Capability Portfolio

UNSW Defence Research and Technology

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Professor Attila Brungs
Vice-Chancellor and President, UNSW

From the Vice-Chancellor and President

UNSW is proud of its growing contribution to Australia's defence and security through its enduring and deepening relationships with the Department of Defence, the Australian Defence Force, national security agencies and the defence industry sector.

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 in Australia.

For the past 54 years, UNSW Canberra at the Australian Defence Force Academy has been providing undergraduate education for Trainee Officers and supporting their career progression through post-graduate research and education upskilling.

At UNSW we are very proud that our alumni count among Australia's most senior defence force leaders. They are operating from seabed to space in a constantly changing military environment, driven by accelerating technological innovation across the essentially human activity of securing Australia's vital national interests.

In 2017 UNSW's Defence Research Institute was created to turbo-charge UNSW's defence-related research activities across all our faculties in Sydney and Canberra.

By deepening our trust-based relationships with Defence planners, UNSW's research community is increasingly pivoting towards solving complex defence problems by applying breakthroughs in dual-use technologies such as artificial intelligence, quantum computing, cyber-security, and human and decision sciences.

In 2022 UNSW, in partnership with the University of Adelaide, was selected by the Commonwealth to deliver a $250m defence trailblazer program over four years aimed at driving greater integration of academia and defence industry in accelerating the translation of fundamental research to scaled up sovereign manufacture of those capabilities that will be critical for our servicemen and women.

These include quantum materials, technologies, and computing; defensive hypersonics and countermeasures; information warfare and advanced cyber-security technologies; robotics, autonomous systems, and artificial intelligence; and defence space technologies.

This Capability Portfolio showcases UNSW excellence in defence research and technology and highlights our work across academia, government, and industry, as well as with global policy makers, to create a hub of defence-related knowledge and outcomes for the communities we serve.

From the Deputy Vice-Chancellor Research and Enterprise

The UNSW Division of Research and Enterprise is responsible for facilitating engagement between our academics and partners across government, industry, and the defence community, and with like-minded international partners.

Over the past three years, UNSW's Defence Research Institute has worked closely with our Knowledge Exchange and faculty teams to generate over $100m in defence-related research opportunities while concurrently strengthening UNSW's top standing among Australia's defence and security-focused universities.

UNSW has pivoted toward defence as a strategic priority in response to policy signals from the Commonwealth, New South Wales and ACT governments.

Release of the 2020 Defence Strategic Update and Defence Science Technology Strategy, as well as the AUKUS announcement in 2021, crystallised for universities an increasingly important entrepreneurial role, needed to accelerate translation of fundamental research into rapid proto-typing and scaled-up sovereign manufacturing of new Australian defence capabilities.

This encompasses the full spectrum of defence activities, from organisational design, leadership, conflict studies and logistics, to in-orbit edge-AI, hypersonics, nuclear engineering, quantum computing, advanced cyber technologies, and undersea sensing. Hosting state-of-the-art research infrastructure in these areas, UNSW proactively seeks to leverage our exceptional multi-disciplinary research expertise in the pursuit of collaborative opportunities with the Department of Defence, defence industry primes and SMEs, other universities, and international partners.

In 2021 UNSW achieved Defence Industry Security Program accreditation and implemented sector leading measures to counter foreign interference.

UNSW is committed to playing a critical role in translating world-class defence and national security research into enduring transformational solutions in support of Australia's national interest. With the release of this Capability Portfolio, we invite our partners, both prospective and current, to explore opportunities for deeper collaboration with UNSW in pursuit ever-greater national security innovation and impact.

Professor Nicholas Fisk AM

Deputy Vice-Chancellor,
Research and Enterprise UNSW

Security & Defence PLuS: Advancing AUKUS

An initiative of the PLuS Alliance, Security and Defence PLuS is an academic research and educational collaboration aimed at advancing AUKUS, the trilateral security partnership between Australia, the United Kingdom, and the United States of America.

The AUKUS partnership strengthens the ability of each country to support mutual security and defence interest by promoting deeper information and technology sharing in advanced military capabilities. The Security and Defence PLuS initiative aims to enhance the statecraft within the AUKUS Partnership by utilizing each university's unique capabilities in, and approach to, academic scholarship and research.

The PLuS Alliance (Phoenix, London, Sydney) combines the strengths of three leading research universities on three continents – Arizona State University, King's College London and UNSW – to solve global challenges and increase access to world-class higher education in high-need areas.

Projects

Security & Defence PLuS will be an intellectual engine behind AUKUS, providing research, analysis, education, and a convening function at the intersection of academia, policy, and practice. Projects include:

- **Expert Commentary**
  A collected essays series will provide insight and analysis of the possibilities and challenges inherent in AUKUS from leading scholars and practitioners from all three nations.
- **Briefing Book**
  A curated collection of AUKUS reference material, from official statements and agreements to key news releases will become a go-to resource for academic researchers and practitioners.
- **Research**
  World-class faculty from our three universities will bring multinational, interdisciplinary expertise to solve the toughest challenges in the Indo-Pacific security environment.
- **Education**
  Professional Development courses (distributed, resident, and hybrid) will equip a generation of practitioners with the technical fluency, regional understanding, and common strategic insight to secure a free and open Indo-Pacific.
- **Conferences and Workshops**
  Starting in Canberra in November 2022, regular convenings will bring together scholars, practitioners, and policymakers in a spirit of open dialog and intellectual inquiry.
- **Information**
  www.securityanddefenceplus.plusalliance.org

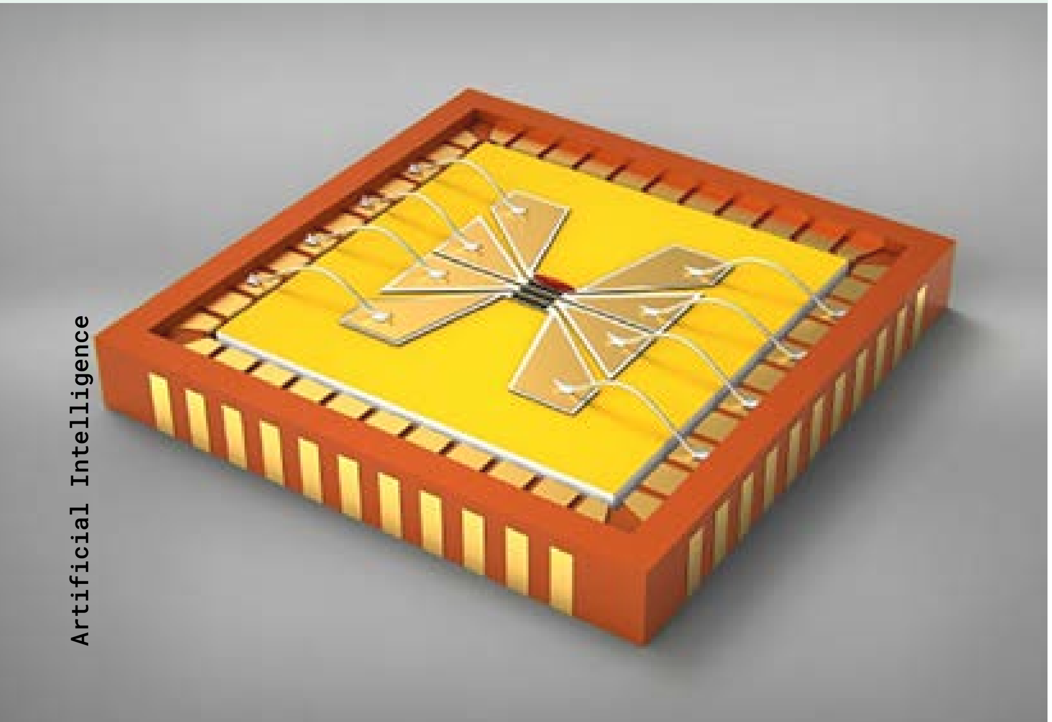
SECURITY
& DEFENCE
PLuS

AUKUS Defence Research and Technology

Artificial Intelligence

Advanced Opto-Electronic Sensors

Electrical and optical sensors for autonomous vehicle navigation, imaging, and environmental physical and chemical sensing. The devices include metasurfaces for image enhancement, hybrid photodetectors based upon combined metasurfaces and two-dimensional materials, and opto-electronic integrated sensors for early fire detection.



Competitive advantage

- Novel devices such as metasurfaces that enable night-vision, mid-infrared cameras, hybrid two-dimensional photodetectors with metasurfaces
- Expertise in a broad range of areas including integrated optics (nonlinear optical devices, photodetectors and lasers) and electronic devices
- Experienced in design, fabrication and characterisation of integrated opto-electronic devices

Impact

- Superior devices that are being tested in autonomous vehicles and internet-of-things systems

Successful applications

- Metasurfaces for radar applications
- Night vision systems
- Highly efficient photodetectors

Capabilities and facilities

- Full design capability with various software packages (Lumerical, CST and COMSOL Multiphysics)
- Fabrication of integrated opto-electronic devices (semiconductor lasers, photodetectors, nonlinear optical systems)
- Specialised opto-electronic laboratories with dark field microscopes, lasers and equipment capable of measurements from ultraviolet to mid-infrared

Our partners

- IEE (Luxembourg)
- Seeing Machines (Canberra, ACT)

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Automatic Mental State and Task Load Recognition

From Speech and Wearable Sensors

Automatic emotion and mental state recognition from speech and behavioural signals via novel methods for automatic assessment of depression and automatic task load estimation from wearable sensors. Research outputs are very highly cited and are being deployed commercially at scale as part of a smartphone-based depression assessment tool.

Competitive advantage

- State-of-the-art automatic detection of depression from speech
- Leading automatic analysis of eye activity and head movement from wearable sensors
- Deep expertise in time series machine learning, including fusion of multimodal time series
- Unique expertise in ordinal regression
- Long track record of successful industry partnership

Impact

- Patented wearable eye activity-based task analysis and depression detection from speech
- Multiple keynote presentations and invited tutorials at peak international conferences
- Among top few researchers worldwide in this area in terms of publication citations

Successful applications

- Novel algorithms deployed at scale via commercial depression detection smartphone app (Sonde Health, US)
- Proof-of-concept automatic driver frustration detection system

Capabilities and facilities

- Large team of senior and early-career academic staff, postdoctoral fellows, PhD students and many honours students
- Vast library of unique custom task datasets of speech, eye activity and movement from wearable sensors
- New soundproofed, ripple-controlled lighting studio facility for recording of speech and behavioural signals under a range of different protocols
- High performance computing capabilities and a large library of custom code and scripts

Our partners

- Sonde Health (US)
- US Army, Lifeline
- Data61 (CSIRO)

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Autonomous Field Vehicles

Persistent autonomous operation of commercial-grade field vehicles such as agricultural tractors, bulldozers and other mining vehicles, military vehicles and civil construction vehicles.

Competitive advantage

- Patented autonomous vehicle systems technology, which allows vehicles to operate without drivers, increasing productivity and reducing operational costs
- The technology is fully tested and commercial ready
- The machines are highly intelligent and backed by sophisticated multi-sensor data fusion, advanced image processing, and complex non-linear vehicle guidance algorithms

Impact

- Lower cost transport, agricultural and mining operations
- Vehicle operations in high risk environments. e.g IED countermeasures

Successful applications

- Developed and built high precision autonomously-guided construction machinery for Makinex
- Converted Komatsu D65-EX bulldozer to a full autonomous bulldozer in partnership with Komatsu
- Completely developed and patented a sophisticated high-precision broad acre planter for Grains Research and Development Corporation (GRDC)

Capabilities and facilities

- Multi-sensor ground-based and airborne precision 3D terrain mapping systems
- Advanced image processing algorithms for image enhancement
- Advanced and robust vehicle guidance algorithms for all types of drive and steer systems
- Sophisticated data compression and data fusion algorithms

More information

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Data-Efficient Machine Learning and Optimisation in Dynamic Contexts

Expertise in data-efficient machine learning systems (techniques that can work effectively with minimal training data and without the need for large-scale annotated data) for heterogeneous and multimodal sensor data, towards models that can work well on the edge, and are tailored to address dynamic and adversarial contexts and behaviours.

Competitive advantage

- Data-efficient machine learning, particularly self-supervised learning with multimodal data.
- Human-centred behaviour modelling
- Edge AI and federated learning
- Individual, group, and population scale behaviour modelling
- Short and long-term spatio-temporal forecasting for different applications: defence, transport and mobility; energy and sustainability; health, wellbeing and productivity
- Personalised behaviour models
- Multi-party optimisation and recommender systems
- Optimal and explainable AI

Impact

- Increased speed of AI and machine learning adoption and operationalisation from development to deployment
- Improved utilisation of existing data sources and infrastructures
- Advanced multiple use cases and scenarios enabled by AI and machine learning as opposed to single task focus
- Novel behaviours previously unseen (e.g. during natural disaster, terrorist attack, or pandemic lockdowns) can be predicted well in advance
- In defence, models learned in one domain can be adapted to other domains

Successful applications

- Predictive analytics systems for smart cities (deployed)
- Personalised task assistance for working professionals (in collaboration with Microsoft Research and RMIT University)
- COVID-19 detection from unlabelled cough sounds and respiratory signals

Capabilities and facilities

- Conducting human behaviour ethics-approved study, data collection, analysis, experimentation
- Experience Sampling Methods (ESM) and/or Ecological Momentary Assessments (EMAs) capabilities
- Various wearable sensors
- GPUs for analytics, machine learning/deep learning experiments
- Innovation Central Sydney (Cisco and UNSW), a flexible activity and incubation lab space, complete with Cisco-enabled hybrid work technology and networked sensors

Our partners

- DSTG
- CSIRO
- Data61
- Cisco
- Aurecon
- Northrop Grumman Corporation
- Microsoft Research
- Qatar Mobility Innovation Centre
- City councils and government departments

More information

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Enhanced Processing and Analysis of Human Language Data

Robust and nuanced understanding of human language is central to research, development, and applications of AI and data science. Effective methods of processing and analysing language data can refine and enhance existing methods and models, uncover patterns, and leverage existing knowledge, data, and tools in natural language processing and psycholinguistics.

Competitive advantage

- Unique experience and expertise in next generation language processing with novel methods of employing psychological and linguistic models of language to create bespoke cutting-edge approaches to enhance how we find, analyse, and use human language data in diverse contexts

Impact

- More robust and effective methods of analysing and using language data

Successful applications

- Enhanced quality and usability of machine translation systems
- Improved detection and countering of mis/disinformation on social media
- Validated text analytics to analyse psychological markers in multimodal language data
- Improved analysis of language patterns in forensic and legal settings
- Improved efficacy of text simplification techniques for a wide range of real-world applications in education, entertainment, healthcare, and communications
- Enhanced effects of subtitling and captioning on cognitive load, comprehension, and language proficiency in linguistically and cognitively diverse samples
- Capabilities and facilities
- Knowledge, experience and expertise in online and offline language processing methods, data, and tools

Our partners

- Australian Research Council
- Department of Defence
- European Commission
- Multicultural NSW
- National Accreditation Authority for Translators and Interpreters
- NSW Health

More information

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Ethics of AI-Enabled Military Capabilities

Expertise in the ethical considerations and policy settings of utilising AI, Autonomous machines and weapons in warfare situations. Internationally recognised military ethicist and author of *Should We Ban Killer Robots?* (Polity Press 2022) with expertise on the application of AI capabilities in military contexts.

Competitive advantage

- World leading expertise in military ethics
- Development of policy settings and guidelines for the application of AI in military settings
- Expertise in the ethics of armed conflict straddling philosophy, ethics and security applications

Impact

- Leading an international group of experts and practitioners responsible for developing the 'Guiding Principles for the Development and Use of Autonomous Weapons'
- Engaged with the Group of Governmental Experts (GGE) debating restrictions on Lethal Autonomous Weapons under the Convention on Certain Conventional Weapons (CCW), in Geneva Switzerland

Successful applications

- Developed and delivered extensive wargame experiments exploring ethics of lethal autonomous weapons in urban warfare

Capabilities and facilities

- UNSW Canberra Future Operations Research Group, which offers extensive research capability related to military operations and technologies

Our partners

- Kings College London Centre for Military Ethics

More information

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Human Behaviour Analysis

Advanced data-driven AI enabled computational algorithms for the automatic analysis of human behaviours that can infer users' psychological and mental states. Such algorithms can be adopted in various technologies and application settings, including medical diagnostics, mental health assessment, military and defence applications, or any user-adaptive system.

Competitive advantage

- Machine learning and data mining techniques supporting behaviour and physiological analysis
- Cross disciplinary design of interactive and adaptive learning technologies
- Feature engineering and extraction using signal/image processing

Impact

- Automatic assessment of cognitive load supporting decisions about human performance in specific circumstances
- Early diagnosis of medical disorders (mental, physical, behavioural, functional)
- Advancing the understanding of underlying mechanisms in psychological disorders

Successful applications

- Emotion recognition from voice, face and physiology
- Prediction of cognitive load from physio-behavioural data
- Prediction of perceived personality from vocal and facial behaviours
- Early detection of Mild Cognitive Impairment

Capabilities and facilities

- High-performance computing facilities and capabilities for training machine learning models
- Soundproofed, light-controlled study facility for running experiments
- A range of audio, visual, physiology, and eye-tracking sensors to collect multimodal data

Our partners

- Bull Imperial College London
- Carnegie Melon University
- Ecole Polytechnique Fédérale de Lausanne (EPFL)
- University of Geneva
- University of Glasgow

More information

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Maritime Autonomous Vessels and International Law

The use of maritime autonomous vessels (MAVs) is creating regulatory and enforcement opportunities and challenges under international law. This research fills a critical gap in responses in international law through focusing on the threats posed by MAVs to international maritime security law, including transnational crime, terrorism and military operations.

Competitive advantage

- Internationally recognised expertise in international maritime security law
- Engaged with the regulatory and law enforcement frameworks from the perspectives of both criminal law application and relevant authorities governing policing actions

Impact

- Research outcomes have been presented at the US Naval War College, UN Office of Drugs and Crime, and to government officials in regional fora, such as NATO, and to national agencies
- Published in leading international law and security journals including International & Comparative Law Quarterly, Marine Policy, International Journal of Marine and Coastal Law, International Law Studies

Successful applications

- Directly addressed the use of drones to detect irregular migration at sea, the deployment of remote-controlled vehicles in terrorist attacks, and in both supporting and countering drug trafficking operations
- Apply legal frameworks to MAVs and in particular show the interaction of the legal frameworks governing shipping safety, naval warfare, maritime operations and crime suppression

Capabilities and facilities

- Findings highlight and evaluate for policy-makers MAV-related legal developments, particularly possible changes in international maritime security law under the auspices of the International Maritime Organisation and the direction of legal reform being advocated by other major maritime states

Our partners

- Queensland University of Technology
- Australian National University and Australian National Centre for Ocean Resources and Security

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Signal, Information and Machine Intelligence

Developing advanced signal processing techniques and machine learning algorithms to help make better decisions and predictions utilising data drawn from various sources (video, audio, bio-signals, positioning data, etc) while dealing with uncertainty and ambiguity.

Competitive advantage

- Expertise in:
  - Voice biometrics and speech processing
  - Automatic inference of emotion, distress, and mental state
  - Behavioural and biomedical signal processing
  - Machine learning, modelling, and prediction of dynamical, ambiguous quantities
  - Integrating signal processing, system modelling, and machine learning methods

Impact

- Bring together expertise in signal processing and machine learning along with domain expertise and data
- Develop AI systems that answer pertinent questions and deal with ambiguity and uncertainty
- Provide tailored solutions, not simply plug and play technology

Successful applications

- Prediction and recognition of emotional state
- Automated speech therapy system for children
- Characterisation and recognition of speaker attributes in voice biometric systems
- Oral cancer detection from fluoroscopic images
- Diagnosis and monitoring of stress, dementia, depression, heart arrhythmia and insomnia
- Automatic fracture detection from 3D rock imaging
- Accelerating photocatalyst discovering with AI
- Anomaly detection in satellite communications

Capabilities and facilities

- High performance computing capabilities for large scale signal and information analysis, and training machine learning models
- Soundproofed, light-controlled studio facility for recording speech and behavioural signals

More information

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Trusted AI-Enabled Shepherding of Human-Swarm Teams

Technology to enable trusted inter-operation between humans and swarms of autonomous systems and platforms. Shepherding is the ability to guide, influence or reshape a group of autonomous systems towards a goal with optimised efforts to the shepherd and the group.

Competitive advantage

- A unique fully-distributed human-swarm and swarm-on-swarm systems exist that can scale arbitrarily to any size with minimum complexity. This technology achieves this in a structured, verifiable, trustworthy and scalable manner
- Multidisciplinary team with the capacity and facilities to prototype concepts theoretically, through simulation and on real-platforms
- Novel architectures to enable efficient, low-CPU, and highly smart AI-enabled swarm systems

Impact

- Enable commanders to take responsibility of large (semi-) autonomous heterogeneous swarms in a trusted, verifiable, and accountable manner
- CPU and power efficient, highly smart AI-enabled swarm systems
- Autonomous real-time management of the human-swarm relationship
- Scalability of human-swarm logic
- Transparent, explainable, and adaptive swarm control-logic
- Trusted human-swarm operations

Successful applications

- Autonomous coordination policies in ground-air unmanned systems interaction
- Autonomous learning, reasoning and decision-making in dynamic heterogeneous swarm environments
- Distributed contextual awareness for multi-agent systems and its application to military land vehicles

Capabilities and facilities

- Indoor Unmanned Aerial Vehicle (UAV) testing facilities
- High-fidelity simulation environments including air traffic management and modelling of uninhabited all-domains vehicles (UxVs)
- A variety of unmanned ground and air vehicles

Our partners

- Defence Science and Technology (DST)
- US Office of Naval Research US Air Force Office of Scientific Research
- US Army International Technology Center Pacific (ITC-PAC)

More information

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Trusted Autonomy

Expertise in traditional machine learning, ethics in AI, navigation and control of autonomous vehicles, developmental robotics, computational motivation and computational red teaming. This group is unique in Australia due to its mix of expertise and ability to innovate an idea from its conception to its technological solution.

Competitive advantage

- Unique combination of skills covering robotics, AI, simulation and ethics
- Long-standing and deep ties with Defence
- Outstanding facilities for simulation and robotics
- Focus on trusted human-autonomy teaming

Impact

- Trusted Autonomous Systems for Military Operations
- High-fidelity simulation
- Learning from scratch and lifelong learning for Autonomous Systems
- Human and AI based control of multi-robot operations and swarms

Successful applications

- Swarm based machine learning with knowledge sharing
- Demonstration of learning-from-scratch on real robots using neural networks and evolutionary fuzzy systems
- Development of human performance surrogates for high-fidelity military simulations
- Hierarchical deep learning algorithms for robot control

Capabilities and facilities

- Large Indoor UGV/UAV Test Area and VICON Motion Capture System
- Distributed Simulation Laboratory
- Virtual Environment and Simulation Lab
- EEG Equipment for Monitoring Human Cognitive State
- Numerous unmanned ground, aerial and humanoid robots

Our partners

- CSIRO
- Air Force Office of Scientific Research
- DST
- US Army
- US Office of Naval Research
- Indonesian Institute of Sciences
- Nanyang Technological University
- US Naval Postgraduate School

More information

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AUKUS Defence Research and Technology

Cyber

Analysing Encrypted Network Traffic for Cyber Intelligence

Artificial Intelligence (AI) engines trained on stochastic behaviours of network traffic flows are used to detect connected assets, active applications, and emerging attacks. The use of Software Defined Networking (SDN) decouples hardware from software, allowing the solution to scale to Terabits-per-second of network traffic from millions of devices in a very cost-effective manner. The technology has the potential for cyber intelligence in carrier and enterprise networks.

Competitive advantage

- Improved network telemetry and analysis for fine-grained asset and threat visibility
- Automation and orchestration of network operations for enhanced security
- Experience in operational deployments and commercial trials in carrier scale networks
- End-to-end solutions with full ecosystem integration
- Patent protected technology

Impact

- More reliable and secure communications
- Detection of intrusions into and exfiltration from Defence Networks
- Network activity monitoring of embedded devices in contained environments like submarines
- Detection and quarantining of compromised devices in battlefield environments

Successful applications

- SDN solutions deployed in Telcos in Australia; ongoing trials in New Zealand, India, and USA
- Real-time visibility into video streaming, gaming, conferencing, etc. across hundreds of thousands of users in carrier networks
- Real-time health monitoring of complex Internet-of-Things (IoT) environments

Capabilities and facilities

- Large-scale SDN test-bed spanning multiple Australian organisations
- Fully-equipped SDN lab with state-of-the-art hardware and software

More information

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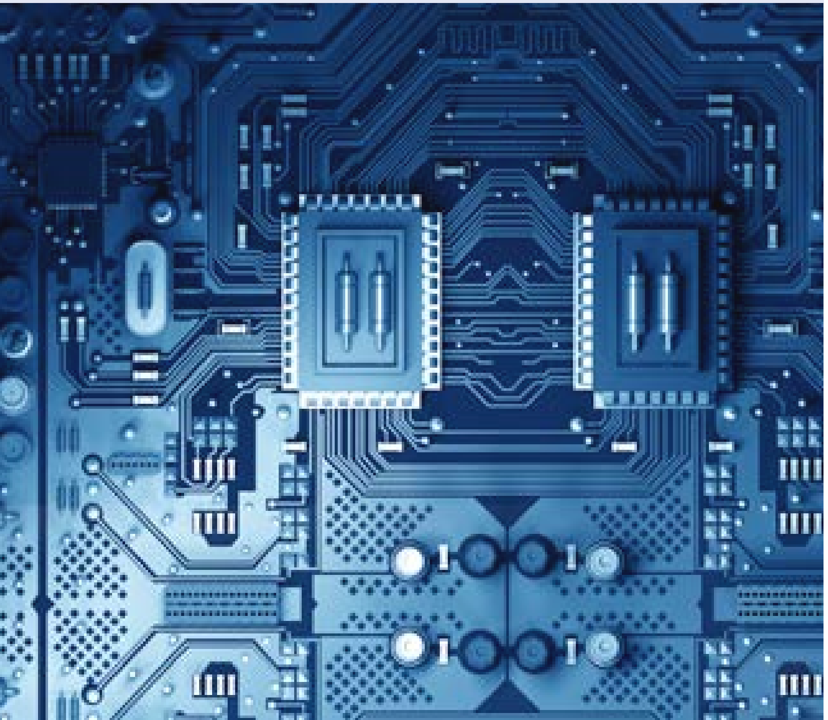
Complex Systems Security

Delivering a better understanding of the security of future networks and platforms including the Internet of Things, Industry 4.0, Industrial Control Systems that run Australia's critical infrastructure, and resilience of social networks against coercion and soft influence



Competitive advantage

- Expertise in next-generation networks, critical infrastructure security, cyber-resilience and simulation
- World class experimentation development platforms and lab facilities
- Strong industry links to develop usable outcomes

Impact

- Development of new processes and techniques to discover vulnerabilities in large scale systems
- A holistic perspective on network development and security analysis
- Increasing resiliency of future networks against cyber threat
- Running wargames and scenario-based learning opportunities to understand future threats
- Cyber influence and security simulation platforms for decision support and situational awareness

Successful applications

- Social Media Dataset Generation, Australian Army
- An Intelligent Risk Evaluation Tool for Safeguarding IoT Smart Airports, Cyber Cooperative Research Centre (Cyber CRC)
- Cyber Supply Chain Mission Assurance, Australian Army
- Cyber Impact Analysis Towards Mission Assurance, Defence Science and Technology
- Secure Software Defined Networking for Multi-Bearer Time-Sensitive Distributed Systems, Defence Science and Technology

Capabilities and facilities

- UNSW Canberra Cyber Range
- Future-facing Internet-of-Things (IoT) Security Laboratory, incorporating realistic Supervisory Control and Data Acquisition (SCADA) and Industrial Control System (ICS) platforms

Our partners

- Information Warfare Division
- Defence Science and Technology Group
- The Netherlands Organisation (TNO)
- Domos

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Critical Infrastructure Security

The Critical Infrastructure Act 2021 requires increased protection of Australian critical infrastructure across 11 sectors. We provide sector-specific solutions following the secure by design principle with operational constraints – e.g., implementing security in systems that cannot have scheduled downtime or only minimal downtime.

Competitive advantage

- Advanced technical expertise in the design and analysis of secure protocols in the communication protocol stack, cyber-physical systems, Industrial IoT, integration of IT/OT systems, risk analysis, and vulnerability analysis
- Expertise in real-time/SCADA systems for various critical infrastructures

Impact

- New algorithms, techniques, attack vectors, zero-day vulnerabilities and defence
- Input to various cybersecurity standards working groups

Successful applications

- Security analysis of Distributed Energy Resource Management Systems
- Security Keyless entry system design for Vehicles for an industry partner

Capabilities and facilities

- Multidisciplinary team with the capacity to design and evaluate critical infrastructure security through emulation and on real platforms

Our partners

- Cybersecurity Cooperative Research Centre (CSCRC)
- Defence Science and Technology Group
- Australian Cyber Security Centre (ACSC)
- Avertro, Cisco
- Jemena
- Mitsubishi Heavy Industries
- TCS Australia
- WBS Technologies

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Cyberspace Law and Policy

Exploring emerging challenges across a broad range of issues arising from the intersection of law and technology. The emphasis is not on technology as such, but rather on the regulation of the social space created by computing networks – 'cyberspace'

Competitive advantage

- Expertise in:
  - Regulation of malware and cybercrime
  - Online content regulation
  - Hacktivism
  - Cloud computing
  - Legal jurisdiction in virtual worlds
  - Intellectual property in digital artefacts
  - Privacy and personal information security
  - Online financial transactions and investment services, e-commerce, e-government
  - Authentication and encryption
  - Internet governance
  - Legal issues arising from threats to networked security

Impact

- Understanding the legal and policy issues arising from digital transactions in online and networked environments assists in policy development in relation to cybersecurity.
- Submissions to various government agencies, including
- Office of the Australian Information Commissioner on Big Data
- Office of the Australian Information Commissioner mandatory data breach notification inquiry
- Consultation on proposals for reform of Copyright Act, including the viability of Orphan Works under a 'Fair Use' exception
- Parliamentary Joint Committee metadata retention and s 313 Telecommunications Act inquiries
- Australian Law Reform Commission Serious invasions of privacy in the digital era

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Deception for Cyber Defence

Deception is an important tool for cyber defence, complementing existing perimeter security measures to rapidly detect breaches, data theft and insider attacks. A factor limiting the use of deception is the cost of generating realistic artefacts by hand. We leverage advances in machine learning for scalable, automated generation of realistic deceptions.

