to hydrogen-electric power.

MONTE will finance the conversion and CAeS will carry out the conversion and integrate its hydrogen-electric propulsion system into the aircraft.

LEFT Hydrogen-equipped Britten-Norman Islander.

TAKING THE HEAT

FROM THE RACETRACK TO THE AEROSPACE INDUSTRY, AN AUSTRALIAN COMPANY IS ADVANCING THERMODYNAMICS THROUGH INNOVATIVE SOLUTIONS.

THE GROWTH IN ADDITIVE MANUFACTURING (AM), or 3D printing as it is commonly known, has enabled the production of complex components and shapes that could not be manufactured by conventional subtractive machining. Healthcare, automotive and aerospace have all benefited as manufacturers produce innovative solutions that advance performance, efficiency, prototyping and product development.

Victorian-based Conflux Technology has embraced AM technology, offering customers improved thermal management by developing and manufacturing complex-shaped heat exchangers that enhance thermodynamic performance and reliability, and save component weight.

The company was established in 2014 by CEO Michael Fuller to produce a heat exchanger specifically for motorsport. The motorsport industry has always been a great proponent of new technology, pushing innovative boundaries through pioneering design and manufacturing processes. Fuller's background in motorsport had exposed him to the challenges of improving thermal efficiency and achieving reliability in a restrictive space.

The humble heat exchanger had its origins in the late 1800s, but has seen many developments and efficiency improvements based on the simple principle of transferring heat from one fluid to another without the two coming into contact.

In its simplest form, a heat exchanger achieves heat transfer by pumping fluid through a series of tubes while passing a heat-extraction fluid through a sealed shell that houses the tubes. The shell and tube heat exchanger is the most common design used in industry today. Several factors influence the performance of a heat exchanger, but it is mainly affected by the fluid velocity and pressure in the hot core.

An AM-manufactured heat exchanger promised reduced weight, enhanced fluid flow and better overall functionality for application to a high-performance race car. However, many outside Conflux were sceptical about whether AM could be applied successfully, as its use in heat exchanger production was largely unproven.

A grant allowed Conflux to engage the skills of the CSIRO Fluids Engineering Group and jointly, they worked on an optimum design to satisfy motor-racing requirements. Motorsport engineers could immediately see the benefits of the technology and their willingness to participate in the test and evaluation of early designs was a confidence booster for a start-up needing to establish itself in a demanding market.

The first Conflux heat exchanger was patented in 2015 with a United Kingdom Accreditation Service-certified laboratory confirming that the unit achieved a fluid pressure profile improvement of some 66 percent and a 22 percent weight reduction compared to a conventionally made motorsport heat exchanger. In addition, the ease of installation and the reduction in the number of components were critical factors in product acceptance.

In 2017, confidence in Conflux to further develop the product range drew significant funding from German-based additive manufacturing investor AM Ventures. The first heat exchanger for the motorsport industry proved pivotal in launching the company and its ongoing development program.

A critical factor in efficient heat transfer through an exchanger is the ability to maintain a constant fluid flow through the exchanger core. A simple way to observe and measure the flow quality is to measure the fluid pressure at the inlet and at the outlet. A large pressure drop indicates the fluid flow is too slow to sustain the desired heat extraction while a tiny pressure drop indicates

General Atomics Aeronautical Systems MQ-9B SkyGuardian remotely piloted aircraft.

the flow is too fast for sufficient heat extraction. Consequently, 'pressure drop' is a common measure of exchanger efficiency and the term used to compare heat exchanger quality. There are several factors affecting that parameter. Conflux's extensive test and evaluation of different internal geometries and fin structures has given them the knowledge and experience to create a design for the best solution in a range of applications. Other issues, such as channel turbulence, surface finish and material choice, are also factors that affect flow characteristics and need to be accommodated by the AM process.

Conflux's detailed design and development work has attracted significant interest from many industries. Aerospace, chemical, refrigeration, general automotive, and semiconductor industries all provide opportunities that would benefit from Conflux technology.

CUSTOMER COLLABORATION

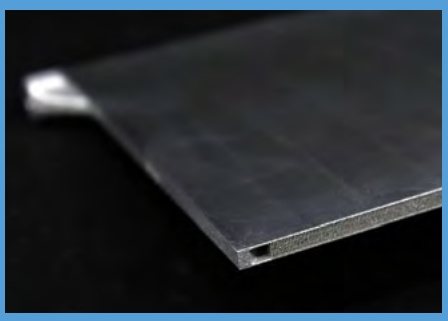
The Conflux approach to solving customers' heat-transfer problems starts with a complete appraisal of the existing process or establishing an in-depth understanding of a potential new application. Existing thermal management problems may involve ineffective heat transfer, a higher than acceptable pressure drop, a change of fluids requiring a new assessment, or different temperature reduction techniques.

In most cases, the production of a prototype is necessary to enable bench testing to qualify the bespoke design and to ensure compatibility with the customers' application.

AM delivers many remarkable benefits; it is highly configurable and offers the flexibility to quickly reconfigure and reproduce parts after minor design changes. Changes to the prototype designs can be resubmitted for qualification test without the need to retool. The procedure can also be scaled up to accommodate the application and is only really limited by the size of the AM machine.

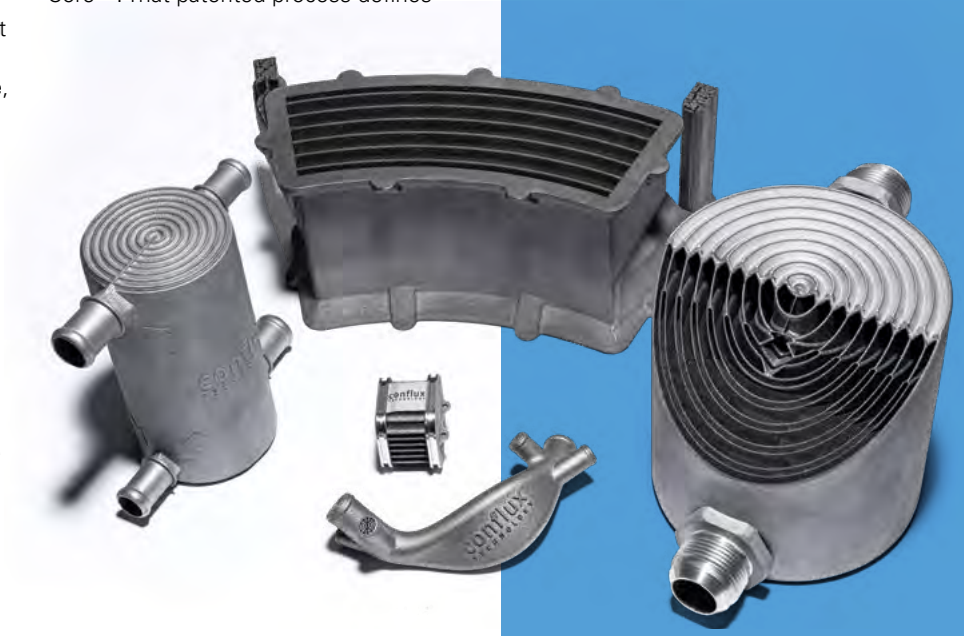
At the heart of each Conflux heat exchanger development is the Conflux Core™. That patented process defines

ABOVE Conflux's additive manufactured heat exchangers achieve extraordinary microfeatures, thin walls and fins.



ABOVE The Conflux AM cold plate.

BELOW Different conflux AM heat exchangers: liquid to liquid, air to liquid examples in Aluminium and Monel K500.



the different elements of the internal core design, the construction of the internal geometries and the 3D-printing process.

3D-printed heat exchangers can be easily installed and integrated into a customer's application. The introduction of the Conflux Cartridge drop-in product provides a weight reduction of up to 20 percent compared to a microtube heat exchanger and an improvement in the heat transfer efficiency. The 3D-printed core is embedded in a traditionally manufactured casing, which allows removal for maintenance and a reduction in downtime.

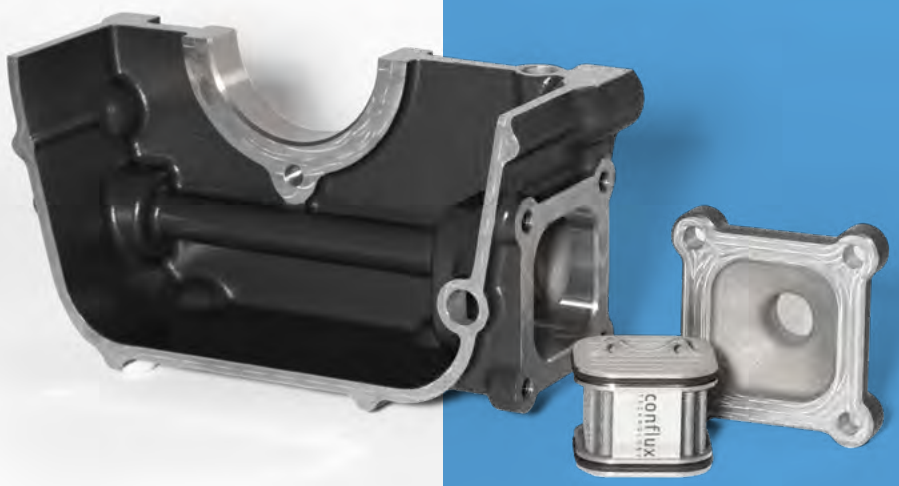
Complex geometric shapes in a 3D-printed microstructure requires stringent quality control. Intensive physical pressure and leak tests are carried out along with tests to prove the unit's functionality. Conflux uses the Australian Synchrotron to identify possible failures in designs produced with thin walls to satisfy specific applications. The Synchrotron enables hidden anomalies inside the completed structure to be seen by displaying a cross-section representation using a CT scan. A recent development with LEAP Australia involving augmented-reality technology allows the customer to see precisely what is happening to the fluid flow and temperature distribution inside the heat exchanger.

AEROSPACE INNOVATIONS

The aerospace industry has many applications for heat exchangers, from military and commercial aircraft to space exploration. Conflux has worked hard to achieve Aerospace Certification AS9100D, including design, and the highly coveted design element allows them to develop and validate an aerospace solution in-house and perform established controls over the whole process.

Aircraft heat reduction requirements are becoming increasingly demanding as more powerful electronics are used. Traditionally, electronic components or modules are fixed to a 'cold' plate that carries heat away from the components.

Conflux innovation uses optimised channels within the plate to provide a more efficient, space-saving solution with a lower weight. To that end, General Atomics Aeronautical Systems Inc is working with Conflux to use the same technology in the design and manufacture of a new Fuel Oil Heat Exchanger for the SkyGuardian and SeaGuardian remotely piloted aircraft.



In further developments, Conflux was awarded a $1 million grant to participate in the Australian Space Agency's Moon to Mars program. As part of that initiative, Conflux has partnered with Rocket Factory Augsburg in Germany to integrate its 3D printing technology specifically to develop a heat exchanger for use in a gas duct of an orbital rocket.

The growth in aerospace applications offers many possibilities, not least as engine and aircraft manufacturers are developing new products based on hydrogen and electric-powered propulsion. While aluminium is used extensively within aerospace, materials such as 316 stainless steel and Monel K-500, a nickel-copper alloy, provide solutions for more arduous and higher-temperature applications.

A Conflux vapour chamber development, basically a heat pipe that provides heat two dimensionally through a process of evaporation and condensation, will open new applications for uncrewed aerial vehicles and other assets that require thermal management.

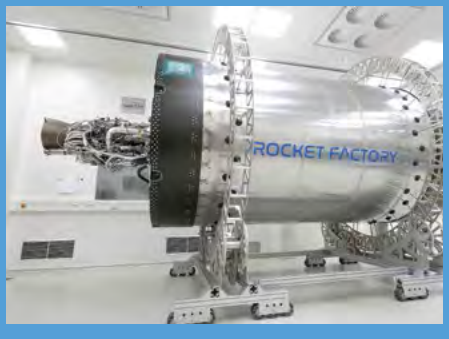
"Conflux heat exchangers derive their performance from highly complex geometries that make use of the inherent freedoms afforded by additive manufacturing," says Fuller.

"Our technical team develops fundamental heat exchanger geometries configured for each customer application. Our production team then delivers under AS9100D certification so that our customers in the aerospace sector fly further and more efficiently."

