GROUP OF EIGHT AUSTRALIA

Curated:

Capability to support AUKUS Pillar II

THE UNIVERSITY OF WESTERN AUSTRALIA

MONASH University

Australian National University

THE UNIVERSITY of ADELAIDE

THE UNIVERSITY OF MELBOURNE

UNSW SYDNEY

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

THE UNIVERSITY OF SYDNEY

Contents

Introduction

As Group of Eight (Go8) Chief Executive, I take great pride in presenting the curated AUKUS Capability of the eight Go8 members, released in conjunction with the Go8 Defence Security Dialogue held at the Australian High Commission in London in June 2024.

Our universities are at the forefront of Australia's research effort and nowhere is this more evident than in the defence related research and education we undertake.

This research effort provides a strong foundation to turbocharging our efforts to support the AUKUS platform – and we stand ready to further support the nation's defence research effort in bringing AUKUS to successful delivery.

The Go8 universities undertake 70 per cent of all university based research in Australia and receive more than half of the total university sector's defence R&D investment.

Our universities, all ranked in the top 100 globally are critical to the success of AUKUS with significant capability in all areas identified under Pillar II.

We are a trusted partner and have been at the forefront of globally defining defence and security technology and systems advances for many decades.

We are not afraid to say we are home to the best – and proud to be so.

Being the best, striving to never be anything less has enabled the Go8 to build solid defence research partnerships.

But we want to do so much more and we want to ensure we work to have Defence and our global partners better understand and have more visibility of what we can provide.

This is what sits behind this publication. Our curated capability statement sets out who within the Go8 can help and what we can do.

Vicki Thomson
Go8 Chief Executive

Curated capability to support AUKUS Pillar II

A detailed understanding of our capability in each of the AUKUS Pillar II streams provides a basis for establishing how our universities can – and do – contribute to the AUKUS partnership, through our research and education.

The success of AUKUS, Australia's future research capability and our national security will, in a large part, be dependent upon understanding our existing capability and how best we leverage that expertise.

The foundation already exists as underscored by the variety of activity in the six main and two additional Pillar II streams across the eight universities, the global footprint of the Go8 in these streams, and the extent of collaboration in these areas with AUKUS partner institutions.

Across the eight universities, there is the potential to drive AUKUS focused workforce development through undergraduate and postgraduate courses in related areas; capacity-building via defence institutes; and career and skill-based partnerships with industry.

Figure 1: Grid showing AUKUS Pillar II capability across the eight Go8 universities

Go8 University	Undersea capabilities	Quantum technologies	AI and autonomy	Advanced Cyber	Hypersonic and counter-hypersonic capabilities	Electronic warfare	Innovation	Information sharing
University of Queensland	✓	✓	✓	✓	✓	✓	✓	✓
Australian National University	✓	✓	✓	✓	✓	✓	✓	✓
UNSW Sydney	✓	✓	✓	✓	✓	✓	✓	✓
University of Sydney	✓	✓	✓	✓	✓	✓	✓	✓
University of Melbourne	✓	✓	✓	✓	✓	✓	✓	✓
Monash University	✗	✓	✓	✓	✓	✓	✓	✓
University of Adelaide	✓	✓	✓	✓	✓	✓	✓	✓
University of Western Australia	✓	✓	✓	✓	✗	✓	✓	✓

Go8 Global footprint in AUKUS-related research

The Go8's collective research output in 15 fields listed below, shows that **the Go8 is the prominent Australian contributor in the majority of the AUKUS-related areas.** That research is underpinned, as it must be, by quality, with a greater percentage of Go8 research appearing in the **world's top 1 per cent citations than our global counterparts for many of these fields.**

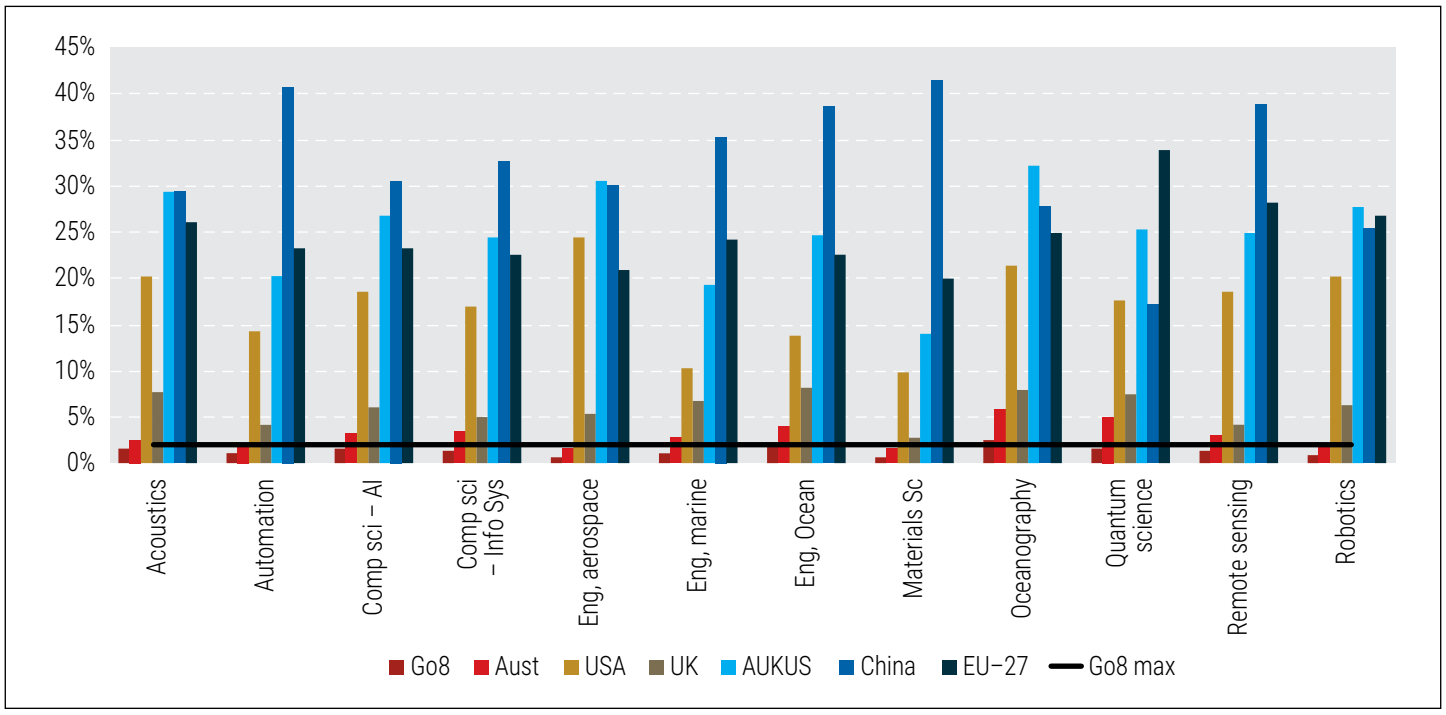
Research area	Relevant Pillar II stream
Acoustics	Undersea capability
Automation & Control Systems	AI & Autonomy
Computer Science, Artificial Intelligence	AI & Autonomy; Advanced Cyber
Computer Science, Information Systems	AI & Autonomy; Advanced Cyber
Engineering, Aerospace	Hypersonic & counter-hypersonic
Engineering, Marine	Undersea capability
Engineering, Ocean	Undersea capability
Materials Science, Coatings & Films	Undersea capability
Oceanography	Undersea capability
Quantum Science & Technology	Quantum
Remote Sensing	Undersea capability
Robotics	AI & Autonomy

Go8 Volume of research in AUKUS-related research

In global terms, Go8 research has the largest footprint in Oceanography (2.5 per cent of global output), followed by Ocean Engineering (2.1 per cent), Quantum Science (1.7 per cent) and AI (1.7 per cent).

This is a remarkable performance out of just eight universities when we consider Australia's population, at almost 27 million is around 0.33 per cent of the global population – 40 per cent that of the UK, and around 8 per cent of the US[1].

Chart 1: % of global publications in AUKUS Pillar II research areas by AUKUS, country/ region and Go8, 2018–2022



1 References data from the Australian Bureau of Statistics, United Nations Populations Fund, UK Office for National Statistics, and the US Census.

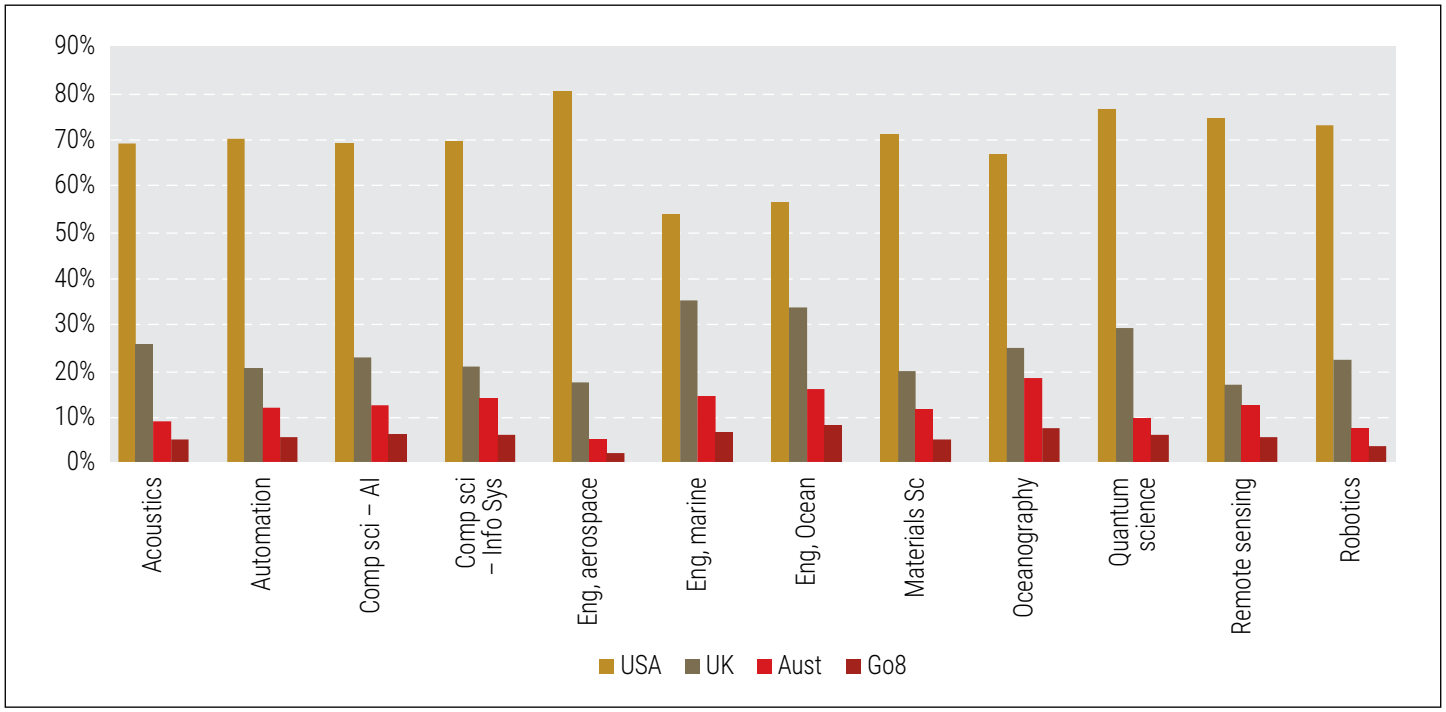
Curated capability to support AUKUS Pillar II

Go8 proportion of AUKUS partner publications in AUKUS-related research

Further examination of how Go8 universities compare to our AUKUS partners in terms of the proportion of research publications also involving UK and/or US, shows a comparatively **greater Go8 involvement than globally.** Ocean Engineering (8.4 per cent) becomes the top area of involvement, followed by Oceanography (7.9 per cent), Marine Engineering (6.7 per cent), Quantum Science (6.6 per cent) and AI (6.2 per cent).

Regardless of the area of research, it is clear that Go8 universities dominate the Australian contribution (ranging from 43 per cent of Australian research for Information Systems to 66 per cent for Quantum Science).

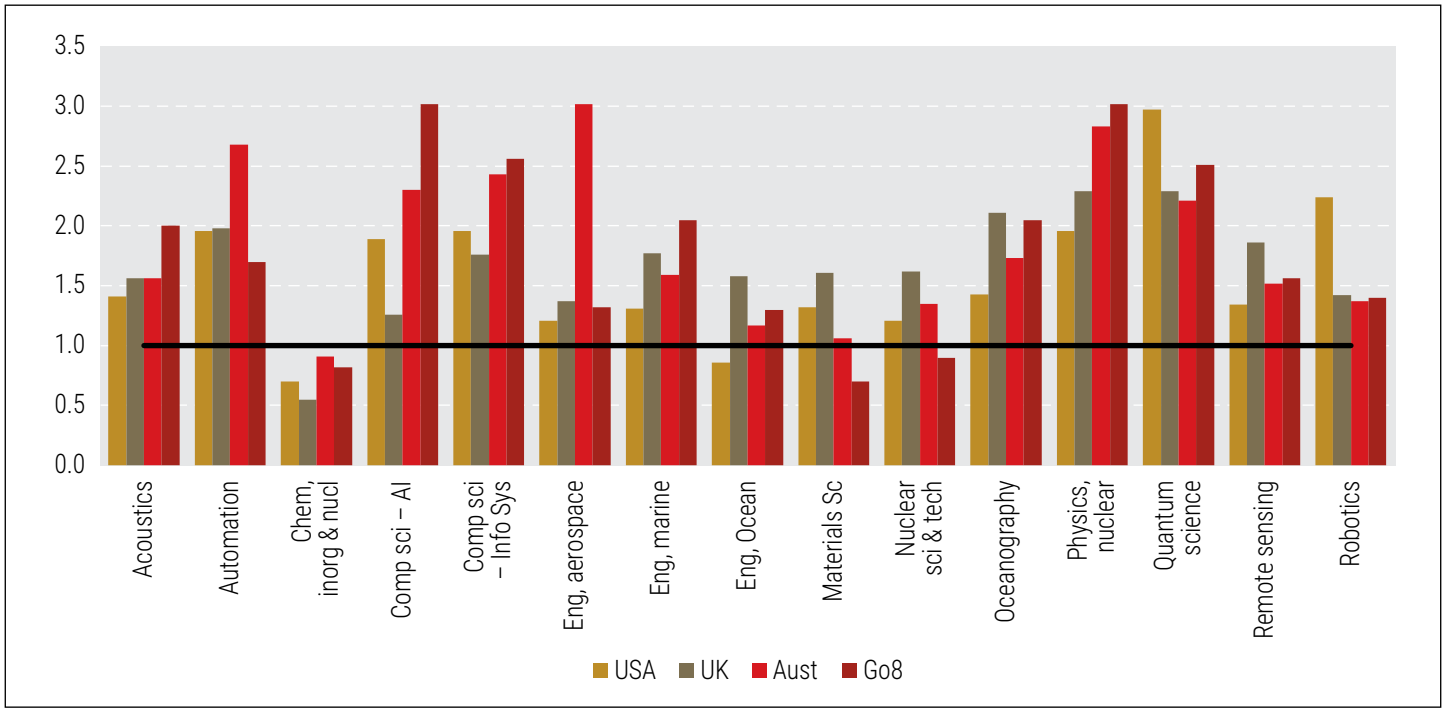
Chart 2: % of AUKUS partner publications in AUKUS Pillar II research areas by country and Go8, 2018–2022



Go8 Quality of research in AUKUS-related research

Our impact is particularly significant when considering the proportion of Go8 research publications cited in the top 1 per cent of global citations in AUKUS-related research. This is remarkably stark when compared to the total proportion for Australia, UK and the US respectively. Overall, across the 15 areas of research, the Go8's share is 3.5 per cent (Australia 3.3 per cent), US at 2.7 per cent and the UK at 2.5 per cent, of publications in the top 1 per cent cited. This is underpinned by the Go8's strengths in AI, Oceanography, Marine Engineering, and Acoustics.

Chart 3: % of documents in the top 1% globally cited publications in AUKUS Pillar II research areas by country and Go8, 2018–2022



The University of Adelaide

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Skills and capability

The University of Adelaide hosts a strong and embedded program of fundamental and translational research in Defence relevant technologies with significant funding from the Australian Department of Defence. The University is also a lead partner in the Defence Trailblazer, together with Go8 member UNSW, Sydney and over 50 industry partners. The Defence Trailblazer is a pioneering research translation initiative aimed at strengthening collaboration between academia, industry and defence. The University has been a member of the Australian Government's Defence Industry Security Program (DISP) for nearly a decade.

The University's research addresses AUKUS Pillar II priorities, with strengths in artificial intelligence and autonomy, quantum technologies, and advanced cyber technologies.

Partnerships, both nationally and internationally, are an important element of the University's approach to Defence research.

THE UNIVERSITY of ADELAIDE

The University partners with 12 Australian universities in Defence research and key international partners include the University of Maryland College Park, the University of Exeter, and the University of Nottingham.

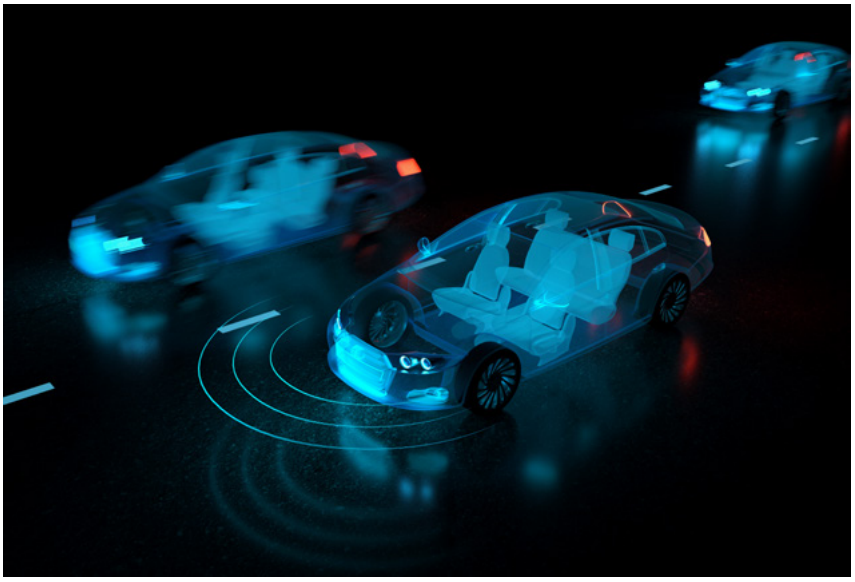
Research strengths

Undersea capabilities

The University has a long history of collaborative research with Defence in acoustics, vibration and control, with application to undersea acoustic signature management and continues to deploy these capabilities in fundamental and translational research efforts.

Quantum technologies

The University undertakes a significant proportion of fundamental and translational research in quantum technologies funded by the Department of Defence. These include quantum-assured PNT (position, navigation, and timing), quantum sensing, and quantum materials.



Artificial Intelligence and Autonomy

The University hosts Australia's largest concentration of artificial intelligence and machine learning researchers in the University's Australian Institute for Machine Learning (AIML). AIML has a key focus on computer vision.

The University's capabilities across this area include the technical and human sciences with expertise in simultaneous location and mapping in autonomous vehicles; robotics and autonomous systems; and human autonomy teaming.

The University of Adelaide

Advanced Cyber

Advanced cyber research is multi-disciplinary, drawing expertise and insights from cyber security, communications networks, psychology, data science, and artificial intelligence. Each area has industry connections that provide pathways to real world impact and experience across cyber-AI, deception and influence.

Hypersonic and Counter-Hypersonic Capabilities

The University undertakes research in counter-hypersonic technologies including directed energy counter-measures based on ultrashort and short pulsed lasers (USPL).

Together with key partners, the University operates specialised laboratories where qualified students and Defence personnel can gain hands-on experience in working with these advanced capabilities.

Electronic Warfare

The University's research contributes to the Electronic Support element of Electronic Warfare, with research in advanced electromagnetic sensing and in radar systems.

Research infrastructure

In partnership with Government and industry, the University has established a number of world-class research institutes and centres which support AUKUS Pillar II.

Research infrastructure includes:

- The Institute for Photonics and Advanced Sensing (IPAS) suite of laboratories
- The Australian Institute of Machine Learning (AIML)
- The Cyber Innovation and Research Centre (CIRC), a joint Defence Science and Technology Group (DSTG) and University facility.

The University also has facilities for hands-on collaborative research and experience for acoustics, vibration, and control; quantum technologies; advanced cyber; and USPL.

Workforce development

In addition to the University's 'business as usual' education and higher degree research programs, the following programs are specifically focused on AUKUS Pillar II priority areas:

- Masters in Marine Engineering includes submarine design and topics on undersea technologies
- Defence Trailblazer Industry PhD program (across five AUKUS Pillar II areas)
- South Australian Government Industry Doctoral Training Centre (IDTC) PhD scholarships in Quantum
- Summer internships in cyber for undergraduates with DSTG supervisors (advanced cyber)
- Leadership and participation in NATO Locked Shields Exercise (advanced cyber)
- USPL PhD program (counter hypersonics).

The University of Adelaide

Collaborations

Major partners include:

- The Australian Government's DSTG and the Department of Defence
- Group of Eight partners – UNSW, University of Sydney and the University of Melbourne
- Robotics and Autonomous Systems research collaborations with 11 Australian Universities:
  - » Deakin University
  - » Swinburne University of Technology
  - » Australian National University
  - » Western Sydney University
  - » University of Technology Sydney
  - » University of Sydney
  - » Macquarie University
  - » Queensland University of Technology
  - » UNSW
  - » University of Melbourne
  - » University of Adelaide
- US: The Applied Research Laboratory in Intelligence and Security (ARLIS) at the University of Maryland College Park – co-ran a two-year international seminar program and now exploring a variety of joint collaborations in information warfare and advanced cyber
- UK: The Ministry of Defence funded Defence Data Research Centre (DDRC), led by the University of Exeter, with the Universities of Surrey and Liverpool
- AUKUS: The Digital Disruption in Defence Research Community (D3RC) with partners DDRC, University of Adelaide, Stanford University, MIT Lincoln Laboratories, and ARLIS.

Key examples

Defence Trailblazer

The Defence Trailblazer is transforming defence innovation through a collaborative partnership between the University, UNSW, and partners, with support from the Australian Government's Department of Education.

QuantX

QuantX Labs is developing a suite of quantum sensor and precision timing products to enhance communications, navigation, surveillance, and defence systems, led by their Cryogenic Sapphire Oscillator the "Cryoclock".

Centre for Augmented Reasoning

The University's Centre for Augmented Reasoning (CAR) is a four-year AU$20 million investment by the Australian Government's Department of Education in people and research to develop the high-calibre machine learning expertise Australia needs to be an active participant in the machine learning-enabled global economy.

Key personnel

The University and its partners consider a list of key personnel as sensitive. Further information should be requested via the University's Defence and Security Institute at E: defence@adelaide.edu.au

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The University of Adelaide

Defence Trailblazer

The AU$240 million Defence Trailblazer is transforming defence innovation through a collaborative partnership between two Go8 universities – the University of Adelaide and UNSW – and industry partners, with support from the Australian Government's Trailblazer Universities Program.

It is an exemplar of academic, industry and government collaboration to advance AUKUS objectives, bringing together 42 industry partners including small-medium enterprises and multinational Primes with Australia's top two defence-focused universities.

Partners include Lockheed Martin Australia, Babcock, SAAB Australia, Cisco, Northrop Grumman Australia, Ratheon Australia, Thales Australia, as well as locally grown companies such as Silicon Quantum Computing, Innovor Technologies, and Diraq.

The Defence Trailblazer will strengthen Australia's defence sovereign capabilities through the commercialisation of new technologies and solutions, as well as develop specialised knowledge and skills to equip the next generation of innovators to meet current and future workforce needs of defence. These include in key areas such as:

- quantum materials, technologies and computing
- defensive hypersonics
- cyber technologies
- robotics and AI
- defence space technologies.

Defence Trailblazer *(continued)*

Research in support of industry includes topics such as quantum key distribution communications, a collaboration with Northrup Grumman, and AI algorithms assessing the cognitive load of aircrew, a partnership with CAE.

As well as conducting research that will deliver capabilities aligned with AUKUS Pillar II, the Defence Trailblazer program is running a Workforce, Innovation and Culture portfolio that includes an industry-education gateway offering a range of opportunities for collaboration. This portfolio is also running a series of cybersecurity upskilling activities in addition to innovation programs that will build an ecosystem system that support entrepreneurs, researchers and students accelerate.

It is estimated that the Defence Trailblazer project will deliver AU$1.5 billion in terms of net economic benefit for the Australian economy over the next 10 years and develop 100 new products, directly create more than 1,000 jobs and another 1,400 additional jobs throughout the wider defence industry[2].

2 https://ministers.education.gov.au/chisholm/new-240-million-trailblazer-project-create-defence-industry-future

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Skills and capability

UNSW is committed to advancing AUKUS through enduring and deepening relationships with the Department of Defence, the Australian Defence Force and industry. A main driver for UNSW's creation in 1949 was the realisation that the technological innovation that had been key to Allied success in World War Two required more engineers and technologists across all disciplines to drive economic growth. Today UNSW is actively involved in a range of domestic and international research collaborations with government and industry in the three AUKUS nations, with each pivoting towards solving complex problems and applying breakthroughs in technologies related to AUKUS Pillar II capabilities.

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Complementing world-class defence research, UNSW provides a range of accredited education programs that support AUKUS objectives.

UNSW has been educating officers in the Australian Defence Force for over 50 years and is proud to have alumni among Australia's most senior defence force leaders that are operating from seabed to space.

Understanding the importance of lifelong learning for professionals in the defence sector, UNSW also provides a suite of tailored and stackable short-courses and executive education programs.

In addition to hosting a Defence Research Institute that works across the entire university to stimulate and unify defence related activities, UNSW runs flagship programs: the Defence Trailblazer and Security and Defence PluS. Through these programs UNSW is working with a broad range of domestic and international partners to advance AUKUS and shared national security interests.

Research strengths

Undersea capabilities

The undersea research team at UNSW has an impressive track record in various areas of wireless communication, such as acoustic communication, signal processing, AI-enabled sensing, channel estimation and tracking, array signal processing, error control coding, secured undersea networking, localisation and navigation of autonomous underwater vehicles, and underwater sensor data collection. The team also works with unmanned aerial vehicles for submarines' covert communications and intruder interception. The School of Electrical Engineering and Telecommunications' Wireless and Acoustic Communications Research Lab has first-class research and development facilities which are highly beneficial for AUKUS objectives. These facilities are crucial for developing undersea communication and sensing algorithms and prototypes. They are also essential for navigation of autonomous underwater vehicles for intruder interception and underwater sensor data collection.

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Quantum technologies

UNSW has a long history of world leading research in quantum technologies. Beginning in the late 1990s, and continuing until today, UNSW has been at the centre of Australia's Quantum Technology research effort. UNSW has many world-leading quantum technology research groups (more than 15 groups encompassing more than 150 researchers) across the Faculties of Engineering and Science as well as at the UNSW Canberra campus.

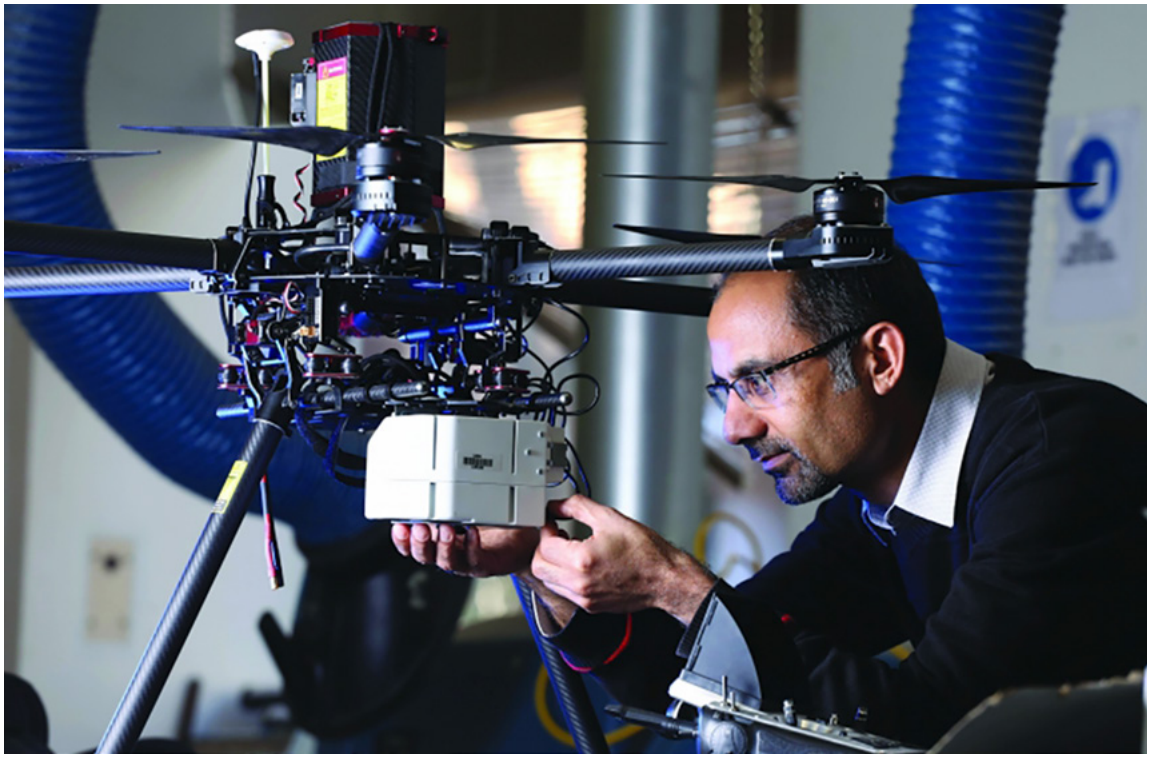
UNSW also has a strong presence in the field of quantum communication and quantum sensing. The latter area is focussed on using quantum techniques to enhance timing measurements for network operations and enhanced super-resolution limits for detection of satellites and astrophysical objects. In the quantum communication area, UNSW has been largely focussed on the use of quantum key distribution via satellites to deliver unconditional communication security over large distances.

Alongside these strengths are additional capacity in quantum simulation, spin control hardware and related technology, and significant fundamental research efforts targeted at emerging quantum technologies in sensing and computing, strongly overlapping with the Quantum Technologies, Advanced Cyber and Information Sharing streams of AUKUS Pillar II.

Comprising over 300 academics and providing support to more than 50 research groups, labs and centres, the UNSW AI Institute spans across multiple faculties including Engineering, Science, Business, Law & Justice, Medicine & Health, and Arts Design & Architecture, with a specific Defence-related research focus centred at UNSW Canberra.