Competitive advantage

- Deep understanding of machine learning models for creation of digital artefacts that simulate characteristics of many IT assets and processes
- Skills to undertake large-scale user studies to evaluate human perception of deceptive content

Impact

- Automatically develop realistic deception artefacts at scale
- Deception artefacts that can trick intruders, data thieves or malicious insiders into behaviour that reveals their presence and provides intelligence on their intent or their tactics, tools, and procedures
- New metrics and methods for measuring realism and enticement, two key properties of deceptive content

Successful applications

- Our technology is adopted in commercial cyber deception products for creating fake versions of data and digital assets including documents, software repositories and interaction vents

Capabilities and facilities

- Multidisciplinary team with the capacity and facilities to prototype concepts theoretically, through simulation and on real platforms

Our partners

- Penten
- CSIRO
- Cybersecurity Cooperative Research Centre

More information

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Information Warfare Activities

Examining the changing nature of war and diplomacy with the use of cyber capabilities to understand modern information warfare and influence operations. To assist in the development of effective strategies for engagement in this modern warfare and strategic competition and partnerships.

Competitive advantage

- Expertise in:
  - Information warfare/ influence operations
  - Use of cyber for grey-zone activities
  - Cyber Diplomacy
  - Great power competition in cyberspace
  - Alliances and partnerships
  - Coercion
  - Deterrence
  - Tactics short of war

Impact

- Understanding the context of information warfare and influence operations and applying that understanding to policy and norm development
- Analysis of cyber coercion and deterrence in conflict and measures short of war
- Providing links between humanities scholarship and scientific analysis
- Development of models for testing strategies for information warfare

Successful applications

- Applied understanding and expertise to analysis of AUKUS collaboration in cyber capabilities
- Applying humanities scholarship and research to technologically based problems to expand and deepen understanding to achieve more robust conclusions

Capabilities and facilities

- Capability to research information warfare, influence operations, conduct comparative analysis of historical case studies to apply to modern warfare methods
- Bringing together humanities approaches and more technology-based research

More information

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Information Warfare:

Mis-information, Dis-Information, Mal-information and the Grey Zone

UNSW has a multidisciplinary team specialising in information warfare. Understanding the effectiveness of mis-information, dis-information and mal-information is essential to protecting citizens, institutions and critical infrastructure. We have expertise in cyber security, electronic warfare and information operations using strategic, evidence-based, and academically rigorous approaches. The multidisciplinary team includes engineers, behaviouralists, linguists, narrative and simulation research specialists, and model designers.

Competitive advantage

- Applying a multi-disciplinary approach to Information Warfare (IW) and Grey Zone threats
- A strong understanding of the criticality of detecting and countering Grey Zone threats in a whole-of-government context
- Deep experience in analysing information flows

Impact

- This research capability has already been used by the Australian Defence Force and DSTG
- Members contribute to the Defence Information Warfare STaR Shot including as members of the Information Warfare Innovation Community and Information Warfare Advisory Committee
- Developed models of information flow in commercial cyber-cyber digital twins of social media platforms

Successful applications

- UNSW participated in a research collaboration investigating contemporary mass influence. The resulting research reports are available from: dri.unsw.edu.au/publications-media
- Continued involvement on the Defence IW STaR Shot

Our partners

- Australian Defence Force
- DSTG
- Related industry partners

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Intelligent Security

Development of intelligent cyber security methods for automatically detecting, responding to, and preventing advanced persistent threats in Internet of Things (IoT), cloud and network systems.

Competitive advantage

- Cyber threat intelligence models such as vulnerability assessment, intrusion detection, privacy-preserving, and digital forensics-based statistics, machine and deep learning algorithms
- Automated Penetration testing methods based on AI and deep learning technique
- New testbed architectures for IoT and cloud networks
- Leading analysis of how AI could develop automated cyber applications
- Advanced threat intelligence models for deterring cyber threats and reducing financial losses and critic infrastructure damages

Impact

- The increase in everything-connected, online systems that both sense from and interact with the physical world poses a security risk. The extent to which countries such as Australia are already dependent on cyber-physical systems – which is projected to increase – means that the impact of any disruption is potentially catastrophic

Successful applications

- An Intelligent Threat Evaluation Tool for Safeguarding Smart Airports
- Cyber Risk Intelligence for IoT-enhanced Combat Systems
- From Cyber Resilience to Intelligent Resilience for Autonomous Systems
- An Intelligent Threat Evaluation Tool for Safeguarding Smart Airports
- Secure and Distributed Orchestration Micro-Algorithms as Services at the Edge
- Ensemble Anomaly Detection System
- A pilot: risk management-based framework for developing intelligent systems for natural disasters
- Software Assurance for Cyberworthiness
- Recent Developments in AI and its Applications in Defence and Security as a Dual-Use Technology
- From Boardgame to Wargame – Game Design for Real-World AI-Enabled Analysis
- A pilot database for Industrial Internet of Things (IIoT) for Cyber Security Applications

Capabilities and facilities

- UNSW Canberra Cyber Range Lab
- Digital Forensics Lab
- IoT Security Lab

Our partners

- Defence Science and Technology Group (DSTG)
- Cyber Security CRC (CSCRC)
- US Department of Defence
- SmartSat CRC
- Data 61 CSIRO
- Australian Army
- Office Of National Intelligence
- DXC Technology
- TATA Consultancy Services (TCS)

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Internet of Things Analysis and Applications

The Internet of Things (IoT) presents enormous opportunities to improve interaction with our immediate surroundings. Fully realizing this potential requires sophisticated information analysis, with a focus on data mining and deep learning, human activity recognition, information filtering, and brain computer interfaces.

Competitive advantage

- Predictive human behaviour modelling – covert human activity recognition and indoor human movement tracking
- Brain computer interface – deep learning for decoding brain activities and enabling device control via brain signals
- Large-scale (1000+ sensors), long-term industry system deployment experience in a variety of environments such as buildings, rainforest, farms and lakes

Impact

- Improved automation and better support in a complex environment
- Breakthrough technology outcomes realised through sensor processing, including advances in biometric (face, gait) recognition and wearable systems

Successful applications

- Deep learning for fault detection and localisation in distributed systems, CERA Project
- Opinion fraud detection
- Thing-of-interest recommendation in the Internet of Things
- Human abnormal activity detection
- Smart buildings and environments
- User-friendly authentication for wearable devices, Australia Centre for Cybersecurity
- Battery-free wearable systems

Capabilities and facilities

- LPWAN test-bed in an industrial building
- GPU-accelerated IoT data analytical platform

More information

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Model Checking Knowledge (MCK) in Distributed and Multi-AGENT Systems

Model Checking is a methodology for automated verification of computer software and hardware designs. It is based on algorithms that enable a complete analysis of all possible behaviours of a system model. Standard model checkers verify properties concerned with how a system state changes over time. Our model adds to this a capability for analysing how the knowledge – states of information – of system components evolves over time.

Competitive advantage

- The MCK model checker is one of only a few comparable systems internationally. It is unique in the range of semantics of knowledge and model checking algorithms that it supports including:
  - Observational, clock and perfect recall semantics of knowledge
  - (Subjective) probabilistic knowledge specifications
  - Binary decision diagram based and bounded model checking algorithms
  - Synthesis of implementations of knowledge-based programs

Impact

- Improved software reliability and security

Successful applications

- Detecting non-optimal use of information in computer hardware designs
- Analysis of computer security protocols
- Fault-tolerant distributed computing
- Verification of pursuit-evasion scenarios

Our partners

- US Air Force

More information

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Networked Systems and Security Research Group

A leading capability in the development of Internet of Things (IoT) technologies over the past decade with long lasting collaborations with a number of industry partners.

Competitive advantage

- Holistic approach that encompasses apps, protocols, security, analytics and device management
- Expertise in building and deploying practical IoT systems, including:
  - Design, implementation and evaluation of energy-efficient wireless communication protocols
  - Blockchain technology for IoT
  - Security protocols for end-to-end communication and over-the-air programming
  - Biometrics and authentication
  - Privacy-enhancing technologies
  - Wearable IoT technologies for human activity recognition
  - Device-free sensing with WiFi
  - Batteryless sensing, and
  - IoT for sport analytics

Impact

- Better integration of the physical world with computer-based systems

Capabilities and facilities

- Comprehensive laboratory facilities with state-of-the-art IoT devices

Our partners

- Defence Science and Technology Group (DSTG)
- NEC
- Google
- Tata Consulting Services
- Institute of Infocomm Research, Singapore
- WBS technology (smart buildings with LPWAN)
- Virtual Vehicle Research Centre, EU
- Data 61 (CSIRO)

More information

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Online Influence Simulation

Simulating online social media platforms to better understand the impacts of fake news and online influence on people and societies. This work also provides modern online systems to integrate into wargames and exercises.

Competitive advantage

- The uniqueness of this work is in the development of synthetic populations that accurately reflect real communities and countries. We take a holistic perspective of how opinions are formed and propagated, simulating individuals at scale. This work also provides unique opportunities for human/bot interaction and processing

Impact

- Used in modern wargaming events and exercises
- Applied to verify online influence models developed internationally

Successful applications

- DSTG Influence Wargame, 2022
- Defence IWD Potentium Wargame, 2018-2020

Our partners

- Defence Science and Technology Group
- Australian Defence Force – Information Warfare Division
- Royal Military College, Canada
- Australian War College
- Arizona State University

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Open Source Cyber Threat Intelligence

Open source intelligence platforms are capable of aggregating a vast amount of cybersecurity-related sources. To process such information streams, scalable and efficient tools capable of identifying and summarizing relevant information for specified assets are required. Advanced and novel natural language processing and deep neural networks for scalable, automated extraction of cyber threat intelligence (CTI) are applied to interrogate these data sources and to extract value.

Competitive advantage

- Multidisciplinary expertise in natural language processing, machine learning, linguistics and psychology
- Experienced in the gathering and understanding of forensic evidence of potential cyber threats on a host system or network
- Deep experience working on unstructured data processing (including texts and images)

Impact

- This technology and capability can be used to help information technology (IT) organisations proactively defend against cyberattacks.
- Ability to extract, aggregate, synthesize, and analyse publicly available cyber threat-related documents, articles, reports, and social media.

Successful applications

- Developed a CTI extraction system that can extract the potential cyber threats of a target customer through mining posts on social media
- Research has been deployed commercially by the cybersecurity software company Avertro

Capabilities and facilities

- Advanced multi-disciplinary approach for threat intelligence extraction
- High-performance computational servers for running complex neural network models

Our partners

- Avertro

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Privacy Preserving Technologies:

Risk Identification, Quantification, and Preservation Solutions

Privacy preserving technologies allow users to protect the privacy of their personally identifiable information (PII) by providing limited information to service providers or apps, all while maintaining the functionality of data-driven systems. Our multidisciplinary team includes researchers, cryptographers, engineers, behaviouralists, linguists, and human-centric design experts.

Competitive advantage

- A multidisciplinary team drawn from across UNSW which consists of leaders in their respective disciplines such as privacy, cryptography, user psychology, human-computer interactions
- Strong understanding of privacy leakages originating from user behaviour on the web and hence have a capability to capture, quantify, and eliminate those risks
- Expertise in quantifying risks from anonymized databases (e.g., government, education sector, social media data) that need to be shared with third-parties
- Experience in providing privacy preserved solutions for data-at-rest and continuous data streams through methods such as differential privacy, multi-party computation, and other various encryption schemes

Impact

- Research outcomes used by the Australian Defence Force and DSTG
- Recognised privacy risk quantification methodologies applied to Defence settings
- Designed and developed state-of-the-art privacy identification and preservation solutions for various data types

Successful applications

- Impact of COVID-19 on Privacy and Security of Social Media Platform
- Quantification of User Uniqueness through Touch Gestures
- Adversarial Resistant Obfuscation Method for Web Data

Capabilities and facilities

- A specialised lab with High Performance Computing Facility and latest portable devices

Our partners

- Australian Defence Force
- DSTG
- Cybersecurity Cooperative Research Centre (CSCRC)

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Quadseal Hardware Attack Mitigation

Quadseal is a mitigation technique to stop attackers from obtaining secret keys from block ciphers. Where a conventional encrypting device is accessible it is possible to obtain the secret key in less than 10 minutes With Quadseal the attacker is stymied, making communications channels and other protected items far safer.

Competitive advantage

- First known countermeasure that can thwart both power and fault attacks
- Smallest power area product among all available technologies
- Embedded Systems Laboratory has over 20 years' experience in hardware–software co-design, security and design automation

Impact

- Enhanced communications security

Successful applications

- Our work in pipelined processing systems has been used extensively by Canon Inc.
- Optimised systems used within multiple other commercial environments

Capabilities and facilities

- Side channel analysis equipment for measuring power and electromagnetic radiation
- SASEBO FPGA-based boards to create circuits that can be tested
- Custom made processor boards for testing of software countermeasures

Our partners

- Canon Information Systems Research Australia
- Seeing Machines Inc.
- Defence Science and Technology Group (DSTG)

More information

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Secure and Private Embedded Real Time Analytics

Robust machine learning algorithms in embedded devices to obtain novel insights and enable real-time decision making while ensuring system security and the privacy of users.

Competitive advantage

- Novel business, environmental and system insights through seamless non-invasive monitoring
- Security of networked systems
- Minimal privacy risk for users and improvements in the overall performance and usability of networked systems
- Detection of malicious mobile apps
- Real-time continuous identification of individuals and machines
- Energy efficient sensing of user activities
- Detection of anomalous operation of networks and devices
- Voice biometric systems and countermeasures to spoofing attacks

Impact

- Better security and improved usability of networked systems

Successful applications

- Automatic inference of user emotion and mental state
- Creation of a 'breathprint' for continuous user identification and authentication

Capabilities and facilities

- State of the art laboratories equipped with a multitude of sensors, wearables, and state-of-the-art equipment for signal capture and analysis

More information

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Terahertz Radiation

Terahertz (THz) radiation has strong penetrability and high bandwidth, which makes it ideal as the key technology for the next generation of non-intrusive imaging scanners and ultra-high bandwidth wireless communications beyond 100 GHz.

Competitive advantage

- Suitable for high-resolution and non-invasive imaging
- Developing an integrated physical planar platform for ultra-high bandwidth short-range THz communications (terrestrial and space including WiFi, vehicular and health monitoring systems)
- Utilising advances in photonics to improve the overall system performance in terms of cost, size, bandwidth and coupling losses

Impact

- Offers an enormous unlicensed bandwidth for high-speed wireless communications with a wide range of applications such as:
  - Whisper radio communications over high-attenuation bands, for example, battlefield sensors and on-body health monitors
  - Long distance communications over low-attenuation bands for example cellular, vehicular radar and space communication

Successful applications

- First THz flexible and single-mode waveguide with metamaterial cladding
- Planar high bandwidth photonic crystal waveguide-based devices Hybrid metal-dielectric meta-devices for ultra-sensitive sensing and beam forming
- THz polarization-maintaining filters for imaging, sensing, and wireless communication
- Anti-stealth THz ultra-wideband radar

Capabilities and facilities

- THz Time Domain Spectroscopy system with imaging facilities
- Numerical modelling software such as Computer Simulation Technology (CST) microwave studio and in-house developed analytical codes
- Access to Australian National Fabrication Facility (ANFF) for fabrication of devices

Our partners

- Protemics GmbH

More information

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Trustworthy Machine Learning

Machine learning models can be deliberately fooled, evaded, and misled, raising significant security and privacy concerns. The behaviour of machine learning models, even in edge cases or unseen scenarios, need to be well understood. We specialise in developing trustworthy machine learning techniques and tools, which are explainable, robust, fair, causally responsible, and privacy-preserving.

Competitive advantage

- Deep understanding of vulnerabilities, robustness, and/or biases inherent to machine learning models and their implications
- Expertise in a broad suite of technologies including deep representation learning, interpretable machine learning, privacy-preserving learning, confidential computing, decentralized learning, robustness, testing and verification

Impact

- Design of robust machine learning systems that can resist attacks from strong adversaries, protect user privacy, and produce fair decisions
- Improved transparency and trust in automated systems of the future

Successful applications

- We have developed a wide array of robust machine learning solutions that span deep neural networks, federated learning, and graph neural networks
- Our technology is used in many domains including cybersecurity, design automation, cyberphysical systems, smart cities and transportation, and defence

Capabilities and facilities

- Multidisciplinary team with the capacity to prototype concepts theoretically, through simulation and on real platforms
- High performance computational servers for running complex machine learning models
- Experience in working with a wide array of datasets and application verticals

Our partners

- DSTG
- CSIRO
- Cybersecurity Cooperative Research Centre
- Automi
- ARC Centre of Excellence in Automated Decision Making and Society

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Trustworthy Systems

A recognised world leader in the formal verification of systems software and developer of the first operating-system kernel with an implementation-correctness proof.

Competitive advantage

- Unique capability in the design, implementation and formal verification of security-critical software systems

Impact

- Truly trustworthy (unhackable) software systems with provable security properties

Successful applications

- Cyber-retrofit of Boeing autonomous helicopter (ULB) under the DARPA HACMS program
- Integration into engineering workflow under the DARPA CASE program
- Secure communication device (AltaCrypt) deployed in multiple defence forces
- Laot device for protecting critical infrastructure from cyber attacks
- German company HENSOLDT Cyber developing secure solutions based on seL4

Successful applications

- Design and verification of real-world software systems

Our partners

- DARPA
- Rockwell Aerospace
- National Cyber Security Centre (UK)
- Technology Innovation Institute (UAE)

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UNSW Allens Hub for Technology, Law and Innovation

The UNSW Allens Hub for Technology, Law and Innovation is a partnership between Allens and UNSW Law & Justice, adding breadth and depth to research on the diverse interactions among technological change, law, and legal practice. Our research includes cyber security law and policy (including in cyber-physical systems such as drones), trust and trustworthiness in cyber security, legal arrangements for data sharing, and legal and human rights issues around AI and automated decision-making.

Competitive advantage

- Leading Australian research initiative on legal issues arising in the context of new technologies
- Experience collaborating with Australian government including with Defence

Impact

- Improving legal and policy frameworks in the areas of technology regulation, cyber security, data practices and data sharing – at state, federal and international levels
- Working with government and industry to understand legal obligations in complex, emerging contexts

Successful applications

- Developed high level principles for the use of Big Data applications in defence, national security and law enforcement contexts
- Analysis of legal obligations and public opinion related to the use of "open source" data (including social media) by defence, national security and law enforcement agencies (working with DSTG)
- Created web resource for laws impacting on incentives for cyber security
- Analysis of the role of contract provisions in protecting data in the context of data sharing arrangements
- Resource for SMEs in supply chain for critical infrastructure regarding impact of legislative reforms
- Resource for SaaS providers and government in relation to cyber security and critical infrastructure obligations (in principle agreement)

Our partners

- Data to Decisions Co-operative Research Centre
- Cyber Security Co-operative Research Centre

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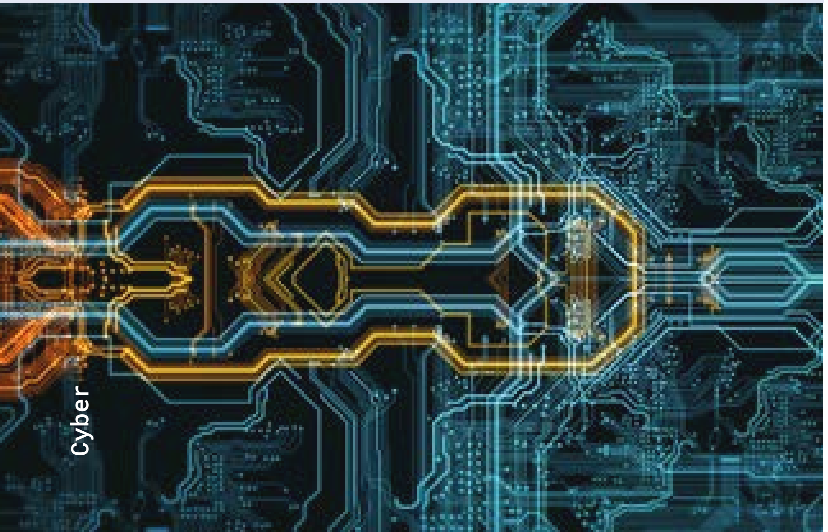
UNSW Institute for Cyber Security (IFCYBER)

IFCYBER draws from and focusses efforts across all UNSW faculties and partners as we 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.



Competitive advantage

- Complementary multi-disciplinary skills matrix in engineering, psychology, management, law, policy, and philosophy
- Dual Research and Teaching focus
- Large critical mass of diverse Cybersecurity focussed researchers
- Explicit multi-disciplinary approach across both Canberra and Sydney campuses to address critical path cyber security capability problems
- End to end cyber security teaching system from undergrad to postgrad & continuing professional education for the Defence and National Security Sector

Impact

- Cyber Security Professionals produced for National Security sector (undergrad & post-grad)
- Improved cybersecurity standards

Successful applications in the Public Domain

- Prototypes of various Cybersecurity software
- Policy submissions (Law Policy)

Expertise

- Complex Systems Security, Hardware/Embedded Systems Security, Privacy-Preserving Techniques, Artificial Intelligence/Data Mining/Social networking, Network/IoT/CPS Security
- Law & Policy: including ethics, policy, law, regulation & governance
- Human factors: including behaviours, useable security, facial recognition, criminal factors, information influence
- Organisations and Business: including organisational change, supply chains, situational awareness
- Secure spaces & IoT Security Laboratories (Both Campuses)
- Distributed Energy Resource Management (DERM) Security Testbed

Our partners

- Defence
- AFP
- CSIRO/Data61
- DoHA
- Cyber Security CRC & partner entities
- National Security industry partners
- Financial Sector Partners
- Law
- Launch Partners – Canberra
- Selected international partners

More information

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Verifiable Confidential Computing for Distributed Trustworthy Systems

Analytics for most applications like Health, Finance and the Internet of Things rely on sensitive data. Confidential computing allows computing on encrypted data, thus protecting user's personal information in the event of data breach. Verifiable confidential computing goes a step forward to ensure accountability, fairness and transparency without disclosing sensitive information.

Competitive advantage

- Expert knowledge on a broad range of cryptographic algorithms including homomorphic encryption, secure multiparty computation and zero-knowledge proofs
- Quantum-safe cryptographic algorithms
- Well analysed solutions with provable security guarantees
- Extensive knowledge and experience with Blockchain design and applications

Impact

- Responsible, Secure and Practical Algorithms

Successful applications

- Distributed Secure Storage Systems
- Queryable Encryption
- Transparent, Trustworthy and Privacy-Preserving Management of Supply Chains
- Transparent and seamless value exchange across different value chains
- Real-time predictive maintenance and process optimisation within a trusted multi-stakeholder environment
- Detecting and investigating crime on blockchain and cryptocurrency networks

Capabilities and facilities

- Ongoing national and international collaborations
- Laboratory facilities with High Performance Computing facility

Our partners

- CSIRO
- Sydney Quantum Academy
- Automi
- Holon
- Smart Trade Network

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Wireless and Acoustic Communications and Sensing

Research and development in wireless communications, satellite communications, and signal processing and machine learning for wireless and acoustic communications. Specialised in designing advanced signal processing and ultra-high reliable communication technologies for next-G and industrial Internet of Things (IoT) applications, including IoT for land and underwater acoustic channels.

Competitive advantage

- Extensive experience in research, design and development of ultra-reliable, dense multi-user communication systems, communication transceiver technologies and communication and sensing protocols
- A team of highly experienced staff comprising academics, research scientists, graduate students and professional support staff.
- Extensive research collaboration experience with leading telecoms companies and organisations

Impact

- Faster, more efficient and reliable wireless and acoustic underwater communications and sensing

Successful applications

- Massive multiple-input, multiple-output technique for next-G wireless networks
- Massive connectivity and low latency machine-to-machine communications
- Integrated communications and sensing for wireless channels
- Integrated acoustic communications and sensing for underwater channels
- Efficient and sustainable wireless-powered communication networks
- Design and analysis of delayed bit interleaved coded modulation
- Efficient cross-layer coding techniques for wireless and underwater networks

Capabilities and facilities

- Wireless communication system design and test facilities – microwave chamber, spectrum analysers, vector signal generators, FPGA development platforms and software-defined radio platforms
- Millimeter Wave communications
- High performance computing clusters for ultra-reliable system performance evaluation

Our partners

- Telstra
- Baicells
- Farmbot
- NI Australia
- Nokia-Bell Lab
- Lucent
- Ocius

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AUKUS Defence Research and Technology

Enabling

3D Visualisation Aesthetics Lab (3DVAL)

Exploring the challenges of visual narratives and developing novel ways to navigate complexity using creative methodologies from the video game, 3D computer animation and Virtual Reality (VR) creative content industries.

Competitive advantage

- Award-winning cross-disciplinary research hub that explores arts-led approaches for visualising complex scientific and biomedical scan data
- Proven ability to deploy design-led modes to the visualisation of complex scientific and biomedical data using 3D computer arts approaches, most recently VR Head Mounted Displays (HMD)

Impact

- Award-winning visualisations with real-world applications, including disease comprehension and rehabilitation.

Successful applications

- VR Pain Management System provides effective distraction to hospital patients experiencing acute pain via a gamified exploration of virtual worlds. A collaboration with St Vincent's Hospital and Samsung
- 'Journey to the Centre of the Cell' project, which recreates a breast cancer cell, was nominated in the Best VizSim Project category for visualisations that have real-world applications, and for the overall Golden Cube award as part of the International 2016 Unity awards in Los Angeles, USA
- 'A fantastic voyage – travel inside your brain and visualise your own stroke' was awarded the 2016 St Vincent's Hospital Innovation & Excellence Award for clinical health engagement, allowing patients to explore personalised vascular scans

Capabilities and facilities

- Wide range of VR/AR systems
- State-of-the-art 3D visualisation creative content studio
- 3D computer workstations
- Render farm systems

Our partners

- St Vincent's Hospital
- Garvan Institute for Medical Research
- ARC Centre of Excellence in Convergent Bio-Nano Science & Technology (CBNS)

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Biodefence Collaboration

The UNSW Medicine Biodefence Collaboration is between the Kirby Institute and the UNSW School of Public Health and Community Medicine; bringing together chief investigators in Epidemic Response and complementary capabilities in public health interventions and acute response to biological threats.

Competitive advantage

- Joint capabilities from three of the world's leading universities; UNSW, Arizona State University and King College London Cross-disciplinary approaches to threat detection

Impact

- Enhanced biodefence

Successful applications

- NHMRC Centre for Research Excellence, Integrated Systems for Epidemic Response (ISER)
- Identifying risk factors of a human-to-human transmissible form of highly pathogenic avian influenza H5N1, UNSW PluS Alliance
- AIAA pandemic risk assessment
- Defence Science and Technology, Chimera evolution

Capabilities and facilities

- NHMRC CRE ISER
- UNSW School of Public Health and Community Medicine
- The Kirby Institute
- Global Security PLuS partners

Our partners

- Emergent Biosolutions
- 3M
- Bavarian Nordic
- Siga
- Technologies
- Leidos
- Sanofi
- Seqirus

More information

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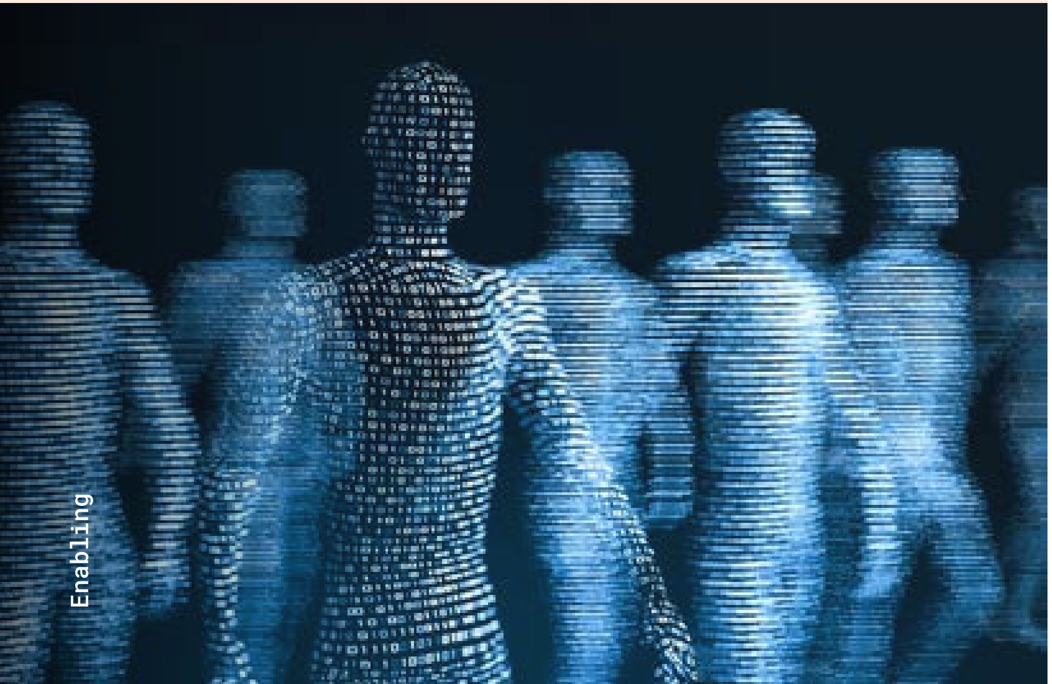
Capability Systems Model-Based Decision Support and Analysis, Research and Independent Assurance

Delivering sovereign, agile, and interdisciplinary research-led, innovative systems thinking, decision support or independent assurance, that can accelerate and advance decision-making and future Defence capability. Using a 'systems thinking' perspective, we interact with stakeholders to understand, simplify and solve problems through interdisciplinary methodologies.