Christopher Rees

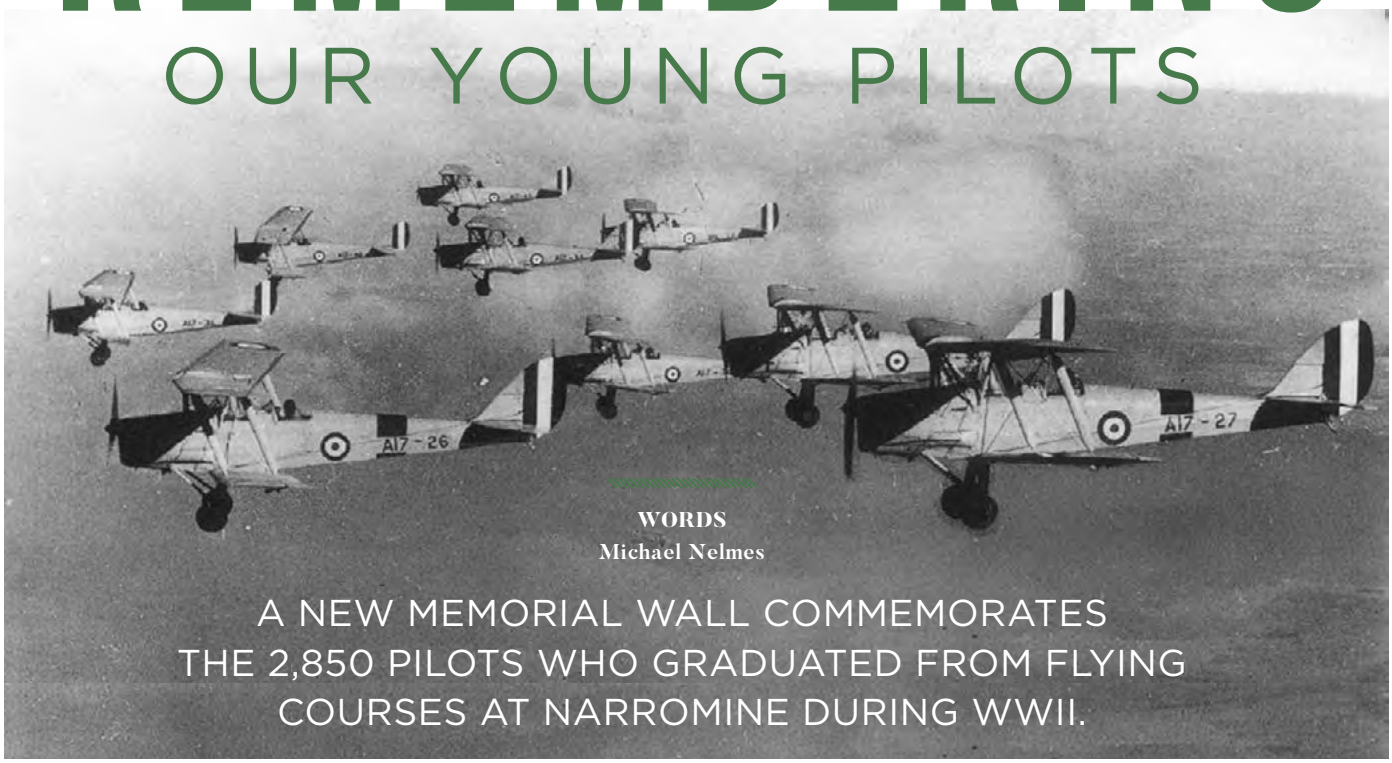
ABOVE The Conflux cartridge heat exchange design allows high performance and efficient heat exchange to be embedded into existing or traditionally manufactured housings. Shown here with an oil transmission housing.

ABOVE Designing for additive manufacturing requires experts at every stage of the process.



ABOVE A Conflux heat exchanger is to be embedded into a gas duct of an orbital rocket for Rocket Factory Augsburg.

REMEMBERING
OUR YOUNG PILOTS



WORDS
Michael Nelmes

A NEW MEMORIAL WALL COMMEMORATES THE 2,850 PILOTS WHO GRADUATED FROM FLYING COURSES AT NARROMINE DURING WWII.

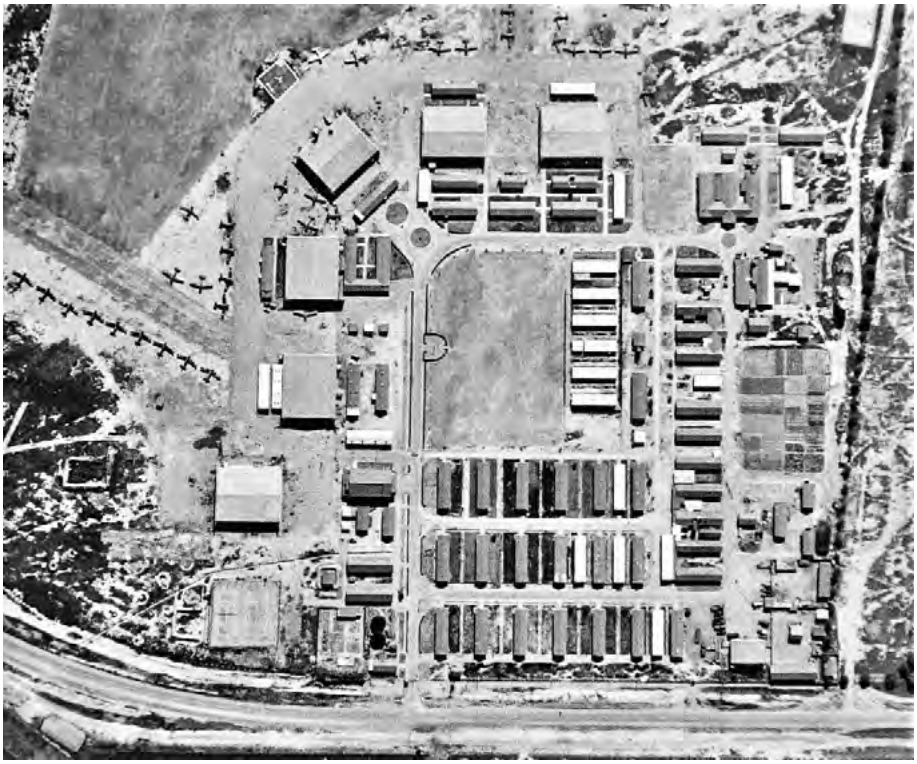
DURING WORLD WAR II, SOME 15,000 YOUNG AUSTRALIANS TRAINED TO BE PILOTS as part of history's greatest aircrew training program, the British Commonwealth's Empire Air Training Scheme (EATS). Initially, the RAAF established flying schools at existing airfields in state capital cities. Then in April 1940, a fifth school was formed at rural Narromine in Central New South Wales, where the local aero club had, in 1928, established a basic airfield. No 5 Elementary Flying Training School (No 5 EFTS) was equipped with some 80 Tiger Moths and with the tempo demanded by the circumstances, the sky over Narromine would have been dangerously congested – so four satellite airfields and numerous emergency landing grounds were created in the region.

For four years through the war, nearly 20 percent of RAAF pilots learned to fly at Narromine with No 5 EFTS. Meanwhile, seven more flying schools were established around Australia. Newly trained pilots were posted to Canada for advanced training, and finally to war theatres around the world. After Japan's entry into the war, many remained in Australia for advanced training.

The Narromine Aviation Museum has stood for 20 years on the former site of No 5 EFTS. Five years ago, the museum applied for government funding to establish a memorial wall, sited on the wartime parade ground, to commemorate the young pilots who trained there. Plans were drawn up for a pair of 20-metre lowset red-brick walls with a sloping concrete top on which large bronze plaques listing the graduates of every flying course conducted at Narromine during the war, 2,850 in all, could be mounted. A quarter of those pilots never returned home, their names notated with a cross. It is sobering to look over the early courses in which crosses mark more than half the names. Although the war situation in later years improved, along with the chances of survival for later

TOP DH.82A Tiger Moth trainers of No 5 EFTS Narromine, 1940. Photo: Narromine Aviation Museum.

ABOVE The style of the six smaller plaques that commemorate units.



HIGH IN THE SUNLIT SILENCE

The 2017 book *High in the Sunlit Silence: The story of fifty trainee pilots, RAAF Narromine NSW, December 1941* by Commander Tony Vine RANR was reviewed in the Spring 2019 edition of *Wings*. The book's title is a line from the famous poem *High Flight* by John Gillespie Magee, an Ango-American fighter pilot who, aged just 19, was killed in a mid-air collision over England. That was in December 1941, just when the men of No 20 pilot course were marching into RAAF Station Narromine.

Bill Gunning, Tony Vine's uncle, was one of those young men. Bill and his crew were killed on 14 July 1943 when a German Bf-110 night fighter shot down their Wellington bomber over Aachen, Germany.

High in the Sunlit Silence is Tony's tribute to his uncle and the other men of No 20 Course. His research is meticulous, citing family backgrounds from which the RAAF drew trainees, their successes or otherwise within the training machine, and their subsequent employment on operations. The families of each member are not only identified, but their military commitments are footnoted and serve to reinforce the enormous impact WWII had on Australian families.

Eighteen of the 50 young men who embarked on No 20 Course were subsequently killed in action or in flying accidents. Of those, Bomber Command claimed 17.

There are men such as Frank Morris, who flew Lancaster bombers on No 460 Squadron. He survived the war and was awarded a Distinguished Flying Cross. However, the squadron lost 1,018 personnel, including 589 Australians. Harry Caswell, a grazier from Brewarrina, who failed pilot training but went on to become a bomb aimer, was killed over France when a night fighter shot down his aircraft. Buzz Benson, who sank two U-boats and was awarded a Distinguished Flying Medal, subsequently became a prisoner of war. Several flew with distinction in the South-West Pacific and in India and Burma. All served proudly and with dedication and, sadly, some with sacrifice.

High in the Sunlit Silence is a remarkable tribute to a small group of ordinary Australians confronted by extraordinary challenges in dangerous skies and, in turn, is more widely a tribute to all Australian airmen who flew and fought in WWII.

Bob Treloar

ELEMENTARY FLYING TRAINING SYLLABUS FOR PILOTS 1939-45

The EFTS course varied through the war from eight to 12 weeks. It came after Initial Training School and before Service Flying Training School which, for those destined for the war in Europe, meant a posting to Canada. Generally, a posting to Operational Training Unit (or Heavy Conversion Unit for UK-based heavy bomber pilots) finished a pilot's training, which totalled almost a year, before he was sent off to war.

FLYING (DH.82A TIGER MOTH)

1. Air experience; familiarity with cockpit layout
2. Effect of controls
3. Taxying
4. Straight and level flight
5. Climbing, gliding and stalling
6. Medium turns
7. Taking off into wind
8. Powered approach and landing
9. Gliding approach and landing
10. Spinning
11. First solo [normally after seven to10 hours of dual instruction]
12. Sideslipping
13. Precautionary landing
14. Low flying (with instructor)
15. Steep turns
16. Climbing turns
17. Forced landings
18. Action in the event of fire (with instructor); abandoning aircraft
19. Instrument flying
20. Taking off and landing out of wind
21. Restarting engine in flight (with instructor)
22. Aerobatics (loop, slow roll, half flick, full flick, roll off top, inverted flick, stall turn)

NAVIGATIONAL EXERCISES

1. First dual cross country
2. Second dual cross country
3. Solo cross country
4. Night flying (minimum five hours, including one hour dual)
5. Out of wind landings and take off

GROUND INSTRUCTION

1. Airmanship (including engines, airframes, principles of flight, aircraft operation and regulations) – minimum 30 hours
2. Aircraft recognition – five hours
3. Armament – 17 hours
4. Drill – eight hours

4a. Physical training and parachute drill – 36 hours

5. Meteorology – eight hours
6. Navigation – 34 hours
7. Signals – 12 hours
8. Instrument flying (Link trainer) – 12 hours
9. Discussions and debates – eight hours

The Tiger Moth contingent made the four-hour flight from Luskintyre NSW. Photo: Michael Nelmes.

ABOVE ACM Houston and museum chairman Peter Kierath OAM view the plaques. Photo: William Kierath.

ABOVE MIDDLE The memorial wall. Photo: Michael Nelmes.

TOP LEFT Aerial view of the training school buildings in September 1944. The aircraft visible are Wirraways of No 8 Operational Training Unit, RAAF. Photo: RAAF Museum.

graduates, nevertheless on average a quarter of the graduates died in service.

Smaller plaques commemorate the wartime units that called RAAF Station Narromine home: No 5 EFTS, No 8 Operational Training Unit RAAF (Wirraways), No 618 Squadron Royal Air Force (Mosquito bombers) and No 93 Squadron RAAF (Beaufighters), as well as commemorating the trainees and instructors who died locally in accidents.

The $150,000 memorial project was supported and funded by the NSW Government in association with Narromine RSL sub-Branch, the museum, and individual donations. The museum's grant application was supported by the Air Force Association (AFA), noting that the memorial would "foster among the visiting community a respect and appreciation for the service of the thousands of Air Force pilots who served their country 80 years ago. An enduring memorial that identifies those who died in service will serve as a sobering reminder of their sacrifice, and the cost of war."

On 14 October 2023, ACM Sir Angus Houston AK AFC (Retd) unveiled the completed monument before a crowd of more than 100 attendees. GPCAPT Peter Norford AM CSC, Director Air Force Heritage, attended in uniform. Geoff Kubank and five other members of the Luskintyre Tiger Moth group flew three bright yellow Tiger Moths in for the event, a sight not seen at Narromine for many years. Their fuel costs were covered by the Fighter Squadrons Branch of the AFA.