Artificial Intelligence and Autonomy

UNSW's research strengths in AI and Autonomy are represented by the UNSW AI Institute – the flagship research institute focused on artificial intelligence, data science and machine learning. Comprising



Dr Simit Raval, School of Minerals and Energy Resources Engineering pictured with a drone-based scanning system

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UNSW staff members have a broad range of experience and specific AI expertise in algorithmic decision theory, robotics, embedded machine learning, edge-AI, trusted autonomy for defence applications, machine vision, human-machine teaming, swarm intelligence, deep learning, deployment of in-orbit machine learning for space missions, data science and analytics, as well as the ethical considerations of using AI and autonomous systems in armed conflict. Key domains include: defence; aerospace; transport and logistics; pandemic and disaster response; health and well-being; and energy, climate and sustainability.

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The UNSW AI Institute works with a range of stakeholders across the defence sector, industry, government and academia on a domestic and international level. An integral part of the Defence Trailblazer Program, the UNSW AI Institute's key research capabilities include:

- Advanced opto-electric sensors
- Automatic mental and task load recognition
- Data-efficient machine learning and optimisation in dynamic contexts
- Enhanced Processing and Analysis of Human Language Data
- Human Behaviour Analysis
- Signal, Information and Machine Intelligence
- Trusted Autonomy
- Mobile and wearable sensing and AI
- Analytics and Forecasting
- Prediction + Optimisation
- Natural Language Processing
- Mobility data science
- On-device AI; Edge and federated learning.

Key funding partners include Defence, government agencies and industry from across Australia, the US and UK, such as the Australian Department of Defence, CSIRO, Cyber Security Cooperative Research Centre (CRC), US Air Force, US Army, US Navy, UK National Cyber Security Centre (NCSC), Cisco Research and defence prime contractors.

Advanced Cyber

UNSW is a leader in conducting excellence in multidisciplinary cyber security research, education, innovation, and commercialisation. This leadership is supported by the renowned UNSW Institute for Cyber Security (IFCYBER), spanning both Canberra and Sydney with over 100 academics across all faculties.

IFCYBER draws from and focusses efforts across all UNSW faculties and partners to identify, address and resolve critical path issues for the Defence and National Cyber Security system, and vulnerable parts of the national economy through a combination of Research, Teaching and Translation.

Key research capabilities and strengths include:

- Complex Systems Security
- Intelligent Security
- Internet of Things Analysis and Applications
- Networked Systems and Security Research Group
- Quadseal Hardware Attack Mitigation
- Secure and Private Embedded Real Time Analytics
- Critical Infrastructure Security
- Deception for Cyber Defence
- Information Warfare Activities
- Information Warfare: Mis-information, Dis-Information, Mal-information and the Grey Zone
- Model Checking Knowledge (MCK) in Distributed and Multi-AGENT Systems
- Online Influence Simulation
- Open Source Cyber Threat Intelligence
- Analysing Encrypted Network Traffic for Cyber Intelligence
- Trustworthy Machine Learning
- Trustworthy Systems
- Verifiable Confidential Computing for Distributed Trustworthy Systems
- Wireless and Acoustic Communications and Sensing.

The UNSW Trustworthy Systems are the world leader in highly secure operating system (OS) technology for real-world use. UNSW's seL4 microkernel, the first ever OS kernel mathematically proven free of implementation defects and able to enforce security, is deployed in defence and other security-critical applications domestically, and in several of Australia's partner nations in the Indo Pacific. Its development is funded by US DARPA and the UK National Cyber Security Centre (NCSC).

The UNSW Information Systems and Privacy (ISPRI) group l has strong capabilities in securing critical networked infrastructure, early and accurate detection of

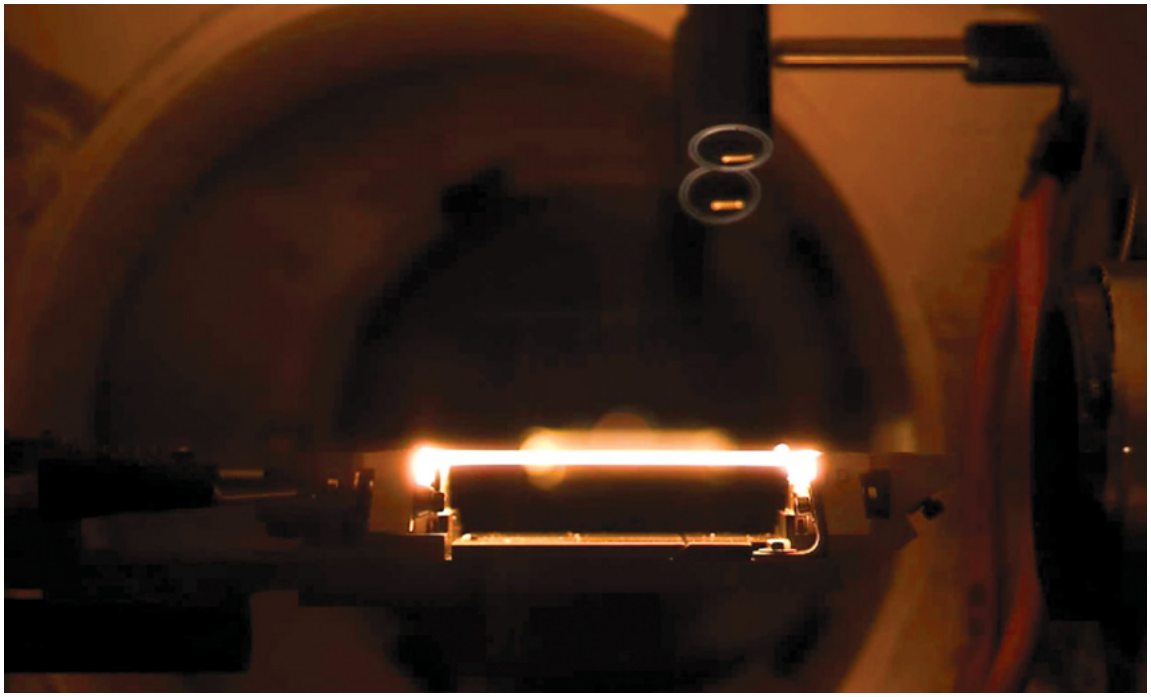
UNSW Sydney

mis/mal/dis-information on social media, applied cryptography and hardware and software security. UNSW has a multidisciplinary team specialising in information warfare, and the impact on citizens, institutions, and critical infrastructure. With expertise in cyber security, electronic warfare and information operations using strategic, evidence-based, and academically rigorous approaches, the UNSW multidisciplinary team includes engineers, behaviouralists, linguists, narrative and simulation research specialists, and model designers.

Hypersonic and Counter-Hypersonic Capabilities

UNSW has well-established research strengths across the field of hypersonics and counter-hypersonics, from the study of fundamental physical phenomena through to very applied work on the design, performance and operation of hypersonic vehicles. These extend from core hypersonics research through to allied capabilities in space, AI and materials science and engineering. These include new flight experiment capability which is being developed with key industry partners

UNSW in-house testng of aerostructures to withstand extreme conditons



to support the development of vehicle and ecosystem technologies by AUKUS partners.

Electronic Warfare

The electromagnetic spectrum is increasingly contested. The three countries will work together to share understanding of tools, techniques, and technology to enable our forces to operate in contested and degraded environments.

capabilities are crucial for forces operating in contested environments, addressing challenges like active jamming, low signal quality, and eavesdropping threats.

In Pattern of Life Deep Learning, UNSW showcases its broad Electronic Warfare expertise, predicting intent and enhancing anomaly detection in the Electromagnetic Spectrum (ES). The university's leadership extends to efficient resource allocation and

Research leaders at UNSW have pioneered diagnostic signal processing, notably detecting bearing faults in drones non-intrusively.

UNSW stands out for its major research strengths in Electronic Warfare, contributing significantly to AUKUS Pillar II capability priorities. Under the research efforts in Signal Processing, UNSW excels in traditional and machine learning techniques, enabling spectrum sensing, target detection, interference suppression, and information security. Research leaders at UNSW have pioneered diagnostic signal processing, notably detecting bearing faults in drones non-intrusively. These

control within congested electro-magnetic environments, emphasising practical applications in signal processing and communications. UNSW's multidisciplinary approach highlights seamless integration, delivering high-quality research outcomes for Defense. The imple-mentation of advanced techniques, such as the MDN-RNN Technique in Passive Electronic Surveillance Systems, solidifies UNSW's pioneering role in shaping the landscape of Electronic Warfare research.

UNSW Sydney

Deep Learning in ES Data

- Applies deep learning for pattern recognition, focusing on predicting intent and enhancing anomaly detection.

Spectrum Management and Categorisation

- Investigates novel techniques for signal categorisation, emphasising efficient resource allocation and control.

Advanced Algorithms for EW

- Develops cutting-edge algorithms tailored for congested electro-magnetic environments and advanced decision-making.

Practical Applications and Holistic Approach

- Extends research to practical applications in signal processing, communications, and related domains
- Adopts a holistic approach, addressing contemporary and future challenges in anomaly detection.

Advanced Techniques Integration and MDN-RNN Expertise

- Excels in implementing advanced techniques, including MDN-RNN, within Passive Electronic Surveillance Systems
- Demonstrates expertise in building artificial agents for different environments using Pulse Descriptor Words.

Spectrum Sensing and Target Tracking

- Utilises traditional and machine learning techniques for effective spectrum sensing and sharing
- Demonstrates proficiency in signal processing for target detection and tracking.

Interference Mitigation and Sensor Processing

- Develops specialised techniques for interference and jammer suppression and mitigation
- Emphasises sensor and diagnostic signal processing for improved functionality.

Information Security and Applications

- Contributes to information security and secrecy in signal processing
- Applies expertise in radar, electromagnetic sensor arrays, and underwater acoustics for diverse operational needs.

Diagnostic Work and Threat Identification

- Makes significant contributions to diagnostic sensor array processing, addressing challenges like bearing faults in drones
- Assists in developing self-sensing capabilities for threat identification in contested environments.

Innovation

UNSW has a strong and demonstrated reputation for achieving success in innovation, entrepreneurship, commercialisation and industry engagement.

In the 2023 Survey of Commercialisation Outcomes from Publicly Funded Research (SCOPR), led by Knowledge Commercialisation Australasia (KCA), UNSW was ranked number one overall for the number of new spinout companies and the highest ranked university in the Australia and New Zealand region for number of new patent filings.

With a dedicated team of staff that work directly with research leaders across the organisation, UNSW has made a significant investment in effective enablers to drive innovation and ensure that the university is in a position to work with the best possible partners to achieve translation of research into outcomes that deliver economic and social benefits.

Further enabling the achievement of these outcomes are a set of dedicated investment funds to provide capital to accelerate UNSW research translation opportunities and successful commercialisation outcomes.

While these initiatives and resources are accessible to all research leaders across the University, UNSW's work on innovation aims to accelerate its respective defence innovation enterprises and shared learning, including ways to more rapidly integrate commercial technologies to solve warfighting needs.

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Information sharing

UNSW can proactively leverage the multidisciplinary research expertise required to address the needed secure information sharing, including the desired expansion and acceleration, as the AUKUS partners work collaboratively in the advanced Pillar II activities. By leveraging existing the expertise detailed below UNSW can translate research into enduring solutions.

UNSW has expertise in a broad suite of ML technologies to build transparency and trust in automated information sharing focused on confidentiality, privacy-preserving learning, and interpretability.

Trustworthy ML

UNSW has expertise in a broad suite of ML technologies to build transparency and trust in automated information sharing focused on confidentiality, privacy-preserving learning, and interpretability (led by Professor Flora Salim). The outcomes of the research have been used in many domains including cybersecurity, design automation, cyberphysical systems, smart cities and transportation, and defence.

Privacy-preserving Data Analytics

Expertise in privacy-enhancing/preserving technologies (led by Professor Wenjie Zhang) is used in various aspects of data management and analytics including local/global differential privacy, privacy-preserving data publishing and advanced machine learning techniques over relational, spatial, and network/graph datasets.

Applied Cryptography

UNSW has research strengths in advancing cryptography applied to secure data management context, such as secure multi-party computing, cloud security for access control, data storage security and verifiable computation (led by Dr Sushmita Ruj). These enable technologies that help regulatory compliance and bridging the gap between privacy law and technology, as well as responsible data sharing in Industrial Internet of Things applications.

Data Platform Technologies

UNSW has applied a suite of decentralisation technologies to build secure and zero-trust data sharing platforms, key capabilities include blockchain, local/global data stores, digital identity and smart access control, data sovereignty and privacy (led by Associate Professor Helen Paik). ML-based assistant technologies help users make data sharing decisions for privacy-sensitive data.

Privacy and Security Regulations

Led by Professor Lyria Bennett Moses, UNSW Faculty of Law & Justice, has expertise in the relationship between technology and law, exploring legal issues in information sharing and using contracts for better governance.

Research infrastructure

Wireless Communications Research Lab

UNSW is home to a wide range of world-class infrastructure that supports research in advanced AUKUS capabilities. Specific to undersea capabilities, UNSW's Wireless Communications Research Lab has the necessary hardware and software to support research related to subsurface communication, providing unique insights into microwave communication, underwater acoustic communication, signal processing, and Software Defined Radios.

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Quantum technologies

For quantum technologies, UNSW hosts several state-of-the-art cryogenic and electronic measurement labs for electric measurements of spin qubits and silicon quantum devices. This infrastructure includes the National Magnet Laboratory, the Fundamental Quantum Technology Laboratory, and the newly built laboratories as part of a UNSW spinoff, Diraq Pty Ltd. UNSW also houses leading semiconductor nanofabrication facilities via a node of Australian National Fabrication Facility and is developing a new experimental quantum communications laboratory to prototype a quantum key distribution system.

In the field of AI and autonomy, UNSW's 3DXLAb is a pioneering visualisation facility forging new territory in integrated thinking to accelerate human understanding of complex datasets, using world-class interactive virtual environments and human-centric interaction design.

AI and Autonomy

In the field of AI and autonomy, UNSW's 3DXLAb is a pioneering visualisation facility forging new territory in integrated thinking to accelerate human understanding of complex datasets, using world-class interactive virtual environments and human-centric interaction design. Likewise, UNSW's National Facility for Human-Robot Interaction Research is a purpose-designed laboratory that investigates how people interact with technological devices and is one of the largest in-door testing facilities for Unmanned Autonomous Systems. As well as housing a Human Performance and Distributed Simulation laboratory UNSW also runs a Swarm Metaverse Facility which augments physical robots with virtual robots to innovate, design, develop and test AI and autonomy teaming concepts.

Cyber technologies research facilities

UNSW hosts several world-class cyber technologies research facilities including a state-of-the-art

Internet of Things and Cybersecurity laboratory, a Cyber Range and a Distributed Energy Resources laboratory that provides new tools to identify and mitigate cybersecurity threats to safeguard Australia's energy sector. Researchers in UNSW also have access to the National Computational Infrastructure (NCI) facility which includes high-performance computing, petascale data and cloud computing capabilities. Through the UNSW Institute for Cyber Security (IFCYBER), the university continues to develop infrastructure to support leading multidisciplinary cyber research in partnership with academia, industry and government.

Hypersonic and counter-hypersonic capabilities

Supporting hypersonic and counter-hypersonic capabilities, UNSW houses a Free-Piston Driven Reflected Shock Tunnel, a Blown-Down Supersonic Wind Tunnel, a Fluidic Control Rig and a Two Stage Gas Gun. Through the Defence Trailblazer program, UNSW has installed a large-scale, multi-metallic, additive manufacturing capability at a CSIRO site in Victoria and is developing a flight experiment research infrastructure. With some of the most advanced infrastructure in the country, UNSW can conduct a wide range of fundamental and applied research experiments into hypersonic and counter hypersonic capabilities.

Core and enabling facilities

UNSW has strong centrally managed core research facilities and enabling infrastructure, supporting the AUKUS specialist facilities and research pillars. These include Research Technology Services (research high performance computing and data platforms) and the Mark Wainwright Analytical Centre (including advanced X-ray labs, electron microscopy, imaging and materials character-isation). UNSW is a partner in a number of key National Collaborative Research Infrastructure Strategy (NCRIS) capabilities, including NCI, Integrated Marine Observing System, Microscopy Australia and Australian National Fabrication Facility and actively facilitates research access to specialist national facilities.

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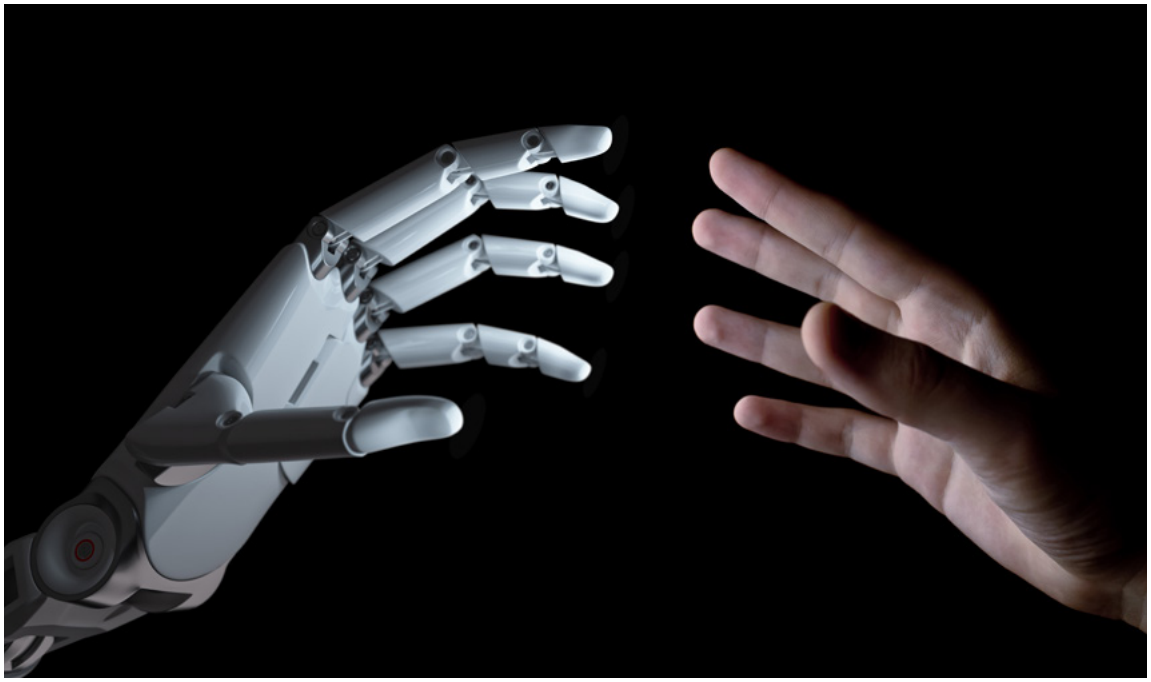

Workforce development

UNSW is committed to growing the workforce needed to support AUKUS Pillar II capabilities. Principally through the Canberra faculty, UNSW provides a range of accredited undergraduate and post-graduate programs to officers in the Australian Defence Force. With its unique and privileged position as an education provider to Defence's leaders, UNSW enriches its students with an understanding of AUKUS capabilities such as hypersonics, AI and cyber as part of their overall educational experience.

Courses

Recognising the workforce demands on industry to deliver AUKUS in partnership with government, UNSW provides 15 per cent of Australia's and 40 per cent of NSW's undergraduate engineers each year. UNSW's science courses also have excellent outcomes that support AUKUS workforce demands, producing graduates with deep disciplinary expertise and a thorough understanding of professional practice.

Demonstrating its commitment to advancing AUKUS, UNSW:

- runs the world's first bachelor's degree in quantum engineering
- offers Australia's only undergraduate cybersecurity degree and has a pioneering, industry co-developed postgraduate equivalent
- offers postgraduate programs in AUKUS related capabilities such as simulation and immersive technologies, data science, engineering science (robotics), capability management, security and defence management, special operations and irregular warfare, and war studies.

AUKUS Workforce Alliance

Further reflecting the university's pivot towards the defence sector, UNSW is a founding member of the AUKUS Workforce Alliance (AWA), a collaboration with the University of Adelaide, Curtin University and defence companies Babcock Australasia and Huntington Ingalls Industries. While specifically addressing the development of a sovereign, nuclear-powered submarine workforce in Australia, the AWA will also lead the development and execution of critical upskilling programs and harness the full potential of Australia's industrial base in support of AUKUS Pillar II capabilities. The AWA will also foster cutting-edge research and practical experience for the future workforce.

Recognising the workforce demands on industry to deliver AUKUS in partnership with government, UNSW provides 15 per cent of Australia's and 40 per cent of NSW's undergraduate engineers each year.

Lifelong learning

UNSW recognises the importance of lifelong learning in supporting the development of a skilled workforce and runs a series of short-courses related to AUKUS advanced capabilities. These courses cover topics ranging from cyber security and cyber offence, naval combat and weapons systems to an introduction to electronic warfare. In addition to further courses being co-developed with Defence industry, UNSW is supporting the development of their workforce through a range of staff secondments and student placements.

Collaborations

Cooperative Research Centres and Centres of Excellence

UNSW has a long history of collaborating with academia, government and industry in support of the areas aligned with, and as part of, the Defence sector. UNSW is a part of the Centre for Quantum Computing & Communication Technology (CQC²T) Centre of Excellence.

The university is also party to multiple defence related Cooperative Research Centres (CRC) which benefit AUKUS Pillar technologies, including:

- Cyber Security CRC
- SmartSat CRC
- Sovereign Manufacturing Automatic for Composites CRC (SOMAC CRC)
- Trusted Autonomous Systems – Defence CRC (TASD-CRC).

Supporting the commercialisation of industry intellectual property for defence related capabilities, UNSW also collaborates with various partners in Cooperative Research Centre – Projects (CRC-Ps).

Flagships supporting AUKUS

Through the PLuS Alliance, which comprises King's College London and Arizona State University, the Security and Defence PLuS initiative is one of the university's two flagship programs supporting AUKUS.

Collectively, Security and Defence PLuS is pursuing new research and education opportunities with Defence, government and industry in Australia, the UK and US, with a focus on bringing trilateral research teams together to accelerate capability in the shared national security interests. Built on a shared commitment to enhance collective defence and security interests, the Security and Defence PLuS is stimulating public discourse and connecting Defence, industry and academia with AUKUS-focused policy, statecraft, research and technology requirements.

The second of UNSW's flagship initiatives, the Defence Trailblazer program, is a partnership with the University of Adelaide that brings

together the united strength of Australia's top two defence-focused universities coupled with 42 industry partners including small-medium enterprises and multinational Primes. The Defence Trailblazer strengthens AUKUS capabilities by developing cutting-edge technologies and solutions, while simultaneously equipping the next generation of innovators with specialised knowledge and workforce skills to meet the current and future needs of Defence.

Defence Innovation Network

Complementing large scale, multi-party collaborations, UNSW partners directly with Defence to conduct research into AUKUS advanced capabilities. As a member of the Defence Innovation Network, UNSW is pursuing research into capabilities such as acoustic modulation microwave communi-cations from unmanned systems to submarines and heterogenous robot teaming. UNSW also conducts extensive research in support of Defence Science and Technology Group (DSTG) into areas such as hypersonic shape distortion, autonomous underwater navigation, and signals processing, to name just a few.

Collaborations with US agencies

As well as enabling Defence in Australia, UNSW supports US agencies develop AUKUS Pillar II capabilities, having drawn on funding from the Office of Naval Research Global, the Air Force Office of Scientific Research, the Army Research Laboratory and the Defence Advanced Research Projects Agency. The university is also growing its relationship with UK's Defence and Security Accelerator and is pursuing a range of research projects that will accelerate the development of capabilities in support of AUKUS objectives.

As well as enabling Defence in Australia, UNSW supports US agencies develop AUKUS Pillar II capabilities.

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Key examples

Partnership with Ocius

In a partnership which reflects UNSW's commitment to advancing AUKUS, the University is working with Ocius – a leading innovator in maritime robotics and machine learning that is based on the Kensington Campus in Sydney and is also a capability provider to the Royal Australian Navy.

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This partnership allows for close collaboration with UNSW researchers, access to UNSW facilities and equipment, and a range of Higher Degree Research and postgraduate student engagement programs. It also supports building 'teams of teams' by enabling collaboration with UNSW's other ventures such as the SOMAC CRC. UNSW's partnership with Ocius was recently awarded Best Industry Collaboration by Knowledge Commercialisation Australia.

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The University of Sydney

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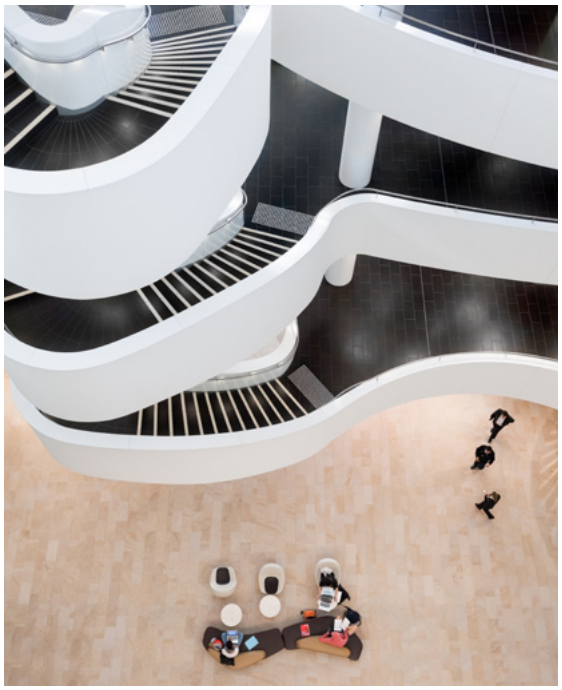

Skills and capability

For almost 170 years, the University of Sydney has had a long-standing collaboration with Defence with developments such as the black box, WiFi, codebreaking and camouflage. A world leading University (top 20)[3], it has since established a focus on Defence, Security and Resilience, aiming at translating its impactful, interdisciplinary research towards solving the greatest challenges.

The University of Sydney's key strengths align with AUKUS advanced capabilities from Trusted Autonomous Systems emphasising innovative surveillance and undersea unmanned technologies to world class Additive Manufacturing and Quantum Technologies which are instrumental in supporting AUKUS's aim of maintaining technological superiority, especially in security applications. Their leading research in AI, Advanced Sensors, Photonics, and Directed Energy contribute directly to the development of

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next-generation military technologies which are key to AUKUS's strategic objectives in the Indo-Pacific region. Their research, including Cybersecurity and Communications, has been essential in developing dual use technology for applications such as protecting critical infrastructure.

Collaboration is critical for the University of Sydney, with impactful industry partnerships with Microsoft on Quantum computing and Thales on underwater sensing, as well as important global government engagement. Facilities such as Sydney Nano enable cutting edge research with strong strategic alignment to AUKUS. The University has doubled its efforts in the development of their staff, partners and ecosystem with initiatives such as the US Study Centre publication on AUKUS future workforce.

At the crossroads of academic research and practical application, the University of Sydney is contributing significantly to the development of advanced technologies for security and defence, critical to AUKUS's strategic goals.

Research strengths

Undersea capabilities

Capabilities and groups

- *Australian Centre For Robotics*, Marine Systems Group conducts vital applied research in underwater vehicle platform development, sensing, navigation, visualisation, and classification of marine habitats using autonomous underwater vehicles. It has led a major national program focused on the observation of marine habitats for environmental monitoring, underwater archaeology, deep-sea geoscience, and mine-counter-measure operations. The group has a Research Hub exploring inspection using autonomy and robotics with potential applications to sustaining and maintaining submarines.

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The University of Sydney

- The *Sydney Manufacturing Hub* focuses on Advanced Manufacturing capabilities and end-to-end workflows, including advanced pre- and post-processing of metals, ceramics, and polymeric-based material relevant to defence underwater structures, propulsion and systems.
- In *Undersea Sensor Tech*, University of Sydney leads in sensing capabilities for undersea operations, with a particular focus on acoustic, optical, and hyperspectral imaging systems.

Research projects

The University of Sydney's strength is not only in having advanced underwater technology, but also in understanding the complex and contested environment that is our coastline and deep sea.

- *Seabed mapping of Australia's margins*: uses Marine geology and geophysics (GIS, multibeam bathymetry, side scan sonar and seismic reflection techniques), to understand Australia's continental margins and seabed characteristics.

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- *Underwater acoustics, marine bioacoustics*: Littoral Warfare, Sensors, Situational Awareness, Environmental impact management working with Defence Science and Technology Group (DSTG).
- *Undersea/Littoral Sensing and enhanced imaging in Obscured Environments*: utilises advanced technology for precise sensing and photometric model and designing novel underwater imaging systems, including hyperspectral imaging for challenging underwater environments, enhancing situational awareness.
- *Autonomous Undersea Vehicles*: research focuses on specialised underwater sensors, imaging systems, and technology for autonomous underwater vehicles. A novel, agile autonomous underwater vehicle (AUV) system capable of operating in complex underwater environments to facilitate littoral survey and operations around structures and over reefs.
- *Cooperative Localisation*: developing asynchronous updates between robots over unreliable and low-bandwidth communication channels, enabling effective collaboration.
- *Multi-sensor Data Fusion*: developing techniques for fusing information from optical, sonar, and hyperspectral sensors to deliver high-resolution models of underwater environments.
- *Autonomous Intervention*: working in partnership with Reach Robotics to deliver autonomous intervention capabilities, allowing robots to work in partnership with operators to complete complex underwater manipulation tasks.
- *Underwater Optical and Acoustic Target Localisation and Classification*: exploring cost-effective approaches for remote monitoring of marine reserves and restricted naval waters using passive sonar and neural networks.
- *Three-Dimensional Reconstruction and Registration*: automation of colour correction in underwater images to create evenly illuminated 3D structure-from-motion models using AUVs and low-cost aerial platforms.