Competitive advantage

- Proven, trusted and independent system modelling and evidence-based decision-support and analysis (including risk-based analysis) across the One Defence Capability System
- Co-design problem solving methodologies combining innovative decision support methods, systems engineering, and enterprise analysis
- Digital engineering frameworks, including testing and evaluation

Impact

- Support and accelerate decision making by addressing the critical analytical gaps in multi-domain operating environments characterised with high levels of complexity, ambiguity, and deep uncertainty

Successful applications

- Workforce modelling and decision-support for Future Navy Workforce into the Nuclear-Powered Submarine Task Force
- Sustainable, scalable Guided Weapons and Explosive Ordnance (GWEO) maintenance system modelling using real time data and Objective Quality Evidence (OQE) for senior committee and government decision making
- Delivery of Enterprise Architecture methodologies for the GWEO Enterprise
- Complex systems modelling for SEA 1000 – Future Submarine transition planning options
- Decision & mission engineering support for the Joint Capability Group and Army for the deployment of C4I systems
- Decision making assurance for the Land Based Trauma System

Capabilities and facilities

- Provision of agile (security cleared), readily accessible and customised project teams to meet Defence and its partners' needs
- World-class 'operationalised' research capability and capacity

Our partners

- Future Navy Workforce Branch
- Navy and Land Capability Divisions
- Capability Acquisition and Sustainment Group (Maritime and Land)
- Defence Science and Technology Group
- Joint Capabilities Group

More information

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Climate Security, Forced Migration and Disaster Response

Climate change is widely understood to have profound national and international security implications. It worsens conflict, stresses militaries, intensifies natural disasters, and triggers forced migration. UNSW researchers have led international debates on climate insecurity, including their implications for national security architectures, the United Nations Security Council, global approaches to climate refugees, and responses to climate-related disaster.

Competitive advantage

- Climate aspects of national security and force transformation
- Climate change and the UN Security Council
- Policy, justice and organisational challenges of climate-affected disaster
- Conceptual and policy debates around the environment and security
- Strategic and human rights challenges of forced climate migration
- Implications of climate change for global food security

Impact

- Our work influenced recommendations in the 2017 Joint Committee on Defence, Foreign Affairs and Trade inquiry into the implications of climate change for Australia's national security
- Our public events and articles have promoted climate change onto the national security agenda through evidence-based research

Capabilities and facilities

- The Environment and Governance research group
- The Asia-Pacific Development and Security research group

More information

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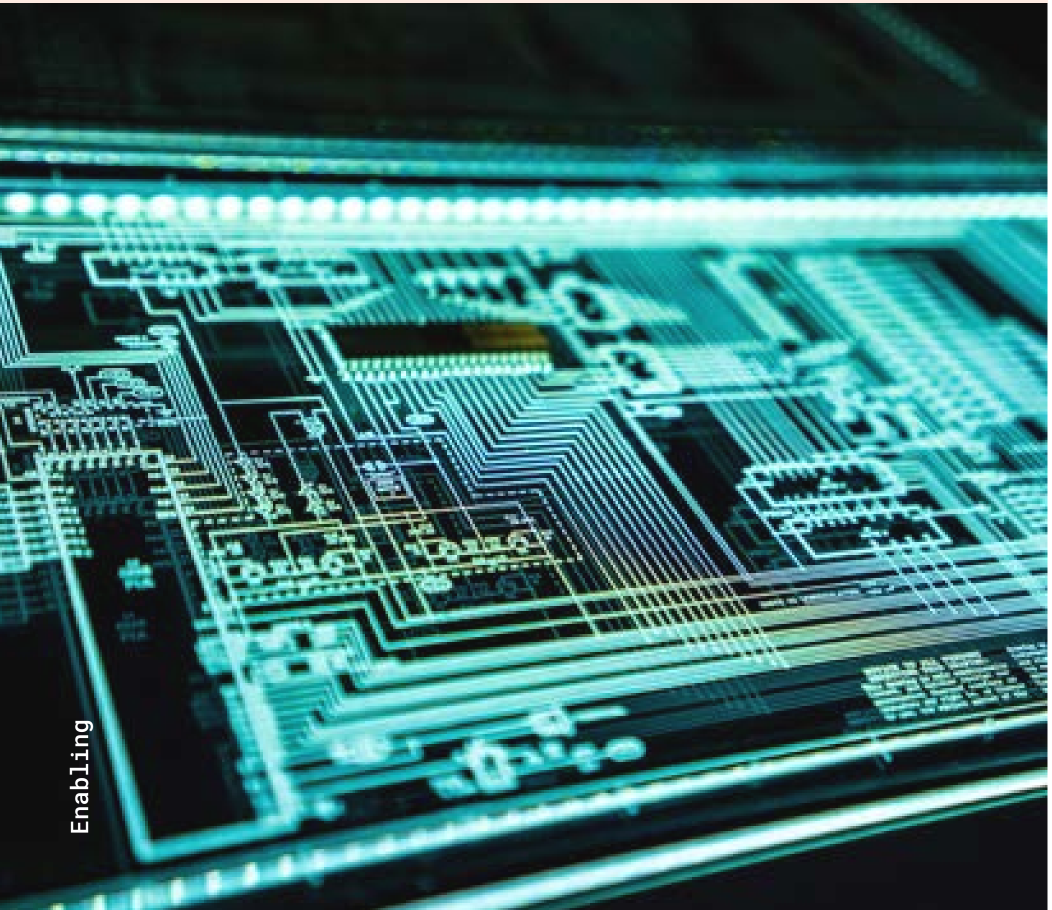
Cyber War and Peace

Combining perspectives from strategic studies and social science research to bring expertise to the military, diplomatic and national security policies for cyber space.



Competitive advantage

- Unique offerings on national security policy and cyberspace strategy
- Ground-breaking research and education on China cyber, military cyber strategies, complex cyber emergencies, and human capital for security in cyberspace
- High-value international networks in leading research centres outside Australia
- Expertise recognised by high-profile military and civilian leaders

Impact

- Contributing to defence policy at a time when Australia is moving rapidly to set up new cyber forces and wide-ranging civil-sector security measures
- Participation in policy development work with governments and the private sector

Successful applications

- Participation in national and international consultations led by government
- Innovative research projects that influence policy deliberations
- International research workshops in partnership with government
- Knowledge transfer through professional education

Capabilities and facilities

- Advanced research capability in military cyber policy, international security and diplomatic aspects of cyberspace, international cyber law of armed conflict, policy for critical infrastructure protection, education policy and workforce issues for cyber security, social media impacts on international security, technologies of decision-making for defence, human rights and cyberspace
- Professional education and postgraduate education in these fields

Our partners

- Department of Prime Minister and Cabinet
- Australian Defence Force
- Defence Science and Technology Group
- U.S. Army Cyber Institute
- NATO Cooperative Cyber Defence Centre of Excellence
- Royal Military College Canada

More information

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Enhancing Generalisation in Human Learning and Judgment

Studying the factors that influence how people generalise what they have learned to new contexts and situations. Basic research in this field provides guidelines on best to optimise generalisation of learned skills and knowledge.

Competitive advantage

- Extensive body of basic research on generalisation provides the scientific basis for improved training methods to optimise generalisation
- State-of-the-art mathematical modelling techniques to gain insight into the processes that drive human learning and generalisation

Impact

- Increased training efficiency – by developing programs that maximise generalisation without increasing length of training
- Increased insights into trainees' sensitivity to biased evidence and improved ability to adjust/correct for these biases

Successful applications

- Generalisation training strategies successfully utilised to improve children's learning of scientific concepts (Hayes et al., 2003)
- Generalisation strategies incorporated into a program for improved understanding of climate science (Kary, Newell, & Hayes, 2018)
- Recent work examined how people generalise from a sample of evidence when this evidence is biased.

Capabilities and facilities

- Access to specialist software for mathematical modelling of human learning and generalisation performance

More information

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Flexible Surgical Robots and Wearable Devices

Expertise in designing teleoperation systems, flexible surgical robots, magnetic capsule endoscopy and soft wearable devices to improve the human quality of life.

Competitive advantage

- World-leading technologies on soft robotics, wearable devices, and flexible surgical systems with multifunctionalities that can be widely applied in various applications
- Expertise in mechanical design, electronics, system modelling, functional materials, and nonlinear control
- Experienced in international patent protections
- Strong collaboration networks in USA, Singapore and Australia

Impact

- Improved the human quality of life with cutting-edge technologies for haptics, entertainment, and healthcare

Successful applications

- World's first flexible endoscopic robot for gastrointestinal cancer treatment
- Soft magnetic capsule robot for weight management
- World's first multifunctional soft electromagnetic actuators, soft planar textile muscles, and microtubule sensors for haptics and robotic applications

Capabilities and facilities

- Full-scale experimental equipment for real-time control and characterisation of robotics and mechanical systems

Our partners

- Prince of Wales Hospital

More information

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Genomics Research and Analytics

The Ramaciotti Centre for Genomics is the largest genomics facility at any Australian University. It is comprehensively equipped with the latest next-generation sequencing (NGS) technology, with single-cell genomics platforms and with high throughput microarray systems. It is funded by the Australian Government as infrastructure of national significance.

Competitive advantage

- Genomics facility with 20 years' operational experience in virtually all areas of genomics
- Highly experienced technical staff and facilities capable of annually processing more than 50,000 samples by NGS and other technologies

Successful applications

- Human genome sequencing, exome sequencing and genotyping
- Rapid genome sequencing and assembly of viral, microbial and fungal pathogens
- Microbiome analysis of samples from humans, soil and water by 16S rRNA or metagenomics
- Short-read and long-read sequencing
- Analysis of gene expression by next-generation sequencing or microarray
- Potential to analyse bioterrorism or biosecurity agents

Capabilities and facilities

- Capacity for end to end projects, including bioinformatics
- Custom-built labs in a new $180Mvbiosciences building

Our partners

- CSIRO
- NSW Department of Primary Industries (DPI)
- The Australian Wine Research Institute (AWRI)
- Garvan Institute of Medical Research

More information

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Great-Power Competition in the Indo-Pacific Region

We provide expertise in the policy, strategic and operational implications of great-power competition in the Indo-Pacific region, including the geopolitical, economic, military and technological implications of heightened friction in specific geographies and categories of competition.

Competitive advantage

- The grand strategy, operational art, current tactics and technologies of sub-threshold, liminal and grey-zone conflict
- Lessons learned from ongoing instances of great-power competition including proxy and surrogate competition
- Emerging technologies and their impact on great-power competition
- Implications of great-power competition for regional institutions and nation-states, and economic arrangements

Impact

- Improved policy, strategy and operational employment of Australian and allied whole-of-government and whole-of-nation resilience efforts
- Improved linkages between Defence and non-Defence agencies within Australia and across the region

Successful applications

- Participation in NATO and Five Eyes futures forums, concept development and experimentation efforts in Australia, UK, US, Canada and Europe
- Pandemic impact modeling for World Bank and United Nations unData program
- Consultation with Australia's Department of Defence and Department of Home Affairs
- Support to NATO's resilience agenda

More information

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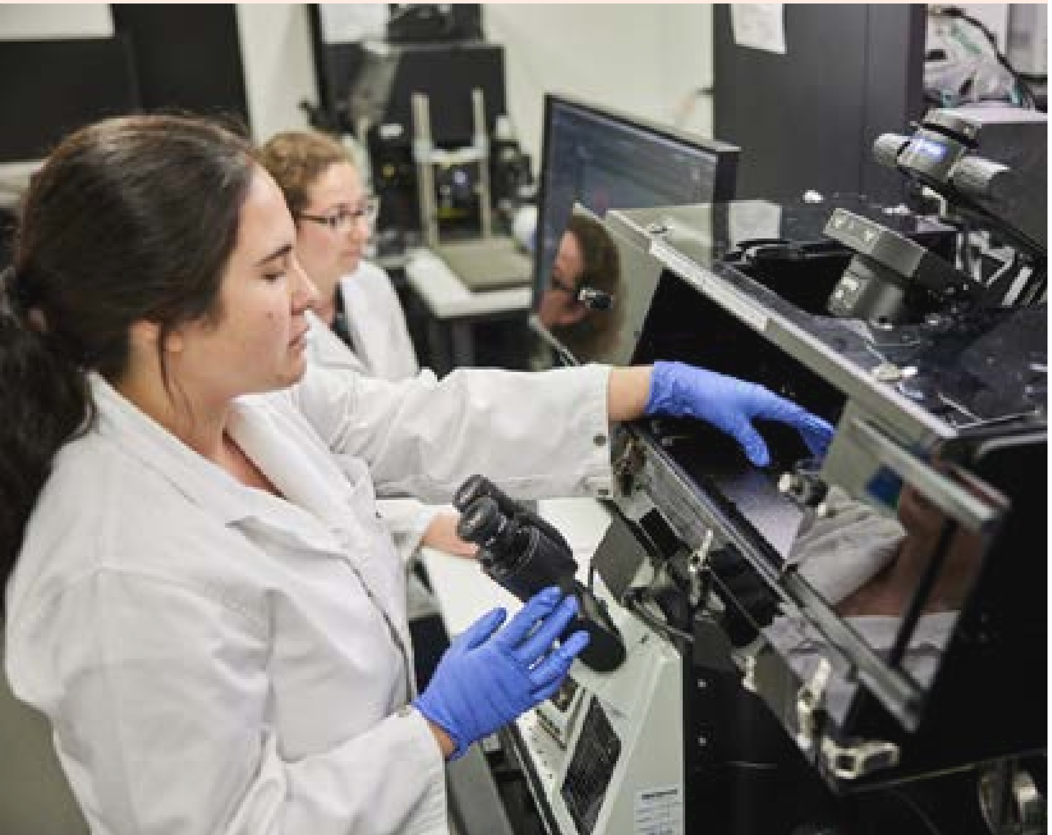
Hyperspectral Microscopy

Developing novel methods of biomedical diagnostics using hyperspectral microscopy to characterise natural colour and morphology of cells and tissues in the body, to determine whether they carry the early hallmarks of disease. This can yield early screening systems for detecting ill but pre-symptomatic individuals.



Competitive advantage

- The method is non-invasive, rapid and easily deployable in the clinic
- The first team to extract detailed biochemical-level information from cells and tissues
- The method is highly sensitive and provides subtle insight into biological processes
- Awarded the Eureka Prize for Innovative Use of Technology

Impact

- This method is expected to impact a broad range of disease conditions, including:
  - Improved therapies for regenerating cartilage injuries
  - Improved diagnostics of cancer of ocular surface
  - Early diagnostics of kidney disease
  - Applications in fertility and IVF industry
  - Veterinary applications
  - Early diagnostics for pre-symptomatic individuals

Successful applications

- Early diagnostics of motor neurone diseases (clinical trial under way
- Related start-up company is in its 5th year of operation

Capabilities and facilities

- High content, high throughput imaging
- Big data analytics
- Bioimaging, biosensing and data analytics

Our partners

- Sydney Eye Hospital
- Fertility SA
- Royal North Shore Hospital
- Macquarie University Hospital
- Macquarie Neurology
- Regeneus Pty Ltd
- Quantitative Pty Ltd
- Prince of Wales Hospital

More information

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Military Security Ethics

UNSW Canberra provides philosophically rigours research on ethical dimensions of conflict, operations and security policy.

Competitive advantage

- Education and research in military ethics with operational and strategic applications
- The ethical dimensions of international security policy, cooperation and governance
- The law and ethics of armed conflict across multiple platforms, conflict types and operational contexts
- The ethics of new military technologies, irregular warfare and specialised combatants such as special forces, private contractors and more, and
- Moral philosophy and ethics – the just war tradition in contemporary times

Impact

- Better ethical decision making

Successful applications

- Deane-Peter Baker created the first massive online open course in military ethics and is a member of the International Panel on the Regulation of Autonomous Weapons

More information

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Nerve Repair and Re-innervation via BaDGE® Naked DNA Therapeutics

Bionic array Directed Gene Electrotransfer (BaDGE®) is a platform technology for targeted delivery of naked DNA. The first clinical application uses DNA encoding neurotrophins to drive regrowth of the auditory nerve.

Competitive advantage

- First-in-class DNA electro-transfer technology for targeted DNA payload delivery to a broad range of tissue targets. It is:
  - Safe (naked DNA)
  - Regulatory permissive (non-viral)
  - Not limited by gene size packaging constraints
  - The highest level of control of the delivery of genes to target tissues
  - High efficiency gene augmentation therapeutics
- Multi-disciplinary team working at the interface of biology, engineering and clinical translation
- A patent portfolio covering all aspects of the BaDGE® platform

Impact

- BaDGE® is broadly transferrable to nerve/brain injury and muscle re-innervation.
- Validated for nerve repair and directed nerve regrowth, CNS neuromodulation, control of muscle contraction
- Broad application potential based on this novel gene electrotransfer technology for discrete targeting of DNA therapeutics in tissues; brain injury, DNA vaccines, oncology, cardiovascular disease, hearing loss, vision

Successful

applications

- BaDGE® cochlear implant neurotrophin gene therapy clinical trial to regenerate the auditory nerve
- Licensing agreements with industry partners reflect due diligence on BaDGE® capabilities

Capabilities and facilities

- DNA therapeutics – models, including cell, tissue and behavioural models, focusing on translational neuroscience applications, including nerve injury, brain injury, hearing and vision, pain, stroke, and traumatic brain injury
- Biomedical Engineering Faculty allows application-specific modelling, design and DNA delivery probe production

Our partners

- National and International Medical Device
- DNA Therapeutics Licensees

More information

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Oculog: Remote Eye Tracking

Oculog is an innovative new remote eye tracking tool that tracks pupil and corneal reflection in a controlled lighting environment to estimate gaze position relative to a stationary or mobile camera. It can potentially be used to track eye movements of many people across a variety of real-world environments. Data can then be auto-aggregated to yield population gaze metrics.

Competitive advantage

- Can track eye movements in real-time from potentially multiple people
- Estimates each individual's gaze pattern relative to either stationary or mobile visual targets
- No point-of-regard calibration required per observer
- No need to wear head-gear that will interfere with observer performance
- Cost-effective solution for a variety of eye-tracking applications

Impact

- Improved biologically-based interfaces for a range of defence applications
- Enhanced security

Successful applications

- Patents with Canon Information Systems Research Australia
- Multiple competitive research grants

Capabilities and facilities

- Eye-tracking hardware and custom software
- 3D animation and modelling for real-time rendering and simulation
- Virtual reality hardware and customisable software for rapid deployment in a variety of research and development scenarios
- Psychophysical resource suites for acquiring perceptual data to assess human perceptual performance in tailored applications
- Computational modelling methods to predict perception/performance

More information

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Organisational Behaviour in Dictatorship

In the rapidly changing international situation, understanding the drivers of behaviour in dissimilar political systems is relevant.

Competitive advantage

- Analysis of leadership decision making and organisational behaviour using cases studies of National Socialist Germany 1933–1945

Impact

- History provides examples and models to assist present-day judgement and decision making

Successful applications

- Extensive publications from subject matter experts

Capabilities and facilities

- World class library resources for studying Nazi Germany and decision making in dictatorships

More information

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Real-Time Human Performance Assessment

Working with technologies that enable real-time cognitive human performance assessment of attention, emotion, motivation, situation awareness, task assessment, and cognitive workload indicators.

Competitive advantage

- Decades of accumulated knowledge and algorithms for real-time human performance
- Software that allows the system to operate with any commercial off-the-shelf system
- Expertise to transform lab-based psychology into in situ real-time metrics
- A technology that works with different data sources and is robust against loss of a data source. A technology that assesses human mental states on a second-by-second basis and integrates them to adapt AI and automation to the human.

Impact

- Real-time improved understanding of human performance and behaviour in organisations
- Improved decision making through real-time cognitive augmentation
- Trusted human-machine environments

Successful applications

- eLearning commercialisation, Smart Sparrow
- Real-time assessment of human performance in air traffic control systems
- Trusted human-autonomy teaming in teleoperation
- User-task co-adaptation for effective interactive simulation environments, offering a generic bi-directional human-machine communication system that allows users to adapt their cognitive load to a task and adapting the task to the user

Capabilities and facilities

- An integrated 12-seat laboratory EEG, Kinect, Eye Tracker, and physiological sensors – for cognitive and behavioural human performance measurement
- High-fidelity simulation environments including air-traffic management and uninhabited all-domains vehicles (UxVs) modelling
- State-of-the-art defence simulation environments including Virtual Battlespace System
- The technology uses multiple data sources including electroencephalography (EEG), facial expressions, language, speech, keyboard, and vibrations

Our partners

- Defence Science and Technology (DST)

More information

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Religion, Gender and Development in the Indo-Pacific Region

UNSW Canberra provides expertise in Islam, gender, and regional development issues with a focus on Indonesia. Internal cultural and social dynamics intersect with regional and global forces for social and political transformation in the Indo-Pacific region.

Competitive advantage

- Expertise in:
  - Islamic politics and economy
  - Gender equality and social inclusion
  - Poverty reduction
  - Rural development policy
  - Civil society
  - Disaster relief and community responses

Impact

- Our expertise influences programs for non-governmental organisations for gender equality and poverty reduction

Capabilities and facilities

- The Asia-Pacific Development and Security research group
- Indonesian Studies
- MOUs with leading Indonesian research universities

Our partners

- Gadjah Mada University, State Islamic University, Jakarta

More information

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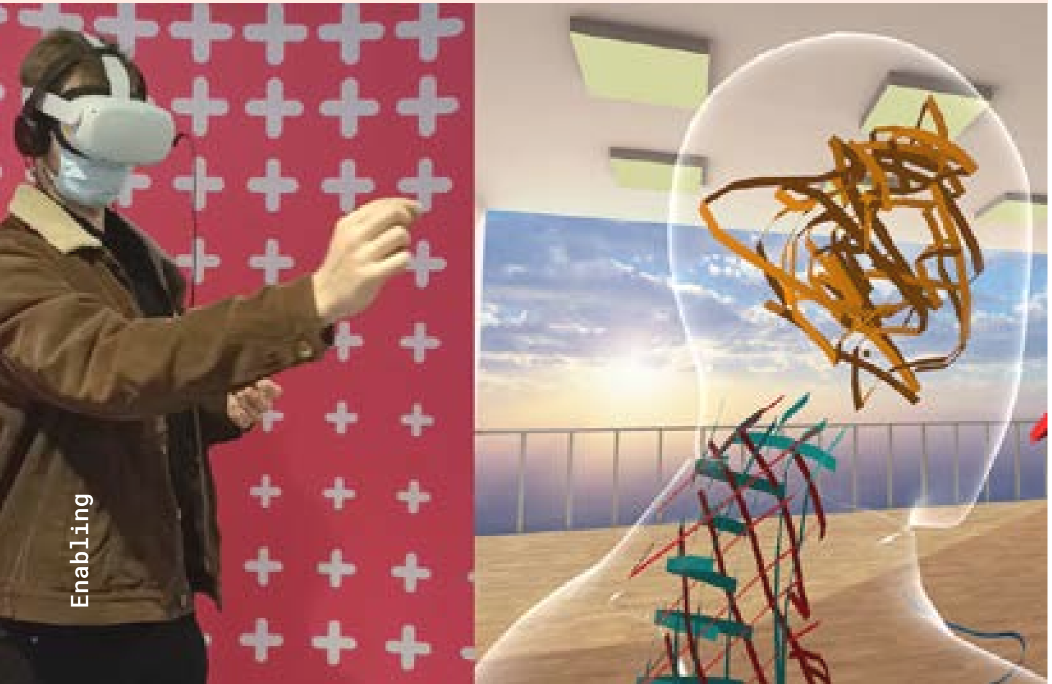
Remote Assessment of Functional Activities

Using sensors, data analysis and extensive clinical expertise, human performance can be remotely monitored in real-life stressful environments and interventions suggested to improve performance outcomes.



Competitive advantage

- Access to a team of clinical experts and engineers
- Ability to interpret sensor data in the context of improving human performance
- Clinical-based interventions
- Remote or rural clinical assessment and support

Impact

- Enhanced human performance through assessment and intervention

Successful applications

- Through the Rehabilitation Glove Project at The Quadriplegic Hand Research Unit, Royal North Shore Hospital a wearable device known as Exoflex was developed to provide applied finger joint movement to 15 joints of the hand.
  - The device provides therapeutic movement, hand assessment and light functional pinch for people recovering from trauma, surgery or burns, and people with permanent paralysis such as those with spinal cord injury.
  - Technology is secured by international patents and licensed to BES Rehab, UK
  - Successfully commercialised and used internationally
  - Multi-award winning

Capabilities and facilities

- Movement control and evaluation especially as the result of intervention
- VR and 3-D analysis
- Detection and interpretation of biomechanical and bioelectric signals
- Rehabilitation Medicine Specialist
- Paediatric Medicine Specialist

Our partners

- Sydney Children's Hospital, Rehab2Kids
- Royal North Shore Hospital, Hand and Peripheral Nerve Surgery Department

More information

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Self-Cooling Vest

A lightweight, self-cooling vest for operation in hot environments. It does not require external power and can operate indefinitely.

Competitive advantage

- Current self-cooling vests are heavy, expensive and either require a substantial power source or must be refrozen, limiting their useful operating time
- Our system is lightweight and cost-effective. It uses no power source and can operate indefinitely
- The system is based on a thermosiphon process. It uses a low boiling point phase change material (LBPCM) with a refrigeration cycle and circulation of helium

Impact

- Reduced heat stress in military personnel

More information

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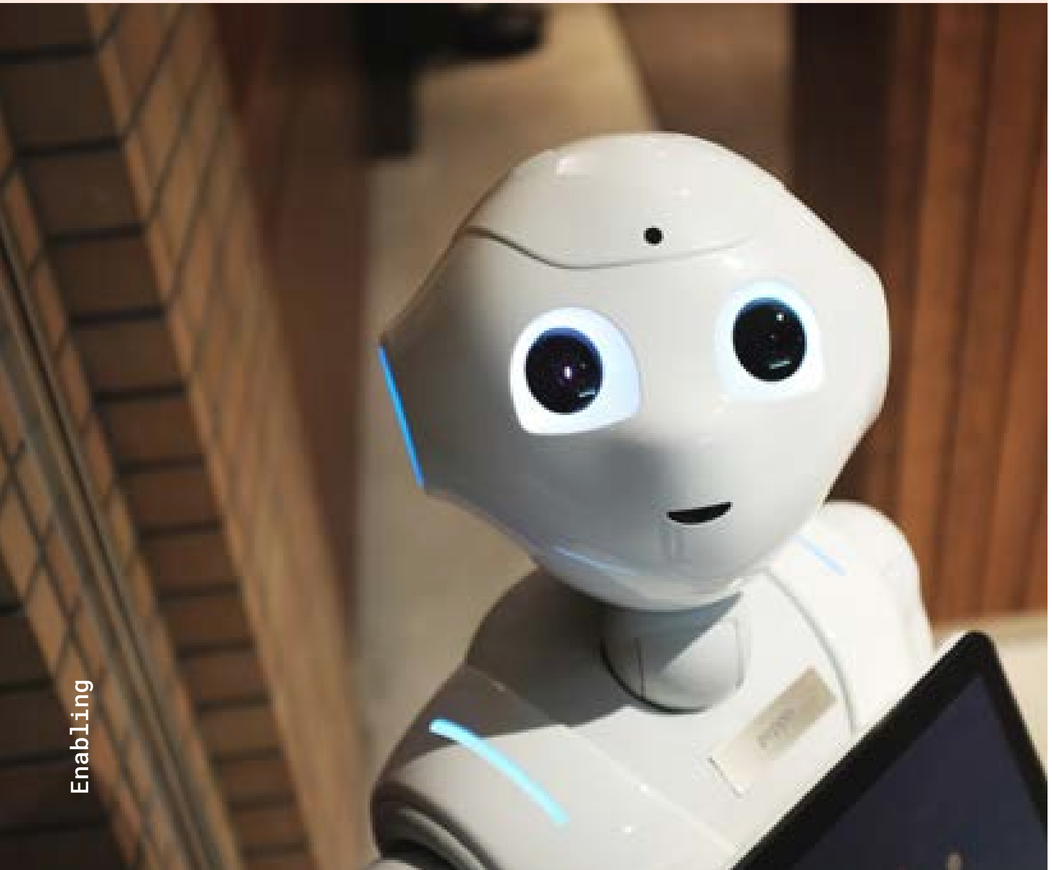
Social Robotics

A cross-disciplinary research environment dedicated to understanding how humans can interact with three-dimensional robotic agents and responsive structures within the context of creative and social robotics. The laboratory aims to provide a structured environment which facilitates the creation of experimental interfaces that promote interactivity in physical spaces.



Competitive advantage

- Pioneered the field of social robotics and one of the few centres in the world – the only one in Australia – which co-developed the terminology of social robotics
- The Creative Robotics Lab is one of the first teams in the world to take an informed multi-disciplinary approach to human-computer and human-robot interface
- Human centric approach – task taking, providing experience and respecting the human interactant regardless of age and abilities

Impact

- Changing the way assistive devices technology can resolve situations with social stigma
- Increasing safety to allow people to stay at home longer

Successful applications

- In relation to robotics, one of the few groups in the world that has done cross cultural studies across socio economic groups and countries
- Teaching interaction with humans, eye contact, focus, not being distracted in interactions; how to interact with people you don't know; acceptable social interaction; social touching

Capabilities and facilities

- National Facility for Human Robot Interaction Research
- Social Robotics Lab
- Largest data collection in the world on how humans interact with robotic technology
- Experts in technology, people, culture, autism and robot morphologies

Our partners

- US Airforce
- Fuji Xerox innovation Japan
- Necta (Data61) Defence
- St Vincents

More information

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Space Law, Policy and Strategy

Global leader in research, knowledge and thinking on space law, policy and strategy. Fusion of inter-disciplinary perspectives, including solid technical foundations, to produce pragmatic solutions and innovations to support a stable, rules-based order for space, consistent with stakeholder interests.