The museum hopes relatives of those whose names are recorded on the memorial will take pride in it, and contemplate the sacrifices of so many thousands of Australian airmen in the air and on the ground during WWII.

Michael Nelmes, Curator, Narromine Aviation Museum

For those interested in the wider story of No 5 EFTS, Michael Nelmes' book, Too damned far out west: Narromine's flying century, *is available from the Narromine Aviation Museum.*

INVENTING THE SPACE SHUTTLE

WORDS Michael Nelmes
PHOTOS NASA (unless otherwise stated)

Enterprise made atmospheric test flights, released from NASA's 747 Shuttle Carrier Aircraft.

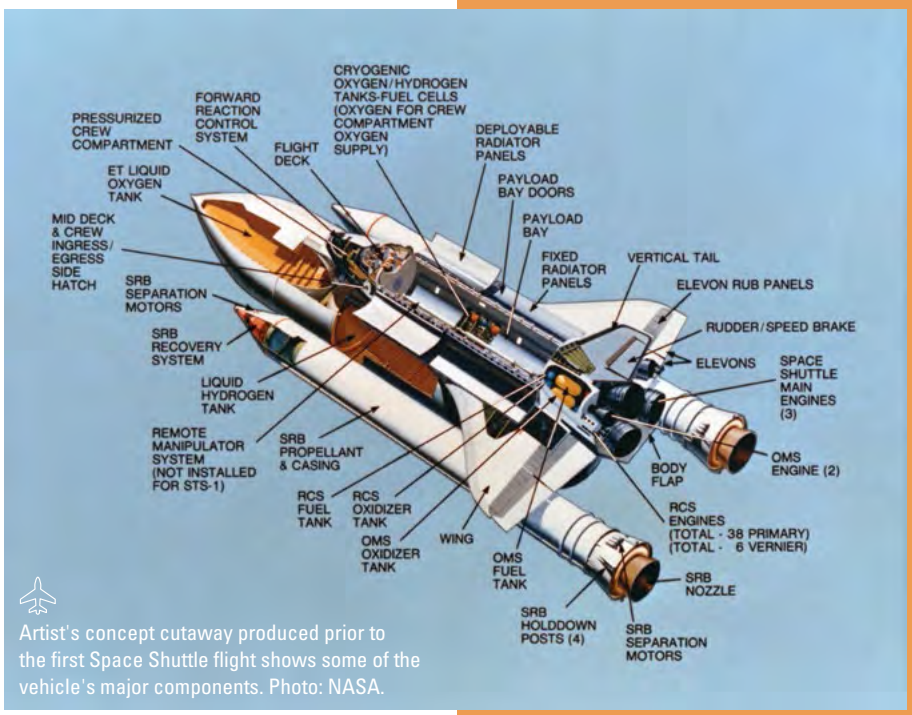
LIFTING BODIES AND SPACE X-PLANES LED TO THE MOST FAMOUS OUTCOME OF THE X-PLANES RESEARCH: THE SPACE SHUTTLE.

THE CONCEPT OF A REUSABLE SPACE PLANE can be traced back to the German pre-World War II proposal for a sub-orbital bomber, *Silbervogel*. But the impetus for the idea of a peacetime space shuttle arose with the space race which, like most races, began with a starter's gun: the firing of a Soviet rocket with a satellite on top.

On 4 October 1957, the Soviet Union launched a modified intercontinental ballistic missile to carry the first satellite, Sputnik, into Earth orbit. In the USA, the reaction was shock and anxiety; clearly, their nation was lagging behind the Soviets in rocketry. At the US Army's Redstone Arsenal at Huntsville, Alabama, a team of German rocket scientists under Wernher von Braun were working on nuclear ballistic missiles developed from the V-2 of WWII. Now they had an even more pressing task: to catch up with the Soviets and put a US satellite into orbit.

They met the challenge. Just four months after Sputnik, America launched its first satellite, Explorer 1, atop a Jupiter C rocket with a Redstone as its first stage. But there was no time for complacency, especially when, on 12 April 1961, Russian cosmonaut Yuri Gagarin was launched into orbit. America's answer to Gagarin, just weeks later, was to launch its first astronaut, Alan Shepard, into space (though sub-orbitally). Nine months later, John Glenn was launched into orbit in a Mercury capsule atop a converted Atlas intercontinental ballistic missile.

The space race ensued through the 1960s, and America caught up. The Mercury one-man capsule program was followed by the two-man Gemini capsules, the three-man Apollo capsules which took men to the Moon in 1969-72, and the Skylab orbiting space station of 1973-74. The Soviets, too, had a manned moon program underway, but it was well behind America's. All those rockets and spacecraft were expendable. NASA's next ambition was to develop a reusable spacecraft.



Artist's concept cutaway produced prior to the first Space Shuttle flight shows some of the vehicle's major components. Photo: NASA.

SPACE PLANES

By 1961, NASA's hypersonic X-15 reusable manned rocket plane had technically achieved space flight. Although it lacked the thrust required to achieve orbit, its research program provided essential information for the design of a winged orbital vehicle. Indeed, one of its pilots, Joe Engle, was to become a space-shuttle pilot.

Meanwhile, during 1963-65, the US Air Force's DynaSoar reusable spaceplane program, developed alongside the cancelled 'aerospaceplane' proposal, launched models (the full-scale craft only reaching mockup stage). Then during 1966-67, three successful launches of lifting-body models provided valuable data on the factors affecting a reusable spaceplane atmospheric re-entry and subsequent landing on *terra firma*.

The British, too, were looking into reusable space planes. Their Multi-Unit Space Transport and Recovery Device (MUSTARD) concept involved a triple-

SPACE SHUTTLE TIME-LINE

1972 – Program announced
1977 – Gliding / landing tests with *Enterprise* from Boeing 747
1981 – First launch of *Columbia*
1983 – First launch of *Challenger*, and first US woman in space
1984 – First launch of *Discovery*
1985 – First launch of *Atlantis*
1986 – *Challenger* destroyed after launch
1988 – Flights resume
1989 – Magellan and Galileo interplanetary probes deployed
1990 – *Discovery* deploys Hubble Space Telescope
1993 – *Endeavor* mission to repair Hubble Space Telescope
1995 – First of nine dockings with Russian space station Mir
1998 – First of 37 missions for International Space Station (ISS)
2003 – *Columbia* destroyed during re-entry
2009 – All subsequent flights are for ISS supply
2011 – 135th and last shuttle flight (*Atlantis*)

vehicle launch, with two outer booster craft separating from the central orbiter after launch and returning to earth for re-use. MUSTARD did not proceed past the concept stage.

In 1969, the US Presidential Space Task Group recommended that a space station, a lunar base and a manned mission to Mars all be accomplished by the year 2000. Those ambitious programs called for a reusable shuttle to supply what would become the International Space Station (ISS) and as a ferry from Earth orbit to the Moon – like the fictional Orion space clipper in the 1968 film *2001: A Space Odyssey*.

While the cost of the lunar base and Mars mission postponed those programs indefinitely, NASA decided that a shuttle for low Earth orbit – orbiting at a height of just a few hundred km – was achievable. Its immediate tasks would be to carry and retrieve satellites to and from Earth orbit, carry rocket stages for deep space missions and eventually carry components for the construction and supply of a space station.

THE CONCEPT MATURES

The initial shuttle concept called for a manned booster that would separate from the orbiter at a height of 80km and fly back to Earth for a runway landing. The projected cost in 1970 was US$10 billion, the high figure arising from the need for all components to withstand up to 100 launches, re-entries and landings. The cost was deemed unacceptable, and was soon nearly halved by specifying only limited, critical components be fully-reusable.

To gain political support in the wake of the huge national expense of the Apollo moon expeditions, military requirements were built into the shuttle program – for example, spy satellites placement in orbit. In fact, of 570 shuttle missions originally planned, nearly 20 pecent were for the Defense Department. That decision required an orbiter with a 30t payload and a minimum payload bay length of 18m, as well as the capability to glide to a landing up to 2,000km away from its re-entry path. The latter requirement arose from the need to launch from Vandenberg Air Force Base and to deploy military payloads into a polar orbit. For that, the stubby wings of the X-15 or a pure lifting-body design would be inadequate. The shuttle would need large wings.

ABOVE Space shuttle *Discovery* mission STS120 launch in 2007, the 23rd flight to the ISS.

LEFT A few of the early concepts.

TOP OPPOSITE The cavernous payload bay of *Discovery* with its Remote Manipulator System robotic arm, seen from the International Space Station in 2011.

In January 1972, US President Nixon announced the Space Transport System (STS) or Shuttle program and predicted it would "transform the space frontier of the 1970s into familiar territory, easily accessible for human endeavour in the 1980s and 1990s".

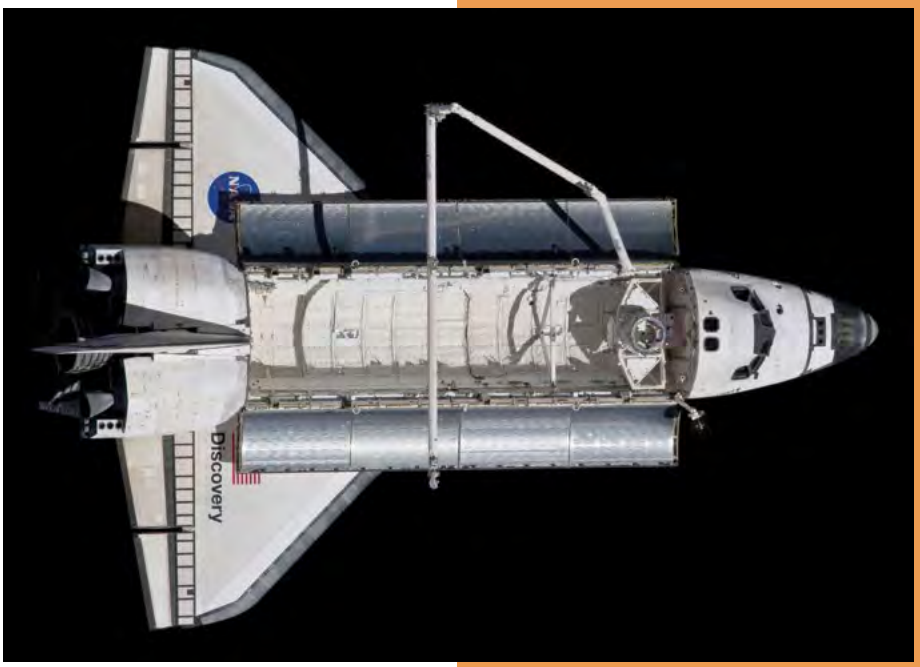
It was realised early that for the shuttle to carry the requisite fuel load and still be of feasible size, it would need to launched mated to a large external fuel tank. It also required a pair of reusable side-mounted rocket boosters using solid propellant, replacing the earlier idea of a manned reusable booster, which once expended would parachute into the sea for later re-use.

FINE TUNING

In 1972, North American Rockwell Corporation was chosen to be the main STS contractor, and the following year the detailed design work was finalised. The shuttle orbiter would be built of aluminium, with reinforced carbon-carbon composite material for critical structures such as wing leading edges. It would be covered with thermal tiles to withstand the heat of atmospheric re-entry. The payload bay was equipped with a Remote Manipulator System (robotic arm) for deploying and retrieving satellites. A pair of large graphite epoxy payload doors served also as radiators of the electronically generated heat build-up, with further cooling achieved using water. The fuselage was wide to accommodate large satellites, and the underside flat to provide dynamic lift and slow its descent during re-entry. Its large vertical tail incorporated airbrakes, to be deployed on landing in order to avoid overloading the wheel brakes.

The orbiter was 37m long, almost the size of a commercial airliner, with delta wings spanning 24m. Its empty weight was 68t. Three large engines were rear mounted. Its pressurised flight cabin and the larger crew quarters below could accommodate a crew of up to eight for a week, and included a galley and zero-gravity sleeping bunks. Beneath the payload bay were high-pressure oxygen and nitrogen tanks for supplying cabin atmosphere. For the first time in any spacecraft, the crew were given large windows.

Behind the crew quarters was an airlock leading into the payload bay, which could be accessed by the crew when suited-up in an Extravehicular Mobility Unit (EMU). Because of the frequency of 'space walks' required during missions, for satellite repairs for example, the EMUs formed an integral part of the space shuttle system. Each suit's portable life support system backpack carried the supplies needed in space – water, oxygen, heat, radio communications and waste disposal for up to seven hours.



The first shuttle, Orbital Vehicle (OV) 101, was built during 1974-76, but it only ever made gliding test flights in the atmosphere. NASA planned to name it Constitution, but President Ford bowed to demand by fans of the science fiction TV series *Star Trek* and its starship, and it became *Enterprise*. The shuttle program called for four orbiters plus a structural test vehicle, and it was the latter, rather than *Enterprise*, which was later converted to orbiter status. Enterprise was also a name used for US Navy ships, a theme continued in the names of the next four shuttles announced in 1979: *Columbia* (OV-102), *Challenger* (OV-099), *Discovery* (OV-103) and *Atlantis* (OV-104). A fifth operational orbiter, *Endeavour*, would later be rolled out in 1991 to replace *Challenger*.