The University of Sydney

Quantum technologies

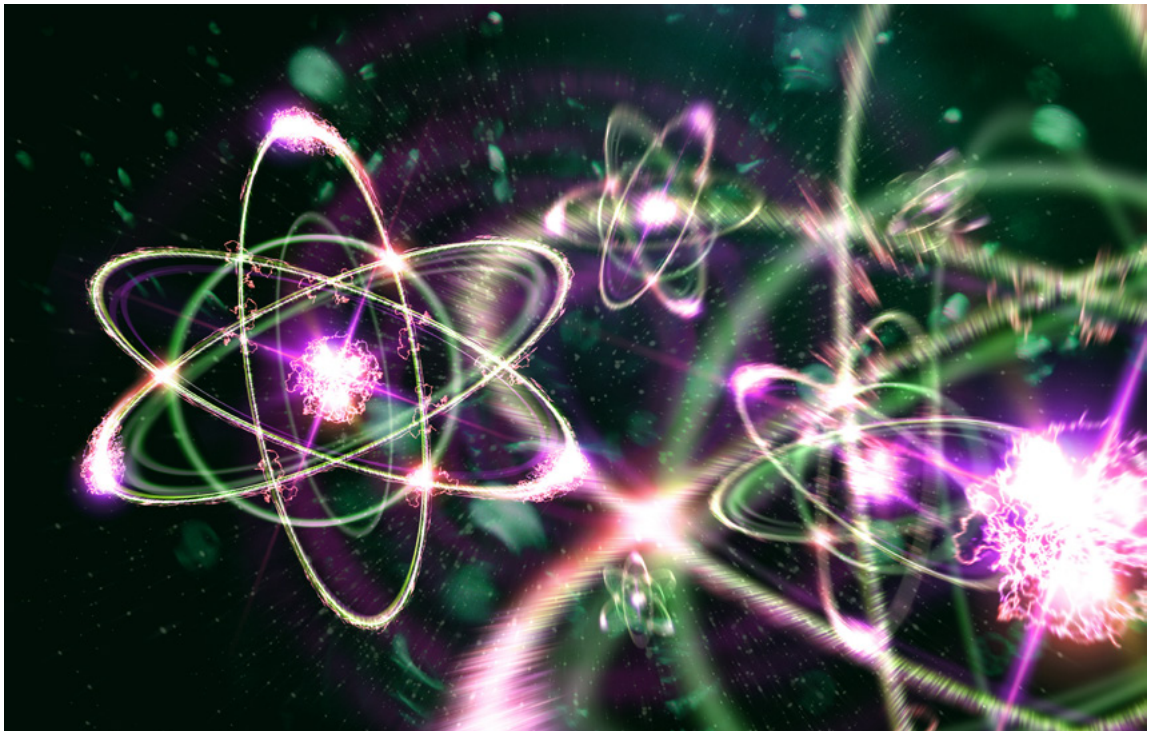
Capabilities and groups

- *Quantum Computation and Information Theory*: The group is a global leader in the design of quantum architectures for error correction and fault-tolerant operation of complex quantum computing technologies.
- *Quantum Control Engineering and Simulation*: focuses on the development of quantum technologies based on trapped atomic ions and specialised high-precision microwave and laser systems. The group currently operates the highest-performance quantum computer in the southern hemisphere and has demonstrated world-leading performance in quantum-logic error rates and coherent lifetimes.
- *Quantum Networks*: building up sophisticated quantum networks through engineering quantum hardware and leveraging these devices to discover new physics.
- *Quantum Photonics*: focuses on creating sources of single photons and entangled photon pairs for quantum communication and computation.
- *Quantum Nanoscience* team focuses on quantum information pressing within condensed matter systems, employing quantum engineering techniques including cryogenic electronics and nanofabrication.
- *Molecular Quantum Science*: engineering better molecular materials using quantum science.
- *Advanced materials for Quantum Computing*: expertise in designing, fabricating, and prototyping photonic integrated circuits suitable for quantum applications.

Research projects

The University of Sydney serves as a global centre of excellence in quantum, tacking long-term challenges in building complex multi-component quantum technologies that are robust to error.

- *Quantum Computing with Trapped Ions*: using a system of trapped electronically charged atoms with applications including timing-keeping devices to improve high precision GPS & PNT.



- *Quantum Sensing*: Heterogeneous integration of diamond based solid-state and robust magnetic field quantum sensors with complementary metal-oxide semiconductor (CMOS) actuation and read-out systems, paves the way towards magnetic field detection that are heavily miniaturised for sensing, positioning, and navigation.
- *Quantum Enhanced Communication project with Defence*: linking microwave and optical technologies for hybrid quantum networks. Long distance secure communications through quantum connectivity between microwave and optical fields.
- *Nanostructure design*: on silicon carbide has led the development of high-quality 3C-SiC waveguides and the pioneering of a Pockels modulator in silicon carbide. Offers potential for ultrafast photonic signal processing in integrated devices and new quantum application opportunities in collaboration with Universities of Harvard, Michigan, and Stanford.

The University of Sydney

- *Micro- and Nanosystems Engineering*: fabrication techniques and integrating mechanics and photonics at micro and nanoscales relevant to quantum with applications in fiber-optical communication, imaging, sensors, and space communications.
- *Nano-diamond Imaging*: improving magnetic resonance imaging, in collaboration with Harvard.

The Sydney AI Centre: explores new horizons in artificial intelligence (AI) and endowing machines with the capabilities of perceiving, learning, reasoning and behaviour.

- *Social science perspectives on quantum computing*: engaged cross collaborative innovation research involving social scientists, natural scientists, engineers, and biomedical researchers, creating innovation knowledge, and actively contributing to innovation and commercialisation by leveraging existing knowledge.

Artificial Intelligence and Autonomy

Capabilities and groups

- *Trusted Autonomous Systems*: a key strength for several leading groups at University of Sydney, with a renowned industry track record in lightweight unmanned aerial systems and underwater automated acoustic surveillance. Specialisation in custom design and rapid prototyping of mission-tailored unmanned aerial systems across land, sea, and air. Expertise includes smart systems with high-end reconfigurable electronics, on-chip Deep Neural Network training, and low-latency time series prediction. The research explores autonomy, including simultaneous localisation and mapping, autonomous control, decision-making under uncertainty, data fusion and adversarial policy optimisation.
- The *Sydney AI Centre*: explores new horizons in artificial intelligence (AI) and endowing machines with the capabilities of perceiving, learning, reasoning and behaviour.

Research includes designing effective and efficient models to extract, represent and understand information encoded in data and build algorithms and theories.

- *Social Science, Law, Business*: University of Sydney's interdisciplinary collaboration involves AI and automation for ethics, regulation, policy, and leadership and leader in AI law. Corporate training offers executive education programs focused on AI fluency programs.

Research projects

- *AI-Enhanced Mathematical Theorem Discovery and Proof*: in collaboration with Oxford University and DeepMinds, as featured in Nature, this research used AI to innovate in knot and representation theory. The AI suggests new theorems and proofs, shifting computers' role in mathematics and highlighting AI's potential to uncover insights beyond human intuition.
- *Language understanding, deception, negotiation*: improving AI's language understanding for effective human interaction, including complex request handling, data analysis with Neuro-linguistic programming, and interactive negotiation games.
- *Edge AI in multiple UAVs for ISR and communications*: aims to develop distributed machine learning algorithms for deployment in multi-UAV Intelligence, surveillance, and reconnaissance (ISR) and communication-centric applications that account for physical constraints and minimises probability of detection.
- *Edge AI on Reduced Chipset*: focuses on research enabling computing and decision-making locally ("on the edge") for faster, more efficient processing.
- *Next generation neurobiological models*: adding neuroanatomical complexity to decision-making models and understanding complex brain dynamics leading to novel AI architectures.
- *Low Power AI with Approximation*: explores AI techniques that provide "good enough" answers, saving time and cognitive load.

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- *Drone on Demand*: collaborating with UNSW and University of Technology Sydney, a framework was developed for rapid drone design and manufacturing, enhancing ISR capabilities funded as a Data61 program partnering with Defence.
- *Privacy and data governance*: automated decision-making and regulation.
- *Using AI for Cybersecurity*: automated cyber intelligence sharing using explainable AI for enhanced threat analysis is being explored.

Advanced Cyber

Capabilities and Groups

- The *Centre for Distributed and High-Performance Computing* is committed to cybersecurity research across mission-critical systems, edge-intelligence, and other AI-empowered environments that span several disciplines, including algorithms, big data analytics, databases, green computing, data centres and clouds, networking, the Internet of Things (IoT) and service science.

- The *Sydney Centre for IoT and Telecommunications* conducts groundbreaking research at the convergence of cybersecurity while developing the theoretical framework and technologies for 6G ultra-reliable low latency communications, which would enable automation of critical infrastructure. The centre has developed a long-range WiFi system for mission-critical applications whilst working on real-time risk and security assessment infrastructure.
- *Other key Sydney expertise* outside of the cybersecurity cluster includes a focus on human decision-making process and how to combat misinformation and detection of foreign influence. Impactful cyber research occurs on a social, regulatory, policy and ethical stance with strengths in Computational Social Network Analysis.

Research projects

University of Sydney's advanced cyber research includes developing machine learning algorithms for privacy assurance in distributed systems with noisy or constrained data and creating efficient methods for private statistical inference in distributed data, and optical encryption.

Research also focuses on mitigating information leakage from side-channels.

Next-generation user authentication is being revolutionised with biometric methods such as brainwave and location data analysis.

Deep learning is being enhanced for class imbalance scenarios by reweighting model loss functions.

Research extends to advanced security technologies, including circuit detection in FPGA chips, optical encryption, elliptic curve cryptography, and strategies to counter AI-generated deceptions.

For critical infrastructure protection, fundamental information-theoretic and physical-layer communication protocols are in development to prevent eavesdropping and privacy attacks in the open wireless medium.

- *Quantum secure communication*: long distance secure communications through quantum connectivity between microwave and optical fields.

- *Supply Chain Security*: algorithmic complexity attack detection and prevention, and scalable detection of mobile app malpractices.
- *Understanding the Threat Landscape for the IoT*: assessing vulnerabilities and attack vectors in IoT devices connected to cloud services and the potential global impact of security threats in various applications.
- *Secure Networked Systems*: balancing usability and security in networked systems and end-user devices to protect against cyberattacks.
- *Detecting and preventing algorithmic complexity attacks*: investigating methods for identifying and eliminating vulnerabilities in modern software systems.
- *Navigating New Cyber Risks Resilience*: optimising decision-making across sectors for improved profits, social outcomes, and wellbeing.
- *Security based on circuit detection on FPGA chips*: a novel way of detecting cyber security concerns based on hardware.

Hypersonic and Counter-Hypersonic Capabilities

Capabilities and Groups

- The *Clean Combustion Research Group* specialises in experimental and computational combustion and two-phase flow research for supersonic and hypersonic propulsion. Operating a world-class laboratory, the group employs advanced laser diagnostics and computational fluid dynamics solvers for critical parameter measurements and predictions. The group has contributed to numerous defence projects in recent years. It is closely aligned with the Sydney Rocketry Team developing new rocket systems and engineering talent.
- The *Sydney Manufacturing Hub Team* conducts research relevant to hypersonic research priorities for the development and application of new advanced materials and advanced manufacturing processes.
- *Advanced Sensors & Countermeasures*: leading experts working on cutting-edge sensors that

could support precise monitoring and control of hypersonics, as well as countermeasures such as electronic warfare.

Research projects

- *Hypersonic Engine Development*: Rotating Detonation Engines (RDEs), integral to the thrust generation in hypersonic vehicles. University of Sydney's combustion group was a key research partner, along with DefendTex, RMIT University and Defence, in the development and testing of Australia's first RDE. The group was responsible for high-fidelity computational fluid dynamics modelling of the prototype RDE, contributing to analysis of engine performance and operational envelopes, and generating broader understanding of hypersonic propulsion and potential countermeasures.
- *Advanced Combustion Modelling for Scramjets and RDEs*: development of engineering models for air-breathing high speed propulsion engines employing complex hydrocarbon fuels. The project is producing extensive data and new physical understanding through direct numerical simulations of supersonic reacting mixing layers impinging on strong shock waves. The aim is to develop practical and effective supersonic propulsion engines for defence and high-speed point-to-point flight.
- *Propulsion Engine Integration and Vehicle Optimisation*: development and application of modelling, simulation and optimisation tools to automate preliminary high-speed flight vehicle design, including simulation of oxidiser tank dynamics, chamber internal ballistics, nozzle flow and flight trajectory.
- *Direct simulation Monte Carlo (DMSC) Modelling*: opensource DSMC code is being used by undergrad students, to model hypersonic bodies, including re-entry vehicles and waverider configurations, as part of ongoing research for high altitude and space vehicle aerodynamics.

The University of Sydney

Electronic Warfare

Capabilities and Groups

- *Sydney Astrophotonics Instrumentation Laboratory (SAIL)*: leads in developing advanced photonic instruments, contributing to photonics and optronics research with direct applications in electronic warfare.
- The *Institute of Photonics and Optical Science*, and groups in the Faculty of Engineering, bring cutting-edge photonics research, focusing on technologies crucial for enhancing electronic and photonic warfare capabilities, supported by state-of-the-art laboratories and facilities for nanofabrication and prototyping.
- *Eggleton Research Group*: located in the School of Physics, this group specialises in optical physics and optoelectronics, hosting the Jericho Smart Sensing Laboratory (2019–) sponsored by the Royal Australian Air Force (RAAF) which develops and prototypes advanced sensors for situational awareness, including wideband radio frequency (RF) sensors.
- *Computer Engineering Laboratory*: known for its innovative approaches to computer engineering, advances field-programmable gate array (FPGA) research and applications essential to electronic warfare.

Research projects

- *Radio Frequency Fingerprinting (RFF) and automatic modulation classification (AMC)*: Specialising in real-time, physical layer deep learning on FPGAs, encrypted RF traffic classification and monitoring, this program enables real-time visualisation of RF sources and scenes.
- *Photonic/Electronic Signal Processors (Counter-Electronic Warfare)*: focuses on converting RF signals to photonics, using photonic processors for enhanced signal processing.
- *Integrated Microwave Photonics*: University of Sydney has multiple and leading research groups working on Microwave Photonics (MWP), a multidisciplinary field that brings together the worlds of microwave engineering and

optoelectronics. Some of this research includes integrating a Brillouin and active-silicon photonic circuit for advanced RF signal processing, as well as on-chip lidar, photonic signal processing, advanced sensing, acoustic & audio detection and localisation, photonic signal processing and integrated photonic circuits operating in harsh environment.

- *Photonic Chip with Integrated Semiconductor Architecture*: An innovative semiconductor architecture that integrates traditional electronics with photonic components offers potential applications in advanced radar, satellites, wireless networks, and 6G telecommunications. A significant advancement in semiconductor technology with implications for electronic warfare and communication systems.
- *Hyperspectral Optronics Sensors*: develops multi-spectrum SWaP-C optimised imaging sensors from the visible to the IR for aerospace and defence.

- *Directed Energy Beam Control and Adaptive Optics*: focuses on optronics innovative solutions for beam combination and steering for high-power directed energy sources.
- *Nonlinear optics; nonlinear waveguides and ultrafast optical signal processing*: new classes of nonlinear waveguides creating a new paradigm for photonic chip based ultrafast optical signal processing, e.g. based on Stimulated Brillouin Scattering that forms high-performance microwave photonic filters for RF sensing.

The University of Sydney

Innovation

The University of Sydney's innovation and enterprise ecosystem supports its defence projects to transform ideas into market solutions that create value and contribute to national security. Each year, University of Sydney executes around 40 licences, options and assignments and their 60 spin-out companies have raised over AU$1 billion in capital over the last 10 years.

Spin-outs from their researchers produce technologies that are relevant to defence, including quantum technology (Q-CTRL, DeteQT), energy (Gelion), medical technologies (Elastagen, Allegra, Kinoxis), robotics (Marathon Targets), and aerospace technologies (AMSL Aero). Other relevant spin-offs include Mission Systems, developing machine intelligence and smart sensing technologies for the new age of autonomous systems and Abyss Solutions, providing autonomous inspection across land, sea, air, and space.

Q-CTRL is partnering with Australia's Defence Force to develop quantum sensors that will deliver quantum-assured navigation capability for military platforms, and with partners working on applications including remote drone detection.

Working very closely with the Royal Australian Air Force, the *Jericho Smart Sensing Laboratory (JSSL)* in the School of Physics is an exemplar of a unique approach to defence innovation, merging design thinking with cutting-edge science to swiftly transform research into actionable prototype solutions for the warfighter and advancing sovereign capability.

Research infrastructure

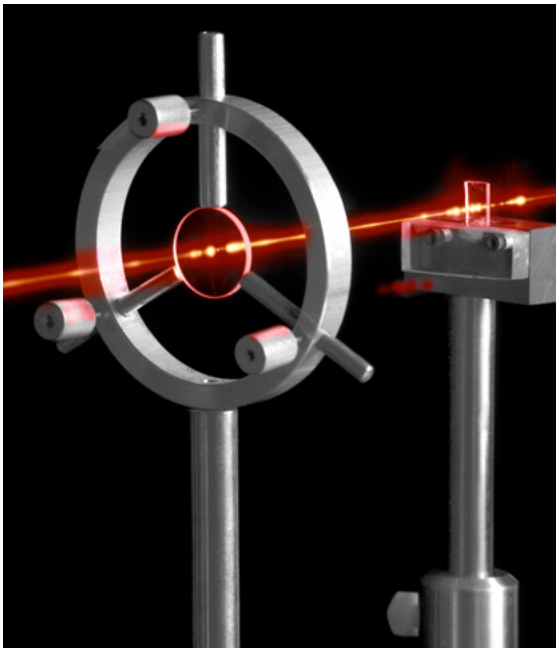
University of Sydney has state-of-the-art facilities and equipment and is investigating with government and industry next steps in their infrastructure strategy including Tech Central, Western Sydney area (AMRFF, Aerotropolis) taking into context key collaborations such as AUKUS.

The *Sydney Nanoscience Hub (SNH)* is purpose-built to explore the nature of matter, design new technologies and engineer them in some of the

best cleanroom and nanofabrication facilities in the world. The building, labs and fabrication facilities are designed to enable the precise measurements needed to access exotic phenomena on the nanoscale. In their highest-precision laboratories, a combination of controls on temperature, air pressure, mechanical vibrations, and electromagnetic interference makes these spaces among the most tightly controlled anywhere in the world. The SNH houses six main research labs as a frontier to research from quantum science to nano photonics.

The *Research and Prototype Foundry (RPF)* offers state-of-the-art instruments and expertise for the fabrication of devices and structures with features on the micro and nano scale. These specialised capabilities allow researchers and industry to develop and prototype quantum, photonic and semiconductor devices with novel functionality. The RPF is also an Australian National Fabrication Facility (ANFF) NSW node and will host University of Sydney's new AU$7.4 million *Future Qubit Foundry (FQF)*, which aims to be a national facility for the discovery and prototyping of critical quantum technologies for global impact. When fully equipped, it will deliver innovative fabrication processes, thorough benchmarking and characterisation, and rapid prototyping capabilities for superconducting qubits and circuitry.

The *Fiber-Optics and Photonics Laboratory* in the School of Electrical and Computer Engineering is a fully equipped laboratory with extensive and comprehensive facilities such as wet benches with fume hoods, optical benches, optical devices, lasers, and an extensive range of Radiofrequency (RF), microwave, and optical system measurement instruments.



The University of Sydney

The *Sydney Manufacturing Hub* is focused on advanced manufacturing capabilities and end-to-end workflows, including advanced pre- and post-processing of metals, ceramics, and polymeric-based materials. The Hub is highly relevant to defence industries and research priorities for the development and application of new materials, forward deployed manufacturing, consolidated parts prototyping, manufacturing and repair, integrated digital platforms, distributed systems security, artificial intelligence, and automation. Plans include a dedicated secured level and equipment specifically for defence-related projects, with a focus on developing components for rockets and missile systems.

The *Sydney Informatics Hub* centralises University of Sydney's capabilities in data science, AI, statistics, modelling, bioinformatics, and high-performance computing. This facility also houses capabilities in information and data engineering that power leading research in AI, machine learning, cyber security and integrated/ distributed digital platforms.

The Sydney Informatics Hub *centralises University of Sydney's capabilities in data science, AI, statistics, modelling, bioinformatics, and high-performance computing.*

The *Australian Centre For Robotics (ACFR)* is renowned for its expertise in robotics, sensors, autonomy and AI. ACFR plays a pivotal role in advancing autonomous systems across a broad range of application domains, including in defence, mining, agriculture, transport and logistics, bush firefighting, space, and maritime sectors. One of the largest robotics research institutes in the world, ACFR has a long history of close engagement with industry. ACFR has worked with Defence on world-first demonstrations of multi- Unmanned Aerial Vehicle (UAV) distributed data fusion and distributed control, development of novel sensing technologies using vision, laser, radar and hyperspectral sensors,

and development of Autonomous Underwater Vehicle systems for littoral survey, UAV planning algorithms for bushfire monitoring and intervention, and learning based dynamic models for training flight simulators.

The Aerospace, Mechanical and Mechatronic School, with strong links to the University of Cranfield, has relevant equipment such as wind tunnels and now boasts a cutting-edge *Eight360 NOVA simulator*, a 360-degree variable stability flight simulator with a virtual reality cockpit that accurately simulates the experience of flying various aircraft, including spaceships. The *Unmanned Aerial Vehicle Laboratory (UAV laboratory)* is equipped with rapid-prototyping tools and facilities to develop novel UAV flight systems and support flight operations. The lab has a Civil Aviation Safety Authority (CASA) approved UAV flight test facility at one of University of Sydney's farms in Marulan (a 2.5-hour drive from Sydney) where the University has 20,000 acres of available airspace up to 2000 t AGL. There is an indoor laboratory with OptiTrack motion-capture cameras to facilitate small UAV flight experimentation.
In addition to the development of innovative flight platform systems, the University's expertise and experience in designing, optimising and operating UAVs remains invaluable in ensuring affirmative cross-disciplinary research outcomes to take advantage of autonomous remote flight capabilities.
The *Sydney Propulsion Lab* focuses on two key areas to advance propulsion technologies for drones, namely hybrid fuel-cell-based propulsion systems and small variable pitch propellers.
The *Clean Combustion Laboratory* supports an extensive range of laser diagnostics methods for the measurements of velocity, mixing, temperature and reactive scalar fields in reacting and non-reacting flows.

The Aerospace, Mechanical and Mechatronic School *... now boasts a cutting-edge Eight360 NOVA simulator, a 360-degree variable stability flight simulator with a virtual reality cockpit that accurately simulates the experience of flying various aircraft, including spaceships.*

Sydney Analytical and Sydney Microscopy and Microanalysis offers comprehensive characterisation capabilities that are fundamental to developing strong, lightweight, durable structural materials and new functional materials or devices with sophisticated properties.

Workforce development

University of Sydney is ranked 1st in Australia and 4th in the world for graduate employability and is continuously investigating efficient methods to enhance the quality and impact not only of its academic staff and students but also key partners. To support a world in rapid transition as well as collaboration opportunities such as AUKUS, the University of Sydney works closely with its partners to ensure students and staff are prepared for the ever-shifting contemporary workforce. The University is nurturing the next generation of leaders who excel academically and possess critical thinking, creative problem-solving, cultural competence, and resilience to thrive in the most diverse and demanding work environments.

AUKUS

For AUKUS pillar II more specifically, the University's United States Studies Centre has long advocated for significant attention to workforce development for AUKUS. In December 2023 the centre published a report, *AUKUS inflection point: Building the ecosystem for workforce development*, based on extensive meetings and interviews across the government and corporate sectors in all three AUKUS countries. The report offers analysis on the current workforce ecosystem and proposes a course on how best to juggle competing workforce priorities to ensure AUKUS can reach its full potential. The Centre pursues interns and government secondments with an AUKUS focus to enable them to gain experience working with the University and subsequently bring those insights to their careers in government, the corporate sector or the tech industry.

Rocketry and Space

The Sydney Rocketry Team, Australia's first university-based rocketry team and Australia's first winning entry into Spaceport America Cup is a

diverse and multi-disciplinary student team that designs, manufactures and launches high-power sounding rockets to a world-class standard. From this success, the team's supervisor has been preparing a bid for an Australian Research Council Industrial Transformation Training Centre on launch and propulsion with appetite to create a permanent network that supports a growing ecosystem and critical workforce on dual use technology of rocket engines and systems for sovereign manufacturing.

The University also hosts the Industrial Transformation Training Centre (ITTC) for cubesats, UAVs & their applications (CUAVA) since 2017. The centre aims to train and create an Australian workforce in sustainable, advanced manufacturing, space, and UAV industries of national importance.

Funded by the NSW government through Space Research Network, the university has also been able to support on campus discovery days called "space camps" for high school students to discover study sections relevant to space studies.

The University of Sydney

Quantum & AI

Sydney Quantum Academy (SQA) is a joint venture between four top NSW universities including University of Sydney with additional funds from the NSW Government. SQA's vision is to build Australia's quantum economy.

Since 2019, Sydney Quantum Academy (SQA) has supported over 160 PhD students and organises a yearly conference and careers fair.

Collaborating with academia, industry and government, SQA is harnessing Sydney's collective quantum expertise to develop diverse talent and a globally recognised quantum ecosystem. Its main focus is around developing the future workforce required to support quantum technology as well as coordinating education and training in quantum technology and associated fields. Since 2019, SQA has supported over 160 PhD students and organises a yearly conference and careers fair.

Sydney Executive Plus, a business school initiative focused on corporate training and micro-credentials, is partnering with Deloitte and Sydney key technical experts, training industry & government on highly technical topics such as an AI fluency sprint course. This is a key example of how universities can support upskilling external workforce on essential technical areas that are rapidly evolving.

Collaborations

The University of Sydney has a track record in collaborating with academic institutions, government and industry in both the UK and US and has been aligning its direction and research capabilities with the objectives of AUKUS Pillar I and Pillar II. The University has a long-standing partnership with Thales working on breakthrough technology in underwater sensing and fibre laser sensors, alongside funded research from Lockheed Martin, Northrop Gruman, and different US Department of Defence organisations.

Examples of major research-based collaborations are as follows:

- The *Jericho Smart Sensing Laboratory (JSSL)* is an exemplar of the University's unique approach

to defence innovation, merging design thinking with cutting-edge science to swiftly transform research into actionable solutions for the warfighter and advance sovereign capability. Established in 2019 in collaboration with the Royal Australian Air Force, led by Professor Benjamin Eggleton, JSSL focuses on designing and prototyping next-gen smart sensing platforms, leveraging expertise in photonics and acoustics, as well as sensing data fusion. This collaboration involves leading-edge science and embedded design thinking, ensuring maximum creativity in partnership with DSTG. JSSL's distinctiveness lies in its integration of a design innovation framework and leading-edge science, expediting the translation of research into practical applications, with particular emphasis on air surveillance and electronic warfare. This approach entails direct engagement with defence operators, prioritising prototype development and testing in classified settings. The JSSL exemplifies the University's commitment to advancing defence capabilities through an innovative blend of design thinking, leading-edge science, and direct collaboration with defence operators.

- In 2023, the *United States Studies Centre (USSC)* at Sydney published more than 25 reports, articles and podcasts on AUKUS and was the most prolific public voice on the AUKUS agreement. When the 'optimal pathway' was announced in March 2023, the USSC had 2.5 more media mentions on the topic than our nearest competitor. As a university-based research centre, USSC provides both evidence-based analysis of AUKUS and timely insights on this fast-moving agreement. The USSC leverages strong ties in all three countries to convene expertise to help break through barriers to actualising AUKUS. In 2023, the USSC hosted more than a dozen roundtables, briefings and meetings with government, the corporate sector and the tech industry. A highlight was a 1.5 track dialogue at the Australian High Commission in

London with more than 50 experts, officials and industry leaders from across Australia, the UK and the US, in collaboration with the Center for Strategic and International Studies and Royal United Services Institute. These fora offer a critical safe space to trial balloon ideas for AUKUS implementation and innovation and foster new connections for collaboration on specific projects. USSC insights on AUKUS have been shared at the highest levels of government in all three countries and we will continue to advance AUKUS Pillar II through action-oriented discussions across government, the tech sector and finance industry.

- *Digital Sciences Initiative (DSI)* is a large academic group with a mission to deliver sovereign capability in the Digital Sciences, the interdisciplinary field that encompasses the study of digital technologies, their impact on society, and the scientific principles underlying their development and application. DSI has a Defence pillar and is focusing on AUKUS advanced capabilities.

Key examples

Advanced Materials & the Australian-United States Multidisciplinary University Research Initiative (AUSMURI)

The University of Sydney has proudly been awarded two Australian-United States Multidisciplinary University Research Initiatives (AUSMURI)[4] since its inception.

These examples demonstrate collaborative efforts between The University of Sydney and US universities and institutions, that focus on transformative research into additive manufacturing and responsive materials.

4 AUSMURI is a major Australian and US investment program encouraging Australian Universities to collaborate with universities in the United States and explore opportunities in designated topics on high priority projects for future Defence capabilities. Funding is being provided by Department of Defence via the Department of Industry, Science and Resources and complements the Multidisciplinary University Research Initiative (MURI) grant program administered by the US Department of Defense.

Additive Manufacturing Research: 3Dadditive

The University of Sydney is significantly invested in the research and development of additive and advanced manufacturing technologies, with its researchers leading numerous advancements in additive manufacturing for defence technology and associated applications.

In 2021, The University of Sydney launched the Sydney Manufacturing Hub – a "factory of the future" that is supported by GE Additive and a range of industry partners in defence, aerospace and biomedical engineering. Pro-Vice-Chancellor (Research Infrastructure) and Director of Core Research Facilities Professor Simon Ringer is leading research into titanium alloys, high-entropy alloys and methodology for multi-scale characterisation of microstructures – areas that are crucial for the application of additive manufacturing in defence technology. Along with his multidisciplinary team, he recently developed a new class of strong titanium alloys by integrating alloy and 3D printing process designs.

His focus on frontier materials science challenges, particularly in understanding phase transformations in extreme conditions of additive manufacturing, will enable the design of new materials with exceptional structural properties. He was awarded an AUSMURI, program led by (US side) the University of Tennessee-Knoxville (UTK) and (Australian side) the University of Sydney. It also involved a total of eight institutions in a program sponsored by the Office of Naval Research (ONR). The other institutions are (Australia) the University of NSW, and (US) University of California Santa Barbara, Ohio State University, Iowa State University, Virginia Tech, and Colorado School of Mines.

The project's success is attributed to its interdisciplinary approach and international collaboration, significantly contributing to Australia's defence technology capabilities in aerospace, maritime, and land-based platforms. The project, called "3Dadditive", has received an overall award amount of AU$3 million, with a further AU$2 million of extension funding.

The University of Sydney

The University of Sydney Spin-off: DeteQt PTY LTD

Navigation in a GPS denied environment is a key element to AUKUS advanced capabilities and overlaps not only undersea capabilities but also PNT, autonomy & AI and Quantum. That is what the University of Sydney spin-off, DeteQt, has been trying to achieve.

A collaboration with University of Sydney Associate Professor Omid Kavehei who has expertise in CMOS chip design, fabrication and testing, resulted in a multi-disciplinary team which was awarded a development grant from the NSW Defence Innovation Hub (DIN).