Competitive advantage

- Fusing decades of military operational and deployed experience with needs for more robust and comprehensive framework for governance of space activities
- Spans military, commercial and civil activities in the space domain
- Founder and on the governance board for Woomera Manual on International Law of Military Space Activities and Operations

Impact

- Strategic space leaders and their advisors have shaped their policies and strategic approach on the basis of this research
- There is a continuing, imperative need to further clarify and develop the normative framework for space activities and this research continues to respond to that imperative

Successful applications

- Regular invited contributions to state and federal government, and international fora
- Transfer of knowledge gained from research through professional education
- Applied by participants from military forces, space agencies, diplomatic corps, primes, SMEs and start-ups, especially in Australia, and throughout the world

Our partners

- Woomera Manual on International Law of Military Space Activities and Operations

More information

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Special Operations in Current and Future Conflict

UNSW Canberra provides expertise in the theory, history, application, ethics and technology of Special Operations in current and future conflict, with a focus on the evolution of unconventional operations, special warfare, grey-zone and proxy conflict and advanced special operations technology

Competitive advantage

- Expertise in:
  - The theory of special operations as applied to contemporary and future conflict
  - History and ethics of special operations, current best practices and application of special operations in sub-threshold, liminal and grey-zone conflict
  - Lessons learned from current and historical use of special operations forces
  - Emerging and disruptive technologies and their impact on special operations, including autonomous systems and remote-access special operations, cyber-kinetic operations and virtual special reconnaissance

Impact

- UNSW Canberra offers the most advanced suite of Masters-level courses in Special Operations of any member of the extended western alliance, regularly drawing international students
- Improved policy, strategy and operational employment of Australian and allied special operations forces
- Modeling and wargaming of future special operations applications and technologies
- Adversary and threat modeling

Successful applications

- Support to Special Operations Innovation and Design efforts in Australia, the US and UK
- Ongoing support to Australian Special Operations Command, US Army Special Operations Command, US Marine Corps Special Operations Command and UK Special Forces
- Historical support to Canadian, New Zealand and NATO deployed special operations elements
- Engagement with the special operations research association, military operations research society and related organisations

More information

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War Studies

Any attempt to predict drivers and motivations in modern conflict is fundamentally linked to historical experience. UNSW Canberra's War Studies provided first class and cutting-edge research that provides insight into Australia's past military experience and how that experience can shape the future.

Competitive advantage

- Leading centre of military history and war studies in Australia
- Global leader in Australian military history
- Proven understanding of ADF needs

Impact

- Give ADF personnel the intellectual edge to succeed in the complex operating environments of the 21st century
- Research to provide guidance for the challenges of great power competition and emerging strategic threats.

Successful applications

- Official History of Australian Peacekeeping Operations in East Timor
- Official History of Australian Operations in Iraq and Afghanistan
- Australia's Vietnam War database
- The AIF project
- Numerous titles published through the Army History Unit

Capabilities and facilities

- Conflict & Society Research group

More information

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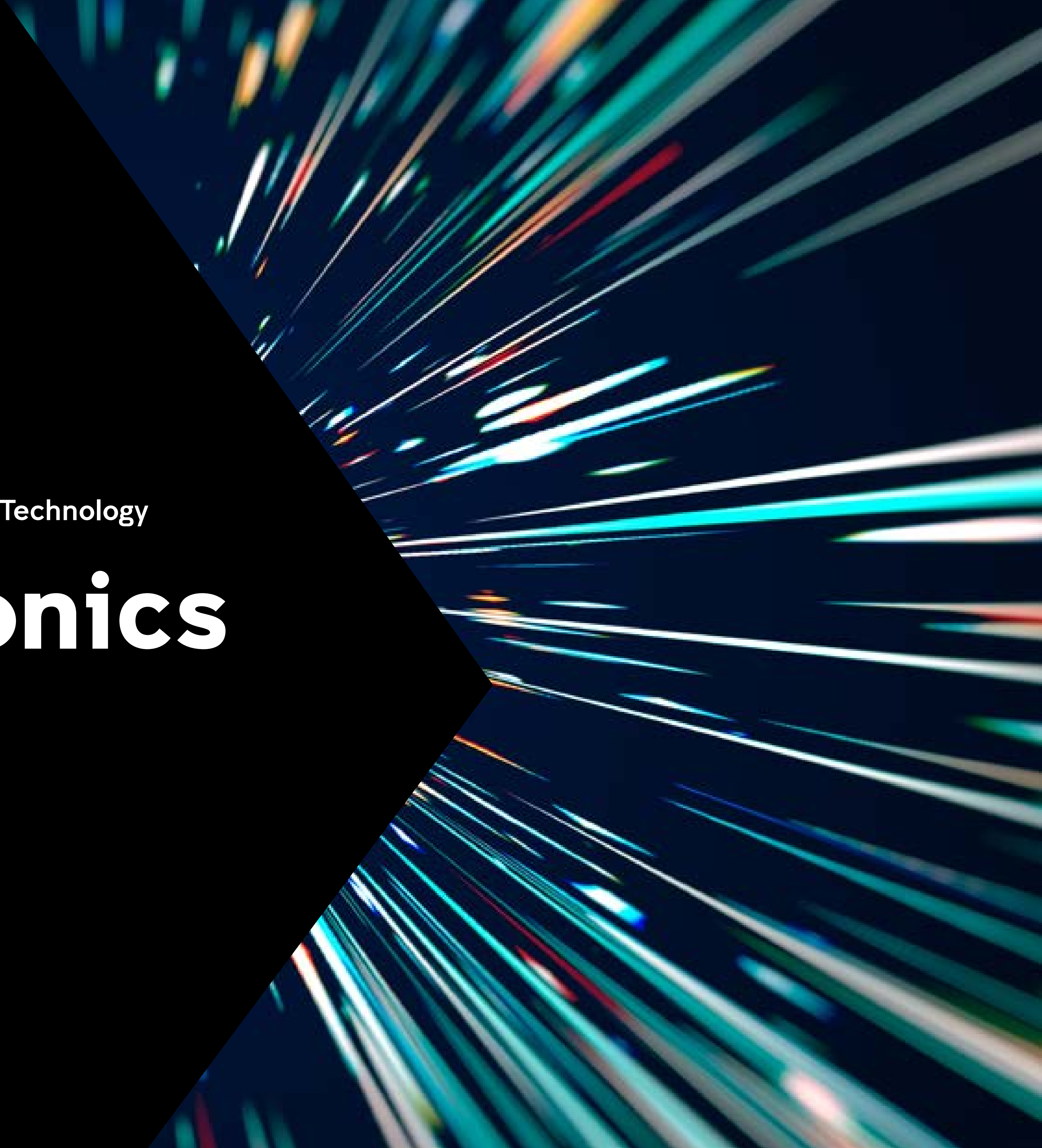
AUKUS Defence Research and Technology

Hypersonics



Directed Energy Systems

We are a leader in power electronics and the emerging use of this technology across a range of critical defence areas including directed energy systems. Power electronics provides effector controllability that is a step-change improvement from conventional systems, and our high-voltage lab provides testing facilities.

Competitive advantage

- The development of semiconductor-based excitation systems of high-power RF systems yielding huge gains in control and effect
- Cost-effective, reliable and predictable response

Impact

- Establishment of a sovereign capability in high-power RF systems
- Early detection of lung cancer leading to radically-improved patient outcomes

Successful applications

- A prototype directed energy system using a co-axial oscillator driven by a HV source
- A miniature nano-second pulse generator for a novel chemical agent detector
- Beagle: an award-winning lung cancer screening device
- A system to accelerate fuel ignition in hypersonic engines
- A current $1.7M project to develop sovereign capability in the area of pulsed-power and direct-energy systems

Capabilities and facilities

- A high-voltage laboratory with 400kV capability and test chambers fit for DE purposes
- A suite of medium voltage pulse generators and associated measurement systems
- Over 20 years of continuous nanosecond pulse generation research using power electronics

Our partners

- Atomic Weapons Establishment (AWE UK)
- BAE Systems
- Raytheon Systems UK
- DSTG

More information

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Gasdynamic Laser Directed Energy Device

The use of a combustion-driven power supply to generate intense light from a hypersonic expansion for countering improvised swarm UAV or other small-scale threats. The simplicity of the design, and power of the device combine to provide a technology that can be deployed where electrical power is difficult to find.

Competitive advantage

- Rugged and powerful source of directed energy
- Can be used where there is no electrical power available
- Simple enough to be serviced in the field

Impact

- Combines an understanding of hypersonics, combustion and laser operation to provide a unique niche capability in directed energy
- Successful application
- Currently being deployed as a proof-of-concept experiment

Capabilities and facilities

- Computer model for population dynamics in the laser
- Diagnostics for measuring state populations while in operation through absorption spectroscopy

Our partners

- DSTG
- Lockheed Martin Corp (USA)

More information

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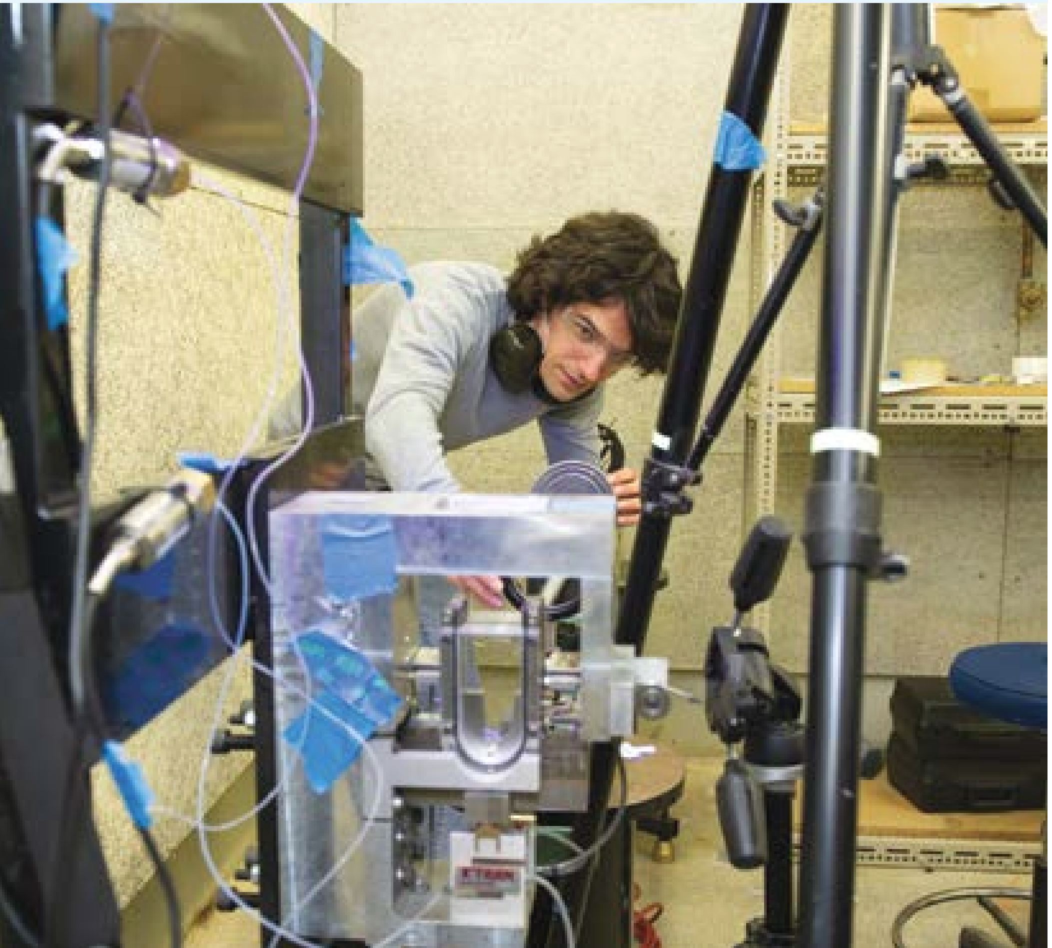
Hypersonic Control

Testing and analysing the performance of control methods and algorithms in flow conditions that are representative of hypersonic flight.



Competitive advantage

- Technologies that test robust control algorithms on representative configurations in hypersonic flows
- Technologies that cover both “algorithm-in-the-loop” testing in wind tunnels as well as “software-in-the-loop” testing via numerical simulation
- Technologies that can evaluate novel actuation methods such as fluidic control and fluidic thrust vectoring

Impact

- Test methodologies enable a steady progression through Technology Readiness Levels of both control algorithms and control actuation approaches by testing them dynamically in flow conditions representative of hypersonic flight

Successful applications

- Dev1elopment of technologies to test both control methodologies and control actuation approaches; supported by the U.S. Air Force Office of Scientific Research and BAE Systems

Capabilities and facilities

- High-speed wind tunnels including T-ADFA and the Supersonic Nozzle Test Facility
- Partner facilities at USQ and HDT at the University of Oxford

More information

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Hypersonic Flowfield Measurements

World leading laser flow diagnostics

Competitive advantage

- Unique combination of state-of-the-art shock tunnel for generating hypersonic flows and laser-based diagnostics for making precision measurements in those flows
- Wide range of laser-based measurement technologies, including laser-induced fluorescence diode laser absorption spectroscopy and resonantly-enhanced shearing interferometry

Impact

- Design of more efficient hypersonic vehicles
- Improved understanding of aerothermodynamic heating and drag characteristics of hypersonic vehicles
- Testing validity of computational models

Successful applications

- Produced the world's first two-dimensional velocity maps in hypersonic separated flows
- Density measurements 100 times more sensitive than existing technologies
- Fastest scanning temperature measurement technology currently in existence (1.6 million temperature measurements per second)
- International collaboration in comparison of state-of-the-art computational methods
- Multiple funding streams including US Air Force programs

Capabilities and facilities

- T-ADFA free-piston shock tunnel
- YAG-pumped dye laser system
- Diode laser absorption spectroscopy system

More information

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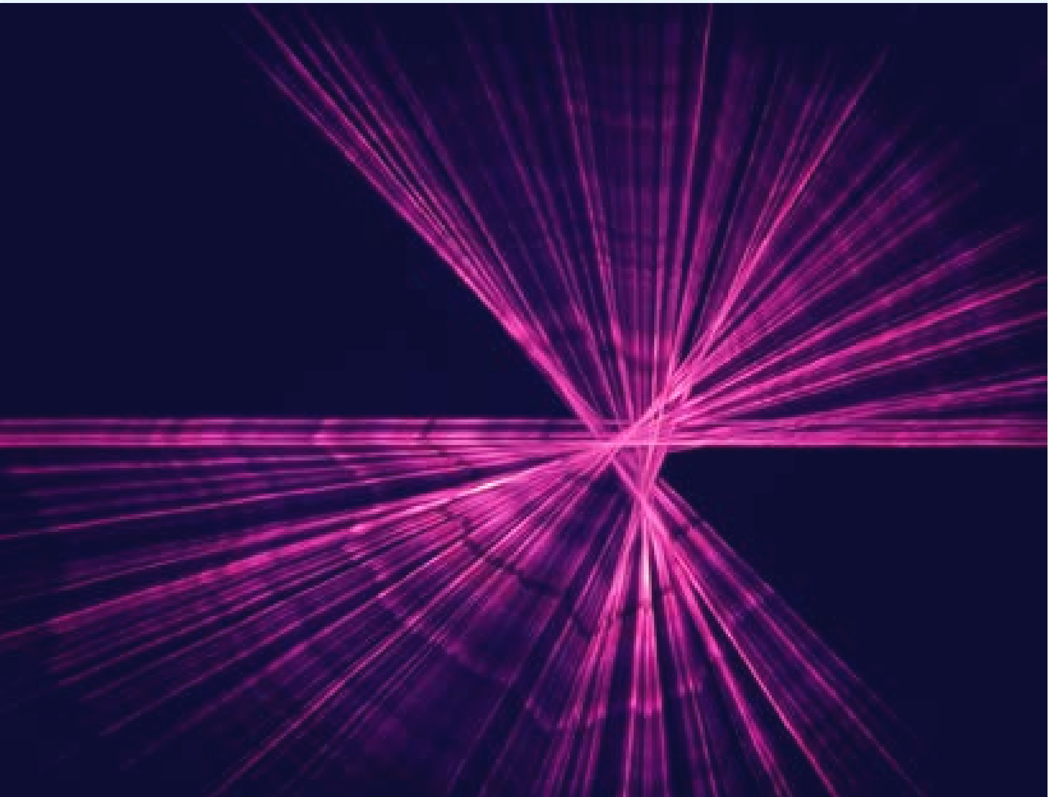
Hypersonic Ignition Enhancement

Making a scramjet work with hydrocarbon fuels requires faster ignition than would usually occur. We have developed a range of ignition enhancement technologies to enable supersonic ignition and flameholding.



Competitive advantage

- We have developed the laser ignition technology for scramjet combustors
- We have also investigated the benefits of nanosecond-discharge ignition for scramjet propulsion

Impact

- Enabling technology for supersonic combustion
- Operation at higher altitudes – increasing the available flight envelope for the propulsion system

Successful applications

- First demonstration of laser spark ignition
- Capabilities and facilities
- T-ADFA Free-piston shock tunnel
- Scramjet combustor
- Laser and nanosecond discharge ignition systems
- Advanced laser diagnostics for measuring combustion products and temperatures

Our partners

- US Air Force
- DSTG
- University of Virginia, Ohio State and Arizona State Universities

More information

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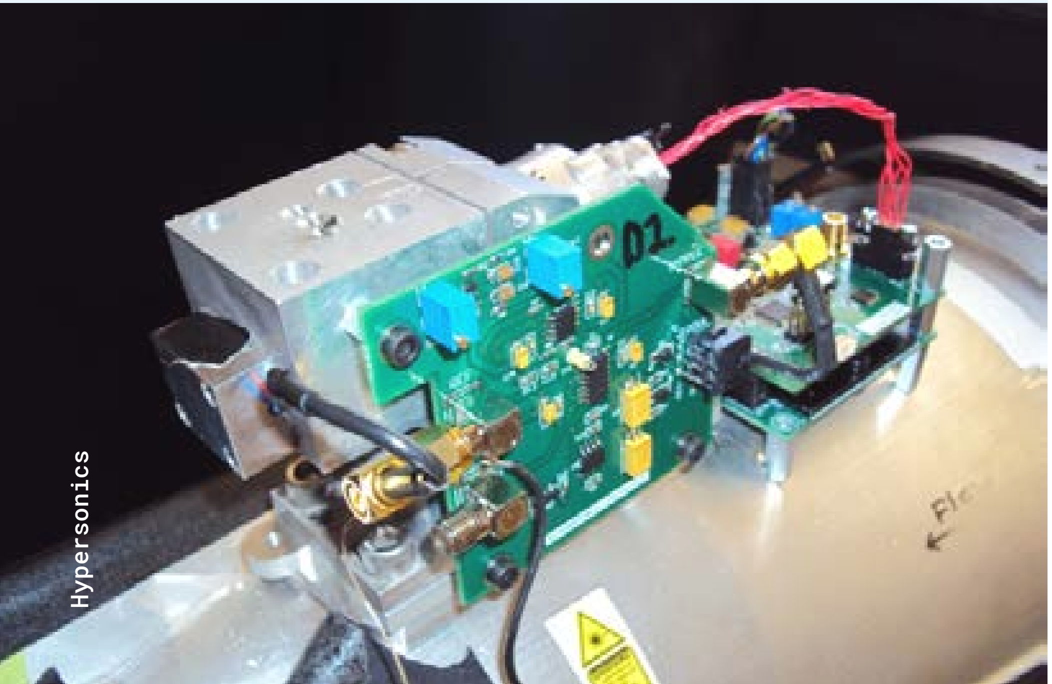
Hypersonic Inlet and Combustion Sensors

Hypersonic vehicles require sensor and actuator systems that are both very fast and non-intrusive. Our research group has produced a rugged laser-based inlet sensor that has survived more than 20 g acceleration in a flight test environment.



Competitive advantage

- We have developed the first flight-tested laser-based inlet sensor
- Capable of measuring temperature, speed and angle of attack at high rates

Impact

- Essential sensor for control of hypersonic vehicles
- Combined with combustion sensors, it can provide a complete engine monitoring system

Successful applications

- Flight tested as part of the SCRAMSPACE project

Capabilities and facilities

- High-speed spectroscopic system
- The world's fastest temperature measurement

Our partners

- US Air Force
- DSTG

More information

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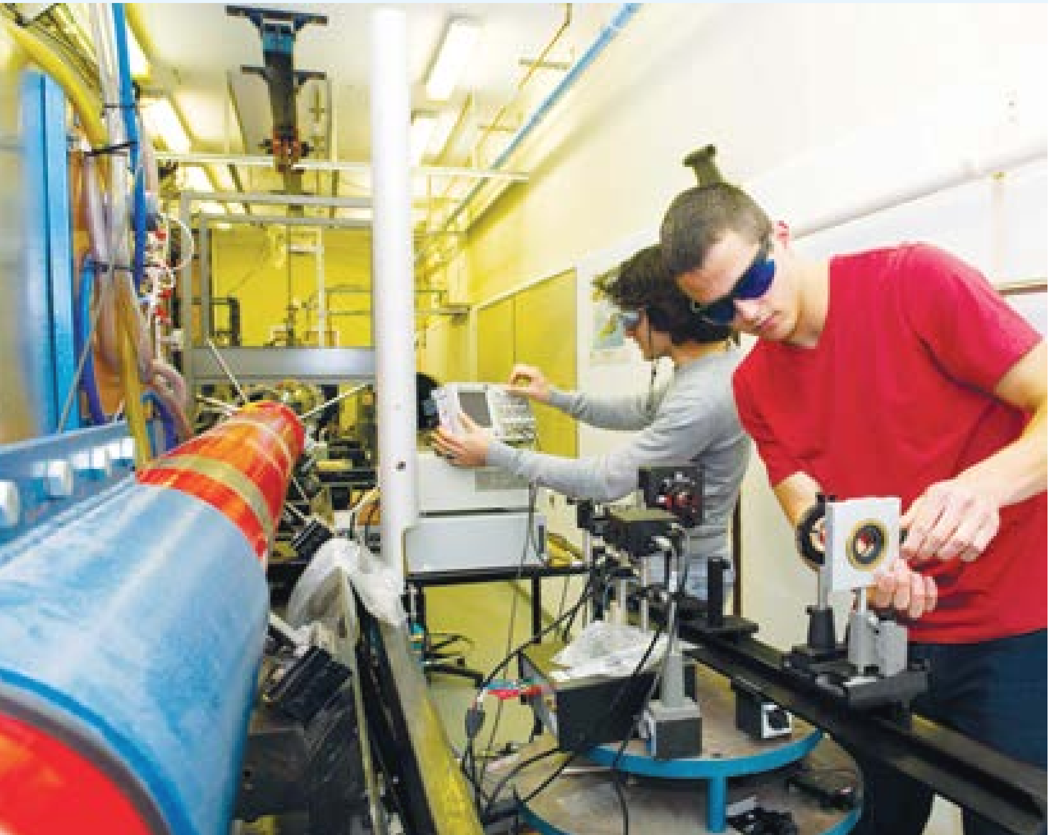
Hypersonic Vehicle Performance

Reducing the risk of high-speed flight testing and development through the application of simulation validated via scaled, dynamic free-flight testing in wind tunnels



Competitive advantage

- Highly-instrumented, low-inertia, dynamically-scaled, rapidly-prototyped, models with on-board instrumentation for free-flight testing in hypersonic conditions
- Measurement of the aerodynamic derivatives of a design across a range of attitudes in a single experimental run using on-board instrumentation in tandem with high-speed video tracking
- Quickly validate numerically-derived aerodynamic databases using a small number of wind tunnel experiments and the performance of arbitrary vehicle shapes
- Ability to investigate high-speed separations including and stores release in addition to quantifying the associated multi-body aerodynamics

Impact

- Rapid assessment of vehicle performance
- Reduced requirement and risks associated with flight testing
- Use of ground-based test facilities to assess numerical designs and identify unforeseen issues
- Rapid assessment of geometric design, mass distribution and separation approach

Successful applications

- Free-flight technology has been successfully applied to multiple programs including the Defence Science and Technology Group (DSTG)/AFRL HIFiRE program and ESA's HEXAFLY-International program
- Initial vehicle designs have also been tested for Reaction Engines Limited (Skylon) and Hypersonix (SPARTAN)

Capabilities and facilities

- Multi-fidelity numerical tools for assessment of vehicle performance
- Ability to design models and experiments
- Ability to design and fabricate bespoke on-board electronics
- High-speed wind tunnels including T-ADFA

Our partners

- TUSQ at USQ
- HDT at the University of Oxford
- M6LT at the United States Air Force Academy

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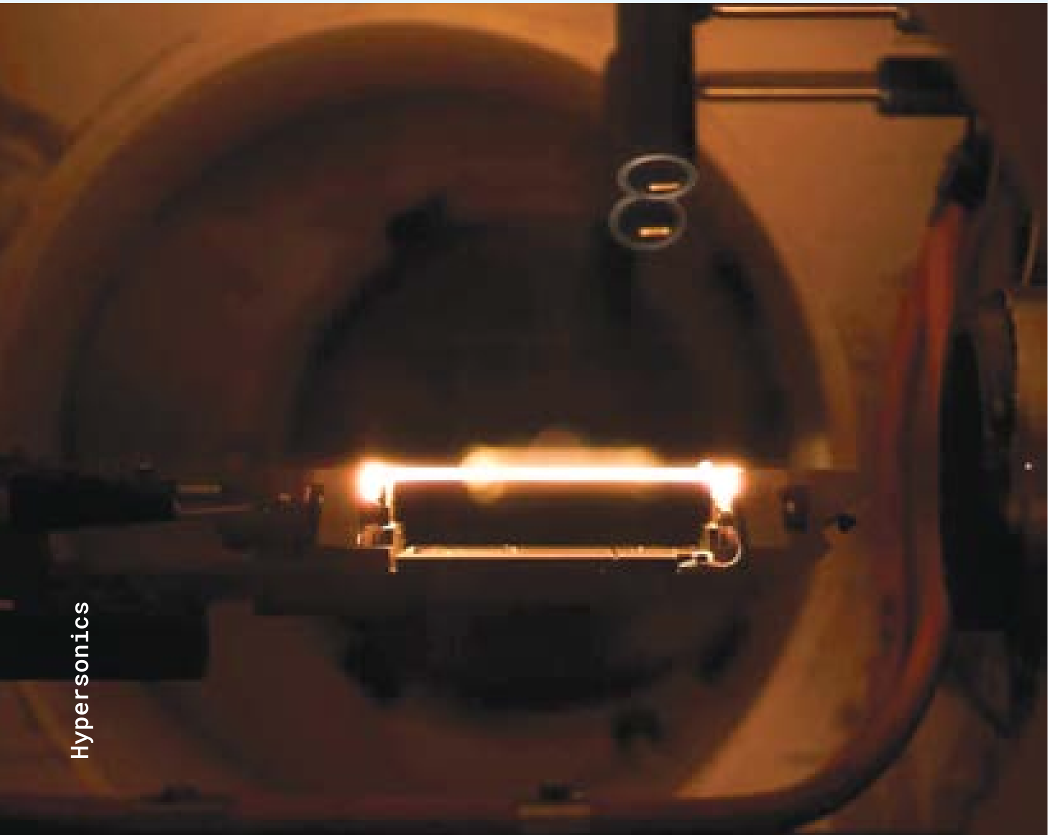
Hypersonic Vehicle Structures

Developing, validating and testing structural designs, components and materials to operate in the extremes of hypersonic flight



Competitive advantages

- Expertise in the design and testing of aerostructures to withstand the extreme conditions experienced by a vehicle during hypersonic flight
- Expertise extends to both the development of numerical tools as well as the experimental methods to predict and measure the performance of structures, sub-components and materials exposed to hypersonic flight conditions
- Measurement and test technologies cover both ground-based measurements and in-flight measurements

Impact

- Test and prediction technologies enable the increase in technology readiness levels of structural designs, sub-components and high temperature materials by exposing them to the thermal-structural conditions representative of hypersonic flight. This leads to the optimisation of vehicle designs and reduced requirements for expensive flight testing

Successful applications

- Expertise and technology has been applied to the design and evaluation of aerostructures and subcomponents for the HyCAUSE (DARPA/AFRL/ Defence Science and Technology (DST)), SCRAMSPACE (UQ-led consortium) vehicles and the onboard measurement of thermal-structural performance in-flight under the HIFiRE (DST/AFRL) and HEXAFLY-INT (ESAled consortium) hypersonic test flight programs

Capabilities and facilities

- Experimental facilities and diagnostics to test the structural performance of materials and components under flight-representative temperatures and thermal gradients
- The ability to combine thermal loads with representative aerodynamic loads in supersonic and hypersonic wind tunnels
- Deployment of diagnostic technologies onboard hypersonic flight-test vehicles for real-time measurements

More information

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Materials Testing for Extreme Environments

The success of defence's hypersonic capabilities will rely on the operation of advanced materials functioning at extreme temperatures for long periods of time. We offer capabilities for testing advanced alloys and ceramics at the range of cryogenic to elevated temperatures relevant to hypersonic aerospace systems.