GLIDE TESTING

Previous rocket planes such as the X-15 had been carried to altitude by a B-52 mothership, but the shuttle was overweight even for that behemoth. The best option was a Boeing 747 Jumbo airliner. NASA bought a 747 from American Airlines and converted it to carry the orbiter on its back; it also transported the orbiters around the country pre- and post-mission.

ABOVE The Soviet Union's shuttle, *Buran*, nearly completed in 1982.

ABOVE *Buran* mounted on its Antonov An-225 transporter at the Paris International Air and Space Show in 1989. Photo: MSGT Dave Casey.

Astronauts Fred Haise and Gordon Fullerton took *Enterprise* on the first of five 'piggyback'- launched glide tests in 1977. Less than six minutes after release the orbiter was back on the ground at Edwards Air Force Base in California. A microwave beam approach system relayed distance, height and angle information to onboard computers to aid approach for landing.

THERMAL PROTECTION

A critical element of shuttle development was effective, reusable heat shielding to prevent the craft from thermal destruction during atmospheric re-entry. The solution was with a layer of 31,000 small tiles of silica fibre over the exposed surfaces of the shuttle. Each tile was of different size, shape and thickness, and printed with an individual serial number for identification. A reinforced carbon-carbon composite of graphite cloth, soaked in resin, covered the nose and wing leading edges which would reach 1,700°C. Black silica-based tiles covered the next hottest areas (the undersides and front section, which would reach 1,260°C), while white tiles covered most of the fuselage. Nomex felt reusable surface insulation covered the upper wing surfaces and payload bay doors.

The tiles were light and fragile, and it was feared those covering the first operational shuttle, *Columbia*, might not survive re-entry. (Some did, in fact, detach during each spaceflight). Before the first launch about 15 percent of the tiles were removed and their undersides soaked in a resin compound, more than doubling their weight. To compensate for the added weight, on later orbiters the white lower-temperature tiles, a quarter of the total, were replaced with lighter blankets of silica fibre.

ENGINES & FUEL TANK

Designing and building the three main Rocketdyne RS-25 engines was challenging, as no such high-powered engine had previously been designed for multiple lift-offs. As rocket engines are subjected to extreme stresses and temperatures, many components need overhaul or replacement between launches.

Each engine provided 213t of thrust – greater than the Atlas rocket that took John Glenn into orbit in 1962. Fuel was pumped to them by high pressure turbo-pumps, and the engine bells or nozzles were cooled by pumping cold hydrogen through lateral tubes. The engine trio was required to fire for nine minutes, almost until orbital velocity was reached, with engine power varying between 65 and 109 pecent in a sequence designed to minimise structural stresses on the craft from aerodynamic forces.

After the main engines were shut down, two smaller and simpler engines called the Orbital Maneuvering System gave the orbiter a final boost into the desired orbit. They used an internal fuel supply of monomethyl hydrazine and nitrogen tetroxide oxidiser and, like the main engines, their bells could be gimballed to provide directed thrust.

For attitude control in space, 44 small thrusters in the shuttle's nose and rear achieved the effect of aerodynamic control surfaces in the atmosphere.

The external tank (ET) held more than 600t of oxidiser (liquid oxygen) in its upper section and 100t of liquid hydrogen propellant in its lower section, completing a 2,000t total shuttle launch weight. Hydrogen was chosen over kerosene or alcohol for its high-energy density. The tapered oxygen tank section included anti-slosh baffles to keep the tank from resonating, which would have dangerously stressed the struts attaching the ET to the orbiter. The ultra-low temperatures of the hydrogen and oxygen had to be maintained for six hours from commencement of filling until launch, so the tank was covered with an epoxy-cork insulation and a polyurethane-like foam coating. Though painted white for the first two launches, the ET's paint was subsequently left off to save a quarter-tonne of weight – hence its bare orange-brown finish.

In 2003, a detached piece of ET insulation spelt disaster for *Columbia* and its crew – it had struck and punctured a wing leading edge during lift-off, which then burned through during re-entry. Ice from the ET also posed a problem when pieces of it detached and struck the fragile tiles, although this was partially solved by installing a hood on top of the ET to syphon off vented oxygen.

SOLID ROCKET BOOSTERS

Even the prodigious power of the three main engines was insufficient to propel the loaded shuttle into orbit. To augment them, two solid-rocket boosters (SRBs) were mounted either side of the external tank and fired for the first two minutes of launch. Cost determined the choice of solid over liquid fuel. The pair of SRBs provided the majority of thrust, 2,600t, and their nozzles were steerable.

Their casings were originally made of steel, but were later replaced with a lightweight graphite fibre-plastic compound. The SRBs were reusable, equipped with three top-mounted parachutes, which saved NASA some US$40m per launch. To produce the required thrust profile over time, the solid propellant was shaped to different cross-section patterns along the booster's length, with a star shape for larger surface

ABOVE USAF Space Force's small Boeing X-37B Orbital Test Vehicle (and its X-40 test platform) made six space flights, riding a launch vehicle into orbit between 2010-2022.

LEFT Bob Crippen and John Young (second and third from left), who made the first shuttle flight, with the crew of the last mission, STS-135.

The Dream Chaser reusable lifting body spaceplane flight test vehicle, 2013. Photo: Ken Ulbrich.

area where higher thrust was required (at launch and again at high altitude). The propellant was a mixture of aluminium powder, ammonium perchlorate oxidiser, and iron oxide catalyst, with a burn temperature of 3,200°C.

At a height of 44km and a speed of 5,000kph, the SRBs were separated from the ET with explosive charges and descended to the sea under parachutes. Impact with the water had to be under 100kph to minimise damage for re-use. Each SRB included an explosive charge to destroy it by radio control in case it came down over a populated area. The floating boosters were recovered by ship and towed to shore.

Meanwhile, the main engines continued firing until the external tank was empty, and the tank was ejected.

Before each mission, the orbiter was mated to the external tank and SRBs in the Vehicle Assembly Building at Cape Kennedy, Florida. The mating was accomplished with just three attachment points between orbiter and tank. The fully assembled shuttle was then rolled out to the launch tower on a 4,500t, caterpillar-tracked mobile launch platform.

Normally its payload was then installed vertically in the payload bay, although the largest payloads such as Spacelab modules were installed prior to the shuttle being raised vertically. The payload doors were then closed, and a few hours before lift-off the crew boarded and climbed into the cockpit.

LIFT OFF!

On 12 April 1981, the 20th anniversary of the first manned spaceflight, *Columbia* lifted off. Anxiety was high. Never before had a US spacecraft carried astronauts on its first flight. The Mercury, Gemini and Apollo programs had all begun with unmanned launches. However, all went well. After atmospheric re-entry, the two pilots controlled the shuttle using conventional control columns and foot pedals to operate the control surfaces. As a spaceplane its aerodynamics were inferior to that of conventional aircraft, making it difficult to fly, although an automatic pilot system controlled by a series of five IBM computers could take over flying when required. After a few years of service, the original 1972-vintage computers were replaced.

END OF AN ERA

Early in the shuttle program it was clear it was not as cheap to operate as expected, and other launch programs were soon developed to augment it. The European Space Agency developed its Ariane rocket around the same time as the shuttle's debut, proving a viable competitor and therefore reducing the shuttle's customer base. In preparing each shuttle for a mission, numerous unforeseen cost blow-outs appeared, and NASA budget cuts didn't help.

Ultimately the shuttle failed in its goal to reduce the cost of spaceflight. In its final year, 2011, the cost of a shuttle mission was estimated at US$18,000 per kg of payload, some three times that of expendable rocket launch costs, and many more times that when the shuttle's development and infrastructure costs were factored into the equation.

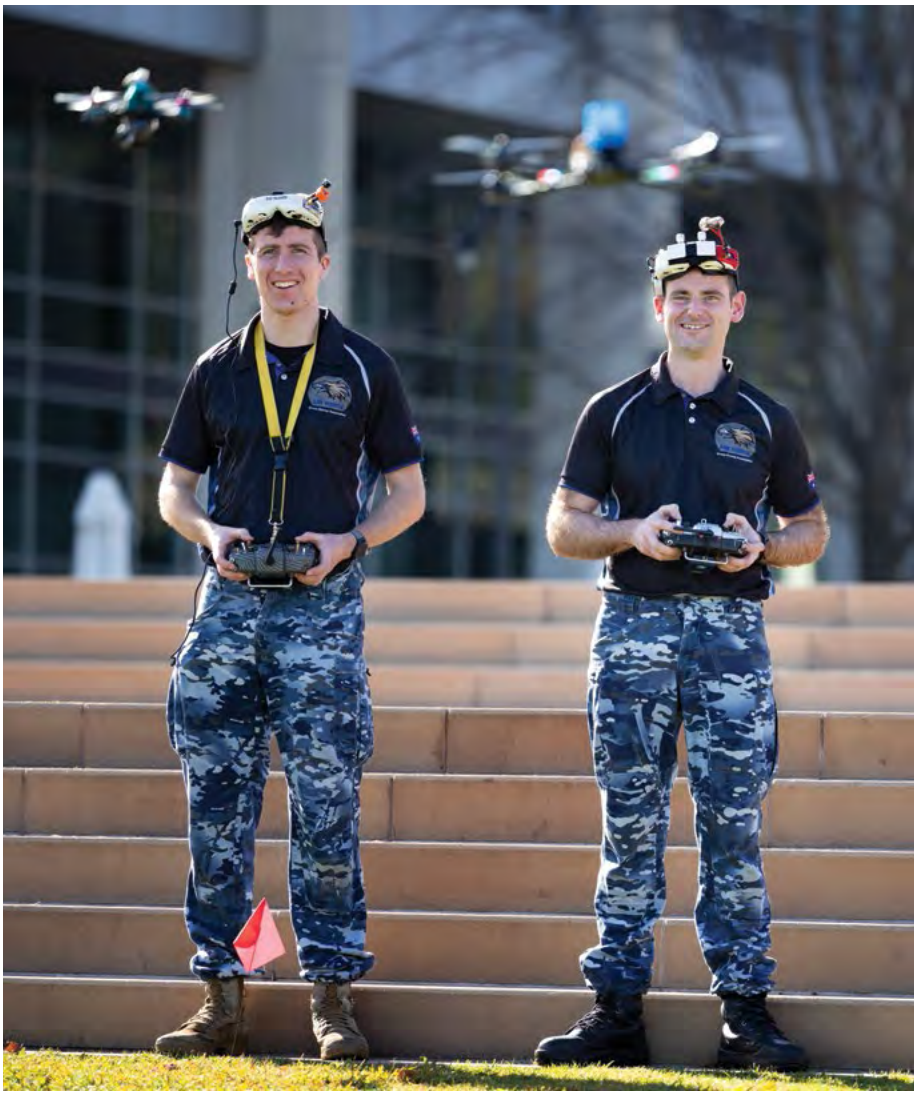
The program also cost the lives of 14 astronauts (more than in any other space program) and two shuttles in 135 flights. NASA's 'get it done' culture had resulted in some corner-cutting, notwithstanding the extensive and laborious post-flight inspections and repairs, and that has often been blamed for the losses.

Nevertheless, the life of the shuttle program was extended to twice the period originally planned and uses were found for it in addition to carrying satellites and space station components into orbit. Over its 30-year operational life many zero-gravity experiments were conducted onboard, and it had some useful spin-off developments. The spaceplane concept has continued on a smaller scale in some of the X-planes, like the X-37, and NASA's Dream Chaser which is intended for resupplying the ISS, although unlike the shuttle they require a separate rocket for launch. At the time of writing, the space shuttle remains the only winged, crewed spacecraft to have achieved orbit and a return to earth and a conventional landing.

The four surviving shuttle orbiters are displayed in the USA: *Atlantis* at Kennedy Space Center, Florida; *Discovery*, Udvar-Hazy Center, Virginia; *Endeavour*, California Science Center; *Enterprise*, Intrepid Sea, Air & Space Museum, New York City.

AERIAL SPORTS

AIR FORCE DRONE RACING HARNESSES THE SAME SKILLS AND COMPONENTS AS THE BROADER AIR FORCE.



THE GOVERNMENT'S DEFENCE STRATEGIC REVIEW 2023 highlights the importance of fielding ADF capabilities that provide "impactful projection"; degrade an adversary's competitive edge and threat speed at much longer ranges. Those principles are similarly applied by skilled sports pilots in drone racing using networked communications to digitally project themselves with remotely piloted drones to operate in a distant three-dimensional sports track. Air Force drone racing is a microcosm of a macro-organisation that exists to deliver air power.

Like the Air Force, success in drone racing is based on four key components: an organised body; skilled operators; task-specific equipment designs; and working safely in a competitive environment. Drone pilots manoeuvre their drones competitively in a distant airspace congested with obstacles and competitor drones, with localised maintenance support poised to retune and repair damaged equipment quickly to continue the race program.