The co-founder, former University of Sydney Deputy Director at Sydney Nano and Professor in Physics and now President of Infleqtion Australia, James Rabeau, has been working on diamond magnetometry since around 2009 with the award of his ARC Future Fellowship, initially focussed on nanoscale imaging with diamond. Over time, he started to look at the possibility of using diamond magnetometry for navigation, using the magnetic field map from earth to accurately locate position. This is critical for both military and civilian applications for "PNT" and an aspect of situational awareness that remains a challenge.

To make devices useful in real applications, the magnetometer had to be made to be useful outside of the lab. Many attempts were made to miniaturise systems, including a case where a silicon chip of significantly reduced size, weight and power was fabricated at MIT.

A collaboration with University of Sydney Associate Professor Omid Kavehei who has expertise in CMOS chip design, fabrication and testing, resulted in a multi-disciplinary team which was awarded a development grant from the NSW Defence Innovation Hub (DIN). The grant enabled the team to hire Dr Thomas Boele as a quantum engineer who was instrumental in establishing the test bed and helping to design the device.

The project was challenged by starting at the same time as the COVID-19 pandemic. However, with the NSW-based industry Perceptia, the team succeeded in designing and fabricating chips and now have a small scale, integrated quantum diamond magnetometer. Timing was perfect given a strong global interest from defence organisations in developing alternative PNT solutions (PNT without GPS which has numerous risks associated with it). The team has since received funding from the US Department of Defence Asian Office of Aerospace Research and Development (AOARD) to further develop aspects of the technology. The team now has a working prototype and is considering different avenues to fund and commercialise the tech through the University spin-off DeteQt Pty Ltd.

This spin-off is an important example of how innovation in science and engineering has been adapted to challenges and application and to real world problems. This product is relevant to AUKUS advanced capabilities, providing undetectable, un-jammable, and passive navigation for military use, focusing on precision, high-resolution, reliability, and broadband magnetic field sensing. Understanding the restrictions in the application it will be integrated in, the competitive advantage is in the miniaturisation of the instruments while balancing performance parameters such as sensitivity, spatial resolution, and bandwidth against constraints like size, weight, and power.

Unlocking Quantum Potential: The Pioneering Partnership of the University of Sydney and Microsoft with Station Q Sydney

The University of Sydney's partnership with Microsoft represents the largest single investment in quantum computing in Australia.

Located at the Microsoft Quantum Laboratory in The University of Sydney's Nano Institute, led by Professor David Reilly, this collaboration has been a key contributor in positioning Australia at the forefront of global quantum advancement. The laboratory is one of only five experimental facilities globally funded by Microsoft and is part of the Microsoft Station Q network.

The University of Sydney

The partnership merges the University of Sydney's academic strength with Microsoft's technological capabilities and is focused on developing the interface between classical and quantum systems to advance quantum technology globally. It is a significant step towards scaling quantum devices for practical uses. The laboratory's features state-of-the-art equipment and development of scientific and engineering talent made possible through Microsoft's substantial investment.

The partnership is a pivotal step in the quantum revolution. By combining academic research with industrial might, this collaboration not only accelerates technological advancements but also ensures Australia's significant role in the emerging quantum economy.

By combining academic research with industrial might, this collaboration not only accelerates technological advancements but also ensures Australia's significant role in the emerging quantum economy.

This case study and international collaboration demonstrates The University of Sydney and Microsoft's critical contribution to the AUKUS Quantum Arrangement, focusing on the development of advanced quantum capabilities. Their collaborative efforts in quantum research and development are not only pushing the boundaries of technology but also directly supporting the strategic objectives of the AUKUS alliance.

Key personnel

Personnel with expertise across several Pillar II streams

Undersea capabilities, Hypersonic and Counter-Hypersonic Capabilities, Electronic Warfare, Innovation, and Information Sharing

Photonics, sensors, optics, microwave, situational awareness

Professor Benjamin Eggleton
Pro Vice-Chancellor (Research)
Director Jericho Smart Sensing Lab
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Undersea capabilities, Hypersonic and Counter-Hypersonic Capabilities, Innovation, and Information Sharing

Advanced materials characterisation and design, including advanced alloys, ceramics for SONAR, materials for extreme environments and corrosion minimisation
Professor Julie Cairney
Pro Vice-Chancellor
(Research Enterprise)
Professor at Aerospace, Mechanical and Mechatronic Engineering
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Undersea capabilities, Hypersonic and Counter-Hypersonic Capabilities

Materials, Additive Manufacturing, Microstructure, Characterisation
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Advanced Manufacturing, Additive Manufacturing, Industrialisation, Qualification & Certification, Production Technology, Applied Technology, Space, Satellite, Aerospace, Rocket Engine, Propulsion
Mr Bruce Mclean, Chief Engineer,
Sydney Manufacturing Hub

Metallurgy, materials science
Professor Simon Ringer
Pro-Vice-Chancellor
(Research Infrastructure)
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Undersea capabilities, Quantum technologies, Artificial Intelligence and Autonomy, Electronic Warfare

Integrated photonics, Photonic signal processing, Microwave Photonics, Sensing
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Undersea capabilities, Artificial Intelligence and Autonomy

Autonomous systems, marine robotics, sensors, AI
Professor Stefan Williams
Director Digital Sciences Initiative
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Quantum technologies, Advanced Cyber, Electronic Warfare

Optoelectronics, chiral optics, polaritonics, Optical spectroscopy, Chemistry, nanoscale semiconductor materials
Associate Professor Girish Lakhwani
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The University of Sydney

Artificial Intelligence and Autonomy, Hypersonic and Counter-Hypersonic Capabilities

Aerodynamics, fluid flow measurement, instrumentation, applied computational fluid dynamics
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Artificial Intelligence and Autonomy, Advanced Cyber, Electronic Warfare, Innovation, and Information Security

Big data, data, cybersecurity, national security, emerging technology, intelligence, information warfare
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Artificial Intelligence and Autonomy, Electronic Warfare

Space physics, space weather, satellites, CubeSats, plasma physics, radio emissions, nonlinear processes
Professor Iver Cairns
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Hypersonic and Counter-Hypersonic Capabilities, Electronic Warfare

Photonics, Optronics, Spectral Imaging, Specialty Optical Fibres, Optical Sensors
Professor Sergio Leon-Saval
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Quantum technologies, Electronic Warfare

Computer engineering, FPGA, machine learning, signal processing
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Personnel with expertise in a single Pillar II stream

Undersea capabilities

Robotics, Nonlinear Control, System Identification, Machine Learning, Optimisation
Professor Ian Manchester, Director, Australian Centre for Field Robotics
Director, Australian Robotic Inspection & Asset Management Hub (ARIAM)
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Marine geology and geophysics, seabed mapping
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Quantum technologies

Quantum computing, communication, networks, theoretical
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Quantum information theory; quantum measurement and control; quantum computing; quantum many-body physics
Professor Andrew Doherty
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Social science perspectives on quantum computing
Professor Steven Maguire
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Artificial Intelligence and Autonomy

Natural Language Processing (NLP); natural language processing; NLP; human-computer interaction; HCI; dialogue systems; code generation; databases; data science; bots; gaming bots; ChatGP
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School of Computer Science
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Unmanned Aircraft Systems
Professor KC Wong
Professor Aerospace, Mechanical and Mechatronic Engineering
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AI in Defence research and application
Professor Dan Corbett
Director of Defence Research
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Big data, data, cybersecurity, national security, emerging technology, intelligence, information warfare

The University of Sydney

Law, intellectual property, generative AI, AI ethics
Professor Kimberlee Weatherall
Professor of law, Chief investigator of ARC Centre of Excellence for Automated Decision-Making and Society
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Advanced Cyber

Wireless communications, digital communication theory, error control coding and multi-user detection
Professor Branka Vucetic
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Decision Support and Cognitive Modelling
Professor Sabina Kleitman
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Cybersecurity, privacy, Internet of Things (social networks), mobile networks and mixed reality
Dr Kanchana Thilakarathna
Senior Lecturer in Distributed Computing
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Hypersonic and Counter-Hypersonic Capabilities

Combustion, multiphase flows, turbulence, propulsion, energy
Professor Matthew Cleary
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Advanced Sensing – acoustics, optical, infrared
Dr Tomonori Hu
Project Lead – Smart Sensing
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Electronic Warfare

Photonics, Integrated Photonics, Microwave/Radio Frequency (RF) Photonics
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Silicon photonics, Optoelectronics, Photonic Integration, Microwave Sensing, Advanced Packaging
Dr Alvaro Casas-Bedoya
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THE UNIVERSITY OF SYDNEY

Photonics Sensors, optical fibers
Professor Simon Flemming
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Innovation and Information sharing

Defence policy, strategy, international security, alliances, AUKUS, military operations, doctrine
Professor Peter Dean
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Policy, United States Studies Centre
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Strategy, international security, Asia, geopolitics, US strategy, capability development, defence industry
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The University of Melbourne

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Skills and capability

The University of Melbourne's world-leading expertise across a range of science and engineering disciplines holds direct relevance to AUKUS Pillar II and has led to new capabilities and technologies including autonomous systems, improved electronic warfare surveillance and detection, advanced sensing including phased array radar and sonar and quantum technologies, cybersecurity and AI applications. The University has deep expertise in complementary disciplines including international law, geopolitical strategy, personnel safety and mental health.

A suite of undergraduate, postgraduate and specialist degrees offered at the University can be tailored to meet the specific AUKUS needs in core and specialist areas relevant to Pillar II capabilities. Dedicated pathways with multiple entry and exit points will support rapid workforce development, providing STEM workforce skills with a focus on underseas capabilities, computing and information sciences, quantum, AI, advanced cyber, hypersonic and counter-hypersonic, electronic

THE UNIVERSITY OF MELBOURNE

warfare, physics, chemistry and mathematics but also inclusive of a broader sovereign capability offering and a clear strategy to grow the STEM talent pipeline.

The University has over 300 international agreements across the globe including strong and productive relationships with key UK and US AUKUS Delivery Partners. The University is committed to prioritising the further development of these strategic partnerships to expand research collaborations and student opportunities with priority institutions including the University of Manchester, the University of Birmingham, Massachusetts Institute of Technology, the University of Sheffield and Penn State University.

Research strengths

Undersea capabilities

The maritime and aerospace systems teams at the University of Melbourne conduct world renowned multi-national research in hydrodynamics. Studies into submarine signatures, biofouling effects on ships and helicopter landings on ships are all conducted in cutting-edge laboratories and wind tunnels. This research is critical to improving the planning and management of ship and submarine operations. Research has contributed to international efforts to understand wakes of underwater vehicles in order to design new tactics to reduce detection.

The University has over 300 international agreements across the globe including strong and productive relationships with key UK and US AUKUS Delivery Partners.

In addition, the University has contributed towards critical developments such as submarine propulsion system optimisation, advanced functional materials, submarine atmosphere control, drag reduction of ships and submarines, multifunction radar, radar tracking and sonar systems. The University also has 'life support systems' technologies and expertise around water and air purification, renewal and recycling that enable living underwater for months at a time.

The University of Melbourne

Quantum technologies

The University has broad capability across various quantum fields including quantum computing, quantum sensing, quantum materials and modelling, fabrication and testing of nanoscale to macroscale architectures, quantum optics and probes. Of direct relevance to AUKUS, work in this space has resulted in the development of novel quantum magnetometers for submarine and ship detection. Other applications include enabling navigation in GPS denied environments, signal processing for Intelligence, Surveillance, Reconnaissance (ISR) and quantum cryptanalysis and encryption to secure military operations.

The University has worked in quantum computing for some two decades as a critical theoretical and experimental node of the Centre for Quantum Computation and Communication Technology. In collaboration with IBM, the University of Melbourne established the sole university-based IBM Quantum Hub in Australia and New Zealand. Researchers are working at the forefront of practical quantum computing, spanning areas from quantum machine learning, quantum simulation and quantum algorithms to quantum error correction and fault-tolerant architecture design.

Research into the fundamental and theoretical understanding of quantum mechanics is driving the development of new areas of quantum impact including defence, biological and medical technologies, finance, and optimisation. There is deep involvement in the design, fabrication and analysis of materials and devices for quantum technology. Current research also seeks to extend the performance of quantum technologies beyond the current technological state.

Artificial Intelligence and Autonomy

The University of Melbourne's AI research addresses many different aspects of AI, encompassing deep learning, data mining, machine learning, natural language processing, and agent-based systems. The theories and techniques can be applied to a wide range of practical

problems, including cybersecurity, health, finance, and government. Areas of expertise include AI Assurance, AI and Autonomy, Computer Vision, Natural Language Processing, Machine Learning, Human-Machine Teaming, Explainable AI and Digital Health.

As AI-based systems are being more widely used to detect and respond to cyber attacks, these AI systems are themselves becoming a major focus of cyber attacks. An active focus of research is adversarial machine learning and AI assurance, which aims to develop robust AI systems that are resilient to attacks, such as poisoning of training data, designing adversarial examples that fool AI systems, or introducing backdoor attacks that create vulnerabilities in the supply chain for AI subsystems. This research has resulted in significant collaboration with Defence in areas such as demonstrating the risks of adversarial attacks on AI-based systems in cyber defence, designing defences against such adversarial attacks with strong guarantees of robustness, and anticipating new attacks of the future when adversaries start using AI to automate their attacks.

The University of Melbourne

Autonomy

The Melbourne Information, Decision and Autonomous Systems (MIDAS) Laboratory is at the forefront of autonomous systems research for defence and civilian uses. The lab focuses on technological advances in automation, control systems, analytics, machine learning, system optimisation and coverage control using swarms of multiagent systems including unmanned underwater vehicles (UUVs) and unmanned aerial vehicles (UAVs).

AI, Ethics and Legal

The Centre for Artificial Intelligence and Digital Ethics (CAIDE) facilitates cross-disciplinary research, teaching and leadership on the ethical, technical, regulatory and legal issues relating to Artificial Intelligence (AI) and digital technologies.

CAIDE seeks to explore the impact, deployment and governance of emerging technology across society, combining legal, ethical and social perspectives with technological

expertise to guide the development and appropriate policy settings for effective use of such technologies across society.

Advanced Cyber

Cyber-related research at the University addresses key challenges around threat detection and the development of technologies to protect communications systems and other critical infrastructure. Key expertise in this area includes network security and cryptography, anomaly and network intrusion detection, adversarial machine learning, authentication and authorisation, distributed systems security, formal verification, fuzzing, information security management and network auditing and accounting.

The cyber security team deals with developing AI-based systems to detect attacks in large, complex systems, using formal methods to design platforms that are resilient to attack, designing robust controllers for critical infrastructure, and providing a legal framework for the governance of cyber operations that span a range of jurisdictions.

Hypersonic and Counter-Hypersonic Capabilities

The development of long-range precision strike capability in the region introduces new operational challenges for defending Australia. The University's research into the dynamic mission optimisation of hypersonic flight vehicles seeks to understand the capabilities of hypersonic systems given this changing environment. This involves the integration of modelling and control systems with the design of next generation hypersonic platforms.

The University's research also addresses vehicle robustness in the presence of sources of uncertainty arising from factors unknown during the trajectory design phase including environmental disturbances, moving end points and modelling error. This approach has the aim of shifting from near-optimal model design to providing confidence guarantees of mission completion in the presence of uncertainty, whilst maintaining computational tractability.

This work extends beyond the hypersonic domain and has crossover effects into other disciplines including

control systems, optimisation, and fluid dynamics. Research outcomes can also be applied to the broader sector of advanced manufacturing where simulation tools and control systems are increasingly relied upon in the manufacture of complex systems.

Electronic Warfare

Modern digital technology is enabling the development of advanced antenna systems and the management of spectrum in contested environments. The University has significant expertise in advanced electromagnetic modelling and radio frequency (RF) system design to improve electronic warfare surveillance detection capability. Other key areas include cognitive radar, cognitive electronic warfare, cognitive communication, spectrum management for autonomous networked systems, sensor networks for bandwidth, constrained environments, and compressive sensing.

The University has designed and developed cutting-edge subsystems for telecommunications and defence. These technologies are recognised as critical to the development of next generation defence platforms.

Innovation

Melbourne Connect is a purpose-built innovation precinct anchored by the University of Melbourne with a vision to replicate the critical mass of innovation seen in places such as Kendall Square, Cambridge MA. The precinct redefines how businesses, researchers, government and entrepreneurs work together.

Accelerator programs

Melbourne Connect hosts the Melbourne Entrepreneurial Centre, a gateway to the entrepreneurship opportunities available at the University and oversees the Translating Research at Melbourne (TRAM) and Melbourne Accelerator Program (MAP) accelerators.

TRAM is Australia's premier university-based research impact accelerator. TRAM provides the research community with experiential training in crafting a value proposition from high-quality research, enabling the creation of commercially viable solutions to high-impact problems.

MAP provides 10 selected startups with mentoring from some of Australia's most brilliant business

minds, access to a global network of advisers, channels to partners and investors, and AU$20,000 in seed funding (with no equity taken).

Fishermans Bend

Planned to open in 2026, Stage 1 of the Fishermans Bend campus will be a super hub for innovation, with space for industry to co-locate. The deliberate integration of the commercial tenant areas with the University of Melbourne will deliver a truly unique and exemplary workplace.

Adjacent to Defence Science and Technology Group (DSTG), Fishermans Bend will be home to leading Defence industry manufacturers. With a focus on advanced manufacturing, defence technologies, materials and energy, Fishermans Bend offers an unprecedented collection of research and testing facilities to enable interdisciplinary collaboration and partnerships with the Defence sector and support the advancement of defence-related manufacturing capability in Australia.

Funding for startups

Venture capital funds Tin Alley Ventures and the University of Melbourne Genesis Pre-Seed Fund have been established to support research and new ideas through all commercialisation stages – from proof of concept through to investment-ready startups on the path to social and commercial success at scale.

The University of Melbourne and Breakthrough Victoria's Genesis Pre-Seed Fund backs early-stage startups with high potential. It supports researchers, students, alumni and innovators from affiliated organisations to take their innovation to a point where their startup is attractive to seed funding partners.

Melbourne Accelerator Program (MAP) provides 10 selected startups with mentoring from some of Australia's most brilliant business minds, access to a global network of advisers, channels to partners and investors, and AU$20,000 in seed funding (with no equity taken).

Tin Alley Ventures, a joint venture between the University and Tanarra Capital, is a University-dedicated venture capital fund that invests in high potential ventures developed within the University of Melbourne ecosystem from seed stage through to pre-IPO stage. This fund can accelerate the development of commercially relevant technologies aligned with ASCA's objectives around enhanced sovereign manufacturing capability and emerging/disruptive technologies.

Information sharing

The University holds Defence Industry Security Program (DISP) membership for Governance, Personnel, Physical and IT. With a dedicated Defence Security team, the University has the requisite security arrangements to work with Defence and industry and is exploring higher security networks and facilities at Fishermans Bend. The University's security team is integrated with its Research Integrity and Export Controls Office and has experience managing ITAR[5] related programs with industry.

Research infrastructure

Fishermans Bend

Scheduled for completion in 2026, Stage 1A of the University's new Fishermans Bend Campus has been designed to accommodate large scale equipment, laboratories and testing facilities unparalleled in the Southern Hemisphere including:

- X-Tunnel, a new state-of-the-art supersonic wind tunnel capable of high Reynolds numbers. The largest wind tunnel of its kind in Australia
- A Hybrid Continuous Loop Air-Sea Tow Tank (HyCASTT) and Deep Manoeuvring and Directional Wave Basin (DMAD)
- State-of-the-art wind/wave current interaction facilities
- An Energy Propulsion and Generation facility unique in Australia, and one of a very small number globally, that will be able to undertake experimental research and development at 100 kW to MW scale
- Industrial-scale fabrication and construction spaces.

5 US International Traffic in Arms Regulations

THE UNIVERSITY OF MELBOURNE

Melbourne information, decision and autonomous systems (MIDAS)

MIDAS are at the forefront of autonomous systems research developing technological advances in automation, control systems, analytics, machine learning and system optimisation. MIDAS has deployed decoys in defence ships against advanced anti-ship missiles. The autonomous networked platforms must optimise their trajectories to ensure a successful defence.

Advanced Protective Technologies for Engineering Structures (APTES)

The APTES group conducts risk assessment, modelling and vulnerability analysis of buildings and infrastructure against natural and man-made hazards. Key projects on which this group has been engaged as lead consultant include risk assessment and strengthening of landmark structures, government buildings, embassies and critical industrial facilities in Australia and abroad.

The Hunt Lab

The Hunt Lab engages in analytic performance and related activities with expertise in epistemology, analytics, intelligence studies, disinformation, risk analysis and futures thinking, expert elicitation and software development.

Other research groups and laboratories with defence applicability include:

- The Melbourne Centre for Data Science
- The Centre for Artificial Intelligence and Digital Ethics
- The Cloud Computing and Distributed Systems (CLOUDS) Laboratory
- The AI and Autonomy Lab
- The AI Assurance Lab
- Melbourne Energy Institute
- Infrastructure asset protection and management group
- Walter Bassett Aerodynamics Laboratory

- Control and Signal Processing Lab
- The Centre for Advanced Defence Research and Enterprise – Operating in Chemical, Biological, Radiological and Nuclear Environments (CADRE-OCE)
- Structures and Materials group
- Indoor air quality group
- Impact design group
- Information Systems group
- Human Robotics Laboratory
- Integrated Computational Materials
- Academic Centre of Cyber Security Excellence (ACCSE).

Workforce development

The University has an extensive track record in working with industry and government partners to address critical gaps in workforce capacity. The following are some examples of the University's initiatives to boost R&D-based Australian workforce capacity in AUKUS Pillar II areas as well as the Defence sector more broadly.

Graduate Certificate in Scientific Leadership

A collaboration between the University of Melbourne and DSTG, this course supports mid-career transitions from specialised science, technology, research and business professional roles into scientific leadership. Through the program, students gain access to distinguished leaders and mentors from across the Defence ecosystem, while developing practical management skills in a learner-focused, industry aligned environment.

The course is structured as a blended learning program where students take part in intensive residentials and online learning under the guidance of their workplace supervisors and Defence mentors.

Partnership with DSTG

The University has a long-standing partnership with DSTG and engages in various activities to build relevant research capacity and innovation in support of DSTG's strategic objectives. These activities include secondment and exchange

opportunities for university and DSTG personnel, collaborative research projects, and scholarships to support under-represented groups in the defence community. Through close partnership with DSTG and key partners, the University supports the delivery of defence and industry-ready solutions while contributing towards Australia's national defence capability.

National Centre for Advanced Defence Research and Enterprise (CADRE-OCE)

Led by the University, CADRE-OCE was established in collaboration with university partners (University of Adelaide, Queensland University of Technology and UNSW) and the Department of Defence. It is one of the largest OCE R&D consortiums and seeks to address the challenges arising from chemical, biological, radiological and nuclear (CBRN) threats. The centre provides Defence with front door access to the latest cutting-edge technologies, research, training and a skilled workforce to build sovereign capabilities and enable safe operation in CBRN environments.

An AUKUS-ready workforce

An effective AUKUS workforce will rely on a pipeline of qualified STEM graduates, particularly engineers and scientists, who will strengthen Australia's sovereign capabilities in critical Pillar II streams quantum, AI, hypersonics, advanced cyber, underwater capabilities and electronic warfare. Workforce needs are anticipated to primarily draw from graduate to senior engineers and scientists with backgrounds including computer science, electrical engineering, mechanical engineering, physics and mathematics.

Responding to the need for rapid workforce development, the University will educate 'nuclear-aware' engineers and scientists, who understand the nuclear environment through new curriculum content and work integrated learning opportunities. Six named majors in the Bachelor of Science program will feature new, nuclear-specific, third year subjects.

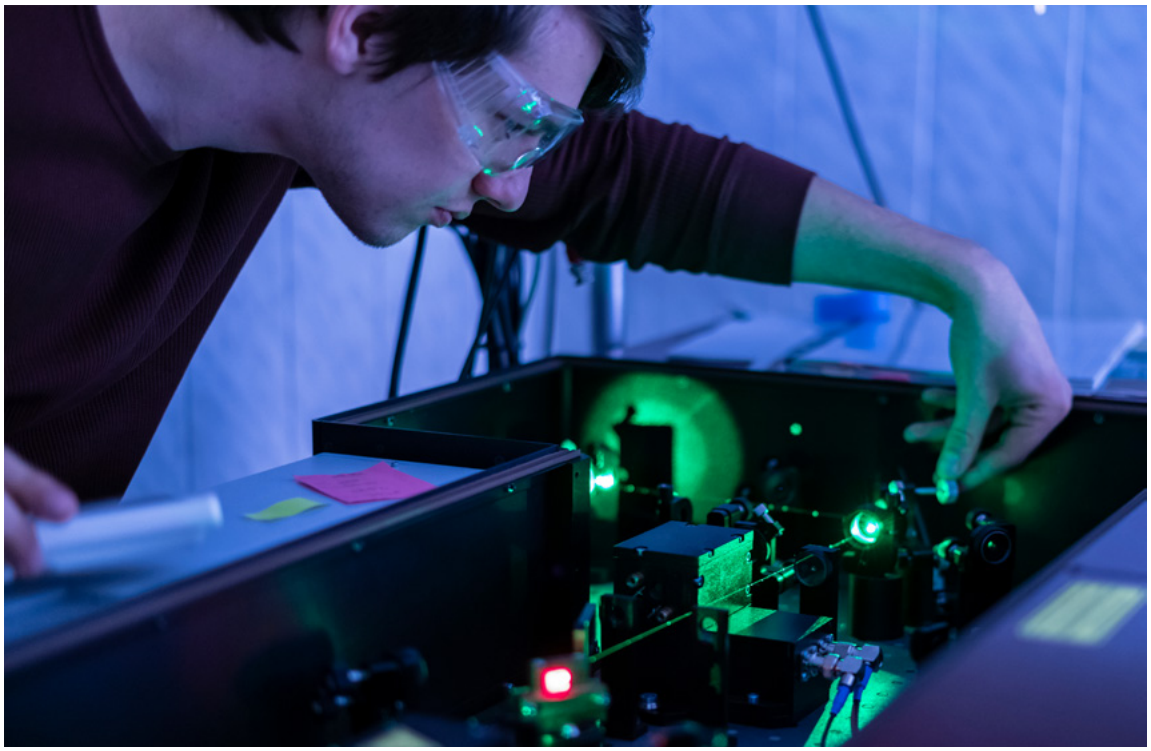
The University of Melbourne

The University is positioned to offer a wider value proposition that includes multiple entry points into AUKUS relevant programs including our Graduate Certificate in Scientific Leadership, VET collaborations and stackable, articulated microcredentials. By providing flexibility for lateral entry points and deploying a range of approaches to make our programs easily accessible, the University will deliver the transformational change needed to build the AUKUS workforce.

Collaborations

IBM Quantum Innovation Centre

The University of Melbourne (led by Professor Lloyd Hollenberg) leads the sole university-based IBM Quantum Innovation Centre in Australia and New Zealand. Through its role as an IBM Quantum Innovation Centre, the University has access to utility-scale quantum computing infrastructure – and able to provide this access to other institutions-to advance research in quantum computing,



and build a skilled quantum workforce, and develop quantum solutions for practical industry problems. The University is also an initial member of the IBM Quantum Network, a collaboration of 300+ Fortune 500 companies, academic institutions and national research labs and start-ups focused on developing the software and expertise needed to bring the benefits of quantum to broader society.

Adversarial Machine Learning

In the fields of AI and cyber security, the University has had a collaborative research project with DST Group on adversarial machine learning for cyber over several years. An important impact of this project has been to raise awareness in Australian Defence and other government agencies that adversarial machine learning is a valid concern for cyber security, in contrast to the traditional research focus on adversarial machine learning for image classification tasks.

ARC Centre of Excellence for Quantum Computation and Communication Technology

The University is an academic partner (University of Melbourne team: Professor David Jamieson and Professor Jeff McCallum) on the Australian Research Council (ARC) Centre of Excellence for Quantum Computation and Communication Technology. Led by Professor Michelle Simmons (UNSW Sydney), the Centre is focused on the delivery of cutting-edge quantum research and full-scale quantum systems to bring significant economic benefits to the Australian community and beyond. Combining the expertise of seven Australian universities (including four Go8 universities) and over 25 national and international partner organisations across government and industry, the Centre represents one of the world's largest dedicated efforts in quantum computation and communication. Key collaborators include international partners from the UK and US as well as DSTG.

The University is also an initial member of the IBM Quantum Network, a collaboration of 300+ Fortune 500 companies, academic institutions and national research labs and start-ups focused on developing the software and expertise needed to bring the benefits of quantum to broader society.

The University of Melbourne

Key examples

The University of Melbourne is embedded within a rich defence ecosystem and has maintained productive relationships with key defence stakeholders across government and industry. These long-standing partnerships reflect the shared trust in and value of the work that takes place across organisations.

New sonar processing techniques

The University of Melbourne, in conjunction with a large Australian-based US prime company, has developed new sonar processing techniques for novel underwater surveillance techniques. This technology holds promise of providing wide-area surveillance and choke point tracking of vessels.

Australian-US Cyber Research Program

The University is leading the Australian research team in collaboration with US universities (Carnegie Mellon, University of California San Diego, University of Wisconsin). The Cohesive and Robust Human-Bot Cybersecurity Teams joint MURI-AUSMURI program is developing advanced Artificial Intelligence-based cyber protection systems and enhancing the robustness of human-AI teams in contested environments.

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THE UNIVERSITY OF MELBOURNE

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Monash University

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Skills and capability

Monash University's capability in working with Defence is grounded in its Strategic Plan, *Impact 2030*, which commits Monash to a path that is driven by purpose. Through research, education and innovation, the University weaves industry and government into the fabric of our institution, to address the global challenges of our time: geopolitical security, climate change, and fostering thriving communities.

Monash University has a long history of working with Australian and international governments in relation to Defence projects in pursuit of international peace and security.

Over the last five years, Monash researchers have received over AU$263 million in funding involving collaborations with defence organisations (including more than AU$80 million involving Australian Defence organisations and more than AU$50 million from US Defence organisations) spanning basic and applied research, industry cooperative research centres, organisational training and workforce preparation.

MONASH University

Partners include the Australian Defence Forces, Department of Defence, the Defence Science and Technology Group (DSTG), the Office of National Intelligence, the US Department of Defense, the US Office of Naval Research, Intelligence Advanced Research Projects Activity (IARPA) and Defense Advanced Research Projects Agency (DARPA).

Research strengths

Monash has capabilities of relevance to AUKUS across both pillars, including design, operation and maintenance of submarines, quantum technologies, artificial intelligence, cybersecurity, hypersonics and innovation. Primarily based across three world-leading Faculties including Engineering, Science and IT, Monash's research strength is highly collaborative and interdisciplinary in nature.

Monash Engineering is a global top 100 engineering school :

- **#54 in the world**
- **#1 in Australia for Engineering & Technology.**

For over 60 years, Monash has developed groundbreaking, globally recognised research across engineering and applied sciences, from nanomanufacturing to healthcare engineering, and from decarbonisation to robotics.