Competitive advantage

- World class expertise in testing, understanding, and predicting advanced mechanical behaviour of materials (fracture toughness, fatigue crack growth, creep fatigue, etc.) in extreme conditions such as cryogenic temperatures to well above 1000°C in oxidizing, vacuum, and inert gas environments

Impact

- The safety and reliability of hypersonic aerospace systems are reliant of specialised materials (ceramics, intermetallic compounds, heat resistant alloys & superalloys, etc.) that can withstand the extreme operative conditions for long periods of time, and a detailed understanding of the relevant materials performance is essential for the design, deployment, and maintenance of these systems

Successful applications

- We have performed successful projects on materials currently used in, and being developed for, applications in advanced aerospace structures and aeroengines

Capabilities and facilities

- Quasistatic (e.g. tensile, fracture toughness, etc.) and dynamic (fatigue crack growth, creep-fatigue, etc.) testing capabilities in extreme environments relevant to hypersonic applications: cryogenic temperatures to well above 1000°C in oxidizing, vacuum, and inert gas environments

Our partners

- US Department of Energy
- US National Technology Energy Laboratory
- US Idaho National Laboratory
- US Oak Ridge National Laboratory, Precision Castparts (PCC Structurals)
- Plansee SE Corporation
- Titomoc Ltd. Pty

More information

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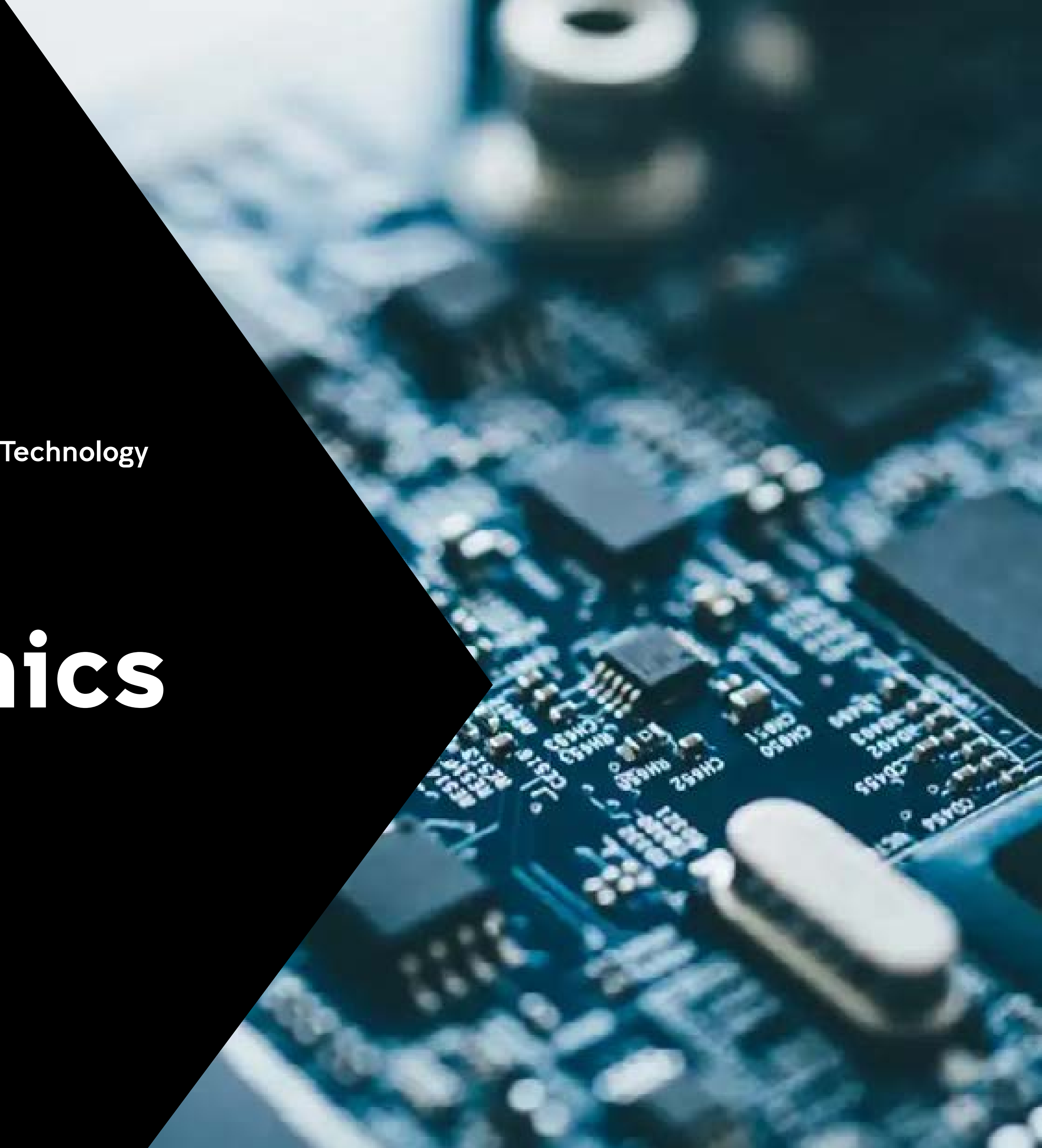
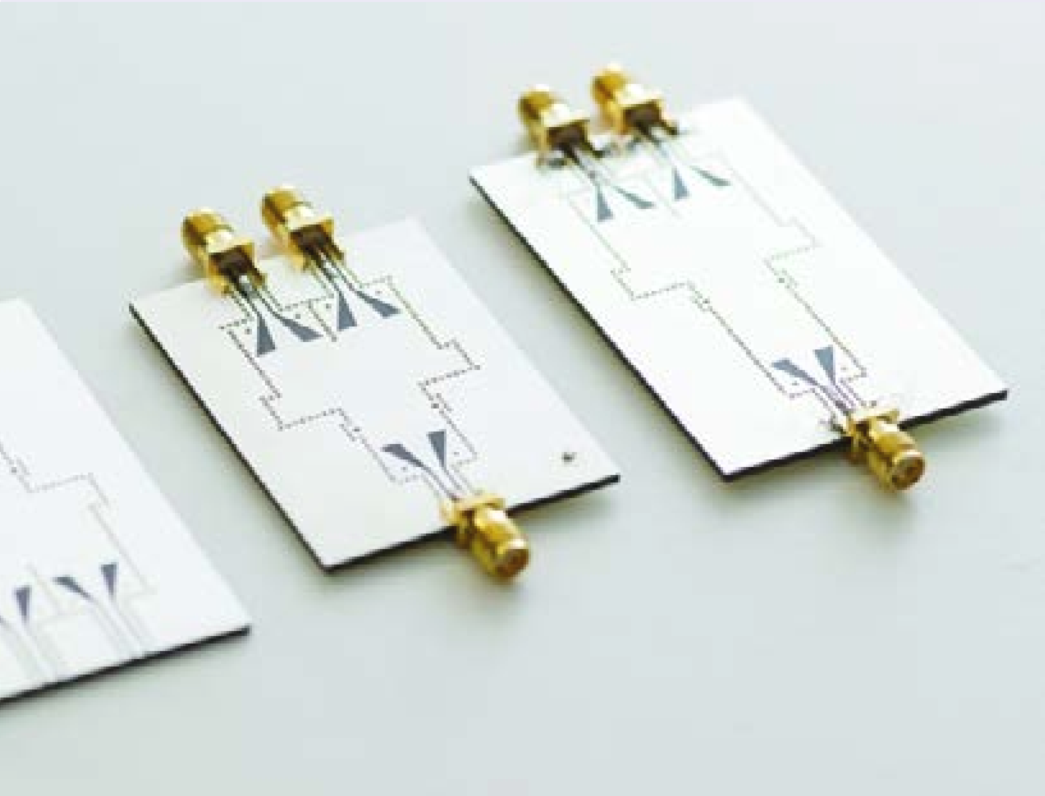
AUKUS Defence Research and Technology

Micro Electronics



Microwave and Millimetre Wave Research

The Microwave and Millimetre Wave (MMM) Laboratory is an international leader in radio frequency microelectromechanical systems (RF MEMS) and microwave and millimetre-wave devices for mobile and satellite communications.



Competitive advantage

- Research and development of novel devices such as reconfigurable microwave and millimetre-wave switches, switch matrices, filters, antennas and directional couplers
- Expertise across a range of technologies including microstrips, striplines, coplanar waveguides, rectangular waveguides, substrate integrated waveguides and 3D printing
- Experienced in performing cutting edge measurement, characterisation and modelling of the effects of microwave and millimetre-wave radiation on the human body

Impact

- Superior communication devices

Capabilities and facilities

- Specialised test and measurement equipment, including Agilent PNA, Anritsu VectorStar and Microprobe Cascade
- Sophisticated and powerful simulation tools, including Agilent ADS, Ansys, Coventorware, Sonnet, Comsole Multiphysics and Cadence

More information

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Nano/Micro Optical, Electrical and Mechanical Systems on Silicon Chips and Integrated Circuits

Design, fabrication and measurement of nano- and micro- scale systems with mechanical, electrical and/or optical functionalities on a silicon substrate or CMOS integrated circuit, enabling the development of novel and advanced sensors and actuators.

Competitive advantage

- A suite of novel patent-protected technologies, which include:
- High aspect ratio sharp nanotips – CMOS compatible and integration with nano-scale devices at unprecedented density, not possible with any other technology
- PZT microlens micro-actuators – record-breaking large displacement and resonance frequency and small footprint micro-lens piezoelectric actuators for micro-optics application
- Low thermal budget polysilicon films – thick and low stress silicon film with low thermal budget suitable for microelectromechanical systems (MEMS) formation on top of CMOS
- Delivering record-breaking high gauge factor piezo-resistive polysilicon films with low thermal budget

Impact

- New devices for next-generation electronics

Capabilities and facilities

- Advanced semiconductor manufacturing tools in ANFF at UNSW and other nodes around Australia
- Mark Wainwright Analytical Centre (MWAC) for process monitoring, diagnostic and film characterisation
- MEMS measurement lab equipped with Polytech MSA-500, providing the capability to measure dynamics of nano/micro structures with sub-nanometre displacement resolution
- Silicon photonics characterisation optical bench set-up with automatic nano-positioners, deterministic polarisation controller, and 7.5 GHz spectrum analyser

More information

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Reliable Electronics

Aerospace systems with high performance, real-time requirements are increasingly implemented using commercially available field programmable gate arrays (FPGAs). This requires FPGA-based systems able to operate in high radiation environments.

Competitive advantage

- Rapid, power efficient recovery from radiation-induced errors in FPGAs to achieve state-of-the-art system availability and reliability rates
- High-level synthesis of reliable subsystems to reduce design, implementation and test timeframes
- Functional verification tools to validate dynamically re-configurable FPGA designs

Impact

- Reliable FPGA-based mission critical systems designed to operate in high radiation environments
- Flexibility to rapidly adapt to changing environments and new requirements
- Reduced system lifecycle costs

Successful applications

- Dynamic partial reconfiguration demonstrator, Defence Science and Technology (DST)
- RUSH reconfigurable hardware platform for exploring new reliability techniques developed and flown on EU QB50 CubeSat and Hydra mission to the International Space Station, with further missions planned
- Rapidly generating highly reliable FPGA implementations, Thales Alenia Space and General Dynamics NZ

Our partners

- Australian Centre for Space Engineering Research
- Solinov Pty Ltd

More information

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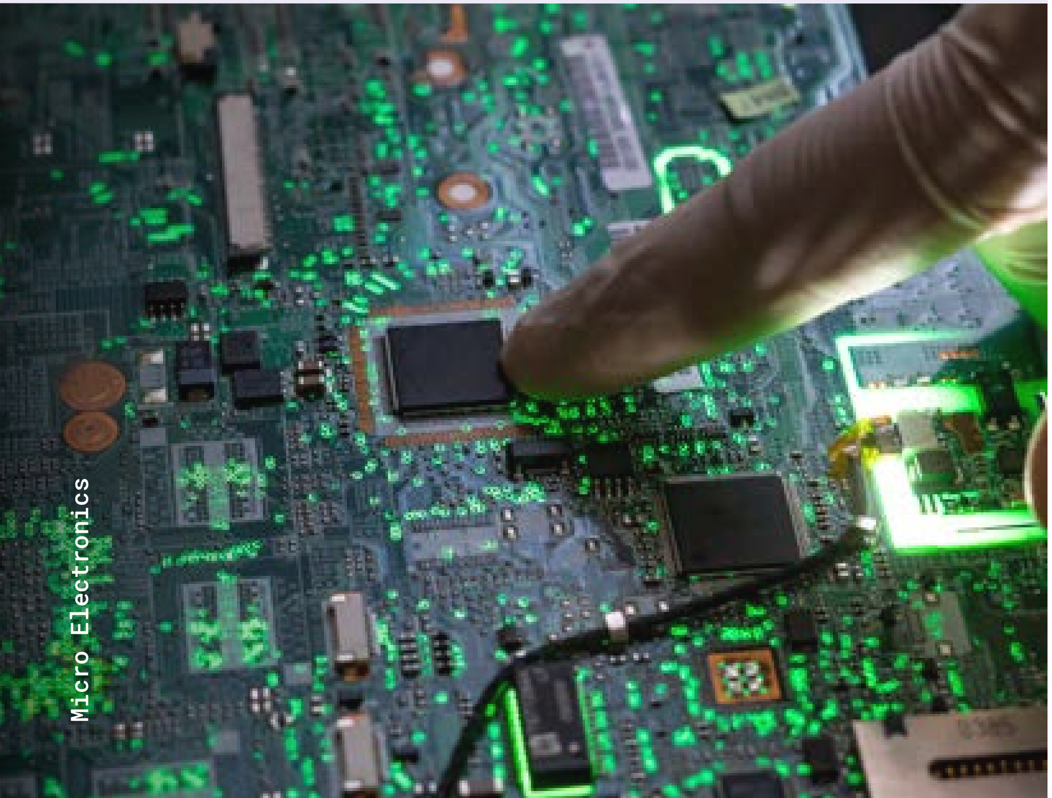
Semiconductor Nanowire Electronics

The fabrication of nanoscale devices featuring inorganic semiconductor nanowires and organic electronic and bioelectronic materials enables novel electronic applications such as bio-compatible devices.



Competitive advantage

- Electron-beam lithography of polymer electrolytes and ionomers for electronics applications
- Deposition and nanoscale patterning of ultra-thin (< 50nm) parylene films for nanoscale device applications
- Fabrication of semiconductor nanowire devices
- Electrical characterisation of semiconductor nanowire devices

Impact

- Harnessing the advantages offered by nanoscale structures including power to size ratio and enhanced functionality and durability

Successful applications

- Development of nanowire transistors with gate-all-around structures with multiple independent gates and polymer insulators
- Nanoscale patterning of ion-conducting polymers for use as gate structures for nanowire transistors
- Nanoscale devices for ion-to-electron signal transduction
- High-performance p-GaAs MESFETs for nanowire CMOS
- Ultra-thin parylene films as patterned insulators in nanoscale devices
- Nanowire devices for bioelectronics applications

Capabilities and facilities

- Equipment for electrical measurements down to 1 Kelvin and magnetic fields up to 9 Tesla (with full-sphere rotation)
- Custom-built parylene deposition system for ultra-thin film deposition
- Electrical characterisation of devices under controlled atmosphere

Our partners

- Collaborations with numerous internationally respected teams

More information

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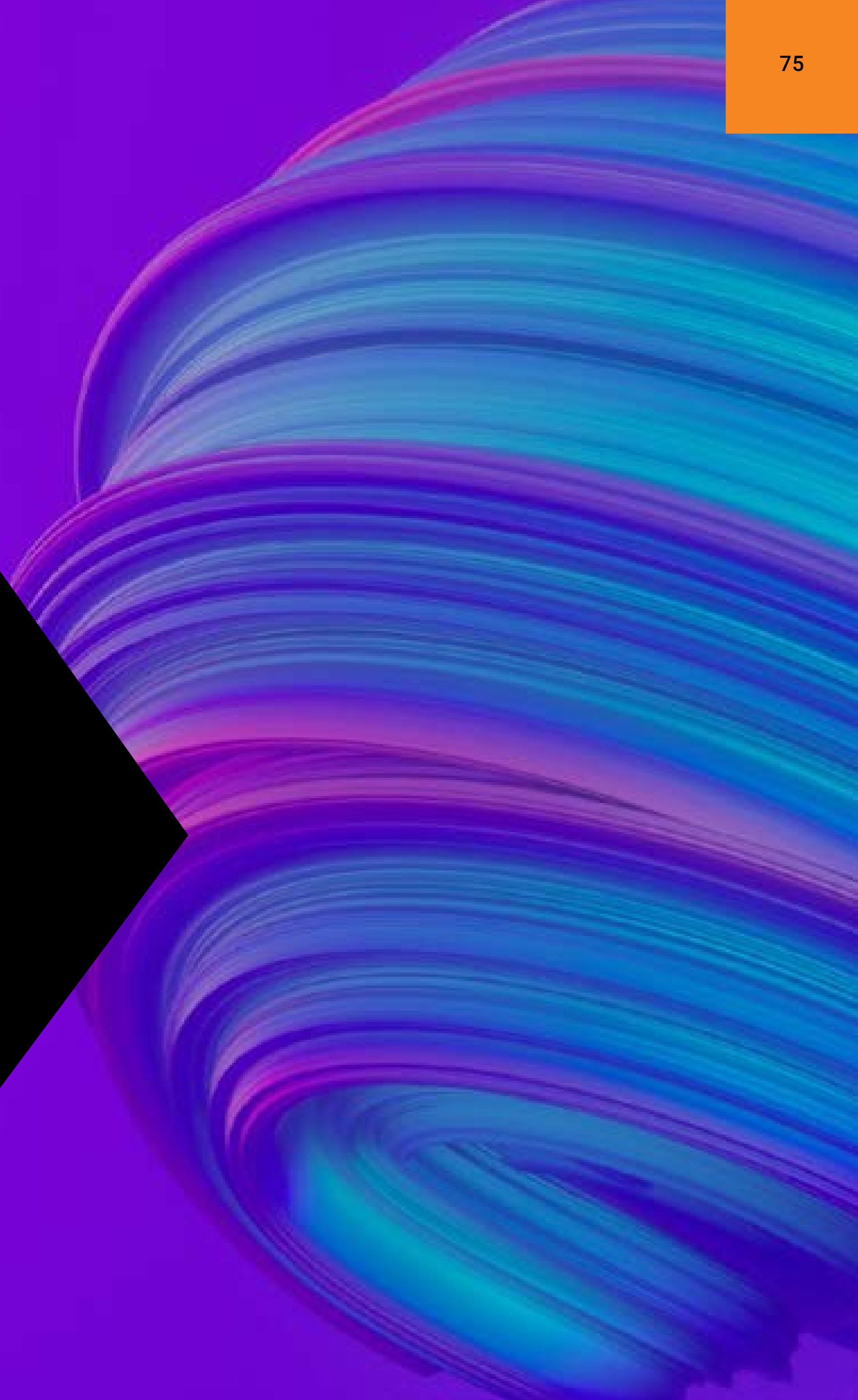
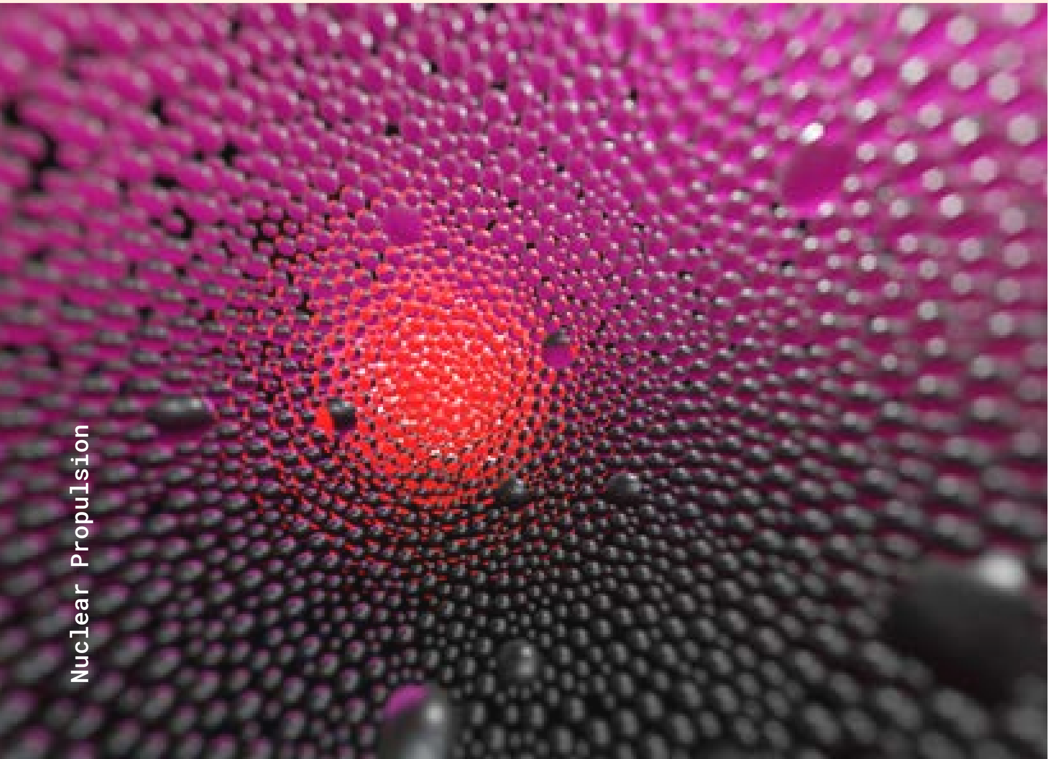
AUKUS Defence Research and Technology

Nuclear Propulsion



Advanced Radiation Shielding Materials

We have developed new approaches to materials selection that combine fundamental nuclear physics with an engineer's understanding of nuclear applications. These methods enable us to select optimal shielding and structural materials for a range of nuclear applications in including thermal, fast, and fusion-relevant neutron fluxes.



Competitive advantage

- Materials selection using the full range of nuclear interactions at all neutron and gamma energies
- Systematic, analytical approach that charts every nuclide without using computationally expensive Monte Carlo simulation

Impact

- We can design radiation shielding materials to optimise against density, mass, spatial or other constraint, for any input radiation flux

Successful applications

- Radiation shielding design for superconducting compact tokamak fusion reactor

Our partners

- Tokamak Energy

More information

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Blockchain Technologies for Nuclear Safeguards

Australia faces new diplomatic challenges to exercise untested clauses in its nuclear safeguards agreement for non-proscribed military activities. Blockchain technology is a solution that balances information sharing while maintaining security in nuclear safeguards.

Competitive advantage

- UNSW developed and tested SLUMBAT, the world-first blockchain demonstration for nuclear material accounting and control on blockchain
- We continue to work on cutting edge blockchain technology that combines the expertise of nuclear engineering and computer science research

Impact

- World-first application of blockchain to nuclear safeguards information systems.

Successful applications

- SLUMBAT (2018)
- SLAFKA (2020)
- SLIMNAC (2022)

Capabilities and facilities

- Practical knowledge and experience working with nuclear safeguards
- Nuclear engineering
- Comprehensive research expertise for understanding networks, cryptography, distributed ledger & cloud infrastructure

Our partners

- Finnish Radiation and Nuclear Safety authority (STUK)
- Stimson Center
- International Atomic Energy Agency

More information

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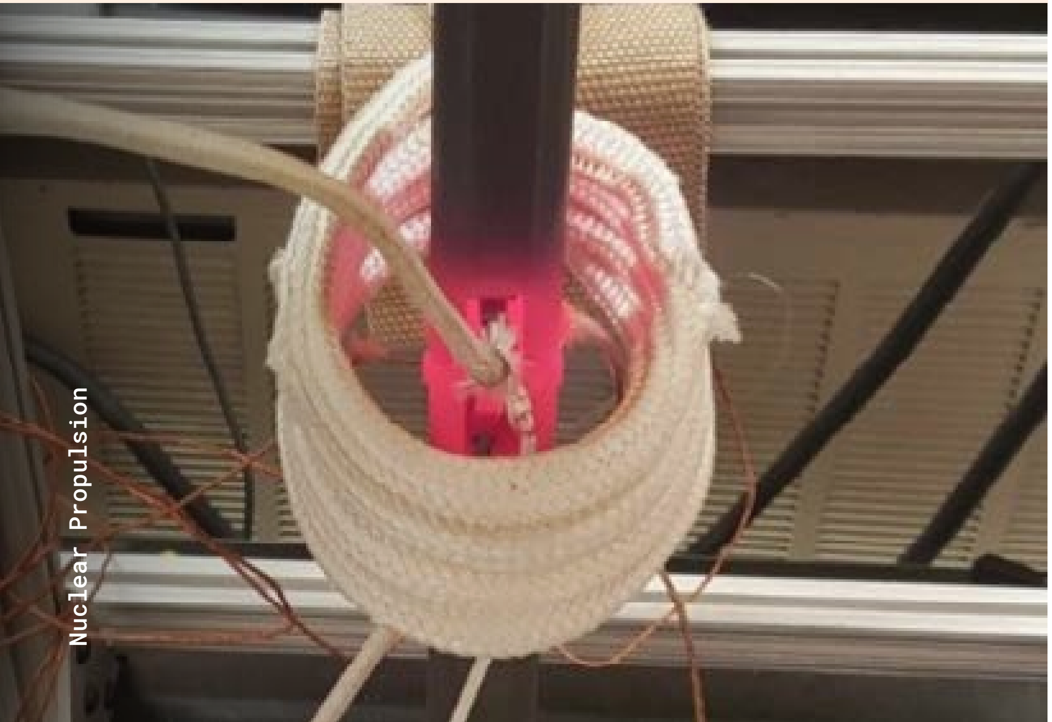
Materials Testing for Extreme Environments

The success of defence's nuclear submarine capabilities will rely on the operation of advanced materials functioning at extreme temperatures for long periods of time. We offer capabilities for testing advanced alloys and ceramics at the range of cryogenic to elevated temperatures relevant to nuclear power generation.



Competitive advantage

- World class expertise in testing, understanding, and predicting advanced mechanical behaviour of materials (fracture toughness, fatigue crack growth, creep fatigue, etc.) in extreme conditions up to, and well above, 1000°C in oxidizing, vacuum, inert gas, or aqueous environments

Impact

- The safety and reliability of nuclear power generation systems are reliant of specialized materials (graphite, heat resistant alloys & superalloys, intermetallic compounds, ceramics, etc.) that can withstand the extreme operative conditions for long periods of time, and a detailed understanding of the relevant materials performance is essential for the design, deployment, and maintenance of these systems

Successful applications

- We have performed successful projects on materials currently used in, and materials being developed for, applications in advanced nuclear power generation systems

Capabilities and facilities

- Quasistatic (e.g. tensile, fracture toughness, etc.) and dynamic (fatigue crack growth, creep-fatigue, etc.) testing capabilities in extreme environments relevant to nuclear applications: temperatures up to, and well above, 1000°C in oxidizing, vacuum, inert gas, or aqueous environments

Our partners

- US Office of Nuclear Energy
- US National Technology Energy Laboratory
- US Idaho National Laboratory
- US Oak Ridge National Laboratory
- Precision Castparts (PCC Structurals)
- Plansee SE Corporation
- Titomoc Ltd. Pty

More information

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Nuclear Engineering Education and Training

Nuclear capability hinges on the skills and advanced level of nuclear engineering knowledge in the nuclear workforce. Training Tier 3 professionals takes up to 20 years, and research training including PhD and research experience is a part of this advanced study. Nuclear engineering is an interdisciplinary application of engineering science and is taught alongside other engineering specialisations.

Competitive advantage

- UNSW offers advanced nuclear engineering education starting from honours level undergraduate, through postgraduate, to PhD and beyond
- Australia's leading engineering university, located in Sydney

Impact

- Training the new generation of nuclear engineers through UNSW programs, courses and short courses for industry and government

Successful applications

- UNSW Nuclear postgraduate coursework programs: masters, graduate diploma, and graduate certificate
- UNSW PhD programs in nuclear engineering
- Short courses for government and Defence

Capabilities and facilities

- Education design, program and course development, engineering labs, and infrastructure of Australia's leading engineering university

Our partners

- Department of Defence
- Australian nuclear science and technology organisation (ANSTO)
- OECD Nuclear Energy Agency

More information

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Nuclear Fuel Analysis and Testing

Researching the next generation of nuclear fuels for pressurised water reactors and future designs like the lead-cooled fast reactor. High density nuclear fuel compounds uranium nitride, uranium silicide and metallic fuels are under increased consideration to improve accident tolerance and enable higher power density with increased safety margin.

Competitive advantage

- Integrated research capability for analysis of fuel test results combined with ab-initio and multiscale modelling of nuclear fuel performance in accident conditions

Impact

- Quantitative measurements of corrosion rates, phase changes, and thermal expansion in nuclear fuel compounds undergoing corrosion, cross-referenced to atomic-scale modelling

Successful applications

- Discovery of strain effects in in-situ hydriding of U3Si2 accident tolerant fuel
- Measuring crystallographic thermal expansion in doped and modified fuel compounds
- Corrosion-resistant additions to UN fuel pellets to control oxidation in steam

Capabilities and facilities

- Nuclear materials research group with expertise across nuclear fuel research from experimental design to complex data analysis, contextualization, and model validation
- Experimental facilities developed jointly with Australian Centre for Neutron Scattering
- Routine access to large scale computational infrastructure

Our partners

- Australian Centre for Neutron Scattering
- Los Alamos National Laboratory
- Westinghouse Electric

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Nuclear Technology and Society

While nuclear technology represents an enduring option for affordable and abundant energy for societal development and decarbonisation, a fraught relationship with society curtails its potential role in many scenarios. We work to identify common ground for conversations on the merits, limitations, and challenges around nuclear technology between stakeholder groups.

Competitive advantage

- Nuclear engineering research group with in-depth, expert knowledge of nuclear safety, benefits and future trajectory for technology
- Active collaboration with social sciences, law, and medicine faculties. Partnering with UNSW Design Studio DesignNext for futures analysis, co-design and workshop methods

Impact

- Co-Charing OECD-NEA working group ‘rethinking the relationship between nuclear energy and society’ as part of global forum on nuclear education, science technology and policy

Capabilities and facilities

- UNSW Allens Hub for Technology, Law and Innovation
- UNSW research infrastructure including research ethics, compliance, and research management
- Experts in public surveying, focus groups, co-design and technology ethics

Our partners

- OECD Nuclear energy agency
- Multiple universities worldwide member of the NEA global forum in nuclear education, science, technology and policy

More information

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Radioactive Waste Management

We have extensive experience in the examination of actual and potential nuclear waste repositories and in assessing optimal approaches to remediation and/or containment.

Competitive advantage

- Team of geochemists and environmental engineers with extensive experience in radioactive waste site investigation, risk assessment and remediation approaches based on both experimental and computational skills

Impact

- Undertaken R&D with ANSTO on both legacy and analogue nuclear waste sites/repositories and published research outcomes extensively

Successful applications

- Currently investigating legacy nuclear waste site on southern outskirts of Sydney
- We have previously investigated use of subsurface uranium deposit (in the Northern Territory) as analogue of a nuclear waste repository

Capabilities and facilities

- Superb experimental and computational facilities at both UNSW and ANSTO
- We have made extensive use of the Australian Synchrotron for sample characterisation

Our partners

- Australian Nuclear Science and Technology Organisation
- United States Nuclear Regulatory Commission
- Japan Atomic Energy Research Institute

More information

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Zirconium Alloy Lifetime Prediction

Alloys of zirconium are the pre-eminent structural material for core internals of pressurized water reactors, whether used as civilian powerplants or for naval propulsion. Lifetime limiting factors for zirconium alloy components include hydride cracking and radiation growth.