The drone racing community established an Australian First Person View Association (AuFPV) to specifically support drone pilots using first-person view (FPV) goggles to remotely pilot a radio-controlled drone using visual references delivered via a video feed from a drone mounted camera. AuFPV sets the standards for drone racers, operators and clubs around Australia. The Air Force Drone Racing Association (AFDRA) administers drone racing as an Air Force-approved sport and complies with the governing rules and principles set by the AuFPV Association.

LEFT AFDRA vice president, Flight Lieutenant Nicholas Eberl (left), and president, Flight Lieutenant Jake Dell-O'Sullivan, flying their racing drones during Air Force Drone Racing Association expo day in Canberra. Photo: PTE Nicholas Marquis.

Racing drones are a dual-use technology evolved from radio-controlled model aircraft and adapted to exploit the networked communications systems within the approved frequency spectrum for remote piloting and video broadcasting. Drone flying complies with the safety rules regulated by the Civil Aviation Safety Authority.

Military aircrew use mission planning software that combines a digital aircraft flight performance and systems model to simulate flying a trajectory over a digitised terrain model of the mission arena. Like military pilots, drone racers use the video game medium to familiarise themselves with the flight characteristics of their drone, and the sensory effects of the absence of tactile feel and a limited field of view. Some video games allow the user to upload a digital file representing the design of an actual 3-D racetrack and allow drone racers to prepare and practise at home in a realistic challenge.

Games can also be networked for the user to compete against the clock or multiple players from the online networked user community. For many drone racers, training can begin and remain in the virtual world. Others use the video game as a tool to prepare for flying in the physical world.

Each drone race is an element of a tournament. Pilots need to plan and manage the complete life cycle of their drone and be prepared for onsite battery replacement, timely battery recharge, maintenance and damage repair, to remain competitive and complete the tournament.

Besides managing the risks of multiple competing pilots independently flying their drones within the same congested racetrack, pilots must actively manage the frequency spectrum and power output of their control and video circuit to avoid interference with other competitors within the licensed frequency spectrum allocation.

A critical drone safety feature is the disarm/arm function that controls the overall power of the drone. The drone is disarmed and rendered passive when not in a race and can also be disarmed by the pilot during a race to prevent an unsafe situation. The 'turtle' manoeuvre is a pre-set switch function that, when triggered, autonomously and momentarily reconfigures the drone propellers to flip an inverted drone into an upright position in readiness for normal flying. Pilots also use the term 'tumbleweed' to describe the drone reaction to ground impact at speed; the drone typically tumbles uncontrollably, bouncing up and down off the ground like wind-blown tumbleweed.

Successfully piloting a racing drone is accomplished through deft 'thrust vector control' – controlling the power and direction of the combined thrust delivered by four independently operated propellers. The pilot uses a joystick controller to command changes in power level and the angle of power application.

BELOW AFDRA trainer FPV racing drone kits.

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AIR FORCE ASSOCIATION

A processor onboard the drone translates the pilot's commands into the appropriate electrical signals to each propeller to generate the total required combined thrust vector. A failure in any system component or propeller is considered catastrophic and results in a 'did not start' or 'did not finish' annotation against a pilot in that heat.

The drone racetrack is marked with standardised obstacles with assigned meanings to indicate the manoeuvres required to negotiate the obstacle. For example, a straight line of cones permits a high-speed transit, a gate marks a position for passing below and/or above the gate height, a single leaf banner can mark a turning-point at any height. Obstacles marked with combinations of gates and leaf banners require pilots to fly combined manoeuvres.

FPV goggles provide the pilot with the main visual references for spatial and attitude awareness, but drone manoeuvres are not determined solely by the visual imagery displayed in the FPV goggles. Advanced drone pilots use their simulator experience to optimise entry and exit manoeuvres at each obstacle in anticipation of the next obstacle. Drone pilots develop an 'airmindedness' specific to the manoeuvring drone and its performance within the 3-D racetrack. Simulator practice becomes essential in building 'muscle memory' for navigating to the next obstacle situated beyond the instantaneous field-of-view of the drone.

AFDRA promotes the safe use of drones within the wider public community while also allowing members to operate under the Defence Aviation Safety Regulations (DASR). Drone pilots operating under DASR also gain familiarity with those unique aviation safety requirements. Each AFDRA member must undertake education and training tailored specifically for racing displays and undertaken as an in-person flying assessment to check members' competency to operate a drone, and their knowledge of all the required risk mitigations techniques and regulations. In addition to understanding how to build and operate drones safely, familiarity with DASR also enables AFDRA members to apply that knowledge in their other Defence roles involving uncrewed aircraft systems and remotely piloted aircraft.

On a flying squadron, a flying supervisor is delegated flight approving authority; on the drone course, the tournament director is the recognised authority responsible for ensuring the track layout and conduct of the tournament comply with the national standards set by the AuFPV. Additionally, the tournament director monitors a combined display of the FPV video feeds from every drone to ensure drone racers comply with the race requirements to correctly complete the racetrack and to resolve any disputes in drone technology, drone applications, and conduct of the tournament. The director also has a critical role in informing public spectators of event safety and race proceedings.

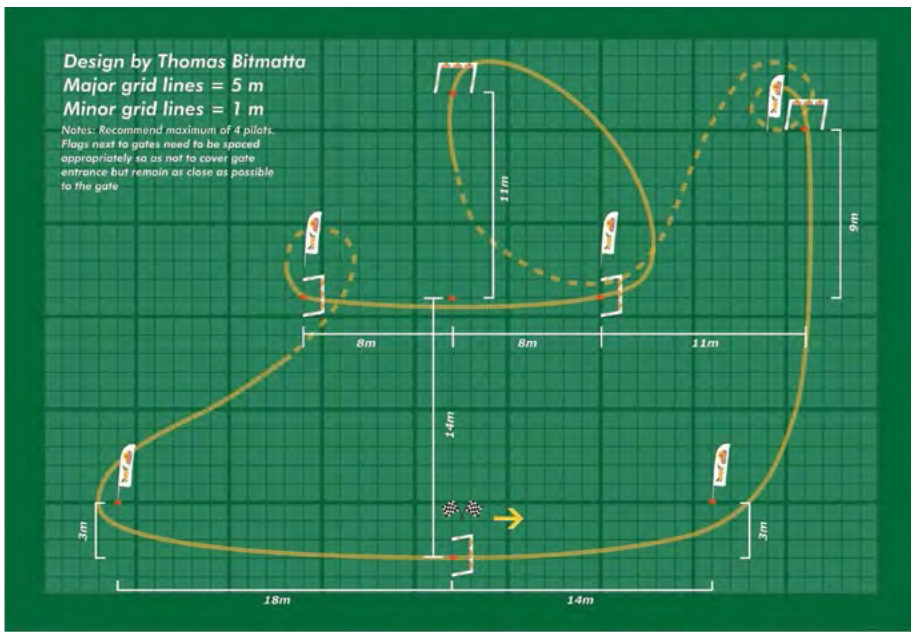
The designs for racing drones are classified by their size and performance. Novices train and compete using the introductory two-inch drone racing class – micro-sized drones that operate in the 'Tiny Whoop' class with a take-off weight below 50g, flying at about 25kph in 1G-turns. Advanced racers compete in the five-inch drone racing class, operating drones with a take-off weight of up to 800g, flying at about 150kph in 9G-turns. Both classes are designed to use a single replaceable battery pack that lasts about three minutes. Battery pack life determines the racetrack design i.e. lap length and the number of laps.

Obstacles can be congested and are the likely chokepoints for accidental mid-air collisions. Drones sometimes bounce off each other, as they do with the ground and racetrack obstacles. Catastrophic collisions can produce battery harness failure, battery separation or damage to propellers and components that renders the drone unfit to fly.

As a microcosm within the larger Air Force organisation that delivers air power for the nation, AFDRA provides an organised body of members with skills and applied technology to make impactful projections with micro-scale air power delivered over distance and time. Drone pilots and technologists use the fundamentals of organisation, learning skills and applied technology, and operate safely in a challenging environment to promote an interest in air power to the workforces of today and the future.

Squadron Leader Michael Spencer, with contributions from AFDRA members Flight Lieutenants Jake Dell-O'Sullivan and Nick Eberl.

LEFT Drone racing is an approved Air Force sport and any Air Force personnel can participate.



BELOW Example of an air mission plan prepared for a drone race event.

WINGS OVER SURFERS

THE INAUGURAL PACIFIC AIRSHOW GOLD COAST PUT ON A CROWD-PLEASING SPECTACLE.

IN A BREATHTAKING DISPLAY OF POWER, precision and international camaraderie, the inaugural Pacific Airshow Gold Coast took to the skies from 18 to 20 August. Set against the stunning backdrop of Surfers Paradise beach, the aviation extravaganza left more than 200,000 attendees in awe and showcased the cutting-edge capabilities of the Australian and the United States military air forces.

Founded by California-based aviation enthusiast and Code Four CEO Kevin Elliott, Pacific Airshow Gold Coast exceeded expectations and carved its place as a marquee event on the Gold Coast's annual calendar. The spectacular three-day event unveiled an array of high-performance machines, awe-inspiring aerobatics, and captivating manoeuvres, transforming the sky into the world's grandest stage.

From the ADF, attendees witnessed the heart-stopping performance of the RAAF F/A-18F Super Hornet, the RAAF C-17A Globemaster III and the RAAF formation display team, the Roulettes. Additionally, the RAAF C130J Hercules made a thrilling appearance, complete with flares, demonstrating its defensive counter-measures equipment.

The debut appearance of the USAF KC-135R Stratotanker Demonstration with a USAF C-17 in pre-contact trail wowed the crowd. That aerial refuelling powerhouse has played a vital role in the USAF's global reach for over six decades. The US Marine Corps MV-22B Osprey, a remarkable vertical take-off and landing tilt-rotor aircraft, demonstrated its tactical combat versatility. Other popular displays were from the USAF C-17A Globemaster III and Royal Canadian Air Force's CC-150 Polaris, a military conversion of the Airbus A310-300 airliner to a multi-purpose, long-range military aircraft for passenger, freight or medical evacuation transport.

ABOVE Air Force Pilot Officer Doug Burton explains how to use the F/A-18F Super Hornet simulator to a young visitor at the Pacific Airshow Gold Coast. Photo: LACW Taylor Anderson.

LEFT The Roulettes' aerobatic display over the Gold Coast. Photo: SQNLDR Tina Turner.

The aviation line-up also included civilian performers Jeff Boerboon in his YAK110 and the precision flying of Australians Matt Hall, Emma McDonald and Aarron Deliu. The show took place over water, offering attendees the chance to experience the action from the beach. As one aviator finished, another seamlessly followed, leaving no dull moments.

Pacific Airshow Gold Coast's impact extended beyond the aerial displays, from the bustling event precinct to balconies spanning the Spit to Burleigh, and a dedicated team, including 116 volunteers, worked tirelessly to ensure the event' success.

Event attendees travelled from near and far; the farthest-travelled guest hailed from British Columbia. The age spectrum ranged from a four-month-old infant to a 99-year-old World War II veteran.

The event has established itself as a highlight on the Gold Coast's calendar and will be back in 2024.

Deanna Nott (WGCDR Res), Managing Director, Wings Public Relations

MISSION ACCOMPLISHED

QUEENSLAND STUDENTS SHOWED OFF THEIR SKILLS IN THIS YEAR'S GLOBAL SPACE CHALLENGE.

IN SEPTEMBER, A GROUP OF YOUNG QUEENSLAND STUDENTS took part in the Global Space Challenge, a virtual space mission in which teams from around the world compete to develop and use imaginative concepts in the space environment. The challenge is an element of the Space Teams program designed by former NASA astronaut Dr Gregory Chamitoff, which accurately models the physics and engineering of spacecraft systems and is designed to educate and inspire budding space travellers and scientists.

The challenge was open to students aged 12 years and up, from school years six, seven and eight. More than 30 scholarships were offered to students through science technology engineering and mathematics (STEM) education organisation One Giant Leap Australia Foundation (OGLA) with support from the University of Southern Queensland's (USQ) iLAuNCH, Geospatial Intelligence and the Queensland Government. Scholarships were awarded based on video submissions that showed not only STEM and space knowledge but also interest and enthusiasm.

The program took place at USQ's Toowoomba campus – the first time OGLA has facilitated a full program in Queensland. Space Teams veterans from NSW – the Scots School, Albury and St Philip's Christian College, Newcastle – also participated.

The competition was a global six-day virtual event with students learning to design a mission to another planet through online simulations. It took students through topics such as the dynamics of planetary systems, spacecraft design, orbital mechanics, astrodynamics, mission planning, piloting skills, atmospheric descent, landing, survival in space, deep-space habitat design and surface exploration. Daily mission training included a one-hour live tutorial on each day's topic with an industry expert.

The competition itself was fierce. Australian students competed in teams of four or five against young space explorers from the USA, Canada, Egypt, India, Lebanon, Ukraine, Papua New Guinea (PNG), the Netherlands and Germany. They were all focused on key mission objectives for a fictional expedition to another world. Participants spent hours on their mission, aided in Australia by OGLA staff as well as online coaching and education provided by Dr Chamitoff.