Monash Science is ranked the best university in Australia for Chemistry according to the 2023 QS World University Rankings. All Faculty of Science schools are ranked in the top 100 globally according to the 2023 QS World University Rankings. Monash Science is ranked within the top 100 for Life Sciences and Physical Sciences in The Times Higher Education World University Rankings 2023.

The Faculty of IT has the largest data science group in the Asia Pacific Region and one of the top five data visualisation groups and optimisations groups in the world. The Data Science and AI department has unrivalled capabilities and researchers are solving real-world problems through the analysis and management of data. Monash's Software Systems and Cybersecurity is home to the leading blockchain research group in Australia and the

Monash University

leading engineering research group in Australia and the Department of Human-Centred Computing is at the forefront of the digital technologies transforming the world and blurring the boundaries between the virtual and physical.

Monash University is innovative and collaborative in its approach to security, risk and resilience. Monash is proactive in strengthening processes, policies and procedures in relation to Defence Industry Security Program (DISP) certification, risk awareness, prevention and management, including preventing foreign interference.

Quantum technologies

Monash has contributed substantially to Australia's Quantum Technology research output, investing significantly into quantum research over the past 15 years. Monash's investment in quantum research is exemplified by the AU$175 million New Horizons Centre, which houses cutting-edge laboratories for six experimental groups specialising in Bose-Einstein condensates, diamond sensors, graphene, topological materials, and solid-state device physics.

Monash research endeavours cover various quantum-related domains, reflecting our multidisciplinary approach to cutting-edge science and technology integrating the research activities of the Faculties of Science, IT and Engineering. These areas encompass:

- quantum-safe cryptography, where we design, analyse, and implement secure cryptographic methods in preparation for the quantum era
- quantum information, where we focus on noise characterisation and mitigation alongside the development of advanced simulators for complex quantum processes
- exploration of quantum matter encompasses exciton-polarons, polaritons, plasmonic phenomena, impurities, semiconductors, and ultracold atoms, shedding light on their quantum properties
- magnetometry, specialising in ultrasensitive atomic gas-based and wide-field diamond sensors for precise magnetic field measurements

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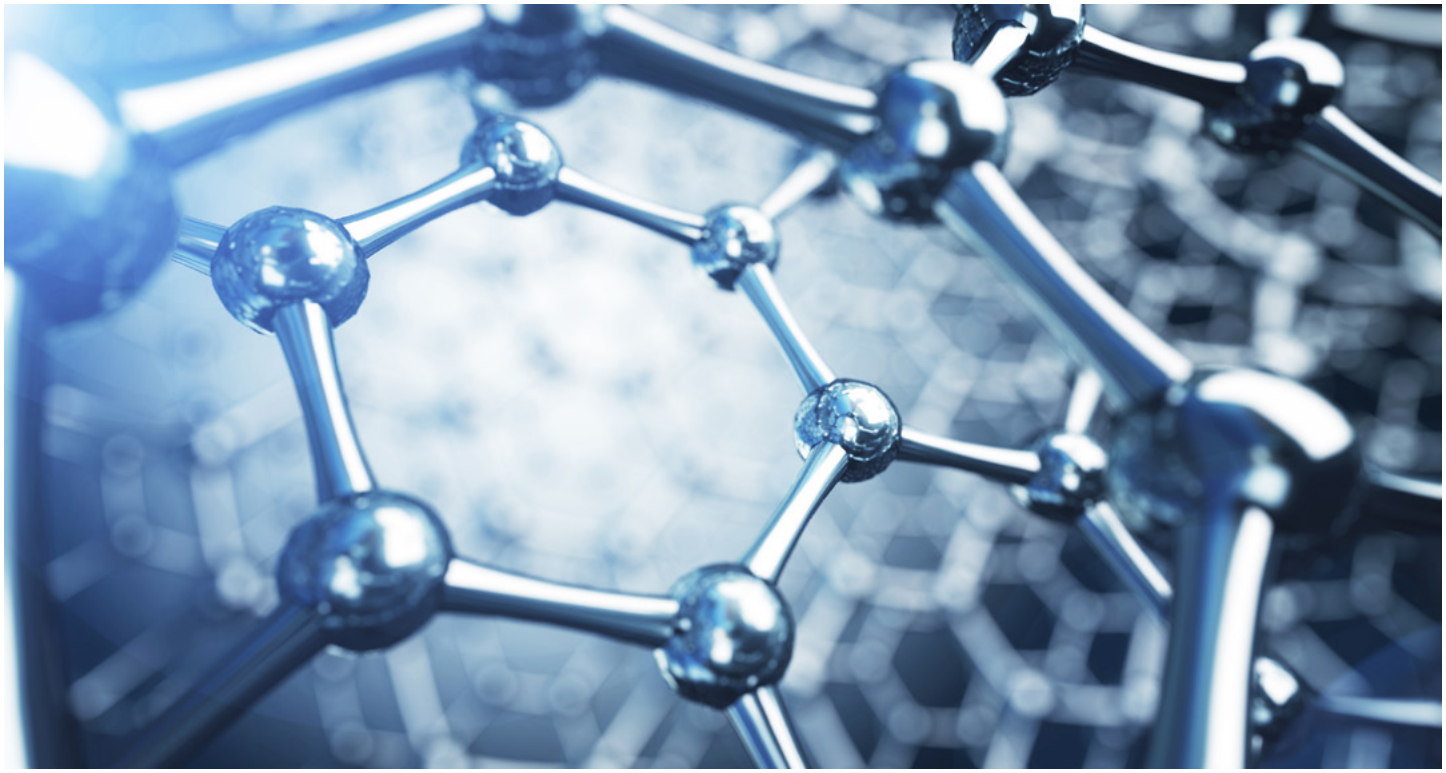

- surfaces, investigating bioinspired and atomically detailed surface engineering and studying 2D materials such as plasmene
- research into electrodynamics simulators, resonance energy transfer, and innovations in transistors, lasers, and spasers
- in nano-scale engineering, involving research into charge transfer, antenna design, detector development, and the exploration of quantum dots and wires
- work bridges classical and quantum technologies, developing and integrating software and hardware solutions harmoniously connecting these realms for enhanced technological advancement.

Complementary quantum computing capability includes developing and integrating software and hardware at the interface between classical and quantum technologies, and quantum-safe cryptography: design, security analysis, and implementation.

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Monash Engineering stands at the forefront of quantum electrodynamics-based quantum device design, leveraging the computational power of state-of-the-art supercomputing resources. Relevant to the AUKUS platform, the university has the skills to design precision sensors, energy and signal generation devices, and high-speed peripheral interconnections achieved by integrating the most advanced engineering design methodologies available today.

The Monash engineering team collaborates extensively globally, including with the Jet Propulsion Laboratory at Caltech, the Institute of Optics at the University of Rochester, New York, and the University of Oxford. In-house expertise and proprietary code extend beyond the domain of quantum device research, encompassing techniques for solving complex coupled partial differential and integrodifferential equations. These methodologies are instrumental in accurately estimating quantum states within materials, devices, and other facets of AUKUS system design.

Artificial Intelligence and Autonomy

Monash's Faculty of IT and its Department of Data Science and Artificial Intelligence (DSAI) in conjunction with the Faculty of Engineering has the following capability:

- Application of AI and Machine Learning (ML) to deliver information warfare capabilities at speed and scale
- Development of new information warfare command-and-control concepts, algorithms and architectures
- Mixed-reality human-machine teaming to support physically embedded workflows
- Designing AI systems to collaborate with human decision makers in high risk, time critical environments
- Design of exploratory AI systems for interactive sensemaking, value-based software
- Multi-agent systems; Agent-based models

- Bayesian: AI; Statistical ML; Explainable AI; Graphical models, Bayesian networks, graph neural networks
- Vision and Language Processing
- Theoretical foundations of machine learning and AI
- Deep learning, representation learning
- Robust and adversarial machine learning
- Plan recognition; Fake news; Evolutionary dynamics
- Ecological, social, epidemiological simulation & modelling
- Time series classification and analytics
- Optimisation software focused on workforce planning, production, schedules, freight, timetabling operations, team coordination to improve situational awareness
- Social and cultural implications of data mining, and online monitoring.

Advanced Cyber

Monash University has a dedicated Faculty of Information Technology and **the largest data science group in the Asia-Pacific region**, the Oceania Cyber Security Centre's (OCSC) which is at the forefront of research to strengthen cyber security capacity and maturity, and to build contextualised digital resilience in Australia and with Indigenous populations throughout the Asia-Pacific region.

The university has one of the top-five data visualisation groups and optimisations groups in the world. Researchers at the Department of Data Science and AI use its unrivalled capabilities to solve global problems through the analysis and management of data.

Monash's Software Systems and Cybersecurity Department is home to the leading blockchain research, post-quantum cryptography, software security, and human-factors cybersecurity group in Australia, and the leading engineering research group in Australia.

Monash University

Monash's Department of Human-Centred Computing is at the forefront of the digital technologies that are transforming the world and blurring the boundaries between the virtual and physical.

Monash has world-class, state-of-the-art research infrastructure supporting its research community, with best-in-field operators providing a one-stop-shop for users.

Located within the Monash Business School, Monash IP Observatory has developed a novel cloud-based, global technology platform that captures real-time information about the world's internet infrastructure, providing a unique informational advantage to defence and intelligence sectors, humanitarian and disaster relief efforts and more. Used in recent global events, the IP Observatory's data can assist a range of defence industries in providing rapid responses to significant economic, political and social events.

Hypersonic and Counter-Hypersonic Capabilities

Monash's Faculty of Engineering Laboratory for Turbulence Research in Aerospace and Combustion (LTRAC) Research Group has internationally recognised expertise in the areas of turbulent flows, combustion, alternative and renewable energy, laser diagnostics and numerical simulation of turbulence. Hypersonics capability includes: free and impinging Supersonic jet flow; hybrid rocket development and rocket propulsion; aero-acoustic sound generation,

coupling to structural vibrations and catastrophic instabilities; compressible flows with shock – boundary layer interaction; and fully compressible high-fidelity simulations using in-house and open source massively parallel direct numerical and large eddy simulations (DNLES) codes.

Complementary mathematical capability exists relating to turbulent flow and the application of theoretical and computational methods to uncover some of the organised vortex structures on which turbulent flows are now known to evolve.

Electronic Warfare

Cyber and electronic warfare capabilities include:

- development of advanced cyber warfare
- electronic warfare and influence operations capabilities
- integration of cyber warfare, electronic warfare and influence operations into a single information warfare capability
- data Engineering: big data management, Internet of Things (IoT) data processing, Urban Fog Edge & Cloud Computing, Spatial databases
- agile transformation
- empirical software engineering
- automated software engineering and testing
- debugging and repair.

Used in recent global events, the IP Observatory's data can assist a range of defence industries in providing rapid responses to significant economic, political and social events.

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Innovation

Monash Innovation is where research discoveries become commercialised innovative solutions for the problems facing our communities, nation, and the world. It is also a training ground for self-directed professionals and entrepreneurs, with programs designed to upskill individuals in translating new ideas into commercially successful outcomes.

Monash University has a proven track record in innovation and commercialisation, with accomplishments over the last five years including: submitting 561 invention disclosures, completing 165 license deals; developing 213 new patent families, bringing our active portfolio to 342 patent families; attracting investments from 13 venture capital funds; and spinning out 29 companies based on Monash intellectual property.

Spinout companies include those related to AUKUS pillars such as additive manufacturing, patented graphene technology that optimises ultracapacitors, novel technology to produce green ammonia and AI and machine learning to simulate organisational processes.

Information sharing

Monash will expand and accelerate sharing of sensitive information, including as a priority enabling workstreams that underpin our work on agreed areas of advanced capabilities.

Research infrastructure

Monash has a cutting-edge network of 25 open-access ISO 9001 certified research platforms that underpins critical research capability across Advanced Manufacturing, Digital Technologies, Energy, Health, Medical Devices and Biotech. These include the Monash Centre for Additive Manufacturing, Monash Centre for Electron Microscopy, Monash X-ray platform and the Melbourne Centre for Nanofabrication. Our Clayton campus is at the centre of the Monash Technology Precinct which has active and enduring partnerships with CSIRO, ANSTO and the Australian Synchrotron and over 13,000 businesses.

MONASH University

Workforce development

A Monash education provides rich learning experiences for students that foster deep engagement across international borders and with other cultures, particularly through Monash campuses across the world, and develop and enhance the generation of innovative ideas and projects, individually or in teams. Monash makes direct engagement between students and industry and government partners, including projects and internships, integral to a Monash education. With over 84,000 students, every undergraduate has the opportunity to undertake industry-based experiences. For existing, and new, workforces we offer a service menu of bespoke and scaleable educational offerings, including through the identification of talent pipeline, professional development, talent diversity and sector wide uplift.

Collaborations

ARC Centre of Excellence in Future Low-Energy Electronic Technologies (FLEET)

FLEET, headquartered at Monash University, is a collaboration of more than 100 researchers at seven Australian universities and 13 Australian and international science organisations. The Centre uses the emerging science of topological materials and atomically-thin 'two-dimensional' (2D) materials to create ultra-low energy electronics that achieve zero, or near-zero, wasted dissipation of energy. FLEET places Australia at the forefront of scientific research – building capacity for advanced electronics research and training today's workforce for the electronics industry of the future. FLEET's Australian partners include the Australian National University, UNSW, the University of Queensland, RMIT University, the University

Our Clayton campus is at the centre of the Monash Technology Precinct which has active and enduring partnerships with CSIRO, ANSTO and the Australian Synchrotron and over 13,000 businesses.

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of Wollongong and Swinburne University of Technology. It is funded by the ARC and by the member universities. Other FLEET partners include Australian Nuclear Science and Technology Organisation, the Australian Synchrotron, California Institute of Technology, Columbia University in the City of New York,

In addition to the emerging partnership between participants, the project will advance sovereign capability to develop maritime intelligence gathering technology for the Royal Australian Navy to underpin stability in our region.

Johannes Gutenberg University at Mainz, University of Maryland Joint Quantum Institute & National Institute of Standards and Technology, Max Planck Institute of Quantum Optics, the National University of Singapore, the University of Colorado Boulder, University of Maryland Center for Nanophysics and Advanced Materials, the University of Texas at Austin, Tsinghua University at Beijing, and the University of Würzburg in Germany.

ARC Linkage Project with Safran Electronics & Defense "Collaborative Sensing and Learning for Maritime Situational Awareness"

The project aims to demonstrate coordinated autonomous sensing of naval assets in dynamic maritime environments, reducing the operational load required to deliver a high quality maritime situational awareness. A realistic simulation-based approach will help Australia develop novel artificial intelligence technology including: self-adaptive strategies for dynamic asset allocation, embedded smart sensing capabilities for naval observation systems and novel approaches to continuous collaborative learning from multi-spectral media. In addition to the emerging partnership between participants, the project will advance sovereign capability to develop maritime intelligence gathering technology for the Royal Australian Navy to underpin stability in our region.

MONASH University

Experimental investigation of the effect of surface roughness on a plane wake using particle image velocimetry

Monash Laboratory for Turbulence Research In Aerospace and Combustion funded by DSTG, 2017–2021

An important contributor to drag on maritime platforms is surface roughness. Current computational fluid dynamics (CFD) modelling tends to assume hydrodynamical smooth surfaces. This assumption can result in an underestimation of viscous drag even for a vessel with a clean hull, thus affecting the performance including propulsion and stealth and the operational envelope of the vessel.

Novel techniques are applied to measure time-resolved and high-spatial resolution instantaneous velocity fields of a rough wall turbulent boundary layer developing on a plate at zero incidence. This enables investigation of its effect on the structure of the wake flow downstream of the blunt trailing edge of the plate on which the layer is developing.

Novel measurements that captured the impact of 2D and 3D surface roughness turbulent boundary layer flow improve inflow into the propeller propulsion system and minimise the wake signature of submarines.

Monash University

Assured Neuro-Symbolic Learning and Reasoning (ANSR) Program

Monash's Vision and Language (VL) Group funded by DARPA, 2023–2026

Purely data-driven, neural network-based approaches to autonomy (e.g. unmanned aerial vehicles and land robots) suffer from fundamental limitations that hinder their application in mission-critical scenarios, as they cannot provide guarantees on safety and other highly-desirable properties. This US-DARPA-funded research proposes HARNESS, a Hierarchical Abstractions and Reasoning for Neuro-Symbolic System, that deeply integrates symbolic modelling and reasoning techniques with neural network-based learning algorithms, yielding a powerful paradigm that achieves strong robustness and generalisability and formal assurances of the system's behaviours.

Nanophotonics

Monash's School of Physics and Astronomy funded by the US Air Force Office of Scientific Research

This project addresses barriers towards optical and quantum information processing, imaging, communications, displays, sensing, and energy conversion requiring interaction and manipulation of light with nanometer-scale objects/structures. Through the design and modelling of nanostructured materials interaction with light UV to near-IR optical measurements, ultrafast response characterisation and single photon correlation, the outcomes result in compact photonic components, high efficiency energy conversion, and single photon sources for quantum information processing.

MONASH University

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Skills and capability

For more than three decades, the University of Queensland (UQ) has been actively engaged in research excellence and talent pipeline partnerships to support sovereign and allied defence capability. The University is a hub for national and international research excellence in five of the AUKUS Pillar II streams. It is ranked among the world's top 50 universities, and in 2023, topped Australia's Best Universities Ranking based on research performance and global reputation metrics.

UQ is home to the largest university-based hypersonics group in the world and as a result, is well-integrated into allied defence science and technological networks. UQ's longstanding partnership with Defence Science and Technology Group (DSTG) underpins Australia's hypersonic capability but also forms a critical part of Australia's engagement with US and UK partners under the emerging AUKUS Pillar II framework.

UQ researchers are actively developing and demonstrating advanced technologies through research collaborations with US and UK partners.

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These include the US Air Force Office of Scientific Research (AFOSR), Air Force Research Laboratory (AFRL), Office of Naval Research (ONR), US Army Combat Capabilities Development Command Army Research Laboratory (DEVCOM ARL), Lockheed Martin Corporation, Boeing Corporation, the US Joint Hypersonics Transition Office (JHTO) and University Consortium of Applied Hypersonics (UCAH) led by Texas A&M University, MBDA UK and Oxford University. Backed by an advanced aerospace community in Queensland and access to inland ranges, UQ is advancing unclassified hypersonic flight testing, including its intersection with quantum sensors and AI technologies convergent with AUKUS Pillar II priorities.

UQ is home to the largest university-based hypersonics group in the world and as a result, is well-integrated into allied defence science and technological networks.

UQ's world class science and engineering faculties support a breadth of research innovation across the other AUKUS Pillar II priority areas in electronic warfare, AI and autonomous systems, quantum sensing, computing and biotechnology, as well as advanced cyber. UQ has considerable strengths in complementary technologies that contribute across capability areas such as nanoscale engineering, advanced materials, human factors, and medical countermeasures.

UQ is investing further in facilities, policies and people which support AUKUS research collaborations. The University houses the 'Bunya' supercomputer, which is the most powerful institutional supercomputer in the Go8. Combined with the University's Collaborative Research Platforms and a range of country-wide National Collaborative Research Infrastructure Strategy (NCRIS) capabilities, UQ researchers and partners have access to cutting edge research infrastructure and test facilities. UQ is strengthening the enabling environment for defence

research through the appointment of specialist personnel experienced in defence engagement, Defence Industry Security Program (DISP), export compliance and other security safeguards. In 2024 the University's DISP Level 2 (SECRET) facility will be certified to enhance information sharing and exchange under the AUKUS Pillar II framework.

- Engineering: Water engineering, civil engineering, tidal energy, wave energy, renewable energy production, coastal engineering, analysis of tidal currents, pipeline survey, limnological processes, sea-ice characteristics, autonomous underwater vehicle, sediment relocation strategy, ports, maritime

In 2024 the University's DISP Level 2 (SECRET) facility will be certified to enhance information sharing and exchange under the AUKUS Pillar II framework.

Research strengths

Undersea capabilities

UQ research strengths in undersea capabilities are located in a number of different faculties and research institutes across the University. The main cross-intersection in these capabilities is in the Quantum Positioning, Navigation and Timing (PNT) area with direct application to undersea imaging and sensing capabilities. The University's main research strengths are:

- Neuroscience and Psychology: Reducing uncertainty in perceptual decision making by training awareness of neurocognitive states', neurocognition and perceptual decision-making for submariners
- Trusted Autonomous Systems: Legal frameworks governing maritime robotic and autonomous systems, artificial intelligence, Arms control law, international law applicable to cyber operations.

Professor Halina Rubinsztein-Dunlop, AO, FAA, FRSB, Director of Quantum Science Laboratory, School of Mathematics and Physics at The University of Queensland has been recognised for her pioneering contributions in micro and nano-laser micromanipulation, including her work with optical tweezers and atom optics, as well as nano-optics with applications in biophotonics

Quantum technologies

Queensland leads Australia in University-Defence partnerships in quantum technologies. UQ constitutes a key node of the Defence Quantum Technologies Research Network, is holder of several Next Generation Technologies Fund (NGTF) grants and is committed to fundamental discovery that leads to field-based deployment. UQ researchers are working with the Australian Department of Defence and industry partners to integrate and package quantum-sensing technologies in military environments.

UQ Quantum researchers work closely with international defence agencies, such as AFOSR and the US Army Research Office (ARO). By leveraging the Advanced Strategic Capability Accelerator Emerging and Disruptive Technology (ASCA EDT), the Queensland Quantum and Advanced Technology Strategy, and the National Reconstruction Fund, UQ will establish the National Quantum Computing Testbed, which would significantly boost quantum computing capability in Australia.

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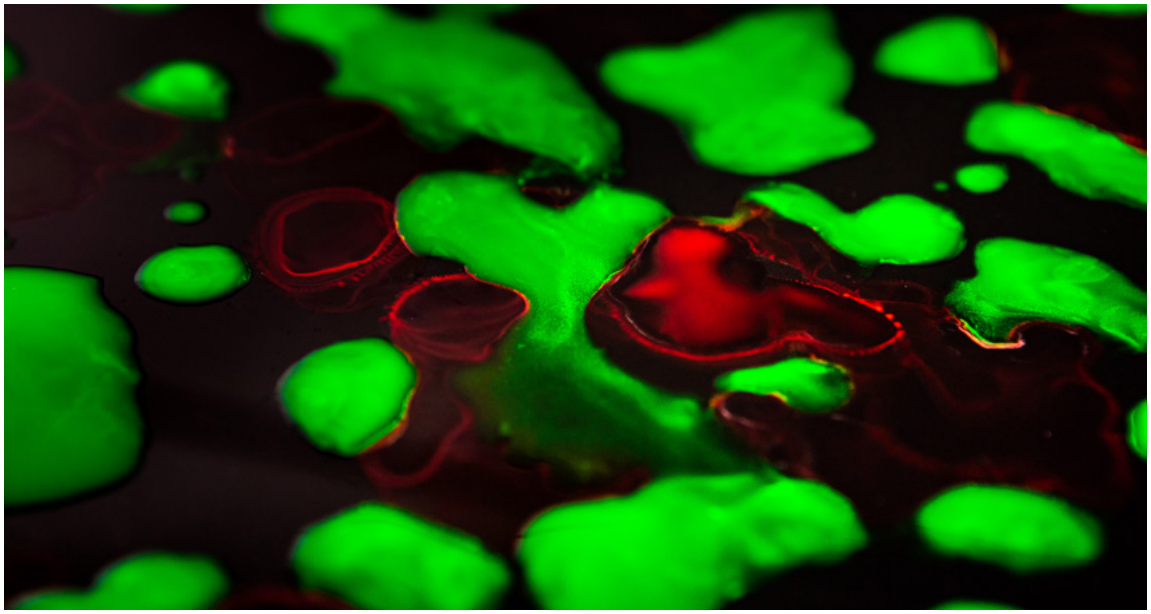
Position, navigation and timing, and situational awareness

UQ is focused on next generation quantum-sensing technologies for situational awareness including improved PNT; improved underwater communications; and improved detection of biological and chemical threats, both artificial and natural. Foci include quantum magnetometers, accelerometers, and sensors that go beyond the capabilities of conventional sensors in detecting vibrations, mass, and communication intercepts. These sensors are crucial tools for navigation in GPS-denied environments, such as underseas, and for through-earth and through-sea communications.

Quantum sensing technologies

UQ is developing an array of quantum-sensing technologies, enabling: gravity tomography, inertial sensing, noncontact weighing, quantum link verification, rotation sensing, and super-resolution imaging. For example, UQ researchers in collaboration with Defence and other key partners including NASA, Lockheed Martin Corporation and Orica, have developed: on-chip acoustic sensors and magnetometers with 100X better sensitivity than previously possible; and state-of-the-art magnetometers that are cryogenic-free, allowing deployment on drones and other



Quantum Dots (semiconductor nanocrystals) courtesy of UQ's Australian Institute of Bioengineering and Nanotechnology (AIBN). The Superconducting Quantum Devices laboratory at the University of Queensland is the leading Australian laboratory in the space of superconducting quantum circuits

low size-weight-and-power (SWaP) applications. Similarly, UQ has made fundamental leaps in new forms of accelerometery based on quantum-matter waves, allowing precision a billion times superior to existing technology, providing a vital capability for precision navigation via dead-reckoning.

Cross-intersection across AUKUS Pillar II streams

There are two main areas of cross-intersection across Pillar II streams:

1. Advanced Cyber, both using quantum link verification to ensure the integrity of physical communication links, and developing quantum learning machines for low-SWAP computation and smart sensing
2. applying quantum sensing for Undersea Capabilities and Hypersonic and counter-hypersonic capabilities, e.g. using quantum sensors on UQ's electric propulsion 'STAje-' flight trials, scheduled in 2024.

Artificial Intelligence and Autonomy

AI capability at UQ cuts across both fundamental and applied research with specific strengths in language modelling (LLMs), machine learning (ML) and data science (DS). Further research is being undertaken into data management, computer vision and multimedia computation, data mining, optimisation and statistics, and human centred AI. Researchers at UQ are leading the world in determining how autonomous systems can operate reliably without knowing the exact effects of their actions or fully understanding of the world around them. They also conduct research on how to ensure that the software that controls autonomous systems is robust and resilient. UQ experts in AI are engaged in research partnerships on large-scale sequential decision-making and tools for complex adaptive social systems in robots with the US Office of Naval Research and the Asian Office of Aerospace Research and Development.

The University of Queensland

UQ specialises in unmanned aerial vehicle platform design (aerodynamics, dynamics, propulsion, control), autonomous vehicle technology, social robotics, bipedal legged locomotion, disposable sensor modules, and embodied intelligence. The UQ Robotics Design Lab (RDL) approaches robotics as a holistic challenge, considering mechanical structure, planning, sensing and algorithm development as a simultaneous design problem.

UQ Cyber is an interdisciplinary research leader in the automation of Operational Technology cyber security using AI, Moving Target Defence and Trusted Computing techniques.

The broad nature of the discipline gives rise to a wide variety of impact areas: the RDL is best viewed as an on-demand engineering problem solving/innovation unit for producing pragmatic, high-Technology Readiness Level (TRL) solutions with clear pathways to implementation. RDL has an ongoing connection with Trusted Autonomous Systems Defence Cooperative Research Centre (TAS-DCRC).

UQ's work in machine intelligence and robotics directly addresses the Artificial Intelligence and Autonomy pillar II area, with a strong focus on innovation work. UQ has spun-off three start-up companies based on RDL research in the fields of mining, athletic wearables and bipedal robots.

Cross-intersection across Pillar II streams

RDL's expertise in drone control and flight systems have intersections in Hypersonics (for hypersonic guidance and control to intercept), and our AI research connects with advanced cyber and quantum.

Advanced Cyber

UQ Cyber is an interdisciplinary research leader in the automation of Operational Technology cyber security using AI, Moving Target Defence and Trusted Computing techniques. UQ Cyber researchers are working on heuristic, machine learning and AI planning approaches to enhance intrusion detection for critical infra-structure industrial control systems and protocols. Techniques are focused on mission assurance and effectiveness against an operational environment of legacy equipment.

UQ Cyber is funded by US DEVCOM ARL on Software-Defined Networking Moving Target Defence approaches, and have full capabilities in provenance tracking, attribution, Internet of Things (IoT) security, cloud computing security risk modelling/assessment, and attack and defence simulations.

UQ has established a leading research group on cybersecurity within the School of Electrical Engineering and Computer Science (EECS). Together with Oracle Labs and DSTG, researchers in formal methods and secure software engineering from UQ EECS are working on solutions which enable the detection and reduction of security vulnerabilities arising in complex, interconnected software systems, and developing interactive and automated tools to assist with identifying and analysing such vulnerabilities. More broadly, UQ Cyber Security undertakes interdisciplinary research across these core areas:

- Secure quantum communications
- Secure communications for space
- Cyber autonomy and automation
- IoT and cyber physical security
- Data privacy and user data control
- Cyber law and ethics
- Secure software engineering
- National security and cyber policies
- Cyber criminology
- Critical Infrastructure.

AI-based intrusion detection and moving target defence have the potential to form a significant part of a broader collaborative initiative under the AUKUS framework, addressing cybersecurity challenges at a larger scale. The importance lies in enhancing defence and national security capabilities, particularly for Australia and its allies, as these projects focus on securing emerging networked systems such as autonomous vehicles and safeguarding various critical infrastructure from evolving cyber threats.