Competitive advantage

- Australia's leading research group for ab-initio modelling of radiation and hydrogen effects in zirconium alloys

Impact

- Predicting engineering properties like ductility, dimensional change and composition from fundamental interactions of high energy neutrons and zirconium alloys

Capabilities and facilities

- Dedicated nuclear materials research group with expertise across zirconium alloy materials engineering from experimental design to complex data analysis, contextualization, and model validation
- Advanced computational modelling capability, with access to leading computational infrastructure

Our partners

- Westinghouse
- Los Alamos National Laboratory
- Imperial College London

More information

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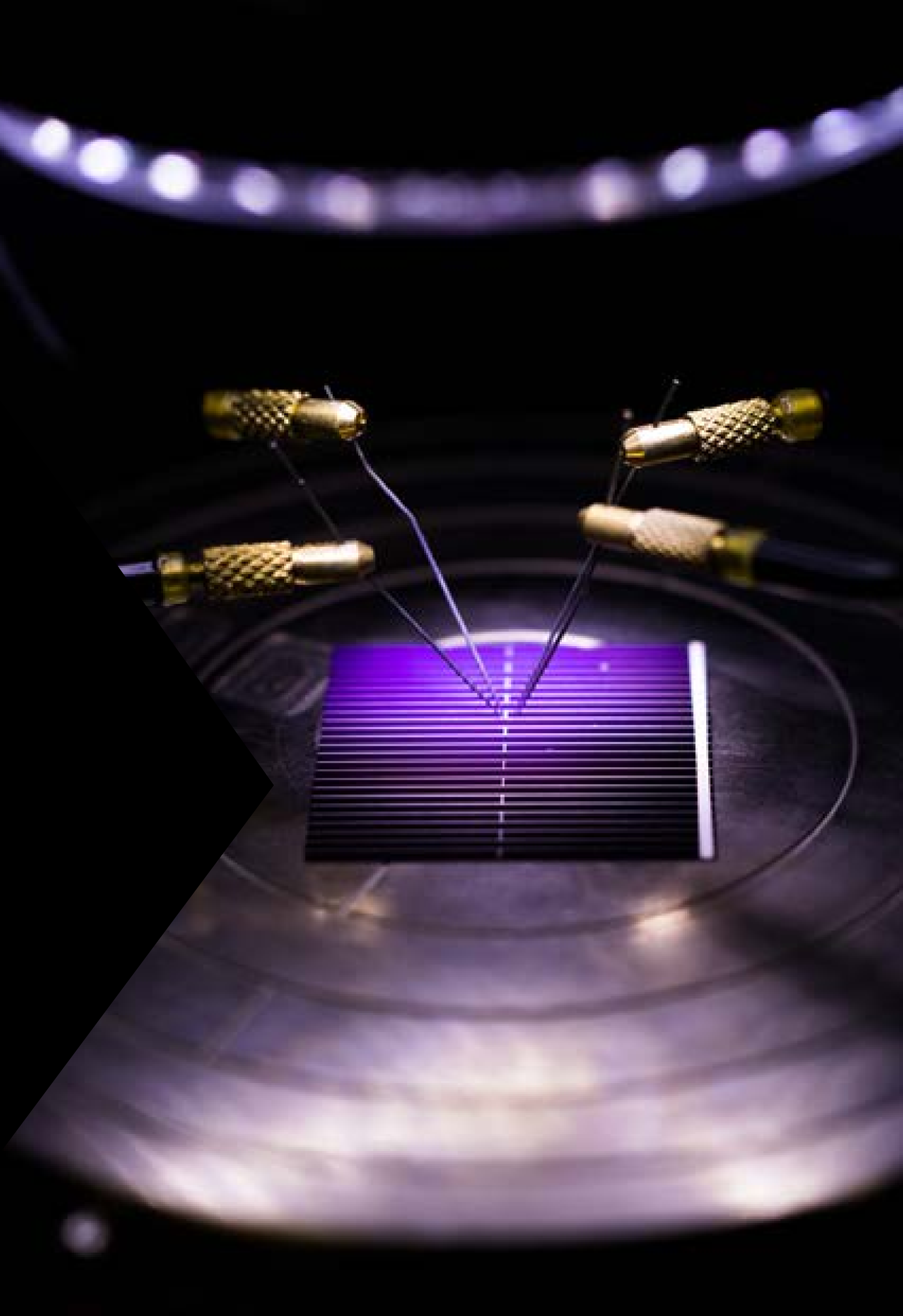
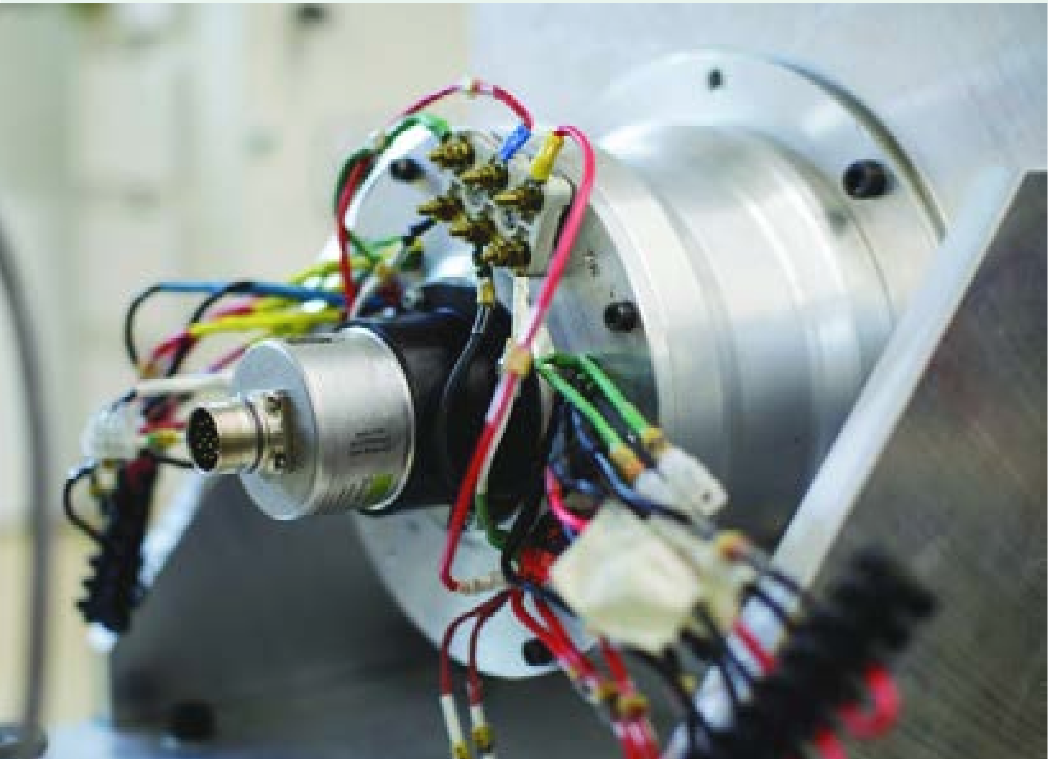
AUKUS Defence Research and Technology

Power Generation and Control



Design & Control of Permanent Magnet Synchronous Machines

Design, optimisation and control of various permanent magnet synchronous machine (PMSM) geometries, delivering improved torque and power density, reduced cogging torque, and extended constant power operating range.



Competitive advantage

- Expertise in highly efficient, low cogging torque, wide constant power speed range permanent magnet synchronous motors, generators and their advanced drive systems
- Development of the first sensorless control and fractional-slot concentrated wound IPM machines
- Expertise in enhanced control techniques, including direct torque and flux control, mechanical sensorless control and model predictive control
- Expertise in PMSMs for application in renewable energy systems
- Expertise in the design, optimization, manufacture and testing of IPM machines with V and other shaped magnets embedded in the rotor, as well as fractional-slot concentrate wound (tooth-coil) PM machines that demonstrate very high torque and power density and deep filed weakening range

Impact

- More efficient motors and generators

Successful applications

- Development of fractional-slot IPM machines
- PWM based sensorless control
- High-speed IPM machines

Capabilities and facilities

- Finite-element packages such as Magsoft and Ansys, with optimisation tools that have been developed in-house
- Two and three-level inverters, several machine drive set-ups complete with shaft position sensors, torque sensors, highly dynamic loads
- Four-quadrant dynamometer, simulation platforms (Matlab–Simulink, PSIM), FPGA and DSP systems with high-performance signal acquisition, estimation and switch gate-drive interfaces

Our partners

- Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC)
- CSIRO

More information

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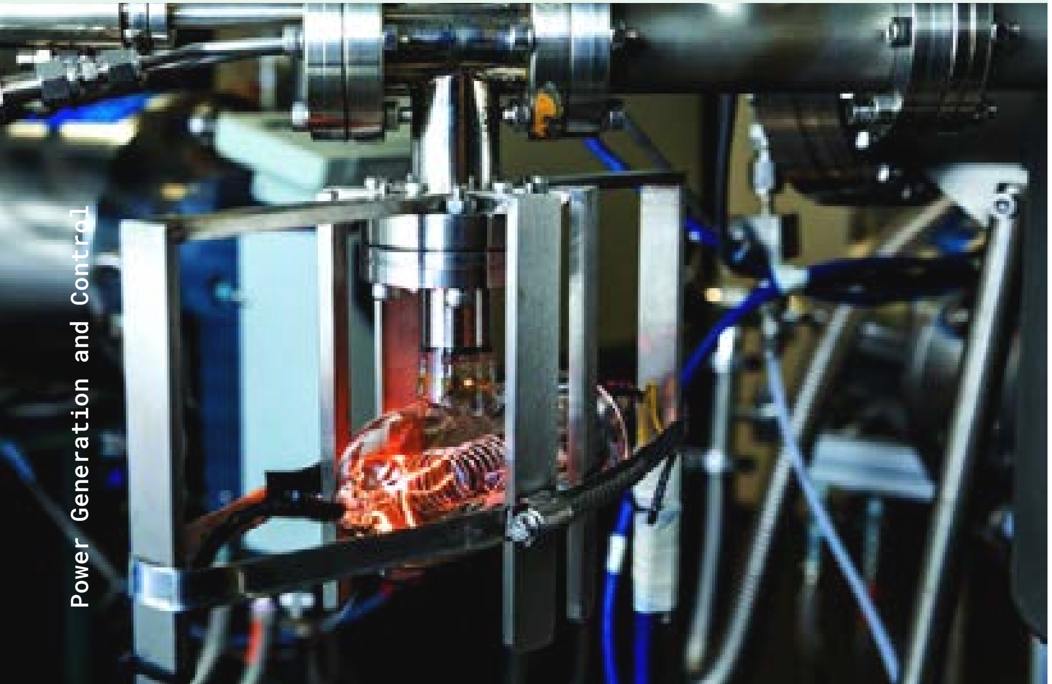
Electrically Conductive Nanocomposite Films

Synthesis of polymer nanoparticles with graphene oxide sheets via mini-emulsion polymerisation enabling electrically conductive films using an ambient temperature process. These films exhibit high electrical conductivity with a wide range of applications as conductive coatings.



Competitive advantage

- Technology represents first example of an approach for synthesis of electrically-conductive graphene/polymer films that form at ambient temperature
- Environmentally friendly process
- Amenable to industrial-scale applications

Impact

- Potential for advanced coatings and sensors with specified electrical, mechanical and barrier properties
- Such composite materials exhibit high performance, tailored mechanical and electrical properties. Applications of these materials include robust anti-corrosive coatings and barriers, supercapacitors and hardened electronics.

Capabilities and facilities

- Synthesis of polymer/graphene thin films with specified level of electrical conductivity
- Synthesis of hybrid polymer/graphene nanoparticles as hybrid materials
- Synthesis of polymer nanoparticles of various size, shape and internal morphology

More information

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Electrolytes and Thin Films for Solid-State Batteries

Responding to the need to safely supply more and more energy from batteries by developing solid-state batteries with wider operating temperature ranges, improved shock tolerance and increased energy density.

Competitive advantage

- New battery chemistries can be implemented for:
  - Higher charge density (Li-S)
  - Lower cost (sodium-ion, potassium-ion)
  - Inherent safety (solid-state).
- Environmentally friendly, inexpensive materials
- Facilities for construction of a variety of battery designs
- Full structural, spectroscopic and electrochemical characterisation, particularly synchrotron X-ray diffraction, to elucidate structure-property relationships at bulk & atomic scale
- At the forefront of work towards development of all-solid-state thin film batteries

Impact

- Understanding the role of grains and grain boundaries on bulk diffusion
- Evaluating the type of atomic-scale diffusion
- Linking structure to local and long-range diffusion
- Using in situ methods to elucidate phase evolution, degradation mechanisms
- Failure analysis

Capabilities and facilities

- Materials synthesis
- Pulse laser deposition growth of certain electrodes
- Access to key analytical techniques such as solid-state NMR, surface analysis and electron microscopy
- Developed a testing apparatus for the operando study of thin film batteries using synchrotron X-ray diffraction during operation
- Use of unconventional techniques such as quasi-elastic and inelastic neutron scattering

Our partners

- The French Alternative Energies and Atomic Energy Commission (CEA)

More information

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Highly-Efficient Thin Crystalline Silicon Solar Cells and Flexible Solar Modules

UNSW's School of Photovoltaic and Renewable Energy Engineering, a global centre of excellence in photovoltaic research, is leading the development of highly-efficient thin crystalline silicon solar cells and flexible solar modules.

Competitive advantage

- Unmatched expertise from over 30 years of world record breaking silicon solar cell development
- Advanced surface and contact passivation technology allows for high-efficiency thin silicon solar cells
- Crystalline silicon technology has proven reliability and longevity, and offers the best compromise between cost and efficiency
- Thin silicon solar cells are flexible, allowing for implementation in lightweight and foldable solar modules that can be used to charge equipment in the field or incorporated into other equipment

Impact

- Cheaper, silent and more efficient in-field power generation for personnel, minimising the need for batteries
- Reduced fuel requirements for deployments

Successful applications

- Solar Energy Research Facility (SERF) – an on-campus R&D pilot line for silicon wafer solar cells
- State-of-the-art labs for cutting edge academic research in silicon wafer fabrication and characterisation

More information

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Hybrid Battery Storage for Microgrids

Battery storage plays an important role in microgrids, improving grid reliability and resilience while facilitating effective operation of critical and frequency-sensitive loads. Battery storage is critical both for daily operation of a microgrid, as well as providing for grid redundancy in extreme events.

Competitive advantage

- A complete test bed and procedures for assessing battery storage performance under different grid events to:
  - Improve the reliability and resilience of grid supply using coordinated microgrid battery storage
  - Improve continuous supply to loads, balanced with reducing demand
  - Provide reliable and economical reserve

Impact

- More reliable and efficient microgrid performance

Successful applications

- Development of a hybrid portable mobile microgrid station system
- Microgrid planning software for urban and remote area
- Hybrid portable mobile microgrid station for Australian Defence Force – a project focussed on hybrid battery storage systems for mobile and reliable power supplies for remote operation activities

Capabilities and facilities

- Energy and power research group with industrial standard software
- Hardware-in-the-loop testing bed for energy storage systems with programmable grid simulations on real time digital simulators (RTDSs)

More information

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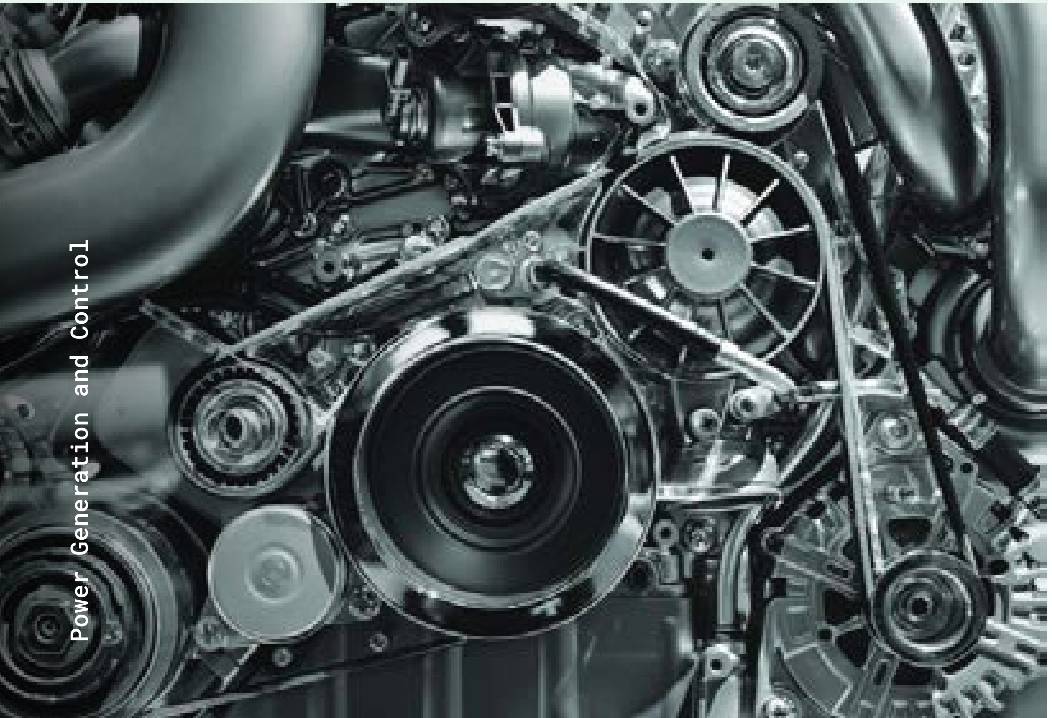
Optically Instrumented Compression-Ignition Engines

Enhancing and optimising propulsion systems for navy fleets, ground vehicles and unmanned aeroplanes capable of running on various fuel types, using optically-accessible compression ignition engines and laser-based two-dimensional imaging of the flames and pollutants inside.



Competitive advantage

- Readily available optical CI engines and laser-based imaging techniques/tools
- Full details of in-cylinder phenomena, not guess-and-check through trial-and-error tests
- Images and movies obtained from a running engine at realistic conditions and thus directly relevant to real-world applications

Impact

- Through flame visualisation and air pollution species imaging, fuel injection strategies required for specific fuel types are identified and tested for practical applications. The results achieve extended range and lower infrared signature

Successful applications

- In-cylinder soot distribution imaging of US Office of Naval Research Global's (ONRG)'s biodiesel fuelled CI engines
- Development of soot particle sampling technique for structural analysis in US Army's diesel engines
- Fundamental ignition process and high-temperature reaction visualised in US Army's multi-fuel capable CI engines for UAS propulsion

Capabilities and facilities

- Group 3 (55-1320 lb) and Group 4 (>1320 lbs) CI engines with full optical access
- Dye and Nd:YAG lasers, high-speed intensified CMOS camera, and intensified CCD camera
- Fully trained postdoctoral researchers and postgraduate research students

Our partners

- Vehicle Research Lab, Army Research Laboratory, USA
- US Office of Naval Research Global

More information

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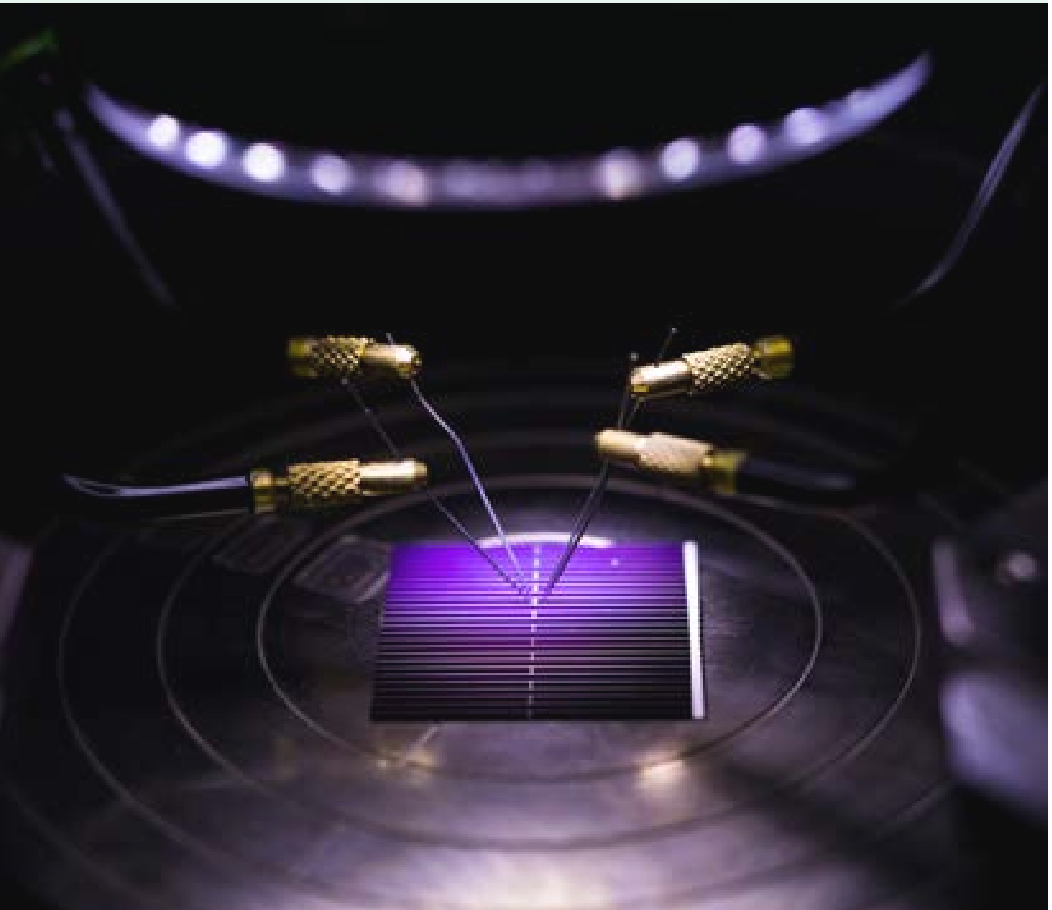
Photovoltaics

UNSW's School of Photovoltaic and Renewable Energy Engineering, a global centre of excellence in photovoltaic research, has over 40 years' experience in photovoltaic device development and metrology. Successful commercialisation of various solar cell architectures and enabling technologies for the photovoltaic industry.



Competitive advantage

- 200 experts in photovoltaic and renewable energy technology
- World-first degree in photovoltaics
- Proven track record in commercialising technologies
- Extensive alumni network, with many in senior industry leadership roles

Impact

- Solar cells across the rooftops of the world

Successful applications

- First 25.0% silicon solar cell more than a decade before others
- PERC solar cell structure developed at UNSW dominates the industry
- Current world-record holder for large area perovskite, CZTS, and one-sun system efficiency

Capabilities and facilities

- Solar Energy Research Facility (SERF) – an on-campus R&D pilot line for silicon wafer solar cells
- State-of-the-art labs for cutting edge academic research in silicon wafer, perovskite, CZTS, organic, and silicon-based tandem (including III-V) fabrication and characterisation

More information

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Space Photovoltaic Solar Cells

Next generation multi-junction solar cells for powering satellites and spacecraft.

Competitive advantage

- Semiconductor material and processes for solar cells with higher efficiency, lower weight and greater radiation tolerance
- Extensive knowledge of multi-junction solar cells and computer simulation capabilities, coupled with collaborations with space cell manufacturers, enables rapid prototyping of devices
- Patented technology for achieving ultra-radiation hard solar cells using interstitial light trapping

Impact

- Reduced weight and hence payload launch costs
- Radiation hardened solar cells for longer missions and/or resilience in high radiation orbits
- Enabling high altitude persistent UAVs

Successful applications

- Demonstrated the use of metal nanoparticles in space solar cells in collaboration, Azur Space GmbH
- Demonstrated the feasibility for achieving radiation hard space cells, Azur Space GmbH and European Space Agency
- Demonstrated the first triple junction solar cell using silicon-germanium-tin alloys, IQE PLC
- Developing ultra-radiation hard solar cells, US Naval Research Laboratory

Capabilities and facilities

- State-of-the-art labs for research in multijunction solar cell fabrication and characterisation
- Solar Energy Research Facility (SERF) – an on-campus R&D pilot line for silicon wafer solar cells

Our partners

- IQE PLC, UK.
- Naval Research Laboratory, USA

More information

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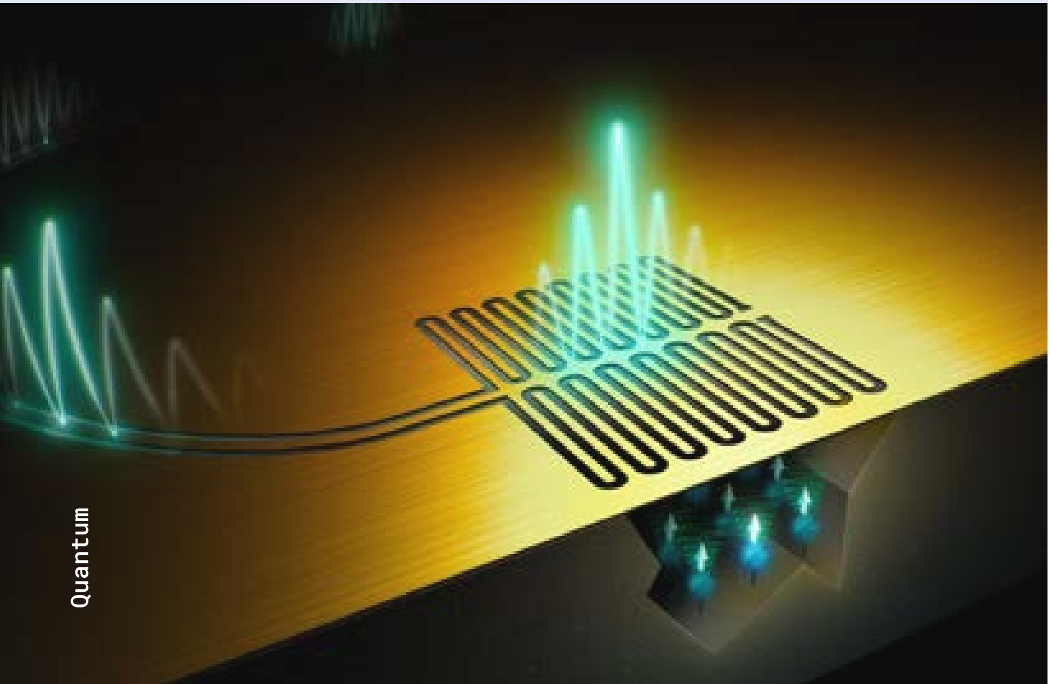
AUKUS Defence Research and Technology

Quantum

Microwave Quantum Technologies

Quantum technologies for low noise detection of microwaves at cryogenic and room temperatures. The low noise measurement of microwave signals is central to many advanced technologies, from satellite communication systems to radar and spectroscopy. Our lab is developing superconducting amplifiers that operate at the quantum noise limit and spin-based amplifiers that function under ambient conditions.



Competitive advantage

- Our quantum-limited microwave superconducting parametric amplifiers offer substantially greater power handling capabilities relative to other superconducting technologies
- We are developing room temperature near-quantum-noise-limited microwave amplifiers, a capability not currently available elsewhere
- Our amplifiers can be applied to precision timing and electromagnetic field sensing

Impact

- Considerable improvement to the signal to noise ratio of microwave signal measurements, leading to enhanced ranges in communication and radar
- Improved fidelity of quantum bit readout in semiconductor and superconductor-based quantum processors
- Enhanced sensitivity in spectroscopy applications, allowing detection of substances at lower concentrations

Successful applications

- We have applied our cryogenic quantum-limited amplifiers to electron spin resonance spectroscopy, greatly improving the spin detection sensitivity

Capabilities and facilities

- Facilities for performing microwave measurements at low temperatures (down 10 mK) and in high magnetic fields
- Capabilities for measurements at the single microwave photon level
- Room temperature optomagnetic facility for microwave quantum technologies operating under ambient conditions
- World-class nanofabrication facilities for the development of semiconducting and superconducting quantum devices

More information

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Multiscale Simulation of Quantum Materials & Devices

A world expert in quantum electronic simulation software development based on first principles and multi-scale techniques. The tools are aimed at guiding design and optimization of quantum technologies, post Moore's Law devices, and exploring applications of emerging materials.

Competitive advantage

- In-house atomistic simulation software capable of multi-million atom simulations
- Fully quantum mechanical description of electronic structure & current flow
- Integrated multi-physics & multi-scale capabilities: stress, electrostatics, lattice vibrations, spin dynamics, multi-electron correlation

Impact

- First-principles based computer aided design of solid-state qubits
- Modelling of material disorder in device operation
- Design of energy-efficient post Moore's Law devices

Successful applications

- Simulations helped to achieve long coherence and high-fidelity in silicon quantum computing devices
- Led to patented designs of nanoscale transistors for US Semiconductor Research Corporation
- Guided successful design of Quantum Hall interferometers in III-V material stack
- The simulation tools are used in leading semiconductor quantum computing groups worldwide, as well as in national laboratories and in industry

Capabilities and facilities

- Large database of semiconducting materials, including III-Vs, IVs, 2D materials, dopants
- High-performance user-friendly object-oriented platform in C++
- Unified materials to device simulation framework from 3D to low dimensional devices

Our partners

- Centre of Excellence for Quantum Computation & Communication Technology (CQC2T)
- Silicon Quantum Computing, Pty. Ltd. (SQC)
- Centre of Excellence in Future Low-Energy Electronics Technology (FLEET)

More information

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Quantum Communications in Space

Quantum communications via low earth orbit (LEO) satellites offer a paradigm shift. We develop and test state-of-the-art quantum communication protocols for space. Our systems provide ultra-high information security in satellite communications, allow for entanglement distribution for sensing applications, and are a major step forward in building the new quantum internet.