"This is the STEM education version of professional mission software and is recognised by NASA itself," says OGLA director Jackie Carpenter. "Students learn very quickly and teamwork is critical to their mission success. From our decades of work and research, we know when developing our future space STEM workforce, it is critical that the so-called 'soft skills' are developed in tandem with technical skills. Students really do learn to communicate and collaborate effectively with this program, which is so gratifying to witness."

OGLA education outreach manager Jenna McCarthy, who was on the ground in Toowoomba, said there was incredible interest and enthusiasm in the challenge.

"Entry videos were very creative, too, which was great to see," she says. "This program is having such a wide regional reach across Australia and also connecting these regions to the world."

Learning about orbital mechnics.

Scholarships were also made available to students in PNG. "I am proud to say we have some super smart STEM kids in our country," said PNG coordinator Keron Kilip, "and we need them to be exposed to such STEM facilities to boost their motivation about science, innovation, ideas, creativity, sustainability, technology and design."

Darin Lovett, executive director of iLAuNCH (a collaborative program between Australian industry and USQ, Australian National University and University of South Australia), said it was an honour to see the future of Australia's space workforce in action and was pleased to support the 32 aspiring astronauts to take part.

While the Global Space Challenge involves a lot of online simulation, the event also required students to leave their screens for some indoor and outdoor practical workshops, including the design of each team's mission motif.

The Queensland schools made an impression with their efforts. Toowoomba-based team MOD-N Inc (mission patch inserted left) won the Middle School section and came second in the overall competition, while a Toowoomba-based student from Concordia Lutheran College won a prize for "Amazing Surface Habitat". An all-girls team, Scooters, came second in the High School division and fifth overall.

"Many of the subjects in Space Teams are advanced topics that I teach at university level," Dr Chamitoff says. "But with Space Teams, students are able to understand, and even design space systems, using a hands-on, visual and interactive approach to the engineering design process".

According to Jenna McCarthy, the gamification of the program is a key to its success and accessibility to young people.

Feedback from parents and students was extremely positive with one parent commenting: "I would like my child to participate in a similar program again, because it was a big learning experience for her, and she really enjoyed it. The activities allowed her to apply her knowledge in real-world scenarios." Another parent observed that it was a life-changing experience for students who have a real interest in space to learn something beyond what is offered in school.

The Global Space Challenge will return next year and OGLA expects it will be even bigger and spread further across Australia. "What better way to celebrate World Space Week next year than having students from all over the world completing the Global Space Challenge?" says Jackie Carpenter.

The next Global Space Challenge will run from 4-10 October 2024. To find out more, see onegiantleapfoundation.com.au.

ABOVE Toowoomba-based team MOD-N Inc.

LEFT Participants receive their awards

Australia's leading STEM provider

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https://onegiantleapfoundation.com.au/

ONE GIANT Leap Australia Foundation

WORDS Flight Lieutenant (AAFC) Paul A Rosenzweig OAM

POWERED FLYING TRAINING

THE AUSTRALIAN AIR FORCE CADETS (AAFC) AVIATION OPERATIONS WING has announced the Cadets selected to undertake powered flying training in 2023-24. The Officer Commanding congratulated all applicants for the high standard of their submissions.

Cadets from No 2, 3 and 4 Wings will receive inspirational aviation experiences through the AAFC Powered Aircraft Capability (PAC) provided by 12 leased Diamond DA40-NG Star aircraft, registered to the Commonwealth of Australia and maintained by Cadets Branch – Air Force. Those aircraft are operated by qualified instructors assigned to the three hubs of the Elementary Flying Training School (EFTS) – Amberley Flight (Queensland), Richmond Flight (NSW) and Point Cook Flight (Victoria).

Complimentary to the PAC is the Powered Service Provider program, which provides a similar experience for Cadets where EFTS does not have a presence, through the use of civil aviation providers and flying schools.

Attending a Powered Flying Course (PFC), Cadets undergo flight training according to the CASA Recreational Pilot License curriculum with the intention of progressing to their first solo flight. PFC is the ultimate aviation training program offered to Cadets and is accredited towards the issue of a pilot license, should the Cadet choose to continue training.

One of the flying training candidates is Cadet Corporal Raahim Zaidi of No 713 Squadron. CCPL Zaidi reflected: "My experience so far with the flying training has been very fun and informative. It has been an amazing opportunity to learn how to control the aircraft properly. I always look forward to my practical lesson every week, where I go out to fly for an hour to put into practice what I learnt during the theory lessons.

"My experience in the AAFC has brought me closer to aviation, and I am thinking of becoming either a commercial pilot, or an aeronautical engineer, as I have found involvement in aviation, no matter what aspect, to be extremely enjoyable."

Scan the QR code for more information, and to download the AAFC Powered Flying brochure.

AEROSPACE IMMERSION

ON SATURDAY 26 AUGUST, a group of Air Force Cadets visited various aerospace companies at Parafield Airport north of Adelaide in an immersive aviation experience. Leading Cadet Aishwarya Srikanth reported on the day: "The exciting day started off with a view and tour of the Cessna 172 aircraft. Everyone was able to closely view the aircraft and we were even allowed to jump into the cockpit of the plane. It was very memorable for me, as I got to view the controls more meticulously and learn more about what each instrument does."

The Cadets also visited the Classic Jets Fighter Museum with its Vought F4U Corsair, salvaged from Vanuatu where it had force-landed in a lagoon on 5 May 1944, and then met with the staff of Flight Training Adelaide and learnt about their operations and training courses.

After lunch, they visited Aerotech Australia. "We got to view the company's firefighting aircraft – the Black Hawks. We learnt about the structure of the Black Hawk helicopters and why they are used for firefighting purposes," says LCDT Srikanth.

The Cadets then visited the Australian Airborne Research Centre, which is affiliated with Flinders University, and Aerostar Aviation, before returning to Flight Training Adelaide to sit in the cockpit of a Diamond DA-40.

"I would definitely recommend attending activities like this, as it provides a larger insight into the aviation world and opportunities in the aerospace industry," LCDT Srikanth says.

BELOW Cadets in the relic of a US Army Sikorsky UH-60A Blackhawk helicopter at Aerotech Australia.

MALAYA-BORNEO VETERANS DAY

AIR FORCE CADETS from No 604 Squadron (Hampstead Barracks, SA) supported a moving and respectful Malaya & Borneo Veterans Day service of commemoration in the City of West Torrens War Memorial Gardens. It was hosted by the SA & NT Branch of the National Malaya & Borneo Veterans Association Australia (NMBVAA) to mark the 57th anniversary of the signing of the Malaysia-Indonesia Peace Agreement on 11 August 1966. That agreement brought to an end the Indonesian Confrontation with Malaysia.

Among those commemorated were 15 RAAF personnel and two Royal Australian Navy (RAN) aviators who lost their lives on operational service overseas during the general period of the Malayan Emergency and Confrontation, including two RAAF members who died at Ubon in northeastern Thailand.

The two RAN aviators who lost their lives in 1965 and 1966 died in flying accidents and have no known grave.

The Air Force Cadets included a Catafalque Party mounted at the Cross of Sacrifice, an Honour Guard, a Squadron Banner Party, NMBVAA Banner Bearers and Vice-Regal Door Openers. The Catafalque Party and Banner Escorts carried innocuous .303-inch SMLE rifles, representative of the era of the Malayan wars of the 1950s and 1960s.

ABOVE Air Force Cadets at the Cross of Sacrifice with Her Excellency the Honourable Frances Adamson AC, Governor of SA, and her husband Rod Bunten.

RIGHT Gliding trainee LCDT Tegan Revolta in the Rest on Arms Reversed position at the Cross of Sacrifice.

SOLO PILOTS

ABOVE CUO Andrew Munro receives his first solo badge from SQNLDR(AAFC) Mark Dorward.

CONGRATULATIONS TO CUO ANDREW MUNRO AND CSGT HARRY HALL (203 SQUADRON), and CSGT (now CFSGT) Heath Mahoney (207 Squadron) who have been awarded their first solo badges.

Squadron Leader (AAFC) Mark Dorward, Commanding Officer and Chief Executive Officer of the AAFC's Elementary Flying Training School, says the aim of the flying training program is to provide a positive and inspirational aeronautical development experience for those who are interested in flying.

The AAFC offers opportunities for all Cadets to undertake a Cadet Aviation Experience flight as a passenger, and then a Pilot Experience flight with a qualified flying instructor for a hands-on opportunity to control an aircraft in flight.

"Opportunities for flying training are limited, requiring an application and selection process. Applications for 2024 flying training courses will be advertised shortly, so if you're interested keep an eye out," says SQNLDR(AAFC) Dorward.

CADETS IN ORBIT WITH THE ISS

CADETS OF THE AUSTRALIAN AIR LEAGUE (AAL) SOUTH AUSTRALIA GROUP recently had the opportunity to take the Air League's motto, *A Vinculo Terrae* (Free from the Bonds of the Earth), to heart when they spoke live to NASA astronaut Warren Hoburg as he orbited above the Earth onboard the International Space Station (ISS).

The link-up took place on the evening of 25 August at the Australian Space Discovery Centre in Adelaide, and was attended by cadets, officers, parents, supporters from the South Australia Group, and Australian Space Discovery Centre representatives. The Australian Space Discovery Centre opened in Adelaide in 2020 at the headquarters of the Australian Space Agency and aims to inspire the next generation of the space workforce with stories of innovation, curiosity and technology.

Using radio equipment provided by NASA, contact was made possible by members of the Amateur Radio on the International Space Group (ARISS) as the station passed over Europe at an altitude of 400km, travelling at more than 7km/s. The cadets had a short window of opportunity before the ISS went out of range.

In preparation for the event, the cadets of South Australia Group took part in a competition where they each submitted questions they would like to ask the astronauts. Following a selection process, 20 cadets were chosen to each ask their question. The questions posed included: what can you see from space, what are the future plans for the ISS, and can astronauts eat ice-cream in space?

With a degree in Aeronautics and Astronautics from MIT and a Doctorate in Electrical Engineering and Computer Science from UC Berkeley, Warren ('Woody') Hoburg reported for duty with NASA in 2017 and launched to the ISS as pilot of NASA's SpaceX Crew Dragon spacecraft on 2 March 2023. In his first mission, he has already conducted two extravehicular activities to install new solar arrays to help power the space station.

In December 2020, Woody was also announced as one of the eighteen NASA astronauts selected as part of the Artemis Program for a lunar mission in 2024.

While the cadets spoke with Woody via radio, the event was live streamed on the internet, allowing cadets in other states and members of the public to watch and listen, with amateur radio enthusiasts from as far away as Germany following along.

Although the AAL was dreamt up in an age when pioneers such as Sir Charles Kingsford Smith and Bert Hinkler were taking to the air in flimsy canvas and wire aircraft, its motto certainly has relevance for the cadets of today.

For further information about ARISS, see *ariss.org*, and for the Australian Space Discovery Centre, see *industry.gov.au/australian-space-discovery-centre*.

BELOW Astronaut Warren Hoburg on board the International Space Station. Photo: NASA.

ABOVE Warren Hoburg carries a roll-out solar array during a spacewalk outside the ISS in June. Photo: NASA.

LEFT During the evening, cadets also had the opportunity to explore the Space Discovery Centre.

BELOW LEFT Using equipment provided by NASA, cadets spoke to Warren Hoburg as he orbited the Earth.

ABOUT THE AUSTRALIAN AIR LEAGUE

The Australian Air League is a youth group for boys and girls aged eight years and older who are interested in aviation as a career or a hobby.

In the Air League they learn about aviation in all its forms through classes in the theory of flight, navigation, aircraft engines and a variety of interesting subjects. The Air League also aims to enable them to achieve their full potential and become better citizens who can effectively serve the community.

With squadrons in most states, the Air League has been serving the community in Australia since 1934. It is entirely self-funding and is staffed by volunteers.

airleague.com.au; phone 1800 502 175

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- P2V-7 Neptune (A89-273)
- Douglas C-47 (A65-94, A65-95, A65-90 - now N2-90)
- CA-25 Winjeel (A85-435)
- English Electric Canberra (A84-502)
- DH-115 Vampire T-35 (A79-637, A79-665)
- Mirage IIIO (A3-42)

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THE POWER OF LOVE

LOVE POWERS EXTRAORDINARY THINGS IN OUR LIVES, WRITES **PETER RING**.

OVER THE YEARS, 'leadership training' kept surfacing in my life: training that was being addressed as a pursuit of the intellect and as a task to perform. Leadership training that was too often run by intellectuals using emotionless language. And then I awakened to the thought that my wife quietly guided our family firmly with love and I began to appreciate the influence of love in that elusive quality called leadership.

Life needs to be a progression of incremental goals that sustain us spiritually, emotionally, physically and vocationally. Attainment of each goal is influenced, both positively and negatively, by the people involved. So, whether we like it or not, other people contribute to our goals and we need to consider our leadership as an everyday influence. We need to contribute to other people's mental state so that we foster positive, confident and productive people around us.