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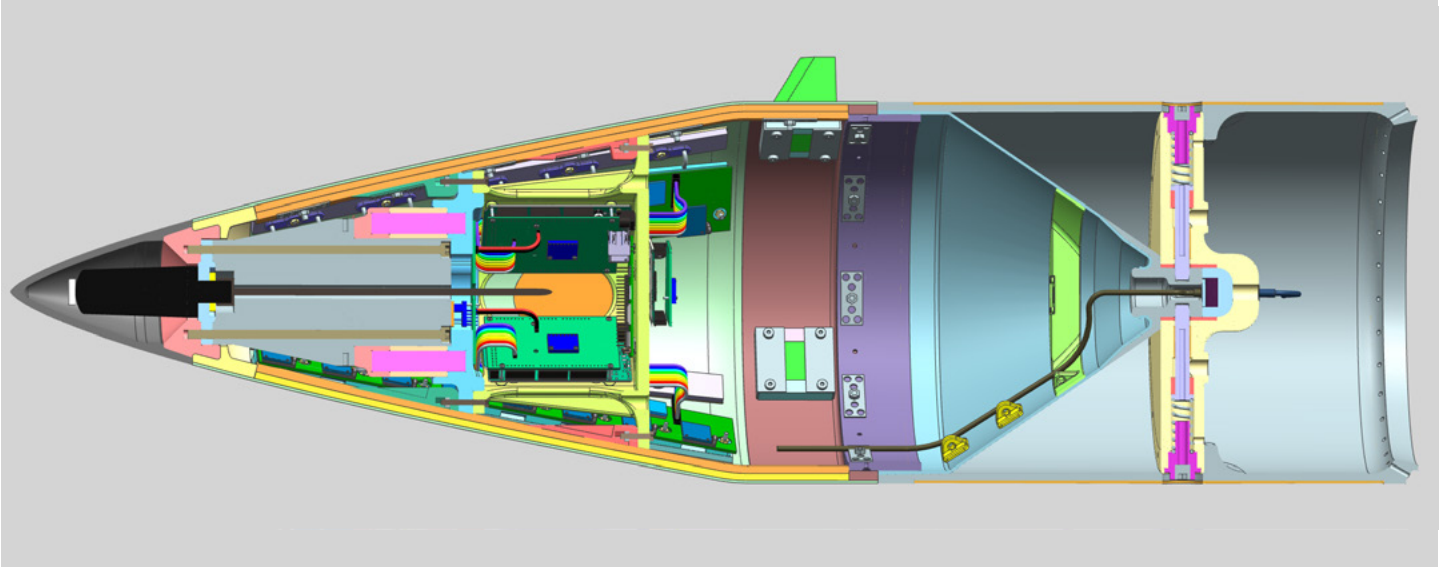

Side view drawing of STAje- Phase 1 flight vehicle, designed to develop a pipeline of trained people in high speed flight testing as well as to explore different approaches to increase the frequency of flight testing at reduced cost. This program is being undertaken at the University of Queensland with the assistance of AIMTEK, Hypersonix, Lockheed Martin Australia and in collaboration with BlackSky Aerospace. It was due to fly in May 2024. Phase 2 and 3 of STAJe- will demonstrate high speed (Mach 2–4) electric propulsion by 2026

Cross-intersection across Pillar II streams

UQ cyber researchers have published in the top journals and conferences on robustness of AI algorithms and technologies against false data injection, privacy and prompt attacks. The group also has collaborations with UQ School of Mathematics and Physics on post quantum cryptography, quantum safe migrations, and quantum authentication.

Hypersonic and Counter-Hypersonic Capabilities

Globally, UQ has provided a significant portion of the world's hypersonic expertise and continues to work closely with government and industry on the applications of hypersonic science and enabling technologies. UQ's research excellence leverages Queensland's advanced aerospace sector, characterised by innovative small to medium enterprises (SMEs),

combined with hypersonics, advanced materials and manufacturing excellence. Queensland's expansive geography provides critical access to inland flight testing of rockets, hypersonic vehicles and associated quantum and AI technologies.

UQ Centre for Hypersonics (CfH)

CFH researchers and research programs have been recognised for their sustained, outstanding contributions and achievements in the advancement of atmospheric, hypersonic flight and related technologies for the past 35 years. The Centre conducts research into all aspects of hypersonic flight, including test facilities, air-breathing engines, rocket flight testing, aerothermo-dynamics, computational fluid dynamics and optical diagnostics.

Strengths and capabilities

- Development of hypervelocity test facilities
- SCRAMjet propulsion (experiment, analysis and design)
- Flight testing experimentation and analysis
- Advanced instrumentation for aerodynamic measurements
- Computational fluid dynamic analysis of hypervelocity flows
- Optical diagnostics for hypervelocity superorbital flows
- Hypersonic electric propulsion
- Magnetohydrodynamics.

Partnerships & collaborations

The DSTG-UQ Collaborative Project Agreement forms the backbone of current research collaboration between UQ and the Australian Hypersonics Research Precinct at Eagle Farm, Brisbane. Streams of research support and interaction include DSTG co-supervision of UQ PhD students, embedded postdoctoral fellows, technicians and other research scientist staff. Longstanding partnerships with US and UK defence primes, and university consortiums supports cooperation on hypersonic technologies as a priority area under the trilateral AUKUS trilateral security agreement.

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Centre for Advanced Materials Processing and Manufacturing (AMPAM)

AMPAM's primary focus is high temperature polymer and ceramic matrix composites for defence, hypersonic and space applications. UQ is the leader in high and ultra-high ceramic matrix composites research and has manufacturing facilities for additive manufacture of metals, including high-entropy alloys and manufacture of ceramic matrix composites up to 2800 °C. AMPAM has equipment for large scale testing and in-depth material characterisation. Researchers at UQ have demonstrated the manufacture of novel high temperature ceramic matrix composites for flight tests and live rocket motor firings for Lockheed Martin, Thales, the Australian Defence Force (ADF) and Hypersonix Launch Systems.

Cross-intersection across AUKUS Pillar II streams

UQ quantum sensors will be trialled in a series of UQ-led hypersonic flight tests under the supersonic electric propulsion project 'STAje-', in 2024. AI experimentation for guidance and control to intercept targets will also be integrated.

Prototype-scale high-temperature graphite furnace (2800 °C) used for the manufacture of ceramic matrix composite components such as nozzle liners, leading edges and combustor sections. Operated by Centre for Advanced Materials and Processing (AMPAM) Staff, Dr Kristian Kudisonga and Associate Professor Michael Heitzmann, University of Queensland

Australian Program Office for Advanced Hypersonics (APOAH)

To meet sovereign defence capability aspirations, Australian universities jointly developed the Australian Program Office for Advanced Hypersonics (APOAH) in 2022 led by UQ. The APOAH currently represents an informal coordination forum for Australian universities with research strengths in hypersonics. The APOAH could be readily formalised as a university alliance for the benefit of advancing hypersonics and counter-hypersonic coordination with allies and partners Under the APOAH umbrella, members have:

- compiled hypersonic capability assessments
- undertaken feasibility studies for advanced concepts
- pursued development of alternative launch site to meet rapid demonstration requirements
- instigated new propulsion systems that offer strategic advantages
- instigated programs to rapidly complete flight testing demonstrations in collaboration with industry primes and SMEs
- successfully experimented with new composite materials manufacturing techniques designed to facilitate rapid and cos- effective flight testing
- contributed to feasibility study for development or extension of a Ground Based Flight Range in Australia to meet increasing tempo of high-speed flight experimentation and demand for flight infrastructure.

Australian and international university membership of the APOAH is non-exclusive and is expected to grow as contemporary hypersonics incorporates an increasing range of technologies.

Electronic Warfare

Microwave Technologies

UQ houses Australia's leading research group in microwave engineering and radio-frequency (RF) systems. The research focus has been on electromagnetic imaging and sensing, in addition to building reconfigurable antennas and microwave devices for emerging on-the-move communications systems.

Researchers have collaborative projects building flat panel reconfigurable antennas for low earth orbit satellites, CubeSats, drones, UAVs and other vehicles. In collaboration with research partners, they have begun work on autonomous satellite terminals for ubiquitous broadband communications and on wideband apertures for multi-functional operation.

The activities in RF systems covers various aspects from hardware to algorithms:

- Bespoke antennas and antenna arrays from radio-frequencies to millimetre waves
- Antenna integration in platforms
- Electromagnetic properties of novel materials, and antenna design with novel/unconventional materials
- Electromagnetic signatures (radar cross-section – RCS), scattering and interaction with materials
- Surfaces, including radar absorbers and "intelligent meta-surfaces"
- Electromagnetic simulations and numerical modelling
- Software defined radio systems
- Digital signal processing: Multi-sensor systems and passive radar.

Cross-intersection across Pillar II streams

The activities in microwave and RF frequencies are enabling technologies, which thrive in multidisciplinary environments and find applications in other Pillar II streams. Examples of active and emerging multidisciplinary collaborations include:

- Spectral RF characterisations of high-temperature materials for use in hypersonics
- Integration of antennas and electromagnetic surfaces in novel composite materials
- Development of ultra-sensitive quantum RF sensors based on superconductive junctions.

Innovation

UniQuest, the commercialisation company of UQ is at the forefront of our activities which integrate commercial technology. Many of our commercialisation outcomes result from partnerships with Defence directly or with established defence contractors. Examples include:

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Quantum Link Verification

Protection of critical communications and operations systems is under threat with the advent of quantum computing, tempting bad actors to "hack now, decrypt later". Current encryption standards therefore present risks. Post-quantum encryption can be used but is computationally expensive and not practical for the bulk of data centre traffic. Quantum key distribution is secure but slow and limited by range.

Researchers at UQ have developed an approach to verify the physical security of optical communications (both through fibre optic cabling and free space) using quantum technology. The comms link can be continuously monitored and, if compromised, data transmission halted or re-directed. Capability is being accelerated through the award of a Defence Science Partnerships contract. Commercialisation is being fast-tracked by UniQuest's own fund co-investing with Venture Capital (VC) funds to reduce time to market for the spin-out company.

Nano-phononic Computing

Nano-phononics is a relatively new area of research, with phononic circuits and analog to electronic or photonic circuits existing today, using vibrations rather than electrons or photons for computing. It offers significant benefits over the other circuit types in that energy consumption is several orders of magnitude lower and it is radiation proof, making it immensely suitable for use in space environments or nuclear hazard areas. Existing control architectures for acoustic waves are limited in their ability to scale and have limitations in their precision and flexibility of features.

UQ researchers have developed an architecture for nano-phononics based on low frequency out-of-plane resonances in membrane circuitry a few nanometres thick which overcomes previous limitations. Demonstration devices have been built proving the technology. Lockheed Martin Corporation has supplemented ARC Linkage funding of this work. Activities to secure investment funding for the spin-out company are proceeding apace, to

make this exciting architecture a commercial reality.

Further illustration of UQ's capability in accelerating defence innovation and integrating commercial technology comes from examples such as:

- Analog Quantum Circuits (AQC), a UQ spin-out company, which designs and fabricates advanced superconducting devices for quantum computing. AQC is strongly supported by the VC industry to enhance sovereign capability
- Quantum Error Correction that improves the feasibility of quantum computers by a factor of ten, along with related technologies to extend the capabilities of quantum communications, which is very new, and this has just embarked on the commercialisation path
- Quantum Key Distribution (QKD) Countermeasures, developed in collaboration with the University of Western Australia, designed to disrupt QKD signals being transmitted by an enemy satellite, has been supported by the Australian Army.

Information sharing

UQ's investment in governance, personnel, physical and cyber security capabilities to meet Defence Industry Security Program (DISP) Level 2 (SECRET) membership requirements has resulted in a comparatively advanced protective security environment at the University. The most significant capability is a Defence-certified Zone 4 physical facility connected to the Defence Secret Network and with secure video-conferencing facilities allowing conversations up to SECRET.

This university-leading capacity to receive, transmit and discuss sensitive and classified information will accelerate the scale-up of sensitive university research and vital industry collaborations.

In addition to meeting DISP requirements, UQ has developed policy and procedures to comply with International Trafficking in Arms Regulations (ITAR) and Export Administration Regulations (EAR)

and has begun developing technical control measures required for handling US Controlled Unclassified Information (CUI). These investments will contribute significant capabilities towards further facilitating critical technology cooperation with the US, both bilaterally and through AUKUS.

Research infrastructure

As a top 50 research intensive university, UQ has a rich fabric of specialised research infrastructure capabilities that underpin research, innovation and development that allow researchers to address some of the world's most challenging problems.

At the core of these capabilities are highly skilled professional and academic specialists. Through numerous partnerships and initiatives with government and industry, UQ has invested in 11 flagship Collaborative Research Platforms, over 60 distributed facilities and services and over 20 initiatives under NCRIS including by hosting central functions or Queensland Nodes.

UQ's research infrastructure offers several platforms and specialised capabilities that support key priorities of AUKUS Pillar II. These include:

UQ has invested in 11 flagship Collaborative Research Platforms, over 60 distributed facilities and services and over 20 initiatives under NCRIS.

- highly specialised analytical, characterisation and/or imaging techniques (Centre for Microscopy and Centre for Microscopy and Microanalysis (CMM), UQ Materials Performance (UQMP), National Imaging Facility (NIF) and facilities in UQ's Faculty of Engineering, Architecture and IT (EAIT) and Australian Institute of Bioengineering and Nanotechnology (AIBN)) that can be used to study structure and interactions in materials from the atomic to macro scales including those exposed to extreme environments (e.g. as experienced in deep ocean or hypersonic flight)

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- world-class nano fabrication and characterisation facilities (Australian National Fabrication Facility Queensland, ANFF-Q), CMM, Quantum Centre of Excellence in Biotechnology (QUBIC)) that support quantum research programs
- high-performance computing coupled to data curation, process workflows and visualisation tools (Research Computing Centre (RCC) and the Australian Research Data Commons (ARDC)) that underpin all of the domains.

UQ's own Collaborative Research Platforms together with a range of Australia -wide NCRIS capabilities are able to collaborate with partners to find solutions relevant to AUKUS Pillar II priorities. For example, there is a significant 'Tier 1' High Performance Computing (HPC) investment from the Australian Government by way of the National Computational Infrastructure (NCI) and the Pawsey Supercomputing Centre, each of which supports major, but discrete, research communities.

- UQ RCC hosts *Australia's most advanced 'Tier 2' supercomputer 'Bunya'*. Tier 2 supercomputers are able to satisfy specific research domains and cohorts that Tier 1 facilities cannot easily or efficiently support. The Bunya facility pushes forward with supercomputer data management systems, innovating on visualisation tools and frameworks, and AI and machine learning infrastructure and frameworks.
- Bunya's capabilities include AI algorithms that perform practical tasks: scene understanding, object recognition, event analysis.
- The Tier 2 capability is also an enabler of edge-computing capabilities, supporting very high throughput institutional and regional scientific instrumentation data processing with interactive and site-specific workflows where urgency, latency, and immediacy of data to compute interactions matter for the outcome of the research endeavour. The Facility also supports research groups

using advanced mathematical methods and numerical techniques to model the dynamics of quantum systems and investigate quantum algorithms.

Australian National Fabrication Facility hosted at UQ (ANFF-Q) has micro and nanofabrication capabilities supporting work in novel semiconductor materials and characterisation. Its fabrication capabilities enable instrumentation and component design and manufacturing. These prototypes can be used in remote sensing and environment monitoring. This is a state-of-the-art facility with infrared technology and micro electro-mechanical systems fabrication processes for broad applications.

Centre for Microscopy and Microanalysis which hosts the *Queensland node of Microscopy Australia* (NCRIS) has advanced characterisation capabilities, critical to structural analysis. Clean-rooms and instrumentation supporting material growth, characterisation, metallisation, electron microscopy, atomic force microscopy, spectrophotometry and fluorometry all underlie breakthroughs in structural and chemical analysis.

Newly established *Drones Collaborative Research Platform* (supported by Auscope (NCRIS)) will aim to gather capabilities across trusted autonomous systems, signal processing, radar/sonar, target tracking and interference through multiple sensor network and object tracking systems through real time online algorithms. Remote sensing research has direct transferability to undersea capabilities.

UQ Materials Performance (UQMP) provides materials and mechanical failure investigation, stress analysis and mechanical design evaluation, wear mitigation and materials design evaluation, materials failure analysis and forensics.

World-class *research and testing facilities support UQ's unique capabilities in hypersonics* and high-temperature materials essential to hypersonic flight and spacecraft.

Workforce development

Undergraduate

UQ's undergraduate offerings provide a foundation of skills and knowledge across the areas of quantum technologies, artificial intelligence, advanced cyber and hypersonics, with courses and programs informed by UQ's substantial research expertise and developed in consultation with industry. These areas are captured within the:

- Bachelor of Science (BSc) – mathematics, physics
- Bachelor of Computer Science – computational science, data science
- Bachelor of Engineering (Hons) – aerospace engineering major.

A range of experiences complement the curriculum connecting students with industry, including:

- Mathematics, physics and statistics students engage in a suite of SMP Summer Industry Experiences with industry partners, including Boeing Research and Technology Australia, Auto and General, and the CSIRO
- Engineering students have opportunities to engage with UQ Space, the leading student rocketry organisation in Australia, and a suite of Summer and Winter Research experiences across key areas
- UQ students are leading the Australian Youth Aerospace Forum providing a five-day live in conference for Year 11 and 12 students investigating careers and pathways in the aerospace industry
- A partnership with the Australian Signals Directorate (ASD) has seen engagement with Careers Expo and a range of networking events, presenting on opportunities across the defence industry.

In the field of hypersonics, UQ has existing collaborations with key AUKUS partner universities and research organisations (including Oxford University, Caltech, Texas A&M, Purdue, University of Illinois, and NASA Ames) and strong exposure to US and Commonwealth Department of Defence programs. Supporting hypersonics through the edX platform, UQ offers a Massive Open Online Course (MOOC) in this field with currently over 21,000 enrolments that

provides advanced level exploration of key ideas and concepts with direct translation to workforce capability.

Postgraduate

Postgraduate offerings at UQ facilitate specialised knowledge and skill development for the existing workforce, with each of our offerings underpinned and shaped by 'above world class' research across all key areas. For example:

- Master of Engineering Science offers students the opportunity for a 4-unit exploration of hypersonics as part of a comprehensive advanced engineering program, and aerospace field of study.
- Master of Cybersecurity supports fields of study (majors) within cryptography, cyber criminology, and cyber defence, with a focus on preparing students as future leaders, researchers, and practitioners in these fields.
- Master of Quantum Technology provides a 'first of its kind' program to develop specialised skills across the quantum technology sector, with the program offering three semester-long research projects that immerse students within leading quantum science research laboratories, and a pathway to PhD study in the area of quantum science.

- Master of Data Science (also supported by the fully online Master of Business Analytics) develops advanced knowledge across machine learning, artificial intelligence and pattern recognition, with industry capstone projects with partners including Oracle Labs, IBM and EM Solutions.

In the field of hypersonics, DSTG has provided funding in support of ten HDR projects, co-supervised with the CfH and AMPAM with students spending time at DSTG facilities.

UQ's world leading research in artificial intelligence and information management has provided the foundation of our leadership of the ARC Training Centre for Information Resilience (CIRES). CIRES aims at building workforce capacity in Australian organisations across data and information pipelines. It engages at a national level to provide AI, data science and machine learning, multi-stream training and partnerships to support the better use and analysis of data and information across a breadth of sectors, including defence.

Higher degree research

HDR students are supported to develop key employability and career skills being able to translate their research skills into future employment outcomes. This includes a HDR internship program with PhD Industry Placements supported through targeted scholarships with more than 100 HDR students annually developing transferable and professional skills, supporting effective knowledge transfer post-PhD. HDR students are engaged with a wide range of innovative projects and research across the whole spectrum of AUKUS Pillar II priority areas, including participation in two UQ Centre of Excellence nodes in Quantum Engineering, and Quantum Computing and Communication, contributing directly to the workforce and engagement opportunities for postgraduate and undergraduate students. In the field of hypersonics, DSTG has provided funding in support of ten HDR projects, co-supervised with the CfH and AMPAM with students spending time at DSTG facilities.

Innovation education

UQ also supports innovation through UQ Ventures – providing students and the wider UQ and Queensland public, non-accredited educational experiences across the innovation journey. With support from the Queensland Investment Corporation (QIC), UQ will develop an accelerator program, open to all Queensland residents, in defence and national security priorities with outputs aiming for dual purposes across civilian and defence applications. This accelerator will sit alongside existing global and local innovation and accelerator programs.

Collaborations

UQ has established a central Research Partnerships function to drive major research partnerships and to support further development of demand driven research. UQ Research Partnerships supports researchers in the development of major initiatives informed by national industry and defence policy priorities, and broader commitments to strategic frameworks with allies and partners.

STAJe: Flight testing of supersonic electric propulsion systems in partnership with Lockheed Martin Australia and MBDA UK

Professor Allan Paull, Chair in Advanced Hypersonic Technologies at UQ funded by Lockheed Martin Australia (LMA) is collaborating with LMA, Lockheed Martin Corporate LMCO (US) and MBDA (UK) to develop two independent high speed electric high propulsion concepts for defence against high speed weapons (DAHSW) (Mach 4) and Intelligence, surveillance, and reconnaissance (ISR) (>Mach 10). A flight program initiated and led by UQ to demonstrate this technology for DAHSW is approaching its first flight, using systems developed collaboratively with local SME, Black Sky Aerospace (BSA). This test will be undertaken at a range that has been developed by UQ in collaboration with BSA at Thargomindah (QLD) to enable AUKUS participants access to high tempo low-cost flight trials necessary for developing high speed vehicles.

UQ Cyber: US Army Research Lab – Virgina Tech University

Associate Professor Dan Kim, Deputy Director of UQ Cybersecurity has collaborated with Associate Professor Jin-Hee Cho at Virginia Tech University in the US and Dr Frederica Nelson at the US Army Research Lab in the US since 2017 to develop:

- an AI-based novel intrusion detection & response system
- proactive cyber defence techniques including Moving Target Defense techniques and evaluation methods mainly applied to software-defined networking and intelligent and autonomous vehicles, funded by the ITC-PAC (currently aka RDECOM-Pacific) and the US Army Research Lab.

AI-based intrusion detection and moving target defence are crucial as they have the potential to form a significant part of a broader collaborative initiative under the AUKUS framework, addressing cybersecurity challenges at a larger scale. The importance lies in enhancing defence and national security capabilities, particularly for Australia and its allies, as these projects focus on securing emerging networked systems such as autonomous vehicles and safeguarding various critical infra-structures from evolving cyber threats.

Key examples

Trial of Inertial Quantum Sensor at RIMPAC Naval Exercise 2022

Professor Warwick Bowen's laboratory at UQ is leading the international development of optomechanical magnetometers, accelerometers, and acoustic sensors. The lab is partnered with DSTG to apply these technologies in Defence applications, targeting navigation and situational awareness.

The sensors are fabricated on a silicon chip and offer an unprecedented combination of sensitivity, power consumption and size.

In 2022, the accelerometers they developed were deployed at RIMPAC 2022 (Rim of the Pacific Exercise), the world's largest international maritime warfare exercise involving forces from Australia, Canada, New Zealand, the United Kingdom and the United States.

The accelerometers were deployed on maritime platforms in proof of principle navigation exercises, with performance that superseded comparable with military grade sensors.

Supporting International Hypersonic Flight Experiments

Professor Anand Veeraragavan and colleagues at the Centre for Hypersonics have led the Australian participation with the core team from Texas A&M, US AFOSR and CUBRC Aerosciences New York that led the highly successful Boundary Layer Turbulence (BOLT II) hypersonic flight experiment, flown from NASA Wallops in 2022.

The UQ team undertook several ground tests in their state-of-the-art hypersonic facilities – the T4 Stalker tube and X3/R shock tunnel. The latter facility managed by DSTG was a key element of the international collaboration between DSTG and AFOSR coordinated by UQ, where a full-scale model of the flight vehicle was ground-tested post-flight, with CUBRC being the sister facility in the US doing a full-scale test pre-flight.

The experimental testing that measured surface heat transfer and pressure will be compared against the flight data on-design conditions, along with additional data taken on off-design conditions to complement the flight experiment and thereby providing valuable information about hypersonic turbulence.

The UQ team undertook several ground tests in their state-of-the-art hypersonic facilities – the T4 Stalker tube and X3/R shock tunnel.

The team at UQ also performed conjugate heat transfer simulations to predict the temporal evolution of the heating of the vehicle during its experimental flight window (portion of the trajectory of scientific interest), that matched very well against other simulations from the Applied Physics Laboratory in the US.

The BOLT engagement will continue with the next flight BOLT 1b, scheduled to be flown from Australia in 2024, and UQ already invited to participate via a request for proposal, which is under consideration.

Key personnel

Undersea capabilities

Water engineering, civil engineering, tidal energy, wave energy, renewable energy production, coastal engineering, analysis of tidal currents, pipeline survey, limnological processes, sea-ice characteristics, autonomous underwater vehicle, sediment relocation strategy, ports, maritime

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Trusted Autonomous Systems – legal frameworks governing maritime robotic and autonomous systems, artificial intelligence, Arms control law, international law applicable to cyber operations

Professor Rain Livoja
Deputy Dean (Research)
TC Beirne School of Law
E: r.liivoja@uq.edu.au

Neuroscience and Psychology; reducing uncertainty in perceptual decision making by training awareness of neurocognitive states', neurocognition and perceptual decision-making for submariners

Professor Jason Mattingley
NHMRC Leadership Fellow,
Queensland Brain Institute
E: j.mattingley@uq.edu.au

Quantum technologies

Interface of nanotechnology and quantum science; including bioimaging, nanophotonics, nanomechanics, quantum optomechanics and photonic/quantum sensing

Professor Warwick Bowen
Director, ARC Centre of Excellence in Quantum Biotechnology (QUBIC)
E: w.bowen@uq.edu.au

Broader UQ Quantum Team:

- Associate Professor Arkady Fedorov – Centre for Engineered Quantum Systems (EQUS)
- Professor Gerard Milburn – EQUS
- Associate Professor Jacq Romero – EQUS
- Professor Tim Ralph – Centre for Quantum Computing and Communication Technology
- Professor Halina Rubinsztein-Dunlop – Deputy Director, QUBIC
- Professor Andrew White – Director, EQUS

Artificial Intelligence and Autonomy

Machine learning, artificial intelligence, bio-inspired computation, complex systems, visualisation, language technologies and social robotics, leading teams that span engineering, humanities, social sciences and neuroscience, state-of-the-art tools for deep learning and other analysis techniques for working with language data

Professor Janet Wiles
Professor in Human Centred Computing (Leads the Future Technologies Thread of the ARC Centre of Excellence for the Dynamics of Language (CoEDL))
E: j.wiles@uq.edu.au

Drone design, Bipedal Robot Locomotion, Embodied intelligence and Disposable drones and exoskeletons

Professor Pauline Pounds
Professor at the School of Electrical Engineering and Computer Science
E: pauline.pounds@uq.edu.au

The University of Queensland

Advanced Cyber

Cyber Security, Cloud Computing Security, Data Privacy, Information Security, Data Control, Data Provenance, Data Tracking, Cyber Crime, Cyber Attack Attribution, Data Accountability, Cybersecurity, AI for Cyber Security, Critical infrastructure security, Industrial control systems security, ICS Security, Privacy enhancing technologies
Professor Ryan Ko
Director UQ Cyber, School of Electrical Engineering and Computer Science
E: ryan.ko@uq.edu.au

Graphical Models for Cyber Security: Model-based Cyber Security Risk Analysis; AI for Cybersecurity & Cyber Security for AI: Securing AI systems and Cybersecurity using AI techniques; Moving Target Defense (MTD): Resilient and Proactive Defence; Evolving Attacks and Defense Automation: Red team and Blue team Automation and evaluation using AI
Associate Professor Dan Kim,
Deputy Director UQ Cyber,
E: dan.kim@uq.edu.au

Hypersonic and Counter-Hypersonic Capabilities

Supersonic plasma flows, hypersonics and computational fluid dynamics
Professor Vince Wheatley
Co-Director Centre for Hypersonics
E: v.wheatley@uq.edu.au

Supersonic combustion of hydrocarbons, hypersonic aerothermodynamics, advanced optical diagnostics for hypersonic flows and microcombustion based portable power
Associate Professor Anand Veeraragavan
Co-Director Centre for Hypersonics
E: anandv@uq.edu.au

High temperature composites and composite durability. Manufacturing process development and modelling, materials characterisation and composite mechanics
Associate Professor Michael Heitzmann, Co-Director Centre of Advanced Materials Processing and Manufacturing Centre (AMPAM)
E: m.heitzmann@uq.edu.au

Hypersonic flight trials (HyShot 1–4, HyCAUSE and HIFiRE 0, 1, 3, 4, 5, 5B, 7, 7B and assisted with Scramspace), Mach 4 electric propulsion, hypersonic plasma engines

Professor Allan Paull
Professor in Advanced Hypersonic Technologies, Centre for Hypersonics and Technical Director Australian Program Office for Advanced Hypersonics (APOAH)
E: allan.paull@uq.edu.au

Electronic Warfare

Bespoke antenna and antenna array design from radio-frequencies to millimetre waves; antenna array design and more

Professor Christophe Fumeaux
EOS Chair in Optical and Microwave, School of Electrical Engineering and Computer Science
E: c.fumeaux@uq.edu.au

Communication systems, passive radar and signal processing, and specifically in the areas of wireless communication, and the use of multiple antennas or sensors for communication, radar and imaging systems

Dr Konstanty Bialkowski
Senior Lecturer, School of Electrical Engineering and Computer Science
E: ksb@uq.edu.au

Innovation

Research Commercialisation

Dr Colin Davies
Head of Physical Sciences, Uniquest
E: c.davies@uniquest.com.au

Information Sharing

DISP, Export Controls, Foreign Interference

Mr Simon Pengilly
Senior Manager
International Safeguards / DISP Primary Security Officer
E: s.pengilly@uq.edu.au

The University of Western Australia

The University of Western Australia contact point:

Professor Gia Parish
Director, UWA Defence and Security Institute

T: +61 8 6488 3390

E: giacinta.parish@uwa.edu.au

Skills and capability

UWA is a key partner in advancing Australia's defence and security agenda and capability needs. Central to this is the **UWA Defence and Security Institute (DSI),** which acts as a hub in WA drawing together UWA researchers and educators with practitioners and partners across the State and the nation in the Australian Defence Force (ADF), defence industry, government, and other universities, to deliver outcomes that collectively progress our national defence and security strategies and capabilities.

AUKUS provides significant context for the role of UWA DSI, supporting Australia and its allies to meet the challenges of this new global era of strategic competitiveness and reduced threat timeline, as well as non-military threats such as climate change. Our commitment at UWA, supported by the robust framework of UWA DSI, is unwavering: **to align our capabilities with Australia's strategic needs, driving forward solutions that support a peaceful, prosperous, and secure future for our nation and the broader Indo-Pacific region.**

UWA prides itself on being a trusted, inclusive and capable partner across the breadth of critical disciplines and technologies for Defence. The core focus areas of technology strength – Quantum, Sensing, AI & Human Decision Science, and Coastal and Maritime Defence – have been strategically crafted to engage with and support key national priorities including AUKUS. These incorporate both breadth and depth in AUKUS Pillar II research areas, with strengths across Undersea Capabilities; Quantum Technologies; AI and Autonomy; Advanced Cyber; and Electronic Warfare.

Our commitment at UWA, supported by the robust framework of UWA DSI, is unwavering: to align our capabilities with Australia's strategic needs, driving forward solutions that support a peaceful, prosperous, and secure future for our nation and the broader Indo-Pacific region.

Research strengths

Undersea capabilities

UWA has scientific and technical expertise and innovative technologies to enhance the operational performance and survivability of Defence platforms and activities in the maritime domain, particularly in and around the Indian Ocean. Experts work together across many disciplines including marine science, littoral/coastal engineering, oceanography, deep-sea science, ocean engineering, offshore geotechnical engineering, and environmental management.