Competitive advantage

- World leaders in quantum communication via LEO satellites
- World-first satellite designs for combined classical and quantum communication
- World leaders in positioning-authentication protocols delivering true quantum advantage
- A large group of highly trained engineers in quantum communication – knowledgeable across all theoretical and deployment aspects of space-based quantum technologies

Impact

- Delivery of free space quantum communication systems
- Foundational elements delivered for the next-generation global quantum internet
- Foundational patented technology in location verification via quantum communications

Successful applications

- Space-based quantum sensing and processing
- Quantum key distribution for satellites
- Global entanglement distribution
- Capabilities and facilities
- State-of-the-art quantum communication testbed and laboratories for free space quantum communications

Our partners

- Northrop Grumman

More information

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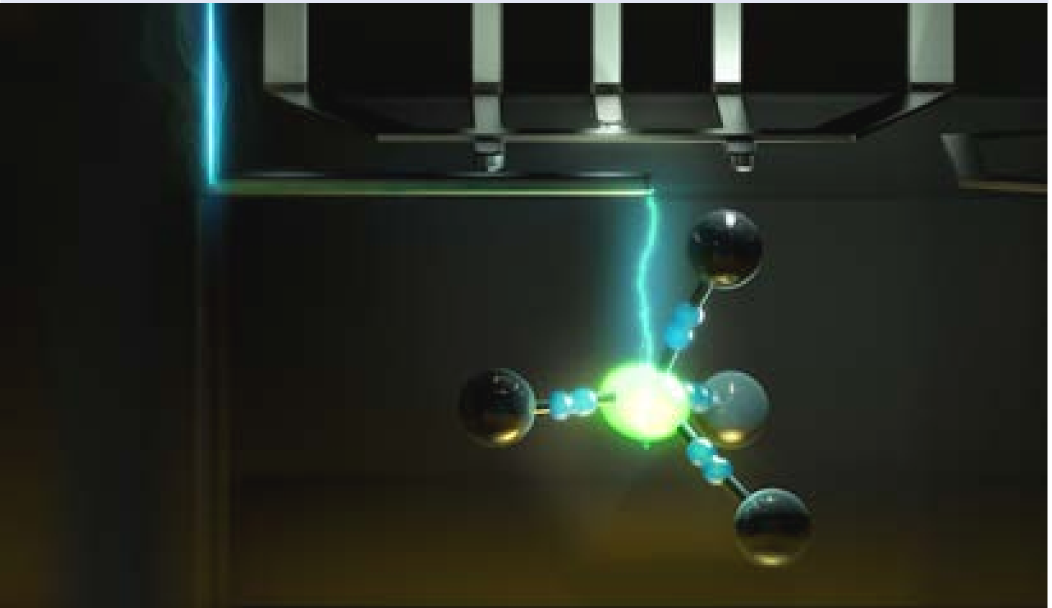
Quantum Computing with High-Spin Atoms

Quantum computers are expected to drastically impact data security, logistics and optimisation problems. The power of a quantum computer depends upon the number of quantum states available for data encoding. We are developing a unique platform that uses high-spin atoms to encode quantum data with unprecedented density.



Competitive advantage

- The first in the world to have demonstrated quantum information processing using single high-spin atoms in silicon
- Each atom contains the equivalent of four quantum bits of information. Atom arrays can be spaced with a pitch of only tens of nanometres, yielding unprecedented density of quantum information storage

Impact

- Quantum computers have significant applications in data security and as nodes for secure quantum communication channels
- High information density simplifies the construction of a fault-tolerant quantum computer capable of real applications
- Access to a fault-tolerant quantum computer, especially if built using silicon manufacturing, will be a key strategic capability in the next decades

Capabilities and facilities

- Leading silicon nanofabrication facilities via the UNSW node of ANFF, and unmatched in-house expertise
- Extensive platforms for quantum measurements in ultra-low temperature, high-frequency, low-noise environment
- International network of partners with access to state-of-the-art theoretical and computational facilities

Our partners

- U.S. Army Research Office
- DSTG
- Sandia National Laboratories
- HRL Laboratories, LLC

More information

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Quantum Materials:

Nanoscale Characterisation of Magnetic and Multiferroic Correlated Electron Systems

Our group performs research in materials physics of complex oxide materials with correlated electron systems (quantum materials), especially fundamental nanoscale electronic, optical and magnetic properties of interfaces and topological structures, with an experimental focus on advanced scanning probe microscopy techniques, including instrument and methods development.

Competitive advantage

- Home-built scanning probe microscopy (SPM) instrumentation capability not available commercially
- Advanced nanoscale characterization not available commercially
- Pioneering work into functionality of topological defects in quantum materials for nanoelectronics

Impact

- Specialized nanoscale characterisation of magnetic, multiferoic and quantum materials

Successful applications

- Consulting and contract research for Intel Corporation, US Office of Naval Research Multiferroic Materials Program, Silanna Pty Ltd., BluGlass Ltd.

Capabilities and facilities

- Australia's only dedicated advanced scanning probe microscopy laboratory
- In-house instrument and capability development
- 7 instruments with wide measurement parameter sample space (temperatures from 4K to 600K, magnetic fields up to 9T, UHV and specific gas environments, in-situ light illumination, variable humidity environment, in-situ tensile and compressive bending stages for nanoscale measurements)
- Group provides and develops unique materials characterisation techniques to design new energy materials and materials for low-energy electronics
- We have > 20 years of experience and a track record locally and internationally

Our partners

- Intel Corporation
- US Office of Naval Research
- Silanna Pty Ltd.
- BluGlass Ltd.

More information

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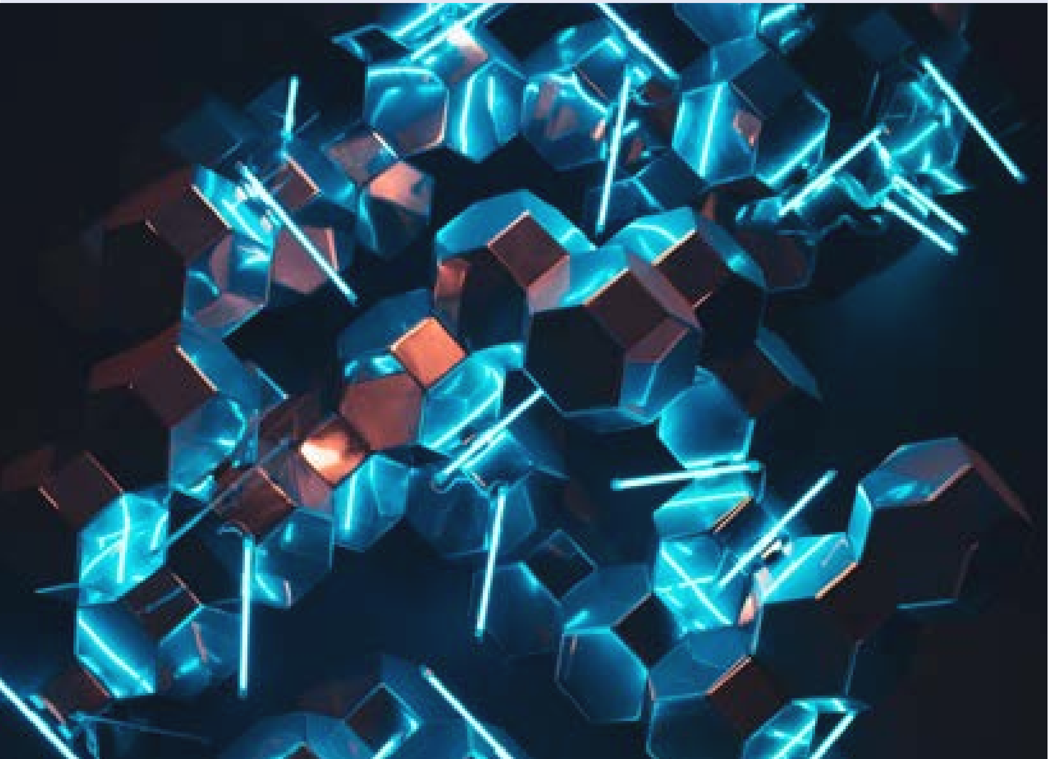
Quantum Sensing with Silicon Chips

The inherent fragility of quantum systems can be exploited to develop advanced sensors for feeble electric and magnetic fields. We are extending our world-leading silicon-based quantum computer technology to demonstrate quantum sensors integrated within a silicon nanoelectronic device.



Competitive advantage

- The first in the world to demonstrate a quantum bit in silicon, using the spin of a single atom, introduced in the chip via an industry-standard technology
- Quantum bits that hold the record of quantum memory time, which translates into a record sensitivity to perturbing electromagnetic fields

Impact

- Sensors are a key technological component of defence systems
- Having quantum sensors within silicon chips could greatly facilitate the integration with other functionalities

Capabilities and facilities

- Leading silicon nanofabrication facilities via the UNSW node of ANFF, and unmatched in-house expertise
- Extensive platforms for quantum measurements in ultra-low temperature, high-frequency, low-noise environment
- International network of partners with access to state-of-the-art theoretical and computational facilities

More information

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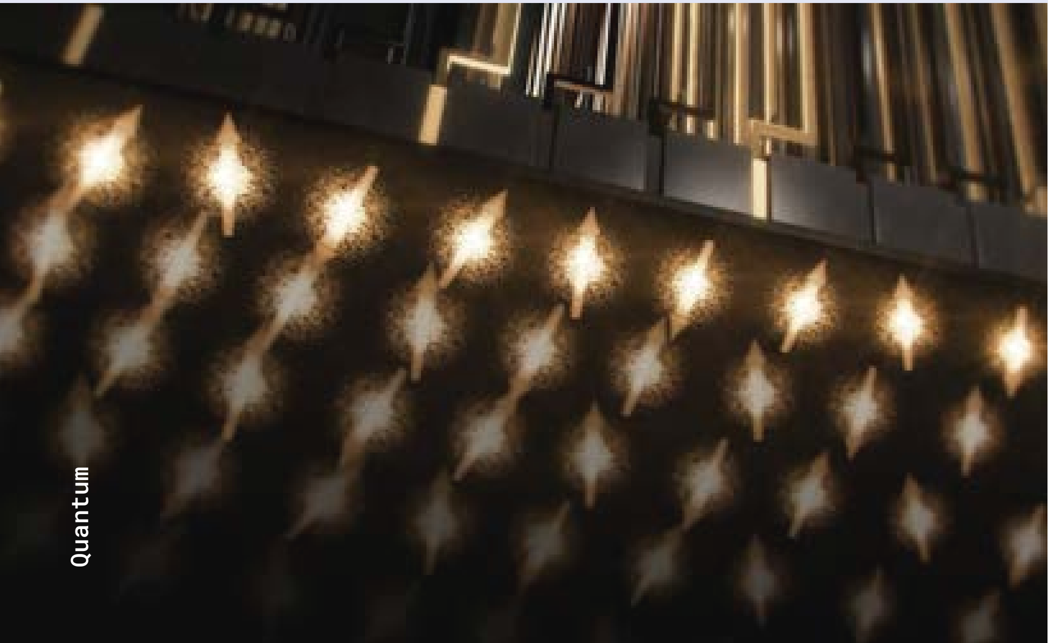
Scalable CMOS Quantum Dot Quantum Processor Technology

Building quantum computing hardware using silicon CMOS compatible processes enables a pathway towards fault-tolerant, universal quantum computing. Leveraging the silicon CMOS industry investment and capabilities provides a means to scale CMOS quantum dot devices to the billions of quantum bits needed to solve challenges of national interest and global significance.



Competitive advantage

- First in the world to demonstrate one- and two-qubit operation in a silicon quantum device using the spin of a single electron in a CMOS quantum dot
- Peer-reviewed architecture for a full-scale quantum processor capable of reaching the billions of quantum bits required for fault-tolerant, universal quantum information processing
- CMOS compatibility allows for integration of control electronics with the quantum processor into a single platform

Impact

- Applications across many sectors including materials research, drug design and optimisation become feasible with the billions of qubits possible using the very large-scale integration of CMOS qubits
- Proven defence and national security applications such as in cryptography become possible with the scale of quantum processor achievable with CMOS compatible qubits

Capabilities and facilities

- Expertise in silicon process development and leading silicon fabrication facilities through the UNSW node of the Australian National Fabrication Facility (ANFF)
- Well-established, low-noise cryogenic measurement platforms for measurement of quantum devices at ultra-low temperatures

Our partners

- Diraq Pty Ltd

More information

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Tailored Quantum Computing Solutions

Providing access to and co-development of bespoke quantum processors for problems in simulation, optimisation and machine learning. High-quality processors based on atom qubits in silicon are manufactured in house using globally leading, high precision proprietary technology.

Competitive advantage

- Uniquely positioned to deliver tailored, high-quality quantum computing solutions to clients
- World's most precise atom-scale qubit fabrication, with the fastest 2-qubit gate in silicon processors, lowest charge noise and high fidelity, fast qubit read-out provide high quality, fast and stable quantum processors
- With our full stack quantum computing team, we can design, manufacture and operate our qubits in house based on the mapping of targeted solutions by our algorithms team

Impact

- Co-development of quantum computing solutions to your needs based on globally leading, competitive technology
- First mover advantage on upcoming disruptive technology relative to competing entities
- Assessment of when quantum computing will impact your industry

Successful applications

- World's first integrated circuit manufactured at the atomic scale
- Using this processor, we have demonstrated the ability to accurately model the quantum states of a small, organic polyacetylene molecule – definitively proving the validity of the company's technology for modelling quantum systems

Capabilities and facilities

- Globally unique end-to-end atom-scale manufacturing capability in house to design and build bespoke processors
- Full-stack quantum computing team in-house for high-quality system-wide processor integration and operation
- Algorithm team to identify and map problems to our processors

Our partners

- Silicon Quantum Computing
- Silex Systems Pty Limited
- Centre of Excellence for Quantum Computation and Communication Technology
- US Army Research Office
- Commonwealth Bank of Australia
- Telstra

More information

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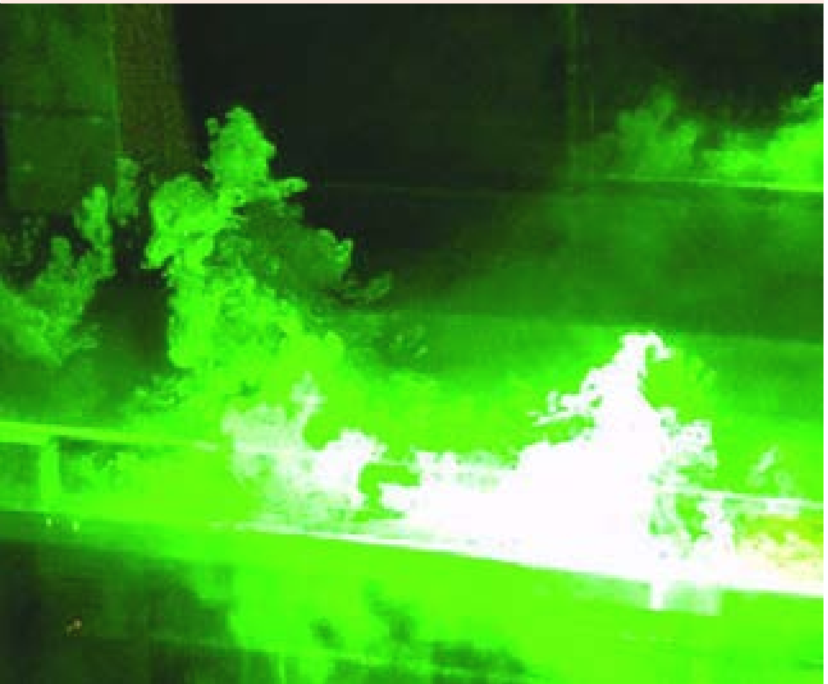
AUKUS Defence Research and Technology

Sensors

Advanced Flow Diagnostics for Turbulent Flow Studies

The development and application of laser-based flow diagnostics in a variety of environments from microfluidics to large-scale wind-tunnel testing.



Competitive advantage

- Novel flow measurement capability to capture fully-resolved
- Three-dimensional flows using image-based techniques, spanning from micron-resolution measurements for microfluidic devices to large-scale wind-tunnel testing of rapid-prototype models
- Ability to capture aeroacoustics using a state-of-the-art anechoic wind-tunnel facility and to probe supersonic flows in a dedicated supersonic wind-tunnel facility

Impact

- Projects in microfluidics and biofluids have impact through improvements in public health, biotechnology and renewable energy technology. Examples include the design and testing of lab-on-chip devices and 3D flow measurement in patient-specific vascular flows
- High-resolution flow measurements in large-scale wind-tunnel facilities have led to societal benefits such as energy savings and reduced emissions through improved aerodynamic efficiency, better design optimisation and flow modelling capabilities. In particular, the development of measurement diagnostics to directly measure wall-shear stress (drag) over complex geometries from experiments

Successful applications

- Developed flow diagnostics, with accuracy beyond current industrial practices, which have been employed to examine turbulent flows in large-scale engineered transport systems (wall-turbulence), urban environments (scaled atmospheric boundary layer conditions) and micron-scaled biofluidic flows

Capabilities and facilities

- Large recirculating wind-tunnel facility for testing at speeds up to 50 m/s with a cross-sectional area of 1.2m x 1m
- Dedicated anechoic wind tunnel facility with simultaneous flow diagnostics
- Supersonic wind-tunnel facility
- Inverted epifluorescent microscopes with laser-based flow diagnostic systems
- Multiple laser-based flow diagnostic lasers and high-speed/high-resolution cameras for wind tunnel testing

Our partners

- Defence Science and Technology (DST)
- LaVision (Germany)

More information

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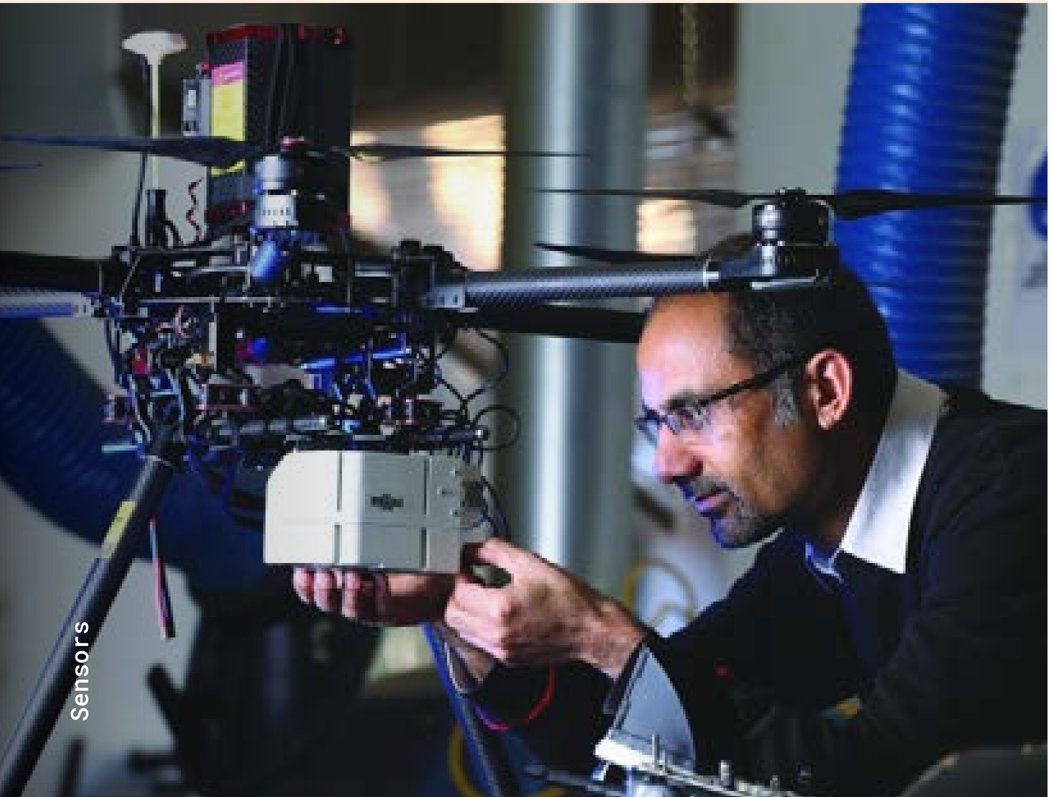
Advanced Sensing Systems

Advanced sensing systems provide an integrated solution for environmental and safety monitoring across a range of industries, including mining, defence, agriculture, forestry, food processing and health.



Competitive advantage

- Expertise in design of application-specific sensor hardware, data acquisition using various platforms including satellites and drones, and customised algorithms to convert the data into solutions
- Environmental monitoring expertise in challenging environments – remote water quality, sensitive ecosystem health, remote monitoring for temperature, pressure, gases etc
- Safety monitoring expertise, including structural deformation, hazardous spillage detection, in situ sampling and warning systems
- Expertise in machine vision – real-time object tracking, target recognition, resolving patterns, image enhancements, and 2D- and 3D-mapping

Impact

- Improved environmental sensing and safety management

Successful applications

- A drone-based scanning system for mapping structural parameters of pit walls, Glendell coal mine, Glencore
- Drone generated spatial data processing software, Agronomeye
- Drone based hyperspectral mapping system to monitor sensitive swamp vegetation, Russel Vale colliery, WCL
- Remote water sampling using drones, Glendell coal mine, Glencore
- Thermal hotspot mapping using drones, Ulan Coal mine

More information

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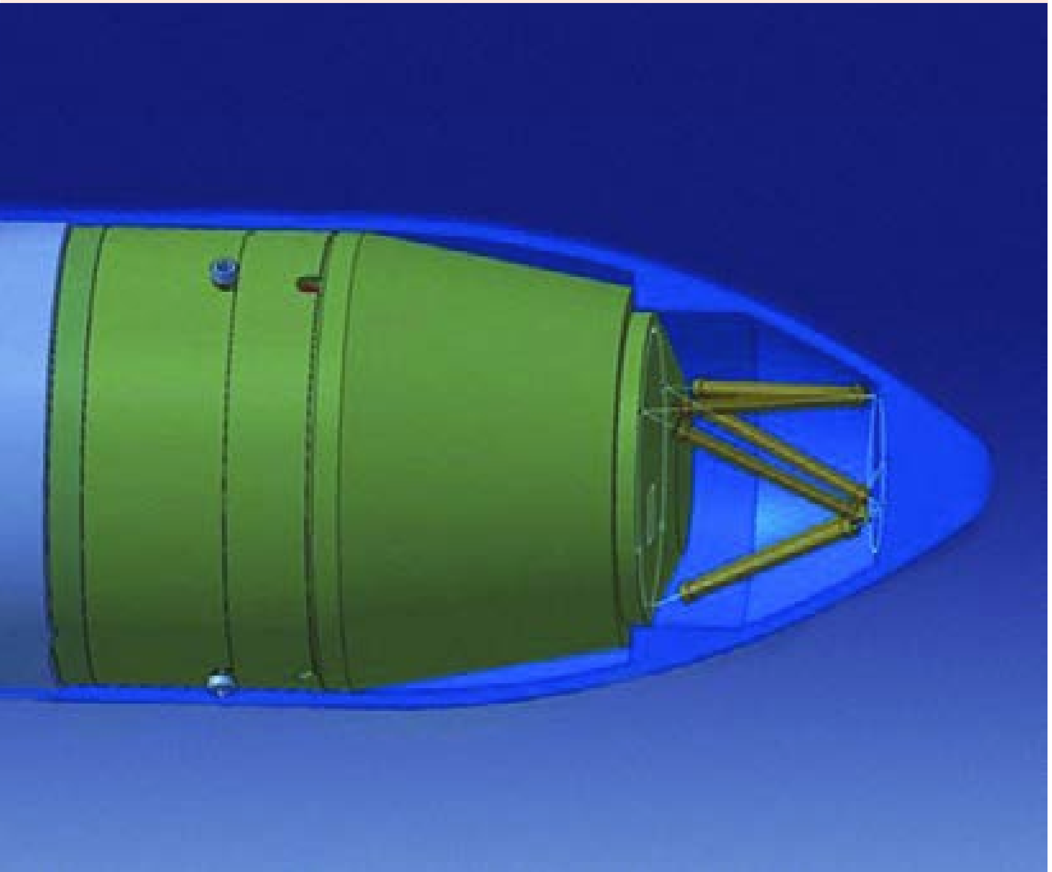
Ground Penetrator Probes

Penetrator probes dropped from a height can quickly deliver seismic monitoring and other geophysical equipment to the subsurface.



Competitive advantage

- Expertise in ground penetrator probes. These offer a number of key advantages, including:
  - Can be delivered via airplane, helicopter or UAV
  - Can be used to quickly build up monitoring networks in remote areas
  - Able to withstand impacts at up to several hundred metres per second
  - Can contain multiple geophysical, geological and other sensing payloads
  - Accelerometer on impact measures depth of penetration and identifies sediment layers, and
  - Able to communicate with base station using radio

Impact

- More rapid and cost-effective geophysical monitoring and sensor networks, including remote deployment

Capabilities and facilities

- Mining Geomechanics Laboratory
- Advanced Visualisation and Interaction Environment

Our partners

- Jet Propulsion Laboratory Caltech
- NASA

More information

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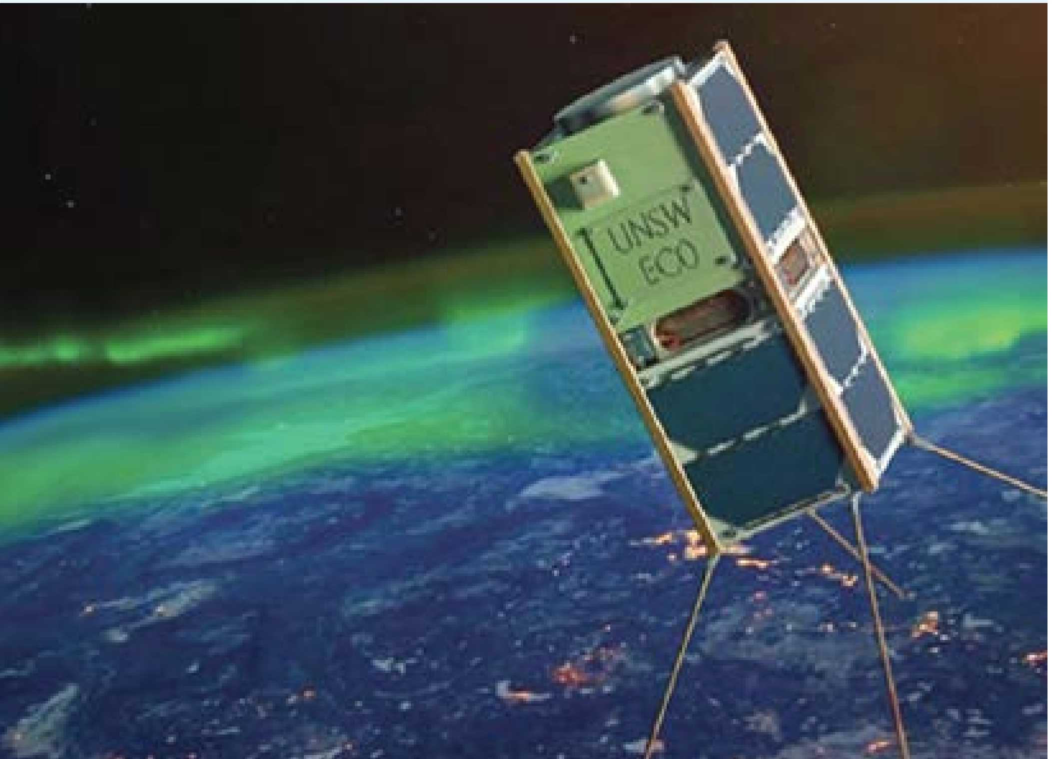
AUKUS Defence Research and Technology

Space

Australian Centre for Space Engineering Research (ACSER)

Launched in 2010, Australian Centre for Space Engineering Research (ACSER) develops space capabilities relevant to the nation's needs through research, innovation and education. ACSER builds and operates its own satellites and spins out technology to industry.



Competitive advantage

- Receiver design for global navigation satellite systems (GNSS)
- Earth observation satellite systems
- CubeSat development
- GNSS remote observation research and space resource utilisation
- Extensive stratospheric balloon experience
- Four experiments on the UNSW-EC0 CubeSat
- Internationally recognised research in off-earth mining

Impact

- Better satellite communication and navigation
- Technology commercialisation opportunities for industry

Successful applications

- Phase 0 of a synthetic aperture radar satellite system (Garada) that can map Australia for soil moisture every three days at 10 m resolution
- UAVs and their applications to develop Global Positioning System (GPS) reflectometry as a new method of remote sensing
- Built and successfully launched two Australian satellites in 2017
- Two models of Global Positioning System (GPS) receiver on-orbit
- Founded Delta V – space business accelerator
- New remote sensing technology: GNSS reflectometry, for Un-crewed Aerial Vehicles (UAV), High Altitude Platform Station (HAPS) and satellite platforms

Capabilities and facilities

- Laboratory facilities suitable for significant testing of CubeSats, including thermal vacuum chamber
- Satellite simulators for satellite navigation

Our partners

- Australian Space Research Program
- Seaskip
- Defence Materiel Technology Centre

More information

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Satellite Navigation and Positioning (SNAP) Laboratory

The SNAP Laboratory has led Australian research in satellite navigation for more than 20 years.

Competitive advantage

- Global Navigation Satellite System (GNSS) receiver design and signal processing capabilities, including:
  - Multi-GNSS receivers
  - Interference and spoofing
  - GNSS remote sensing (reflectometry and radio occultation)
  - Precise positioning algorithms
  - Multi-sensor navigation, and the application of navigation technologies for transport
  - Machine automation and unmanned aerial vehicles (UAVs)
  - Satellite missions

Impact

- Improved precision and robustness of satellite and UAV navigation

Successful applications

- Synthetic aperture radar formation flying, Australian Space Research Program
- Unmanned aerial vehicles and their applications
- Improved detection of interference sources affecting Global Positioning Systems GPS and capability and technology demonstrator (CTD)
- Mapping radar for CubeSats
- Successfully commercialised product for geolocating GNSS jammers
- Company spun off to use reflectometry for sea state, target detection

Capabilities and facilities

- Hardware and software test facilities, including GNSS simulators and field-programmable gate array (FPGA) development tools
- GNSS receivers and other navigation sensor technologies
- Access to a wide variety of UAVs

Our partners

- Defence Science and Technology (DST)
- Australian Research Council Training Centre for CubeSats
- Defence Materials and Technology Centre (DMTC)

More information

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Space Situational Awareness

Novel solutions to Space Situational Awareness (SSA) problems by combining cutting-edge approaches to machine learning within a multidisciplinary space physics, surveillance, astrodynamics and engineering team.