I admired and was inspired by many people I saw as good leaders. I saw they were liked, were excellent operators and, as a result, others willingly worked hard to achieve the set objective. As I was put in more and more demanding jobs, I found I had to involve others more. So, I did what came naturally to me: I analysed, planned and organised, and eventually, despite my trepidation, got to know the people around me. As I became confident in my craft, co-operation with people became easier and I started to observe team results that attracted good comment. Maybe I had become some sort of leader.

I copied some of the habits of my role models. They appeared to be natural networkers, but I later became aware that they worked hard at it. My role models helped others to succeed, and they supported honest input, spirited fun and positive emotions. My role models, without exception, were always open and forthright, mostly quietly, sometimes loudly, but always with affinity.

My role models had strong opinions but always focused on success for the team not for themselves. I learnt good leaders realise few of their challenges are about just the task. Systems and procedures to support the task are essential, but most challenges are about communication, team spirit and human emotions. Leadership is largely about collaboration in producing agreed frameworks. It is then about consistency and delegation within those frameworks, while offering encouragement and supportive advice and sometimes decisions.

Love is one of the most abused words. Love my job. Fell in love. For the love of Mike. Love is blind. Make love. Not for love nor money. No love lost. Love hurts. Love is in the air. Love is the most confusing, misused and whacko word and there are many cultural differences in conceptualising love and understanding its impact.

To me, nourishment is love. I do not mean love in the passionate sense such

as I love you and you love me. But I like to think some people might love some of the things I do. Not just jobs I do, but the interest I show in them and the many other ways I act.

I think love is looking at people and finding the positive things they do and loving that about them. In that context, love is the comfortable, open relationships within the team. That does not mean you overlook bad behaviour.

The power of love is a big concept. The power of love in a team. The power of love in extraordinary courage. The power of love in achievement. The power of love in commitment. The power of love in inspiration. The power of love that keeps human beings together. Love can even drive a person to risk their own life for others.

The word love seems to be socially acceptable in referring an emotional attachment to another or within a family. But, generally speaking, its use is frowned upon in places of business, teams or work and more formal situations.

Pulling petrol as a kid, I learnt something precious from Neville, the garage manager. He was a big and tough Australian National Champion wood cutter. Neville wasn't warm and fuzzy and he was never hugging the trees. He was built like a brick outhouse.

I was serving petrol to a big limo and accidentally spilt a little petrol on the paint. The limo owner started giving it to me and calling me all sorts of an idiot. I was copping it and feeling that was the way life was meant to be. I was always copping it. I had copped it from birth.

Then Neville, the champion woodcutter, said menacingly to the toff, "Don't speak to Peter like that again". My heart swelled. Someone stuck up for me for the first time in my life. Neville had expressed his love not for me but for fairness and no matter how gruff or tough he was in the future, I had seen another part of him – a part that loved everyone's right to some sort of dignity. Love comes in many packets: don't knock it back and don't fail to recognise it just because it is buried in something else.

At the age of 21, I looked at the rough and tumble, heroic WWII and Korean War fighter pilots and, later in life, I realised I had seen love in them. They did not exude love and understanding, they were not dreamy eyed and they certainly did not look lovingly at everyone. But they did practice love in their world. They demonstrated that their fighter pilot universe was friendly not hostile, despite the hostile life they trained for and had lived. They loved our team enough to be open, honest, down to earth and nurturing. They treated all the young fresh-faced fighter pilots, like me, with sometimes intense focus, to make us better pilots and people. Ultimately, I realised that type of love might even have saved my life.

At the ripe old age of 27, I decided to do everything with the flavour I had witnessed in my veteran-fighter-pilot role models. I call it love. You can call it what you want, but we cannot deny that there can be a power in a team that drives extraordinary achievement. I probably did not have much finesse at exploiting the power of love I had experienced, but I was going to try. I was going to be a better leader of myself. I decided that in my leadership role I wanted to have love for my world: tough love, honest love, supportive love, respectful love, inclusive love, cheerful love, love in the fullness of the expression.

One day I was driving through Newcastle to Port Stephens. It was a beautiful day and I was feeling happy and on top of my life. I unintentionally cut someone off when I changed lanes. I signalled an apology, but at the next set of lights, that vehicle pulled up alongside me and the driver threw a small missile at my passenger window. It struck hard. Then the lights turned green and the car accelerated away. Shocked, I saw red. I chased the assailant down the road, intending to ram or punch them. Just as I was catching up, the car turned off the main road. I wanted to follow, but it dawned on me that my objective was to go to Port Stephens, which was straight ahead. I suffered a momentary dilemma. I wanted to retaliate, but I kept getting a message in my head "go to Port Stephens". I finally decided to proceed, but I could not forget the incident: it was boiling in my head and my whole body, leaving me feeling unhappy and unfulfilled. What happened to the love for the world I'd had a few minutes ago?

All the way to Port Stephens, I pondered the instant change in my mental state. I could physically resume my life, but mentally I was still tied up, partially handicapped by that negative feeling. Then I remembered some advice about walking in the park: you can either focus on the dog poo that might be on the ground or focus on the beauty of the park, accept there is poo and step around it. So, with that, I launched back into my newfound challenge to let a little more love into my sole.

Why am I making such a fuss about the word love? Simple. Love powers so many extraordinary things and there is no other word that can replace it. Yet we frequently turn away from using it.

Have a look in your life and identify those people who inspired you and, more importantly, why. Was there some love involved?

> Love is something you and I must have. We must have it because our spirit feeds upon it. We must have it because without it we become weak and faint. Without love our self-esteem weakens. Without it our courage fails. Without love we can no longer look out confidently at the world. You and I need the strength and joy that comes from knowing that we are loved. With it we are creative. With it we march tirelessly. With it, and with it alone, we are able to sacrifice for others.
>
> **Chief Dan George, Tsleil-Waututh Nation**

CASHING IN ON COLLECTIBLES

FROM FINE CHINA TO CLASSIC CARS, COLLECTIBLES ARE BECOMING AN INCREASINGLY POPULAR INVESTMENT.

BEYOND THE CONVENTIONAL investment classes – fixed interest, shares and real estate, there's a segment called alternative Investments. A small subset of that segment, collectibles, is reported to be worth about $650 billion and appears to be growing year on year as more people combine a love of all manner of collectibles with an expectation (or perhaps a vain hope) of turning a profit.

There is no limit to the weird and wonderful objects people like to collect: wine, furniture, books, manuscripts, jewellery, watches, sporting equipment, fine china, bottles, military memorabilia, shoes, old cars, registration plates, petrol pumps and artworks (both physical and digital). If collecting appeals to you, it's worth reminding yourself of some key principles, especially if you're investing with the hope of profit.

VOLATILITY The value of collectible assets will often fluctuate, sometimes wildly, so factor that likelihood into your investment decisions because you may own the asset for a long time, especially in poor market conditions.

BORROWING Your default position should be to not borrow to buy a collectible. Never say never, but if you must borrow in order to buy, think carefully about what security you'll offer (the lender is likely to want your house) and how you'll repay the loan should interest rates rise, the economy tanks or your personal financial circumstances change.

LIQUIDITY In most cases, collectibles are illiquid assets. That is, they cannot be sold and turned into cash easily (unlike publicly listed shares which are generally saleable within 24 hours). Therefore, it would not be sensible to put all your eggs in the one basket. Diversification is the key. Make sure one collectible asset doesn't constitute a huge percentage of your immediately available asset base, lest your circumstances change, and you're forced into a fire sale.

RESEARCH The market for collectibles can be complex, therefore it's important to have a deep understanding of the asset type you're thinking of collecting. For example, if you're interested in the work of a particular artist, research and understand the artist's approach, style, methods, range of works on offer and the history of price movements over the long run.

CONDITION AND PROVENANCE The value of a collectible asset will be influenced by its condition and provenance. For example, the value of a vintage car will be greater if it's in excellent original condition inside and out, complete with its original engine, low kilometres and comprehensive maintenance records from initial delivery. Provenance relates to the history of the asset; notable previous owners, rarity, international appeal and recognition are prominent value adding attributes. You would also be wise to seek an independent expert's report on your proposed purchase. That could be money well spent.

FAKES An increasingly common challenge for buyers of collectible assets is to make sure that the proposed purchase is genuine. Fakes are all too common and the phenomenon is increasing in categories such as collectible watches, art and even historic cars. Independent expert advice on the veracity of a collectible is invaluable. It's worth watching the BBC's entertaining *Fake or Fortune* documentary series (available on ABC's iview) to get a feeling for the issues. Of course, fakes have been around forever. It's just that modern technology has made fake production much easier.

RARITY If you have the only sample of an object people want to collect, you're likely to be on a winner. A good example is British Guiana's 1856 one-cent Black on Magenta postage stamp of which there is believed to be only one in existence. As a result, the only known stamp was sold in June 2014 for $13.5 million… yes, for a one cent stamp! An extreme case, but it emphasises the point that rarity can be very desirable to collectors, but not always so do your homework.

TAXATION If you become involved in regularly buying and selling collectibles, you may be treated by the Australian Tax Office (ATO) as running a business rather than simply engaging in a hobby. There is no clear line of delineation between a business and a hobby, although regularity of transactions, registering a business name and marketing your activities may indicate that you're running a business. There may also be capital gain consequences in some circumstances. If this is of concern, we suggest that you consult the ATO website (ato.gov.au) or speak with a qualified accountant/registered tax agent (consult cpaaustralia.com.au or charteredaccountantsanz.com).

Air Commodore Robert M.C.Brown AM FCA (Ret'd). Chartered accountant, financial educator and independent member of the ADF Financial Services Consumer Centre (adfconsumer.gov.au).

AIR COMMODORE WILLIAM JOHN BELTON

29 September 1937 - 28 August 2023

BORN IN FORSTER, NSW, BILL BELTON COMMENCED his career at RAAF Wagga Wagga on No 8 Apprenticeship Course (Mangoes) in 1954, later attending No 32 Officers Initial Training Course. He graduated from Royal Melbourne Institute of Technology with an Associate Diploma in Mechanical Engineering before commencing duties as an ENG AERO.

His postings included: No 1 Aircraft Depot RAAF Base Laverton; Aeronautical Engineering Officer in-Charge of Control of Technical Plans Air Force Canberra; Staff Officer Aircraft RAAF Paris, France; Staff Officer Engineering RAAF London, UK; and Australian F-18A/B Tactical Fighter Project Sub-Office Arlington Virginia, USA. He completed RAF Staff Course and was a member of several Mirage replacement investigatory teams.

As a senior officer in the headquarters of both Support and Logistics Commands, Bill made an outstanding contribution to the development of contemporary logistics management serving as Chief of Logistics and Chief of Staff to several Air Officer Commanders. He was the instigator of the Weapon System Logistics Management concept that allowed the RAAF to embrace and conduct logistics on an integrated weapon system basis; the concept led to the devolvement of Weapon System Logistics Management Squadrons and more latterly to the formation of System Program Offices. Bill retired from the Air Force in 1992 as Chief of Staff Logistics Command, Melbourne.

Bill was recognised nationally for his leadership in the Australian aerospace profession, and the promotion of Australian aerospace engineering at an international level. He was the project leader for the establishment of the National Air and Space Museum of Australia at Point Cook and was Victorian Division President and Board Director of the RAAF Association. He was a Fellow and strong and active supporter of the Royal Aeronautical Society.

Bill was appointed Member of the Order of Australia in 1985 for services as the Senior Engineering Officer of the Tactical Fighter Project Office in the USA.

AIR VICE-MARSHAL DOUGLAS GEORGE CAMERON AO AFC

8 September 1930 - 30 August 2023

DOUG CAMERON WAS BORN IN NEW ZEALAND and as a member of the Air Training Corps learned to fly on Tiger Moths at what is now Auckland Airport. He was accepted for pilot training by the RAAF and joined No 8 Pilot Course in January 1952, graduating on 8 December with 30 RAAF and seven RAN pilots.

In early 1953, he qualified at Williamtown on Mustang and Vampire aircraft before posting to Japan where he converted to Meteor aircraft and subsequently to No 77 Squadron at Kimpo, Korea in June 1953. He completed six operational missions before the Armistice.

In January 1954, Doug was posted to No 2 Squadron and qualified on Canberra aircraft before a lengthy flight-test career at Aircraft Research and Development Unit (ARDU), Laverton and Avalon. He conducted initial production flight test of Winjeel and Sabre aircraft for GAF and CAC and participated on the Lincoln refurbishment program.

After a posting to Farnborough, UK for No 16 Empire Test Pilots Course in 1957, Doug was employed as an experimental test pilot at ARDU from 1958 to December 1961. He was posted back to the UK's primary flight test organisation, Aeroplane and Armament Experimental Establishment, Boscombe Down, in January 1962 for three years, and was involved in developmental flight testing of RAF and RN aircraft, including the English Electric Lightning fighter.