Crossover areas include submarine control and human-machine teaming (see AI and Autonomy), underwater sensing for submarine platforms (see Quantum Technologies) and electro-optics for electronic surveillance over the sea (see Electronic Warfare).

UWA has defence related research capability across the undersea, offshore, and littoral domains, with complementary strengths all contributing to overall undersea capabilities.

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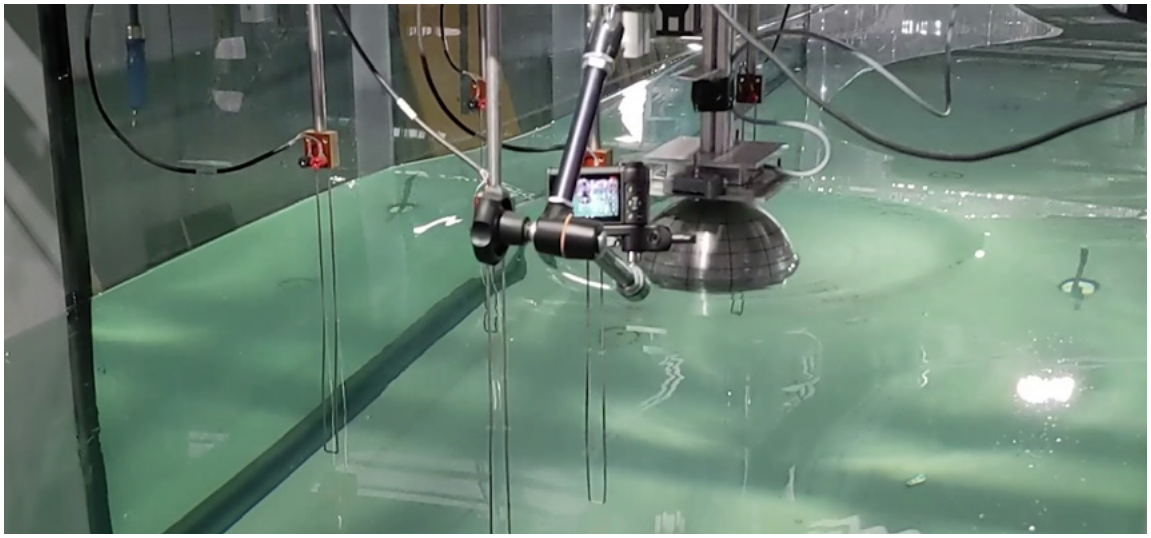


Testing of a generic wave energy converter (WEC) hull in the wave flume at the Coastal and Offshore Research Laboratory at UWA

Undersea

- Expertise with ocean glider technology and use – UWA hosts the Australian National Facility for Ocean Gliders as part of Australia's Integrated Marine Observing System.
- Minderoo-UWA Deep-Sea Research Centre, which develops and deploys full ocean depth rated (benthic) imaging landers, cameras, oceanographic sensors and sampling equipment and other state-of-the-art deep sea exploration vehicles.
- Capability in observing, modelling and understanding the fine-scale ocean variability that affects undersea navigation and sound propagation, including realistic non-linear internal wave modelling tools relevant to submarine navigation and communication.
- Statistical tools for quantifying uncertainty from ocean observations and numerical models that allow the development of operational decision-making tools.
- Marine electronics/power systems for naval vessels including surface and undersea (submarine).
- Human-in-the-loop testing of innovative technology and work design in the submarine Control Room Use Simulation Environment (CRUSE) to achieve undersea decision superiority.

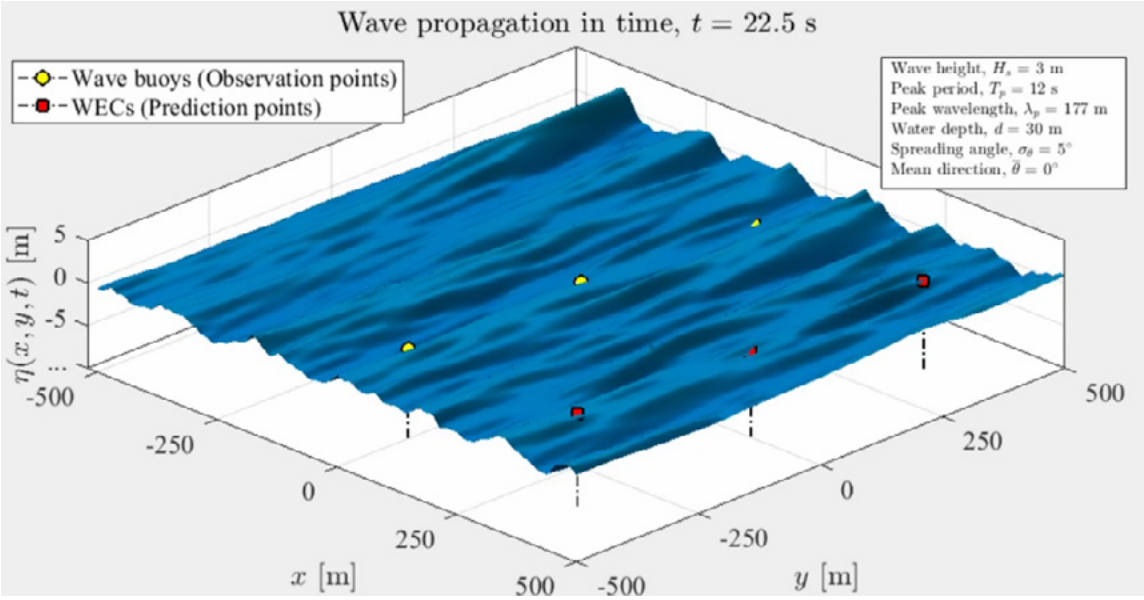
- Human and organisational factors and their role in maintenance dependability and reliability on Submarines in collaboration with the RAN.

Offshore

- Optimisation of the design of marine craft including quantifying the hydrodynamic forces on subsea vehicles in a range of environmental flow conditions using model scale testing and/or Computational Fluid Dynamics.
- Offshore geotechnics, including optimising the stability of subsea infrastructure and the design of novel anchoring solutions.
- Ability to document and map the deepest parts of the ocean.

Littoral

- Detailed numerical modelling capabilities of waves, currents and sediment transport in nearshore and littoral areas relevant to Defence operations.
- Development of novel techniques for the measurement of waves, currents and nearshore bathymetry from in situ instrumentation and remote sensing platforms.



Animation of measured and modelled data of ocean currents and dynamics

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Examples of outcomes and impact

- Ocean gliders – the autonomous underwater vehicle (AUV) project, also known as the ocean gliders project – develops machines that collect oceanographic data, travelling as deep as 1000 metres. The ocean gliders team works to improve the AUVs so they move easily and in all conditions.
- Development and operationalisation of a Machine Learning system that improves the accuracy of numerical wave forecasts. This system is currently running operationally to improve port operations in Australia's northwest.
- Development of nonlinear internal wave prediction tools to inform operation of offshore assets.
- Development and operationalisation of a hybrid physics and Machine Learning system to predict vessel and floating platform motions. This system is currently running operationally to inform offshore operations.

Quantum technologies

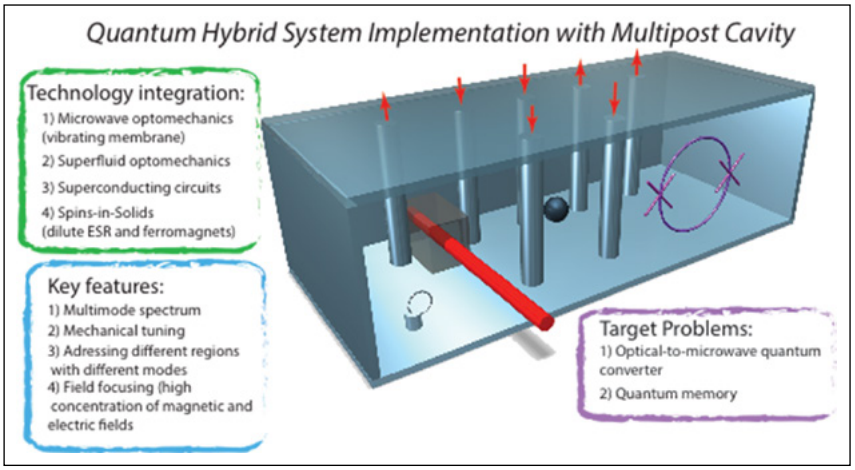
UWA develops new quantum sensor and quantum communications technologies that deliver unprecedented sensor performance and communications security and are world leaders in low-noise precision measurement involving frequency, time and quantum systems.

Crossover areas include sensing and surveillance (see Electronic Warfare), and as previously mentioned, sensing technologies with undersea applications.

Capabilities include:

- Precision patented technology based on hybrid photon-spin polaritons, which could in principle be used for highly sensitive measurements of the magnetic field, or wideband agile low-noise oscillators for radar and datacomms
- Expertise in low-noise precision and quantum measurements, low temperature physics and hybrid quantum systems

- Advanced mathematical methods and numerical techniques to model the dynamics of quantum systems and investigate quantum algorithms providing new possibilities for communication and data processing
- New smaller sensors based on quantum and magnetic technologies with faster and more energy efficient electronics for communications, data processing/ storage and for field-, substance-, gas- and bio-sensing
- Miniaturised gravity gradiometer with improved performance and capable of being deployed from uncrewed fast-moving platforms like UAVs, both airborne and submersibles
- Interferometric Electromagnetic Gradiometer, an ultra-sensitive instrument which measures electromagnetic signatures created by submarines when they are silent and no acoustic tracking is possible. The system can be easily fit into fast moving uncrewed submarine hunters such as drones, UAVs & AUVs
- Microwave sensors that are ultra-sensitive and can localise radio frequency magnetic fields into a tiny volume with a range of applications
- Precision oscillators and clocks including the world's best microwave oscillator which has been used in Raytheon's most precise and sensitive defence radar systems
- Laser systems for disruption of quantum communications particularly between spacecraft and ground stations.



Quantum Hybrid System Implementation with Multipost Cavity

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Examples of outcomes and impact

- UWA developed the lowest noise microwave measurement and oscillator technology in the world, necessary for application in the best precision frequency systems, such as atomic clocks and atomic qubits, resulting in systems operating at the quantum projection noise limit. These inventions were responsible for the products sold by Poseidon Scientific Instruments Pty Ltd (now owned by Raytheon).
- UWA developed technology to transfer stable frequencies over free-space, useful for timing, GPS navigation and datacomms applications. Variations of this technology have also been used in advanced radar systems, and to build ultra-sensitive sensors to detect magnetic, electric and gravitational observables.
- UWA patented novel hybrid opto-mechanical technology to miniaturise a device to measure gravity gradients, useful for the detection of tunnels.
- UWA patented a new type of quantum hybrid sensing element for an intrinsic gravity gradiometer (IGG) for use in sensing variation in a gravity field at a location.
- The Astrophotonics group at ICRAR[6]-UWA is working with Army's Robotic and Autonomous Systems Implementation & Coordination Office, and Air Force's Jericho Disruptive Innovation, to develop technologies and techniques to disrupt satellite quantum communications links.

Artificial Intelligence and Autonomy

UWA researchers from diverse disciplines including computing and information systems, engineering, statistics and the psychological science work to achieve decision superiority on the modern battlefield via human-machine teaming and/or autonomous and intelligent systems.

Applications include surveillance and reconnaissance, real-time information processing and enabling new actions to be planned and executed

6 International Centre for Radio Astronomy Research

with reduced risk to personnel and expensive platforms.

Crossover areas include information warfare (see Cyber Security), adversarial attack identification and defence (see Cyber Security) and autonomous underwater vehicles (see Undersea Capabilities).

Capabilities include:

- Expertise in natural language processing, machine learning, human-machine teaming and explainable AI
- Defence-funded projects in adversarial attacks for explainable AI, deceptive signature identification in adversarial attacks, and defence against adversarial attacks on deep learning
- Advanced algorithms for improved automation, collaborative reasoning and decision-making processes in human-machine teams
- Measuring and improving human trust in automation, designing for transparent automation, and computational modelling of how humans allocate attention and make decisions when teaming with machines
- Computational systems that adapt to or learn from the data, knowledge or environment in which they are working. These systems employ evolutionary learning, optimisation and modelling techniques to solve or improve performance on complex problems. Current projects in the artificial intelligence area include but not limited to:
  - » computational intelligence techniques for optimisation, modelling and control
  - » applications of multi-objective evolutionary algorithms
  - » evolutionary optimisation and design
  - » hypervolume calculation for multi-objective optimisation
- Techniques that allow systems to sense and move within their own environment in either a fully self-directed or human-guided fashion.

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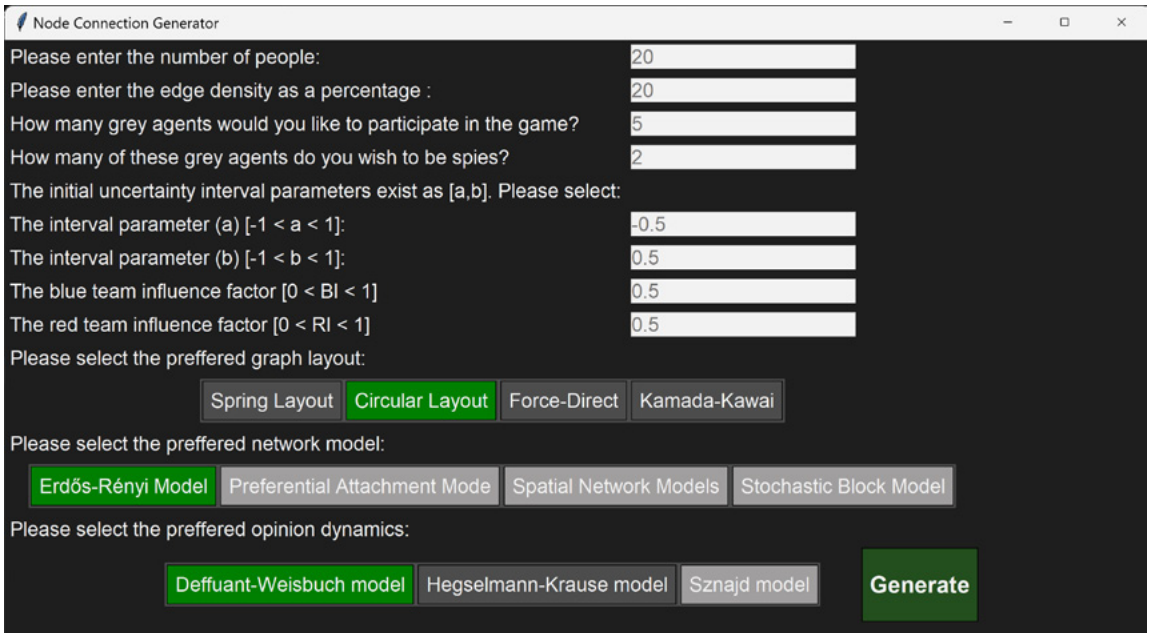
Examples of outcomes and impact

- Robotics and automation research with demonstrated applications in defence, mining and energy, medicine, advanced manufacturing, and agriculture.
- Autonomous mobile robots, include intelligent driving and walking robots, autonomous underwater vehicles, and uncrewed aerial vehicles (reflecting outcomes from multidisciplinary collaboration between AI, computer vision, control robotics, signal and image processing robotics and automation).
- Extracting useful information and patterns (e.g. knowledge graphs) from large collections of industry data.
- Best practice guidelines for designing transparent and usable human-machine work systems.
- A Non-Kinetic Misinformation Wargame which models operations in the information environment and can provide scenario-based training for Defence on the online dynamics of social disinformation.

Wargame user interface



Advanced Cyber

UWA has world-leading expertise in conducting research on human information processing and transmission, the mechanisms of social influence, and, more broadly, culture and its evolution. This helps agencies identify false information, conspiracy theories, and online radicalisation, anticipate its spread and impact, and develop strategies to counteract malign informational influence.

Crossover areas include information warfare (see AI and Autonomy), adversarial attack identification and defence (see AI and Autonomy).

Capabilities include:

- Researchers from multi-disciplinary teams including psychology, human factors, social and behavioural science, economics, computer science, and cybersecurity
- Research toward secure, assured and resilient information systems as relied on by Defence, including Moving Target Defence, Network modelling and analysis, anomaly detection and malware analysis
- Software-induced hardware faults that hinder physical operations and defence techniques against such attacks
- Privacy-preserving techniques and protocols for sensor networks
- Exploiting quantum-inspired machine learning to develop advanced cybersecurity mechanisms
- Formal verification of AI-driven solutions improved security and robustness
- Game Theory with AI
- Using artificial intelligence (AI) and deep learning to improve the detection and mitigation of misinformation and fraud
- Experimental and computational simulations to precisely determine the effects of misinformation on cognition and behaviour
- Design of pre-bunking and de-bunking interventions to reduce the impact and spread of misinformation

- Predicting the outcomes of collective human behaviour (e.g. information transmission and transformation)
- Research into human culture, cultural evolution, and culture change including communication, social influence, and misinformation management in social media.

Electronic Warfare

Research in Electronic Warfare spans collection, integration, and protection of information from Intelligence, surveillance, and reconnaissance (ISR) sources and tactical systems in real or near real time to support decision making; interoperability with allies; automated information processing and reasoning; and human and AI interaction.

Misinformation impacts cognition and behaviour and mitigation strategies including effectively debunking misinformation, reducing misconceptions, and better preparing people for future misinformation

Examples of outcomes and impact

- Misinformation impacts cognition and behaviour and mitigation strategies including effectively debunking misinformation, reducing misconceptions, and better preparing people for future misinformation
- Fostering information and media literacy, critical thinking
- The Non-Kinetic Misinformation Wargame noted previously under Artificial Intelligence and Autonomy.

Related to this is research in Space Situational Awareness, de-risking Defence's dependence on space-based systems through technical expertise and enhanced capability agility. This includes innovative, reliable, and resilient space constellation technologies across communications, Position, Navigation and Timing (PNT) and ISR/Electronic Warfare (EW) for deployed forces, defence and national security.

Crossover areas include quantum sensing and AI and Autonomy.

UWA's competitive advantage is in:

- Infrared Imaging Array technologies with applications in: Night vision and security; Remote weapons targeting systems; ISR; Missile detection systems; Missile guidance and targeting; Space situational awareness; and Remote sensing.
- Optical micro-electro-mechanical systems (MEMS) based technologies with applications in: Stand-off detection of improvised threats; Multi-spectral remote sensing and imaging; Space situational awareness; Target signature recognition and identification; Optical waveguide switching for electronic warfare; High sensitivity magnetometers; Gas, chemical, and bio sensing.
- Modelling and measurement of the effects of the atmosphere on free-space light propagation.
- Modelling of the effect of atmospheric scintillation in satellite/ground optical communications.
- Remote Sensing and Sensing Networks research groups with robotics and automation expertise in sensor networks and data integration, image analysis and recognition systems, automatic target detection, recognition and tracking; acoustic array design and signal processing and acoustic scene classification; audio source separation and enhancement – spoofing and counter-measures.
- World-leaders in ground-to-space laser links for high-precision metrology, laser communications from spacecraft, and quantum key distribution.
- Atmospheric effects and optical propagation projects with National Institute of Information and Communications Technology (NICT), Defence Science and Technology Group (DSTG), and the US Navy laboratories (the Space and Naval Warfare Systems Command, SPAWAR).

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Examples of outcomes and impact

- Demonstrated Australia's first truly-sovereign 320x240 imaging array operating in the midwave infrared (MWIR: 3–5 µm) spectral band. Manufactured from Australian-grown Mercury-cadmium-telluride (MCT) material, this technology can be adapted to operate anywhere in the shortwave infrared (SWIR: 1–2.5 µm), or the longwave infrared (LWIR: 8–12 µm) wavelength ranges.
- Developed MEMS-based micro-spectrometers, of volume less than 1mm^3, in the SWIR, MWIR and LWIR wavelength bands. Recent Defence-funded work on the technology has demonstrated a low-SWAP spectrometer instrument mounted on a drone and operated from an altitude of 100 m.
- Researchers are working directly with Defence on numerous EW surveillance-based projects including electro-optics for electronic surveillance over the sea (including from submarines).
- Ground-station support from CubeSat to Deep Space missions.
- The Astrophotonics group at ICRAR-UWA is working with the Royal Australian Army's Robotic and Autonomous Systems Implementation & Coordination Office, and the Royal Air Force's Jericho Disruptive Innovation, to develop technologies and techniques to disrupt satellite quantum communications links.

Innovation

UWA's Office of Industry and Commercial Development leads UWA's engagement with defence industry, and manages a pipeline of intellectual property, licensing and investment opportunities.

Information sharing

Part of the work of UWA DSI is to assist UWA research staff with the complexities and logistics of dealing with security (cyber and information), foreign interference and export control obligations, as well as to meet the obligations of the university's Defence

Industry Security Program (DISP) accreditation. UWA is a DISP member, with the following levels: Governance Level 2, Personnel Level 2, Physical Security Entry Level, Information Security Entry Level. UWA is compliant with all DISP requirements at these levels, and is working with the Department of Defence to increase the university's Physical Security and Information Security levels to Level 2. This has necessitated improvements in the use and sharing of sensitive information both internally and with UWA's trusted partners.

Research infrastructure

UWA partners across the nation, across the state, and across the university to deliver research infrastructure that is accessible, cutting edge, and drives research outcomes. UWA is a leader or partner in 13 National Collaborative Research Infrastructure Strategy (NCRIS) projects, several of which are relevant to AUKUS Pillar II research as noted below.

Undersea capabilities

- UWA has one of Australia's largest pools of oceanographic field research equipment, which can be deployed from the littoral zone to full ocean depths, including in situ instrumentation, remote sensing platforms, and bioacoustic equipment.
- IMOS Ocean Glider Facility (part of the WA node of the NCRIS Integrated Marine Observatory System), which operates a fleet of autonomous, underwater ocean gliders to make oceanographic measurements.
- Minderoo-UWA Deep-Sea Research Centre, which develops and deploys full ocean depth rated (benthic) imaging landers, cameras, oceanographic sensors and sampling equipment and other state-of-the-art deep sea exploration vehicles.
- The Coastal and Offshore Research Laboratory includes a 54 m long wave flume and the UWA 'O-tube' facility, which is a unique large scale recirculating flume test facility simulating underwater wave and current conditions.

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- National Geotechnical Centrifuge Facility operates the only geotechnical centrifuges in Australia developing a wide range of onshore and offshore geotechnical solutions.
- Waterman's Bay Research Facility: laboratory for marine research with state-of-the-art laboratories and pumped seawater.

Quantum technologies

- The Quantum technologies and Dark Matter Research Lab (QDM Lab) – precision measurement instrumentation and expertise in a wide range of experiments including highly sensitive searches for axion dark matter, Lorentz invariance violations, and changes in fundamental constants.
- UWA & Pawsey Quantum Computing Centre (UP-QCC) – hosts two educational desktop quantum computers, the two-qubit SpinQ Gemini and the three-qubit SpinQ Triangulum system to enable students, researchers, and professionals to upskill in quantum computing and engage with Pawsey's Quantum Supercomputing Innovation Hub, an NCRIS facility of which UWA is partner.
- Centre for Microscopy, Characterisation and Analysis – world class electron, ion, light imaging, and microanalysis facilities, including flagship ion probe and MRI facilities. CMCA includes facilities that are part of the NCRIS Australian Microscopy and Microanalysis Research Facility and the NCRIS National Imaging Facility.
- WA node of the NCRIS Australian National Fabrication Facility – a complete, vertically integrated facility, from materials growth, through device design, fabrication, and testing, to packaging and subsystem assembly, for advanced microelectronic, optoelectronic, and photonic materials, devices and systems (including quantum).

CRUSE lab (undersea/AI & automation). Control Room Use Simulation Environment Laboratory for undersea decision superiority

Artificial Intelligence and Autonomy

- UWA Robotics Lab – developing concepts for the next generation of intelligent mobile robots. The facility includes EyeBot Mobile Robots, EyeSim Robot Simulation, RoBIOS Robot OS.
- Machine Intelligence Group – Computer Vision, Machine Learning, Deep Learning and Pattern Recognition.
- Human Factors and Applied Cognition Laboratory – Task simulation facilities (such as submarine command and control, uninhibited vehicle management, maritime/air contact classification, air traffic control, driving) for human-machine teaming exper-imentation (human in-the-loop studies), including the Control Room Use Simulation Environment (CRUSE) laboratory.

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Electronic Warfare

- WA node of the NCRIS Australian National Fabrication Facility.
- Teranet free-space optical communications ground station funded by the Australian Space Agency – ground-breaking high data rate optical communication technology includes Free-space link, communication system, and link targets: Stationary Jeep Gladiator utility vehicle (folded link distance 2×350m), flying 20-kg class hexacopter (2×250m), and moving Army rigid-hull inflatable boat (2×1km). The Jeep-mounted transportable free-space optical communications terminal was invited to be showcased in the DSTG Launchpad Technology Demonstration Event at 2023 Talisman Sabre.

Workforce development

The University of Western Australia is amongst a handful of universities in Australia who have formed a cross-university institute/centre (UWA DSI) to unify and focus expertise in defence and security research, engagement, and education. As a State leader, UWA DSI's Advisory

Jeep-mounted transportable free-space optical communications terminal from the Teranet free-space optical communications ground station

Board has representation from the defence community and industries, former defence politicians and policy makers and the WA State Government's defence leadership arm that provides a link to expertise and opportunities for our research and contribution to workforce development especially in the context of AUKUS.

As a research-intensive institution, UWA's teaching is led by cutting-edge research and links to industry. This academic success is evident through high completion rates – around 15 points higher than the national average for engineering and around nine points higher than the national average for Sciences (at nine year completion). Accredited courses and industry-linked experts generate capable and connected graduates.

UWA DSI actively works with the work integrated learning (WIL) team and Careers Centre at UWA to leverage the relationships that UWA DSI has with defence industry, knowledge and leadership to support the upskilling that is needed for AUKUS Pillars I and II to be proactive in creating opportunities for students and graduates such as through the State Government's WA Defence Industry Internship and Graduate Scholarship (DIIGS) Program. This is evident through some existing multifaceted partnerships:

- Austal shipping, a prime contractor, has provided vacation work for under-graduates, Masters thesis projects and has previously been co-located on campus to collaborate on research for Smart Ship technology.
- UWA facilitates Dassault Systems competitions and challenges for students to engage on real-world projects using their software, from designing humanoid robots, electric submarines, and solar race cars, to drones and space shuttles. They have a strong track record for converting this student engagement into internships and graduate positions.
- UWA and DSTG regularly co-design and co-supervise masters and PhD projects incorporating close engagement with Defence SMEs. Topics have included enhanced human performance, information warfare, sensing technology and optical communications.

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- UWA's successful Cooperative Education for Enterprise Development (CEED) program links the abilities and training of students, university research expertise (via an academic advisor), and the R&D needs of public and private enterprise – a perfect link for future AUKUS Pillar II workforce needs.

Most recently, this has led to the award of an ARC Early Career Industry Fellowship to a UWA PhD graduate who had been working at HMAS Stirling and has now returned to UWA for the Fellowship.

- UWA has a long-standing and close research partnership with the Maritime Undersea Combat and Surveillance program at HMAS Stirling, dedicated applicable research (AUSMURI funded) and houses the Control Room Use Simulation Environment (CRUSE) that simulates a submarine control room environment. These combine to create a graduate with immediately applicable knowledge and experience to contribute to the workforce and workplace training and design for submarine activities based out of WA. Most recently, this has led to the award of an ARC Early Career Industry Fellowship to a UWA PhD graduate who had been working at HMAS Stirling and has now returned to UWA for the Fellowship.

Other relevant workforce development activities include:

- Associate Degree in Applied Technology, co-delivered with South Metropolitan TAFE: this focuses on the design and integration of sensors which have defence and other applications. The program includes mentoring from local industry leaders.
- In 2023, UWA DSI ran a 2-day AUKUS Pillar I Masterclass for employees of Defence, defence (and related) industry, national, state/territory and local government, education and training institutions, and workforce agencies. Based on this Masterclass, an AUKUS Pillar II Masterclass is under development for delivery in 2024, at the request of the Department of Defence's Strategic, Policy and Industry Group.

Collaborations

Key UWA collaborations include:

Free-space optical communications

- A AU$6.5 million UWA project, which has received funding from Thales and from the Australian Space Agency and is a flagship technology for the SmartSat CRC, employs a new technology that uses super-fast lasers to talk to satellites and spacecraft to deliver 'free-space optical communications', 1000 times faster than the radio communications currently used to communicate in space. The Jeep-mounted transportable free-space optical communications terminal that has been built for this was showcased (by invitation) in the DSTG Launchpad Technology Demonstration Event at 2023 Talisman Sabre.

Technologies to disrupt satellite quantum communications

- Quantum communications links, secured by the laws of quantum physics, promise un-hackable and un-spoofable networking for future communications and navigation systems. However, quantum communications can still be disrupted (jammed). The Astrophotonics group at ICRAR-UWA are working with Army's Robotic and Autonomous Systems Implementation & Coordination Office, and Air Force's Jericho Disruptive Innovation, to develop technologies and techniques to disrupt satellite quantum communications links.

A AU$6.5 million UWA project ... employs a new technology that uses super-fast lasers to talk to satellites and spacecraft to deliver 'free-space optical communications', 1000 times faster than the radio communications currently used to communicate in space.

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(left) Drone with IR sensing array mounted on gimble;

(right) Gimble

Infrared imaging technologies

- UWA's infrared (IR) imaging technologies (IR sensors and MEMS spectrometers) form a core technology capability of the WA node of the TMOS CoE. The IR imaging work includes multiple associate investigators based in US and UK, where UWA shares the expertise in both MEMS and IR Technologies and is the only place globally where all levels of the platform technology (MEMS+IR sensors + bespoke crystal growth for IR sensor material) are co-located in one institution for vertical integration.

Key examples

Key case examples include:

High precision measurement using Sapphire Crystal Oscillators

- UWA's Professors Michael Tobar and Eugene Ivanov and their team's work on Sapphire Crystal Oscillators was licensed to Poseidon Scientific Instruments, now part of Raytheon. The technology has become an essential component in Raytheon's low noise defence radar.