Returning to ARDU in January 1965 as Flight Test Squadron Commander, he qualified on the Mirage at No 2 Operational Conversion Unit in September, and then became heavily involved in GAF production and ARDU weapons clearance projects; development and clearance of a modified 1,300-litre centreline cine camera tank; and supersonic camera pods for the Sidewinder pylons. He was awarded the Air Force Cross for his flight test work in 1968.

Doug left ARDU to complete RAAF Staff College in 1970, followed by the first of several Russell Offices staff planning appointments, returning to ARDU as commanding officer in 1976. Involved in the relocation of ARDU from Laverton to Edinburgh in 1977, Doug finally left ARDU in December 1979 to be Director, Air Force Planning, before promotion in January 1982 and assigned Director General Plans and Policy.

Promoted to AVM in December 1984, he was posted as Commander, Integrated Air Defence System at Butterworth and appointed an Officer in the Order of Australia. He returned to Australia and retired in April 1987.

His 17 years of production and experimental test flying experience during a period of exceptional RAAF aircraft technological development, including four years as CO ARDU, made Doug Cameron the RAAF's most widely experienced test pilot. His calm and humble demeanour belied his qualities as a pilot and a leader.

AIR COMMODORE HARRY FREDERICK FREEMAN

31 October 1936 - 28 July 2023

FRED FREEMAN JOINED NO 8 RAAF COLLEGE COURSE on 17 January 1955 and, before graduating in 1958, displayed effective and skilled performance in all aspects of the college curriculum. He was master of the Life Saving contingent activities and Hockey Champion for four years. He trained on Wirraways in the final year at the college.

Posted to No 25 Squadron, he flew Vampires before completing a Sabre conversion at No 2 Operational Conversion Unit in 1960 followed by postings to No 75 Squadron Williamtown, No 3 Squadron, Butterworth – with two postings to No 79 Squadron to Ubon, Thailand, No 2OCU for FCI Course, No 77 Squadron, Headquarters Butterworth, Mirage conversion then Commanding Officer No 2 OCU.

Fred was a Category A Fighter Combat Instructor; a member of The Marksmen Sabre formation aerobic team; served on the staff at RAAF Staff College; and was Commandant of the Australian Defence Force Joint Services Staff College. Following a posting as Commanding Officer Base Squadron Amberley, he was promoted to Air Commodore and served as Air Attaché, Washington, from 1987 to 1990. He retired from the Air Force on return to Australia after completing 35 years of service.

In retirement, Fred worked part time as a consultant with Coffey Partners International managing an AUSAID program in southern Africa. He was also a volunteer and deputy chair on the state committee for the Duke of Edinburgh Scheme.

When asked about his career, he answered: "How does one compare the satisfaction of commanding the Base Support Squadron at Amberley, the RAAF's largest operational base, charged with the responsibility of providing the total logistic support for its operations with the Marksmen's card-five loops and rolls?"

His time as Commandant, Australian Defence Force Joint Services Staff College, charged with preparing senior officers and students from the Pacific, Asia, Europe, the USA, for future strategic policy-making positions was unquestionably another feather in his cap.

ABOVE LEFT
Marksmen pilots, from left, Bob Walsh, Bruce Grayson, Nobby Williams, Fred Freeman, Stu Back and Ron Johnson.

WING COMMANDER JAMES WALLACE GARLAND

28 April 1942 - 26 August 2023

JIM GARLAND LEFT NAMBOUR in January 1960 to join the Air Force on No 13 Course, the last RAAF College course, as it transitioned to RAAF Academy in 1961. One of eight eligible cadets undertaking a double-major physics degree at Melbourne University campus in the days before the course was developed by the university to be delivered at Point Cook.

An intelligent and natural leader, he was captain of the rugby and basketball teams, and was a senior cadet in fourth year. He graduated with the Sword of Honour and completed pilot training on No 50 Pilots Course followed by a posting to Williamtown to convert to Sabre aircraft.

In 1965, he was posted to No 78 Wing, Butterworth to fly with No 3 Squadron, and a deployment to Ubon, Thailand in 1966. A posting to No 82 Wing, Amberley followed with a conversion to Canberra aircraft and a posting to Vietnam in 1967 where he completed a six-month tour. Selected for F-111C conversion in the US, he successfully completed the course, but delayed aircraft delivery meant that Jim never flew the aircraft in service in Australia.

On return from the US, he completed the Flying Instructors Course at Sale and was posted to No 2 Flying Training School at Pearce, WA where he instructed for three and a half years on Macchi aircraft.

Several staff postings followed, including a detachment to Singapore on ANZUK Force Headquarter staff. On return to Australia and after undertaking the Army Staff Course at Queenscliff, Jim served as an instructor at the Joint Service Staff College. Promoted to Wing Commander, he served in the Force Development and Analysis Division, Department of Defence in 1978 for six months before retiring from the Air Force.

AIR VICE-MARSHAL EDWARD ARUNDEL RADFORD AO

31 December 1935 - 16 August 2023

EDWARD "TED" ARUNDEL RADFORD JOINED NO 6 RAAF COLLEGE COURSE on 26 January 1953 and graduated top of his course in December 1959, winning the Queen's Medal, the Sword of Honour and the Flying Trophy.

Posted to No 22 Squadron, Richmond, flying Wirraways, Vampires and Meteors he suffered an accident on take-off in a Meteor that ended in a ditch off the Windsor end of the runway. The outcome of the inquiry noted "Inexperience, too hot, nil wind, brakes out of adjustment and low brake pressure". As a result of the injury suffered in the accident, Ted was off flying for three months.

In January 1958, Ted was posted to No 2 Operational Training Unit to fly single-seat Vampires, before completing a Sabre conversion. Posting to No 3 Squadron, also at RAAF Williamtown, followed. However, the squadron deployed to RAAF Butterworth later that year – 6,000nm via Townsville, Darwin, Biak, Guiuan and Labuan, because of an unfriendly Indonesia.

In November 1959, he was PA to AOC Operational Command, first to Sir Valston Hancock and then Frank Headlam. Sir Valston was a keen flyer and as a result, the pair flew two Meteors to most base inspections.

Following his posting to Operational Command, Ted completed a science degree at the RAAF Academy, followed by QFI course at Central Flying School and a tour as a QFI at No 1 Basic Flying Training School, the last 15 months as the CFI. He was a member of, and then led, the Winjeel flying display team, The Yellow Streaks, so named because he ensured all the manoeuvres, while spectacular, were designed to be ultra-safe.

In March 67, Ted returned to CFS for a jet refresher and another brief period as CFI, before completing a Mirage conversion and a return to No 3 Squadron as Flight Commander and then Commanding Officer. Once again, another deployment to Butterworth in February 1969, but this time more directly via Indonesia.

Completing Staff College in 1971, he noted that it was "just like boarding school except we were allowed to drink and smoke!". Three staff jobs followed: Central Studies Establishment on force structure studies, Director Joint Plans and Director Air Force Operations.

1977 saw Ted back to flying on F-111s at Amberley before a posting to the National Defence College. A posting as Director General Tactical Fighter Project in 1980 leading teams to France and the USA to evaluate the Mirage 2000, the F-16 and F-18, culminating in selection of the F/A-18.

He was appointed AOC Operational Command, re-titled Air Commander Australia in 1986, after which he was Deputy Chief of Air Staff. He resigned in 1990 after 37 very enjoyable and satisfying years, and during which he flew 28 aircraft types for a total of 4,300 hours.

Ted received the Queen's Commendation for Valuable Service in the Air in June 1967, was appointed a Member of the Order of Australia in 1977 and promoted to Officer in the Order of Australia in 1985 .

In civilian life he was Deputy Chief Executive Operations at Qantas, and Race Director for the London to Sydney Air Race, in March/April 2001, an official event for Australia's Centenary of Federation.

REVIEW BY Alan Lyons

A SOURCE OF PRIDE, THE HISTORY OF NO 22 (CITY OF SYDNEY) SQUADRON 1936 - 1946

By **RICHARD HUTCHINSON,**
No 22 Squadron Association; RRP $55

NO 22 (CITY OF SYDNEY) SQUADRON was formed on 20 April 1936 after the Australian Parliament took advice from Air Marshal Sir Richard Williams, concerned about the war clouds gathering in Europe. Five "city squadrons" were formed.

Under the command of SQNLDR D.E.L. Wilson, the squadron consisted of seven officers, one warrant officer, 16 non-commissioned officers and other ranks. It was equipped with three Gipsy Moth trainers and two Hawker Demon general purpose fighter/bombers.

The squadron's first assignments of World War II were army support and towing targets for anti-aircraft practice. In 1941, the unit was equipped with Anson and Wirraway aircraft and flew coastal patrols along the eastern seaboard. By November 1942, the squadron had moved to Port Moresby, New Guinea and, equipped with Boston light bombers, attacked enemy targets and shipping in the Buna-Gona area.

During an attack on the Salamaua Isthmus, Flight Lieutenant W.E. Newton and his crew were shot down and forced to land at sea. Newton and Flight Sergeant J. Lyon were captured by Japanese troops and later executed. Newton received a posthumous Victoria Cross.

Japanese defences and counter attacks left the squadron with few serviceable aircraft and it was forced to move to Noemfoor to rearm for operations with Beaufighters. In June 1945, 22SQN returned to Morotai and, at the end of the war, moved to Deniliquin, before being disbanded on 15 August 1946.

A Source of Pride is a comprehensive history with an excellent selection of photographs and images, some taken by squadron members during operations.

Order from alanlyons@optusnet.com.au

REVIEW BY Andy Wright

WE TOGETHER: 451 AND 453 SQUADRONS AT WAR

By **ADAM LUNNEY**
Mortons Media Company, UK; RRP $21.55 (Hardcover)

SPITFIRE TITLES ARE OFTEN on aviation bestseller lists, yet areas of the type's history still await their time in the sun or have been written and forgotten.

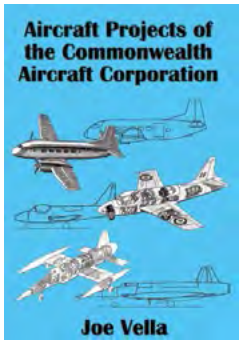
No 451 Squadron's first operations were flown in the second half of 1941 in North Africa. It then moved to Cyprus and the Palestine theatre. Rolling into 1943, the squadron began to see improvements, evolving into a Spitfire unit on Corsica. Its participation in Operation Dragoon in mid-August 1944 finally saw the unit operating in the same country as No 453 Squadron.

Lunney's previous book concluded with 453SQN in Normandy at the end of August. September saw the Australians move bases several times, including back to England. They recommenced ops with a focus on destroying V2 launchers. That intensive period continued into 1945 as 451SQN entered the fray. They had a relatively quiet time until March when an Australian wing (No 123 Wing) finally became a reality.

A strength of *We Together* is the variety of included reminiscences. They extend to groundcrew, pilots as POWs – or on the run – and, post-war, revealing the frustrations of remaining in Europe, the needless loss of men in accidents, and dealing with the Russians. It is as comprehensive as it gets.

A superior shelf-presence results from combining Mortons' house style with dynamic artwork. All the expected endpapers are there and contribute 40-plus pages to the imposing 320-page jacketless hardback.

We Together is a solid, well-structured history. The reading can bog down, when even the tenacious author can add little colour, but that reflects the operational tempo at the time. Enjoy the ride and revel in the history of two Australian squadrons now very much remembered.



PRECIS BY Joe Vella

AIRCRAFT PROJECTS OF THE COMMONWEALTH AIRCRAFT CORPORATION

By **JOE VELLA**
Self-published; RRP $65

THE PRIVATE ENTERPRISE COMMONWEALTH AIRCRAFT CORPORATION (CAC) was established in 1936 by leading industrialists in response to the urgings of AVM Richard Williams for a local aircraft production industry that would support the RAAF. It rapidly expanded to employ a peak of 7,400 personnel in January 1944 and deliver 1,290 aircraft to war's end.

From 1943 to about 1960 there were large and small concepts and proposals that kept it abreast with overseas developments to interest the RAAF, but it was hampered by a lack of aviation research and development funds and an air force with a limited budget unable to support significant design risks.

CAC produced the Wirraway, Wackett Trainer, Boomerang, Mustang, Winjeel, Sabre, Macchi trainer, Mirage (part) and Kiowa helicopter. As well as Pratt & Whitney radial engines; Rolls Royce Merlin; Nene, Avon; and ATAR jet engines. There were joint designs with BAC: RAAF Neptune and Orion system upgrades; Barra sonobuoy development; and Ikara missile launcher production. Only 21 civil aircraft were built.

The book is a reference to the 107 projects of the built aircraft, conceptual designs, aero engines and other aviation works including those which were brief paper ideas. The political and economic context of the era is also explained. It features 101-line drawings, prepared specifically for the book, which complement the CAC factory origin drawings. Performance and dimensional data tables for most of the projects are included. The 405 page book contains 12 chapters, a brief company history, comprehensive appendices and 23 pages of photographs.

Online print-on-demand from Booktopia.com.au; Fishpond.com.au.

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