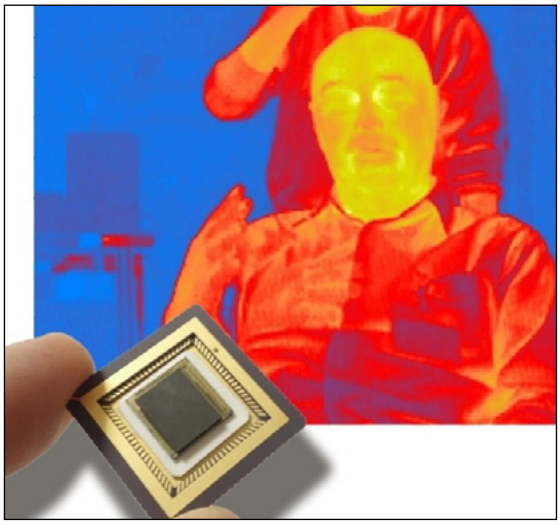
Suppressed Noise Oscillator technology

- *Suppressed Noise Oscillator technology* developed by UWA researchers has been licensed to

Lockheed Martin Corporation (LMC), who provide the only commercially available gravity gradiometers. The licence allows a provision to collaborate with Australian Defence Forces for military applications. The technology is drone-mountable and can be used for detecting voids, tunnels, and underground structures.

MEMS spectrometers for infrared imaging

- The Advanced sensing group has developed *micro-electro-mechanical systems (MEMS) spectrometers for infrared imaging* over many years with a variety of US partners. Past collaborations include with DRS Technologies (with Defense Advanced Research Projects Agency (DARPA) funding) to initially demonstrate the concept of MEMS spectrometer technology for IR imaging. This was followed by partnering with United Technologies Aerospace (with ARC Linkage funding) to extend the MEMS spectrometer technology for integration into a focal plane array for ISR applications, with the developed technology licensed to University of Tasmania at the program conclusion.
- The group currently works with L3 Harris to improve the weight, size and power of Defence communication equipment and undersea surveillance capabilities, using MEMS and photonics (as previously described under Electronic Warfare and Quantum Technologies areas). Under AUKUS, the group has formed a new collaboration with the University of Arizona (two white papers under preparation).



Imaging array with schematic of MEMS-based absorbing layer and (behind), camera still using IR imager

Key personnel

Undersea capabilities

Physical Oceanography, Ocean Dynamics
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Quantum technologies

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Frequency metrology, precision and quantum measurements, quantum physics
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Artificial Intelligence and Autonomy

Human-machine teaming (including submarine command and control, uncrewed vehicle control, land warfare)
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7 https://research-repository.uwa.edu.au/en/persons/nicole-jones

8 https://research-repository.uwa.edu.au/en/persons/charitha-pattiaratchi

9 Dr Gozzard is also relevant to electronic warfare due to work with technologies and techniques to disrupt satellite quantum communication. See https://research-repository.uwa.edu.au/en/persons/david-gozzard

10 https://research-repository.uwa.edu.au/en/persons/michael-tobar/

11 Professor Loft is also relevant to undersea capabilities due to extensive work in submarine control room undersea decision making. See https://research-repository.uwa.edu.au/en/persons/shayne-loft

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Human-centric cyber security, machine learning, misinformation
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Electronic Warfare

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14 https://research-repository.uwa.edu.au/en/persons/jin-hong
15 https://research-repository.uwa.edu.au/en/persons/zhi-zhang

The Australian National University

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Initiatives and Infrastructure

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Skills and capability

A signature capability of the ANU is that the international strength and standing of its humanities and social science (HASS) disciplines matches the quality of its STEM research. ANU has world-leading expertise in international law, regulation and governance, and national security policy, as well as its unique depth of expertise on Asia and the Pacific. These capabilities both support and provide critical oversight of the STEM research that directly intersect with specific AUKUS activities.

The ANU's expertise in STEM research draws on very broad capability that enables researchers to have ready access to prototyping and advanced manufacturing workshops which, in turn, enable device and instrument development and fuel a vibrant start-up culture. The large post-graduate community (more than 400 in STEM and related fields) has access to advanced computational capabilities; advanced nanofabrication, optical, electronic and precision machining capabilities; and a broad range of analytical and research infrastructure.

Australian National University

In addition to collaborations with Australian Defence, the ANU has long-term international collaborations with UK and US institutions, including through grants with the US Defence Force and Defense Advanced Research Projects Agency (DARPA).

Research strengths

Undersea capabilities

The ANU has well developed capabilities in the areas of robotics and autonomous systems, the detection of undersea structures, monitoring undersea seismic activity and modelling of oceanic climate, tides and sea-ice.

As part of a broader research program on submarine navigation, robotics and autonomous systems, research at ANU focusses on detection and target tracking in coastal environments. This research incorporates expertise in several related fields including decision making in uncertainty, automation and control engineering, control systems, robotics and automation, autonomous vehicle systems, intelligent robotics, autonomous agents and multiagent systems.

The ANU's undersea capabilities include the advanced modelling of global oceanographic climate, tides and sea-ice with ANU as the host to the Consortium for Ocean-Sea Ice Modelling in Australia (COSIMA) and the Australian Earth-System Simulator (ACCESS-NRI) projects.

These support the work of more than 180 ocean researchers across eight Australian universities, government agencies and several international institutions including in the US and UK.

Quantum technologies

The ANU is home to a vibrant quantum technology ecosystem, with leading capabilities in fundamental research, quantum physics, and advanced manufacturing.

The ANU recently funded a AU$220 million dedicated quantum research and fabrication facility. This is the single largest investment in quantum science made by an Australian university to date.

The Australian National University

This facility houses key capabilities in atom optics, quantum optics, quantum information theory, quantum computing, communications and sensing, gravitational wave sensing, precision optics, space science, optical material science, material modification and nanofabrication.

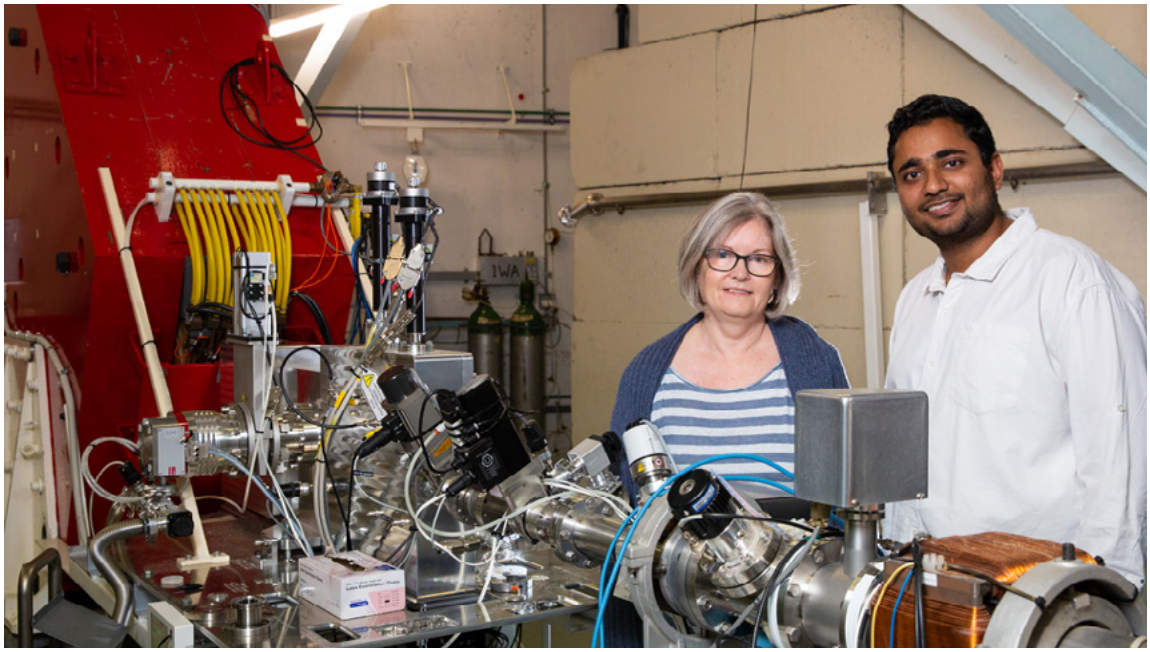
Building on over 40 years of expertise in quantum and atom optics, ANU scientists particularly focus on technologies controlled by, or operating on, photons as applied to optical quantum communications, computing and sensing. With light as the ideal information carrier over distance, a sustained effort has been dedicated to integrating different quantum technologies with optical channels. For example, ANU InSpace recently opened its new optical ground station for satellite communication equipped for quantum communications and the interfacing of quantum memory technology, which will support missions with NASA and DLR (German Aerospace Agency).

The commercialisation framework at ANU is conducive to commercialisation activities and spin-outs. The ANU Physics incubator, *Momentum*, currently hosts four quantum-aligned companies, two materials/composites companies and two national STEM engagement companies.

ANU InSpace recently opened its new optical ground station for satellite communication equipped for quantum communications and the interfacing of quantum memory technology, which will support missions with NASA and DLR (German Aerospace Agency).

Artificial Intelligence and Autonomy

The ANU is highly ranked in the teaching and research of computational modelling and the design of artificial intelligence (AI) intelligent agents in complex real-world contexts. The research integrates areas of AI, machine learning (ML) and vision, natural



language understanding, and robotics, to build autonomous systems that can perceive, plan, and respond to their environment in pursuit of high-level goals and critical enablers.

Areas of research include Human-machine teaming (HUM-T for Defence) and control systems, AI and human-AI interaction, AI and Automated Planning, ML and Automated Reasoning, AI planning for Cyber Red-Teaming and Hybrid Systems, Decision making and planning in uncertainty, AI enabled optimisation on manifolds with applications in robotics, and AI and image processing using geospatial information systems (GIS).

Two ANU spin-out companies, Thaum and Aqacia, hold several government and commercial contracts for implementation of natural language AI systems, and use machine learning to optimise large dynamic quantum atom optic systems. The materials group that created the CTLab, a 3D X-ray imaging facility at ANU, has developed image-based AI solutions under the banner *OreAI* exclusively for one of Australia's largest resource companies.

The Australian National University

Advanced Cyber

The ANU leverages its considerable computing and information sciences capabilities through the Secure Software Systems research group, to research a wide variety of cyber security related areas, including:

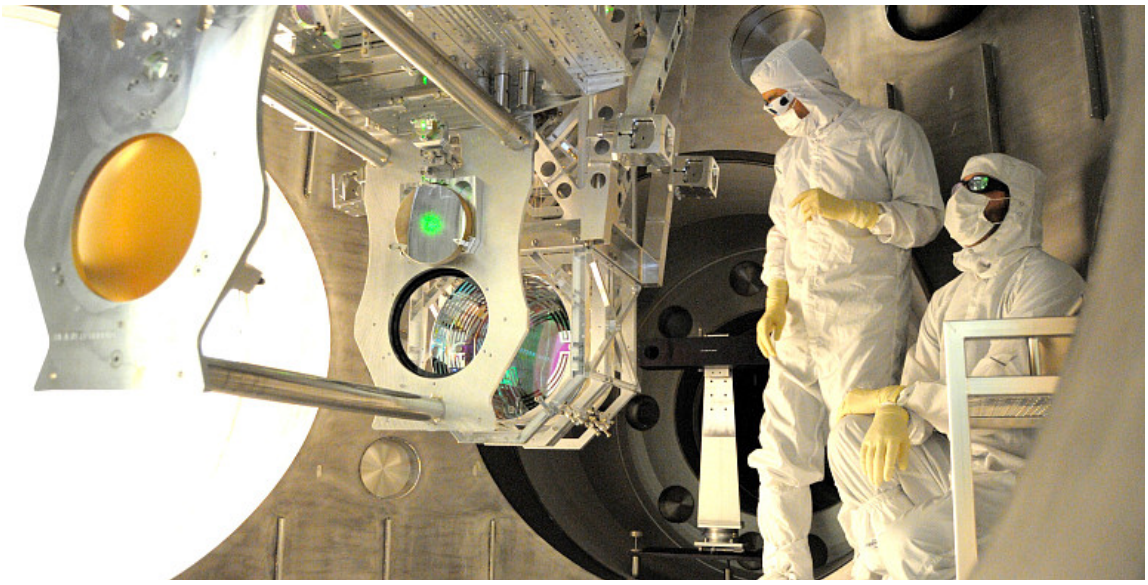
- the intersection of data privacy and secure multiparty computation, derived from sensitive information and that provide provable privacy guarantees
- cyber-physical systems and Internet of Things (IOT): security and privacy
- the security and privacy of protocols and devices and finding vulnerabilities in implementations, advancing security protocol verification methods and language-based secure information flow
- the use of AI and ML to create innovative and secure data storage solutions
- secure ultra-reliable and low-latency communications, intelligent communications
- verification of systems that exhibit a high degree of complexity, making them prone to errors and difficult to verify, including safety-critical systems and security protocols
- formal methods to verify real-time controllers, such as the controllers that are present in autonomous vehicles.

The core strength of ANU cyber capabilities is exemplified though the collaboration on education and research between ANU and the Australian Signals Directorate (ASD). Under a 15-year agreement, this collaboration has resulted in a state-of-the-art purpose-built research and teaching facility housed at ANU. This ASD-ANU Co-Lab brings together ANU academics with technical and analytical expertise from ASD to education and fosters a new generation of cyber specialist equipped to solve real-world cyber challenges.

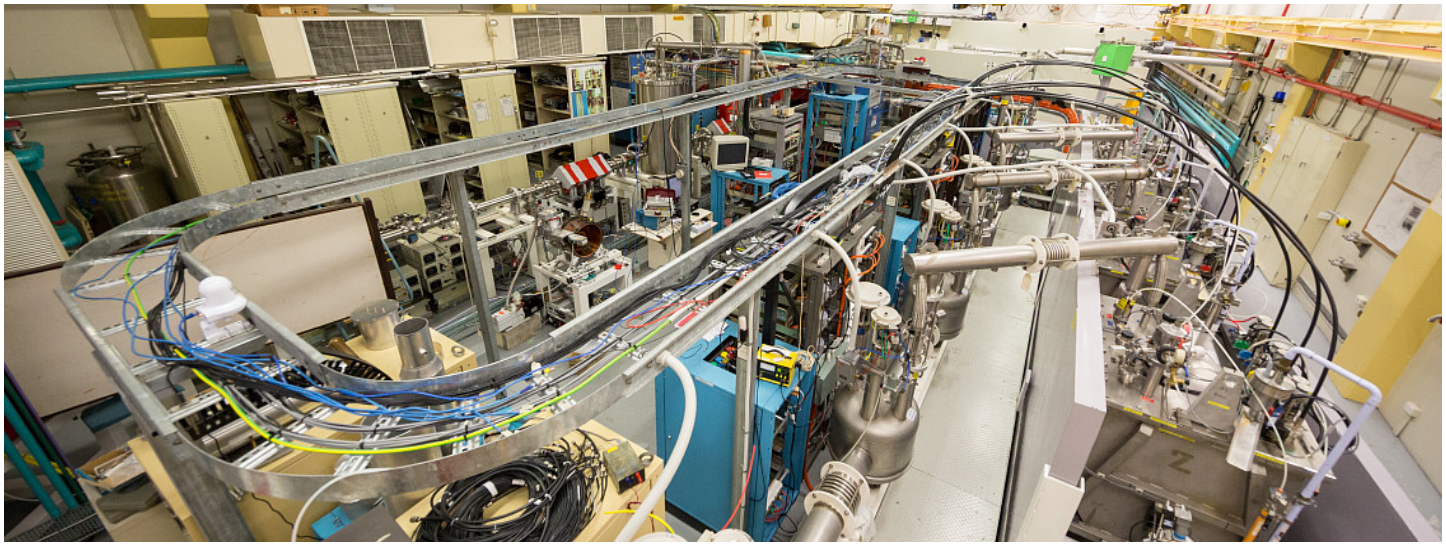
Hypersonic and Counter-Hypersonic Capabilities

The ANU hypersonic capability is provided by the engineering aerospace cluster which hosts a cross-disciplinary collaboration with Defence Science and Technology Group (DSTG), Go8 partner, UNSW, Sydney and the US Airforce Academy. This program studies boundary layer transitions at hypersonic speeds.

The ANU leads the ARC Centre of Excellence for Transformative Meta-Optical Systems (TMOS) which has collected expertise on III-V semiconductor research together with a strength in non-linear optical theory and meta-material design to focus efforts on active IR sensors and integrated optical systems. This expertise is well served through the Australian National Fabrication Facility (ANFF) – the only Australian capability in III-V semiconductors which are required in IR and microwave hybrid devices, key elements in future hypersonic detection/navigation technologies.



The Australian National University



Heavy Ion Accelerator Facility (HIAF), ANU

In addition, OptiFab, an optical fabrication network under ANFF has established an advanced optical fabrication facility to deliver custom optical systems. These offer advanced coating facilities, optical finishing and assembly of single lens elements up to complete telescope systems (including lens less optics for UV and IR). Some of these systems have been tested in space missions in collaboration with NASA Langley Research Centre, Northrup Grumman and Lockhead Martin US.

Electronic Warfare

The ANU has expertise in the areas of information and signal processing where research expands into areas of communications, spatial audio and acoustics, and nano-electro-mechanical systems.

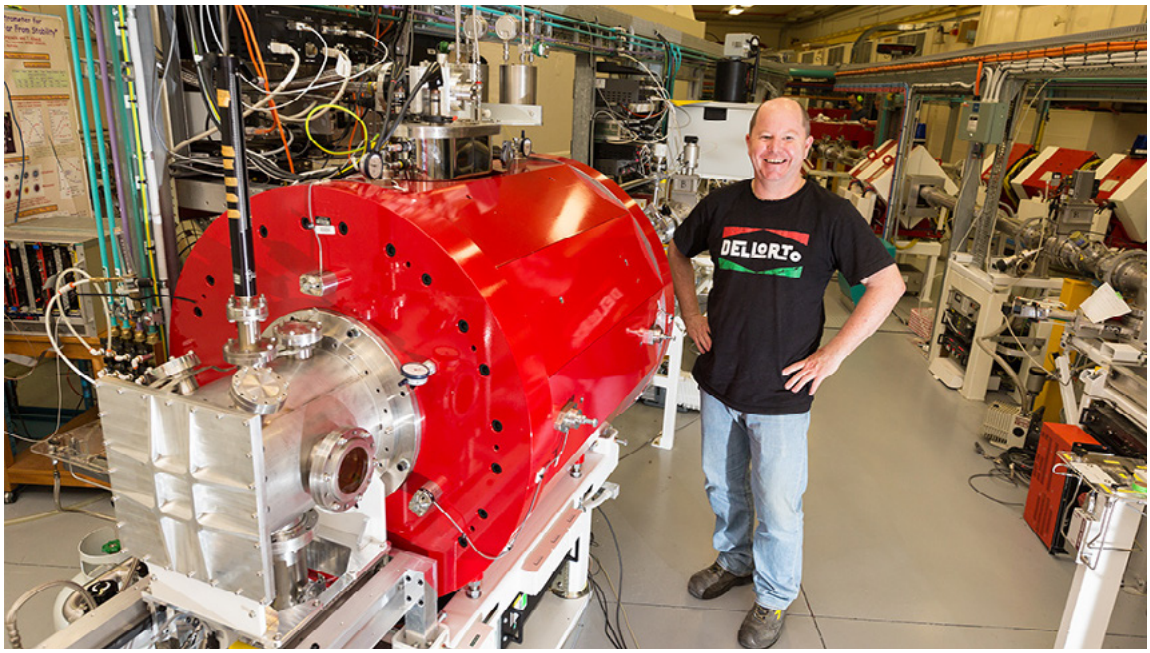
Research is focused on ultra-reliable and low-latency communications, intelligent communications, wireless network security, physical layer security and cyber-physical security.

Innovation

ANU Physics has commercialised eight quantum-inspired companies which are all headquartered in Australia's national capital, the ACT.:

- 2007 QuintessenceLabs involving 80 Australian, UK and US staff, with a focus on quantum-based cyber security, active with Series B

- 2017 Liquid Instruments involving 60 Australian and US staff, focusing on advanced test and measurement instrumentation, closed Series B
- 2018 Quantum Brilliance involving 100 Australian and German staff, focusing on diamond-based quantum accelerator and sensors, seeking Series B
- 2018 Nomad Atomics involving six Australian and German staff, portable atom gravimeter, seeking Series B
- 2019 Thaum involving 15 staff, focused on AI and data science consultancy with hardware development, profitable and not seeking investment
- 2021 Via Photonics involving eight staff, focusing on LiDAR-based technologies, acquired by Advanced Navigation 2022
- 2021 Aqacia involving two staff seeking investment, machine learning solutions, formed a JV under Floquet with 2pi Software
- 2023 Forge Photonics involving four staff, control systems for optical navigation components, early stage.



The Australian National University

Photo of newly built Research School of Physics Building at ANU. This building represents the single largest investment in quantum research facilities by an Australian university. Credit: Gollings Photography 2023

Research infrastructure

The ANU supports several facilities that underpin AUKUS Pillar II research capabilities.

Investment in Quantum Science through state-of-the-art Research School of Physics building

The ANU has invested AU$220 million in an advanced quantum facility that includes 2000 square metres of ultra-stable labs and 750 square metres of nanofabrication cleanrooms that will soon be Defence Industry Security Program (DISP)-accredited. These facilities enable quantum and precision measurement, advanced optical fabrication including unique-to-Australia nano-lathes and advanced optical coating capabilities.

Australian National Fabrication Facility (ANFF) ACT Node (National Collaborative Research Infrastructure Strategy (NCRIS) Funded; ANU Hosted)

The ACT Node of the ANFF supports all aspects of quantum device

development, from optical to semiconductors. This facility provides state-of-the-art manufacturing capability for research in materials and/or devices that require sub-micrometre feature size, including but not limited to, applications in photonics and opto-electronics that underpin smart sensing technology.

National Computation Infrastructure (NCI) (NCRIS funded; ANU Hosted)

NCI brings the Australian Government and the Australian research sector together through a broad collaboration involving the largest national science agencies, universities, industry and the ARC. NCI provides high-performance data, storage and supercomputing expertise to deliver ground-breaking scientific outcomes.

ANU Quantum Optical Ground Station (ANU hosted)

Facilitates research on advanced communications technologies and provides satellite networks with quantum security and global connectivity communicating with adaptive optics.

Australian Earth-System Simulator (ACCESS-NRI) (NCRIS funded; ANU Hosted)

This organisation is a major collaborative undertaking between the Bureau of Meteorology, CSIRO and five Australian universities, in collaboration with international partners. In addition to modelling atmospheric and land-based condition, the modelling of oceans, sea-ice and biochemical oceanographic data may assist in the development and deployment of undersea capabilities.

ASD-ANU Co-Lab (Co-Lab)

The ASD-ANU Co-lab was developed in partnership between ANU and the Australian Signals Directorate. This initiative is hosted at ANU in a state-of-the art purpose-built facility and run jointly by the ANU and ASD staff to facilitate education and training for students in areas of mutual interests to both organisations including cryptography, computational linguistics, secure communications, computing, cyber security, psychology and vulnerability research.

Workforce development

The ANU has been responsive to AUKUS priorities for both Pillar I and Pillar II, with increased investment in facilities and staff, and increased effort on the education and research required to meet workforce needs and capability development. ANU graduates can be found working broadly in national and international defence related industry, broader government and many areas in the Australian Defence Organisation.

ANU, as the only university in Australia with a dedicated nuclear physics department and on-site experimental facility to provide hands-on nuclear training and research, has applied an extraordinary effort to support AUKUS Pillar I capability development.

Pillar I

ANU, as the *only* university in Australia with a dedicated nuclear physics department and on-site experimental facility to provide hands-on nuclear training and research, has applied an extraordinary effort to support AUKUS Pillar I capability development. The ANU provides a full range of education opportunities to increase nuclear literacy across the Australian Government, industry and the public. These range from professional training for government policy makers through the **National Security College** through to undergraduate and postgraduate qualifications.

New STEM programs have been introduced since AUKUS was announced in September 2021, including a Graduate Certificate on Nuclear Technology Regulation, a new major and minor in Nuclear Systems for the undergraduate engineering program, and a new minor in Nuclear Science for undergraduate science students.

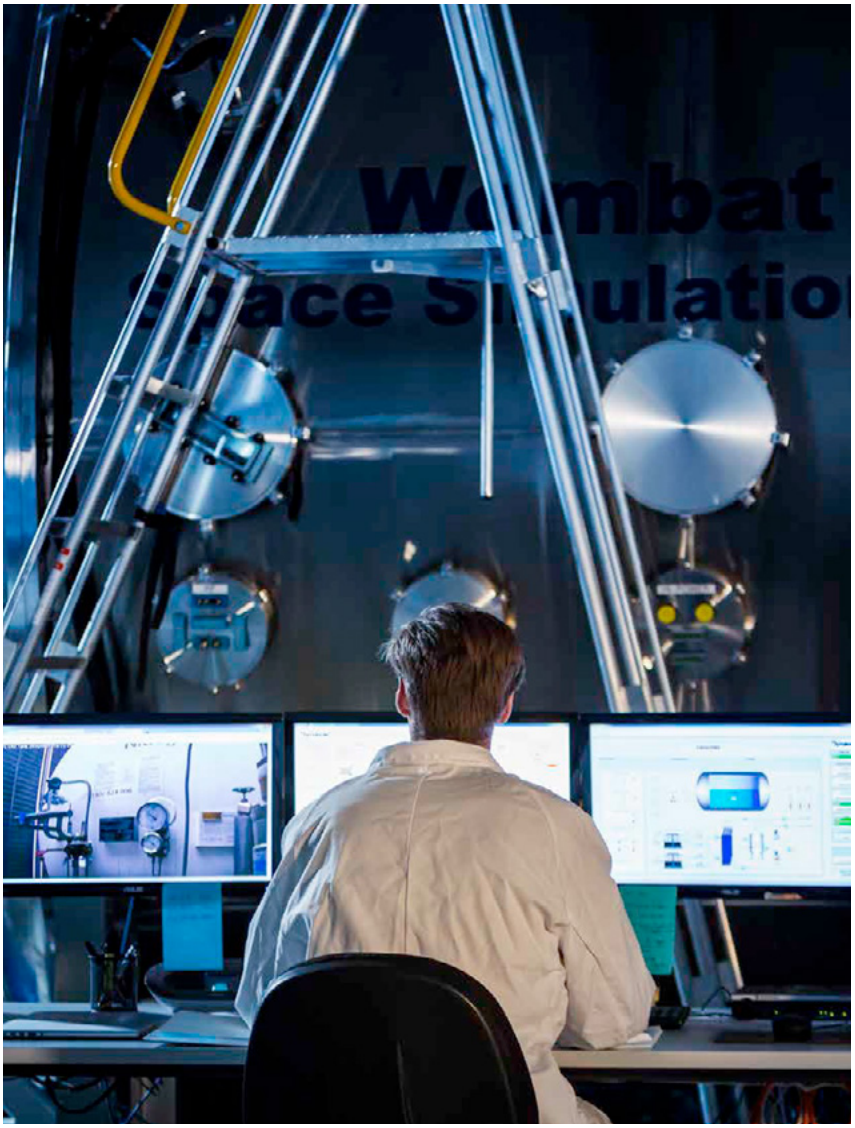
Australian National University

Pillar II

The ANU continues to invest in and support a wide variety of facilities that enables world class research and hands-on teaching in Pillar II areas of interests.

Through the College of Engineering, Computing and Cybernetics students can undertake studies and research projects in robotics, aerospace systems and uncrewed aircraft, artificial intelligence, advanced computing and cyber security, and the human-machine interface.

The ANU Research School of Physics is the largest university-based physics entity in Australia, hosting over 150 academic physicists. Undergraduate study opportunities include courses in quantum and optical physics, the physics of matter and advanced statistical mechanics as well as advanced mathematical and computing science courses offered through the broader College of Science at ANU.



The ANU Research School of Physics is the largest university-based physics entity in Australia, hosting over 150 academic physicists.

Collaborations

ANU researchers collaborate broadly, both nationally and internationally with government agencies, industries and universities on AUKUS Pillar II capabilities including:

ANU-DARPA project on meta-optical materials for operation of unmanned vehicles in low light environments

Supported by the DARPA EXTREME program, this research exploits the application of second harmonic generation to convert IR wavelengths to visible ones. This technology forms the basis of a new light-weight class of night vision glasses for soldiers and has application in the operation of uncrewed arial vehicles in low-light situations.

Secure long-range quantum optical communications

Researchers at the ANU are optimising high-speed advanced communication based on quantum optical techniques. This methodology uses high-powered lasers to provide higher rate of data transfer over longer distances coupled with quantum processing and bright laser beam quantum encryption to provide virtually un-hackable communications guaranteed by the laws of physics.

ANU Quantum Optical Ground Station

The ANU Quantum Optical Ground Station houses a telescope that supports high-speed advanced communication capability with satellites from low-Earth orbit to the Moon and other deep space laser communication. Funded jointly by the ACT Government, Australian Space Agency, CSIRO and German company TESAT, this facility is an integral part of the Australasian Optical Ground Station Network (AOGSN), supported by the University of Western Australia, DSTG, CSIRO and the University of Auckland.

Australian National University

Quantum Brilliance

An ANU based start-up company developing the world's first hybrid quantum-classic computing platform

Quantum Brilliance is a quantum technology company based on intellectual property resulting from research conducted at ANU.

The co-founder and Chief Science Officer of Quantum Brilliance, Lieutenant Colonel Marcus Doherty, was a researcher at ANU before stepping into his company role in Quantum Brilliance. He retains his rank in the Australian Army and is part of the Future Land Warfare.

Launched in 2019, Quantum Brilliance aims to produce light-weight low-powered quantum computers using diamond-based accelerators that can operate at room temperature.

In 2022, spanning facilities in the UK, Germany and Singapore, Quantum Brilliance announced in a new collaboration with a US graphics company, NVIDIA, to accelerate the development of the world's first hybrid quantum-classical computing platform. This critical commercial development seeks to integrate an advanced conventional computational interface with a diamond-based quantum accelerator. NVIDIA is the leading global company in graphics processing chips, so advanced that at times their chips have had US export controls restriction.

This commercial partnership illustrates the potential for Australian tech companies to provide unique advantages for AUKUS partners. Quantum Brilliance won the InnovationAus 2022 Award for Excellence in the Manufacturing Innovation category for efforts to make quantum computing an accessible technology for everyday use.

The Australian National University

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Quantum technologies

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Quantum communications: rare-earth based quantum memories and repeaters with applications to sensing, computing and communications
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Australian National University

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Innovation

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ANU Physics has a lean start-up environment, called Momentum, that includes attractive staff leave provisions as well as access to advanced workshops and laboratories. In the past 5 years we have spun out Liquid Instruments, Quantum Brilliance, Aqacia, Thaum, Via Photonics, Forge Photonics, Flexegraph, New Frontier Technologies and Hyrea.

Information Sharing

Managing secure operations
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GROUP OF EIGHT AUSTRALIA

MEMBERS

THE UNIVERSITY OF WESTERN AUSTRALIA

MONASH University

Australian National University

THE UNIVERSITY of ADELAIDE

THE UNIVERSITY OF MELBOURNE

UNSW SYDNEY

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

THE UNIVERSITY OF SYDNEY

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