Competitive advantage

- Research strength in the field of ionospheric aerodynamic modelling
- Ability to combine high-fidelity numerical simulations with real-world data and machine learning approaches
- On-orbit small satellite capability and unique ground-based space environment simulation facilities to support benchmark quality SSA experiments

Impact

- Space mission experience that quantifies the impact of astrodynamics on spacecraft in Low Earth Orbits (LEO)
- Contributing to increased knowledge and preparedness within Defence regarding critical challenges relating to SSA

Successful applications

- Optical and numerical SSA techniques to the Buccaneer Risk Mitigation Mission spacecraft
- Aero-assisted formation control strategies for the Royal Australian Air Force (RAAF) M2 dual satellite program
- Multiple US Air Force Office of Scientific Research (AFOSR) grants for ionospheric aerodynamic research to enable improved orbital control of LEO spacecraft
- Imaging the deployment of the Planet Flock 3p (the largest number of satellites launched on a single rocket in history) two hours after launch

Capabilities and facilities

- Falcon Telescope Network node
- 0.3m Meade telescope
- Comprehensive space environment simulation laboratory
- Research lab with satellite wind tunnel and small thermal vacuum facility
- Dedicated flight assembly areas, plus assembly, integration and testing (AIT) expertise
- Australian National Concurrent Design Facility which is a national asset for developing space missions

Our partners

- Royal Australia Air Force
- Department of Defence Science and Technology (DST)
- The Air Force Office of Scientific Research

More information

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AUKUS Defence Research and Technology

Undersea Warfare

Advanced Piezoelectrics for Underwater SONAR Applications

Piezoelectric materials are the active components of underwater SONAR system. These materials directly convert acoustic energy into electrical signals for detection and conversely are used to convert electrical signals into underwater acoustic pulses. Their properties dictate the achievable capabilities of a given SONAR system.

Competitive advantage

- World-leading research program in piezoelectric materials characterisation
- Extensive instrumentation for unique and industry applicable piezoelectric material structure and property measurements
- Connections to world-leading groups in piezoelectric materials development for SONAR applications

Impact

- Research in piezoelectric characterisation guides materials fabrication and compositional optimisation
- Advises industry on best material processing conditions for maximising electro-mechanical output and component lifetime

Successful applications

- Contributed to the development of polycrystalline and single crystalline piezoelectric materials for device fabrication
- Novel testing methods and resulting property values guide device engineers in optimal system design

Capabilities and facilities

- Broad range of piezoelectric materials testing capabilities across applicable environmental ranges for underwater SONAR systems
- Novel in-situ structural characterisation equipment to accelerate the material development cycle

Our partners

- Defences Science and Technology Group
- Defence Materials Technology Centre
- Thales Underwater Systems
- US Naval Research Laboratories
- US Office of Naval Research Global

More information

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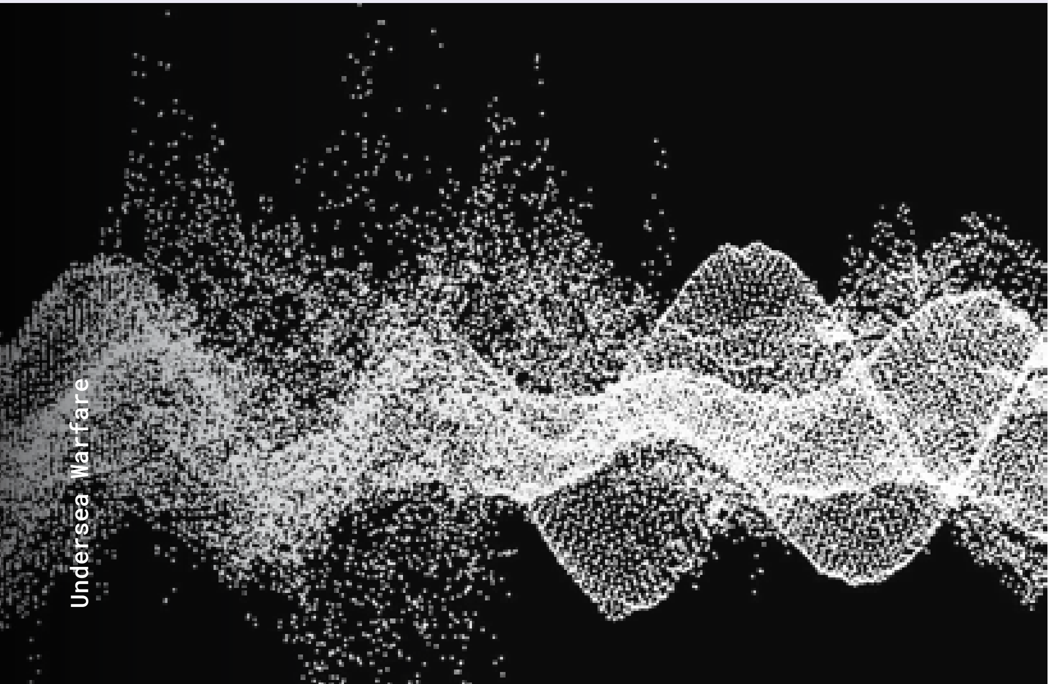
Flow-Induced Noise Prediction, Measurement and Control

Flow-Induced Noise (also known as aeroacoustics and hydroacoustics) is created as air and marine vehicles move, creating a unique acoustic signature. The Flow Noise Group has world-leading experimental and numerical methods that can diagnose noise control problems. Our unique expertise also provides innovative flow-noise control solutions.



Competitive advantage

- World experts in aeroacoustics/ hydroacoustics
- Unique experimental and numerical flow-induced noise capability
- Innovative noise control technology for air and maritime platforms

Impact

- Improved stealth capability
- Reduced signature detection
- Ability to diagnose and control flow noise problems
- Improved assessment of future platforms

Successful applications

- Aeroacoustic measurement capability for Defence wind tunnel
- Hydroacoustic measurement capability for Defence applications
- Development of quiet rotor blades, airfoils, drones and turbines
- Multiple Defence/Industry engagements to identify, isolate and control flow noise

Capabilities and facilities

- World-class aeroacoustic wind tunnel
- Highly accurate acoustic array technology
- Laser-based turbulence measurement systems
- World-leading numerical simulation expertise
- Noise control design

Our partners

- DSTG
- ResMed
- Cochlear
- Daikin
- Dotterel (Drones)
- SETI
- Bradken
- Minetek

More information

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Maritime Security in the Indo-Pacific

The Maritime Security Research Group (MSRG) draws together a unique team of interdisciplinary scholars focussed on security within the maritime domain. MSRG takes a broad approach to maritime security, one encompassing not only traditional hard security concerns but also human security, maritime crime and the 'blue economy'. Current projects include strategic competition and the South China Sea disputes, non-traditional security threats and wider issues of sea power and lawfare.

Competitive advantage

- Understanding of the contemporary maritime security environment in the Indo-Pacific

Impact

- We hold an annual round table for stakeholders on emerging issues. The 2021 roundtable "China in the Maritime Pacific", for example, attracted 100 participants over three days from governments, think tanks and academia

Successful applications

- Our capability has been recognised in a series of external grants and projects for research into areas such as strategic law of the sea litigation by small states against great powers

Capabilities and facilities

- Our group has a unique combination of expertise across international law, history, strategy, naval affairs and a range of Indo-Pacific regional perspectives

Our partners

- We collaborate extensively with a range of other universities embedded in military academies worldwide, as well as hubs of expertise at UNSW Sydney

More information

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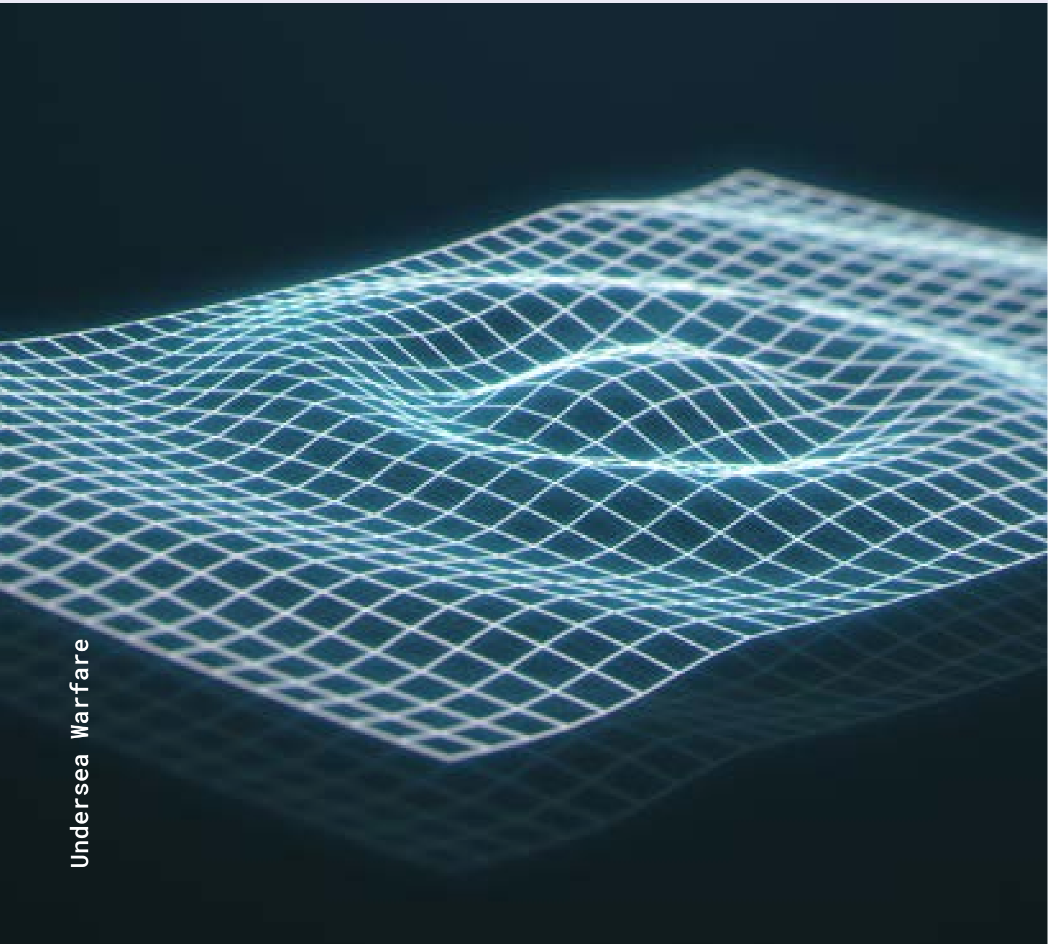
Multi-Optrode Arrays (MOAs)

Development and biological assessment of optical-electrode ('optrode') transducers for recording electrical activity in the body



Undersea Warfare

Competitive advantage

- Multi-disciplinary team working at the interface of biology and engineering
- A patent portfolio covering industrial and biomedical aspects of technology

Impact

- MOAs will lead to the next generation of brain-computer interfaces and enable high-density, high channel count recording from neural and cardiac tissue with applications for brain-machine interfacing, prostheses and cardiac diagnostic systems
- MOAs can also be applied in acoustic sensing networks and used for ocean monitoring (distributed sonars), mineral prospection (geoseismic exploration) and environmental protection (leak detection in water distribution networks)

Successful applications

- Demonstrated ability to map electrical activation in hearts in animal models
- Demonstrated ability to record peripheral nerve responses in animal models

Capabilities and facilities

- Biomedical microfabrication facility
- A range of electrophysiology, animal surgery, and microscopy setups for biological assessment of technology
- Access to engineers and infrastructure at the Australian National Fabrication Facility

Our partners

- Zedelef Ltd

More information

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Optical Sensing Networks

Optical solutions for industrial and biomedical sensing applications. These include monitoring under hazardous conditions such as those found in petrochemical plants, mines and food processing environments, and monitoring and imaging of neuronal activities in biological tissues such as those found in the brain, retina and muscle.

Competitive advantage

- Breakthrough optoelectronic transducers capable of optically reading the output of standard electronic sensors and transmitting via optical fibre for processing.
- Ferro-electric liquid crystals can be used to detect neural activities in biological tissues, providing a means to develop the next generation of brain-machine interfaces. They also form the basis of a new class of monolithic integrated Q-switch lasers.

Impact

- New and safer sensing

Successful applications

- Zedelef – spinoff company created to commercialise research outcomes
- A new high performance optical telemetry system for ocean monitoring
- Currently commercialising two patented technologies: brain machine interface and integrated monolithic Q-switched lasers

Capabilities and facilities

- Two photonics labs for characterisation and materials
- The Australian National Fabrication Facility (ANFF)

More information

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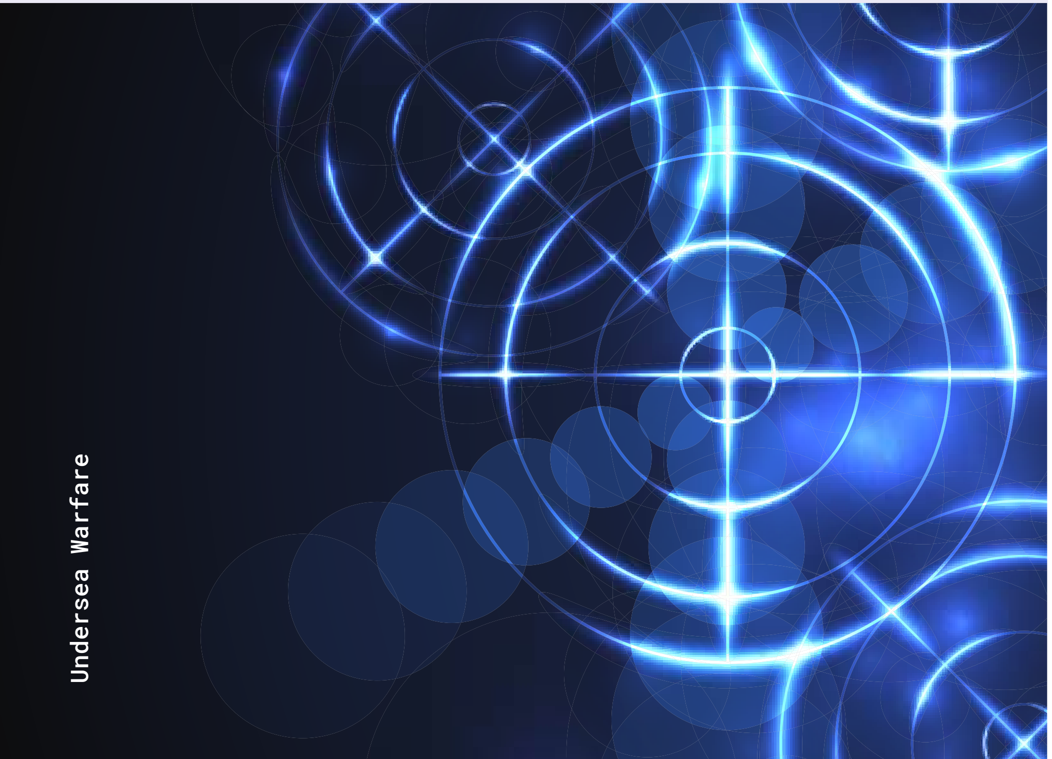
Optical Towed-Array Sonars

The security of coastlines can be greatly enhanced using sonar arrays including those towed by autonomous marine drones. This technology produces low-cost, robust, lightweight and power-efficient towed-array sonars based on optical sensing technologies developed in collaboration with industry partners.



Competitive advantage

- There is a trend towards the use of marine drones to supplement crewed vessels. Central to the viability of this is the development of towed-array sonars suitable for autonomous drones.
  - Patented optical technology based on liquid-crystal transducers has been developed with industry partners. Liquid-crystal transducers translate analogue electrical signals into optical signals passively and linearly
  - It is possible to read optically the output of virtually any sensor (e.g. microphone or hydrophone) and transmit its output over optical fibre, leveraging the advantages of optical networks
  - Cheap, robust, lightweight and very power efficient technology

Impact

- Better coastal security

Successful applications

- Solutions for the mining industry, Ampcontrol, Ocean monitoring, Thales, Industrial monitoring and Schneider Electric

Capabilities and facilities

- UNSW has world class fabrication and characterization facilities related to integrated optics and photonics
- Access to the world-class Australian National Fabrication Facilities (ANFF)

Our partners

- Thales Underwater Systems
- Zedelef Pty Limited

More information

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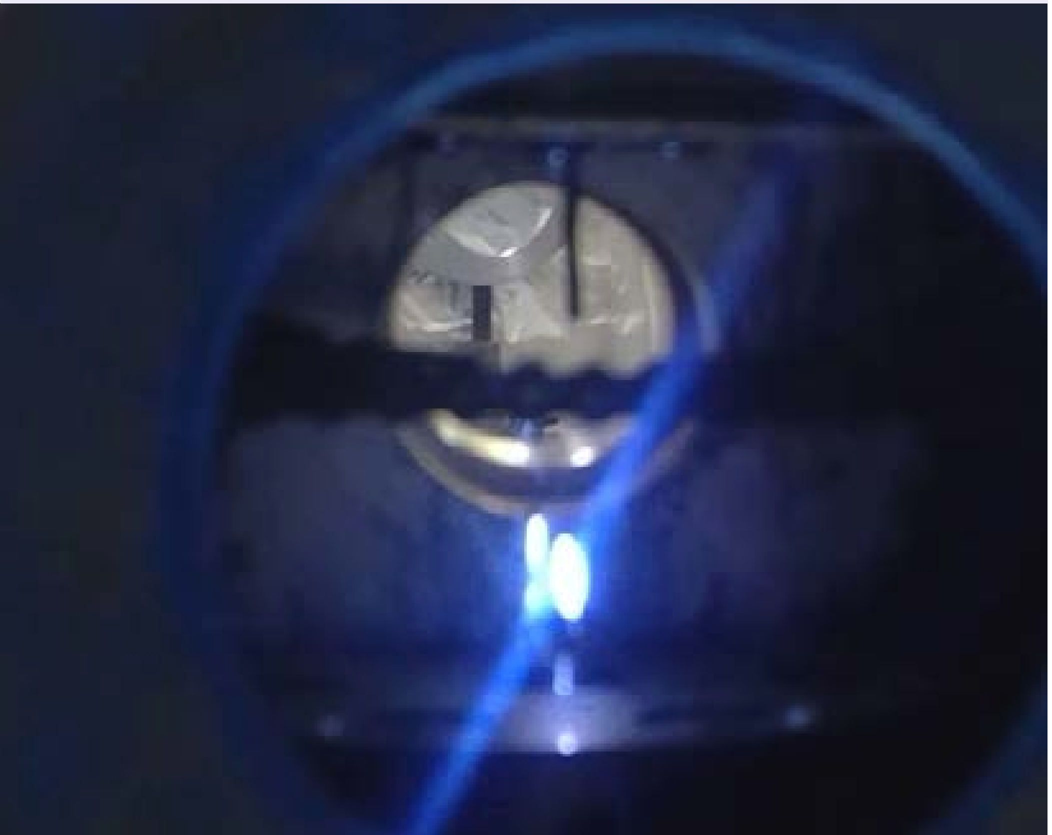
Underwater Blast Wave Facility

A facility for the study of blast waves at high ambient pressures. Combined with high-speed visualisation, this is unique facility can investigate the fundamentals of blast waves.



Competitive advantage

- Operates at pressures in excess of 200 bar with full optical access – highest pressure facility in the world with optical access
- Laser generated blast waves allow study of high-pressure cavitation

Impact

- Study of the behaviour of blast waves at depth
- Investigation of the effects of blast on human/animal tissue
- Study of medical blast wave applications such as shock wave lithotripsy

Successful applications

- Has been used to study the macroscopic and microscopic effects of blast waves on meat tissue

Capabilities and facilities

- High-speed visualisation of underwater blast wave effects
- Developed a robust optical shock wave hydrophone with sub-microsecond response times

Our partners

- Australian Meat Processing Corporation

More information

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AUKUS Defence Research and Technology

Our Centres and Facilities

Quantum

Autonomous Vehicles Laboratory – CBR

This laboratory contains a range of unmanned aerial vehicles and wheeled platforms for the development and testing of autonomous robotic systems.

Creative Robotics Lab – SYD

The Creative Robotics Lab is a cross-disciplinary research environment dedicated to understanding how humans can interact with three-dimensional robotic agents and responsive structures within the context of experimental arts and social robotics. The inhomogeneous nature of cross-disciplinary research demands dedicated spaces that provide appropriate technological infrastructure and a nurturing intellectual environment that encourages experimentation and appreciates the value of unpredictable outcomes. The lab has diverse expertise in sensing, perception, artificial intelligence and real-time systems, together with a long track record of fully engaged collaboration between media, arts and robotics.

EPIcentre – SYD

EPICentre (Expanded Perception & Interaction Centre) is a shared UNSW research centre undertaking visualisation research in the fields of art, design, science, medicine and engineering. The most advanced facility of its kind, EPIcentre represents the next generation in medical imaging technologies, engineering, high-performance visualisation, simulations and applied artificial intelligence. Incorporating an array interactive 3D environments, it enables researchers to simulate experiences such as dementia, psychosis, memory loss and other neurological conditions, providing a powerful way of understanding the experience of sufferers, through immersion in the condition. EPICentre allows, cross-connecting visualisation with applied computational simulation science, artificial intelligence, and creativity in arts and science. It also hosts modern Mixed Reality lab (XR-LAB), where visualisations are being deployed across VR, AR, hemispherical projections and upcoming multi-touch walls.

Indoor Robotics Test Facility – CBR

A large netted area fitted with a VICON motion capture system (MCS) allows indoor testing of drones and other robots, as well as human motion studies, sensor calibrations etc. The facility is mainly used for closed loop testing of guidance algorithms for small unmanned aerial vehicles. The MCS provides full 6DOF motion monitoring with sub-millimetre accuracy at up to 200Hz update rates.

Model Aircraft Laboratory – CBR

This lab consists of radio-controlled aircraft manufacture and maintenance facilities for the study of aircraft guidance, stability and control, particularly in relation to uninhabited aerial vehicle research. Radio controlled RMax helicopter platform and support equipment for field trials of autonomous UAV experiments.

Trusted Autonomy Laboratory (TAL) – CBR

TAL is a facility to enable R&D in Trusted Autonomous Systems. The facility contains a number of robots and allows the conduct of human-machine teaming research and experiments. It is equipped with a continuous audio-video capture system through four cameras and four microphones, two fixed eye trackers, one head-mounted eye tracker, two ECG, three EEG, two 2kx2k displays, two smart boards, and different type of sensors and human-machine interaction devices. The facility is surrounded by touch screens including two large plasma touch screens and a number of computer workstations with different network configurations. The laboratory has licenses for a range of cognitive and data analysis software.

UNSW Data Science Hub (uDASH) – SYD

The facility has access to Australia's fastest array of supercomputers. Simulations that can take days on high end office machines may only take minutes or hours with uDASH's computing power. Firmly embedded in UNSW's rich diversity of centres and facilities, uDASH and its partners have access to the Katana Servers, the suite of computers in the hub and UNSW's EPICentre located at the Paddington campus.

Cyber

Cyber Range – CBR

The Cyber Range is a C7000 blade enclosure connecting SAN storage over fibre channel plus other supporting infrastructure including networking devices. It provides war gaming, training and exercising – with state-of-the-art equipment unique in the Australian university system. The cyber range was co-designed with CSIRO for teaching, training and research.

Hypersonics

Fastest Two-Stage Gas Gun in Southern Hemisphere – CBR

This facility contains 20 kN JJ Lyod and 5 kN MTS mechanical test machines for static testing, 100 kN and 250 kN dynamic test machines for fatigue testing, vertical low velocity gas gun and horizontal medium velocity gas gun, instrumented impact test machines, strain gauges and extensometers.

Hypersonics Laboratory – CBR

This laboratory contains the T-ADFA high-enthalpy free piston shock tunnel, capable of simulating flight at up to Mach 10 at 13 MJ/kg total enthalpy for external aero-thermodynamics, shock wave/ boundary layer interaction and supersonic combustion (scramjet) research. The shock tunnel is combined with advanced laser-based diagnostic techniques for flow characterisation.

Laser Laboratories – CBR

UNSW Canberra has five Laser laboratories. Facilities include: dedicated laser laboratories sharing an acoustically isolated foundation; pneumatically isolated optical tables; two Argon-Ion lasers; one frequency-doubled Nd:YAG laser (1W CW@532nm); an infra-red Nd:YAG laser with feedback control of intensity noise (500mW CW@1064nm); an infra-red fibre laser with feedback control of intensity noise (1W CW@1550nm); several infra-red semiconductor lasers (10mW CW@1550nm); free-space and telecommunications optoelectronics; fast, quantum noise limited, linear photodetectors with associated electronics; an infra-red single-photon detector and radio-frequency and microwave test and measurement equipment. Work in adaptive optics and display surrounds two OKO deformable mirrors and various custom built Spatial Light Modulators. Materials work is conducted in a Class 100 clean room with sputtering facilities.

Mossbauer Spectroscopy Laboratory – CBR

Home to the most developed Mossbauer Spectroscopy Lab in Australia, UNSW Canberra has a suite of Mossbauer spectrometers (three cryostats 2-300 K; furnaces 300-720 K, Doppler speeds up to 800 mm/s).

Quantum

Australian National Fabrication Facility (ANFF) – NSW Node – SYD

ANFF-NSW host over $25M of process tools for the design and fabrication of micro and nano scale devices, with focus on nanoelectronics, nanophotonics and quantum devices supported by an expert team of more than 20 process/equipment engineers (ANFF-Geniuses). The facilities are co-located at UNSW and the University of Sydney, with the UNSW lab boasting cleanrooms for thermal processing, electron-beam and optical lithography, CVD thin film deposition, PVD thin film deposition & Dry Etching, Metrology & Packaging, and Epitaxial Growth Facility.

Centre of Excellence for Quantum Computation and Communication Technology (CQC2T) – SYD

The ARC Centre of Excellence for Quantum Computation and Communication Technology (CQC^{2}T) is focused on delivering world-leading quantum research to develop full-scale quantum systems – encompassing ultra-fast quantum computation, secure quantum communication and distributed quantum information processing.

The Mark Wainwright Analytical Centre – CBR

The Mark Wainwright Analytical Centre (MWAC) houses contemporary instruments for materials characterisation. MWAC manages major instrumentation for the study of the structure and composition of biological, chemical and physical materials. Specific facilities include Electron Microscope Unit, X-ray microcomputed tomography, Nuclear Magnetic Resonance Facility and Spectroscopy Laboratory. Facilities are accessible to external researchers, government and industry users.

Undersea Warfare

Aerodynamics Laboratory – CBR

The Aerodynamics Laboratory is a teaching and research laboratory in the aerodynamics of subsonic and supersonic flows. Work includes aerodynamic testing of aeroplane, ship, train, car and truck models, roof ventilators and wind turbines. Calibration of instrumentation such as anemometers and pressure measuring devices is also conducted. The laboratory facilities include five subsonic wind tunnels (one with moving ground facility), one Mach 2 to 3 blowdown supersonic wind tunnel and a shock tube rig. It also has a wide range of equipment to measure air velocity, pressure, force and flow visualisation. Equipment for various schlieren and interferometric flow visualisation methods. High-speed video cameras with recording speed ranges from several thousand to ten million frames per second plus a SLR camera for single images. Surface pressure measurements – point and pressure sensitive paint surface-wide techniques.

AUKUS Defence Research and Technology

Professional Education Couses

Degrees and Professional Education

Undergraduate and Postgraduate Degrees

Since its inception in 1949, UNSW has maintained a strong scientific, technological and professional focus, and takes pride in the broad range and high quality of educators and teaching programs. The career-focused educational programs gain strength and currency from research activities, strong industry links and strong regional and global engagement. Capability to develop bespoke short courses and microcredentials leveraging the research expertise across UNSW is also possible.

UNSW offers undergraduate degrees and postgraduate degrees by research or coursework across the full spectrum of arts, built environment, business, design, law, social sciences, engineering, medicine and science, and it is the only university in Australia with an advanced nuclear engineering program starting from honours level undergraduate, through postgraduate courses, to PhDs and beyond. UNSW also offers a bespoke undergraduate degree in Quantum Engineering which complements a broad suite of postgraduate courses and research. In support of the AUKUS cyber theme, UNSW also offers a wide range of postgraduate programs in cyber security, data science and analytics.

Visit www.futurestudents.unsw.edu.au to search UNSW degrees.

Short Courses

UNSW offers a variety of professional education, non-award and Massive Open Online Courses (MOOCs) that cater for a wide range of needs for Defence, related industries and the general public in business, IT, languages, data science, law, architecture and planning, defence, visualisation and simulation, medicine and health, design, education and safety.

Courses are available online, on campus or in-house at an organisation's premises and can be developed to suit the specific staff development and training needs of your organisation.

Students who have successfully completed approved professional education courses may be able to use those courses as credit in eligible postgraduate programs.

Read more at www.shortcourses.unsw.edu.au and www.unsw.adfa.edu.au/study/professional-education-courses or contact the Professional Education Courses Unit on (2) 6268 8040 or ProfEdCourses@adfa.edu.au

Professional Education Courses Related to AUKUS priorities

AI and Cyber

- Advanced Exploit Development
- Certified in Cyber Security
- CISSP Training
- Code Review
- Critical Infrastructure Cyber Security (SCADA)
- Cyber Defence
- Cyber Offence
- Cyber Security Boot Camp
- Cyber Security Fundamentals
- Digital Forensics
- Data Exploitation for HQ Operators
- Introduction to Exploit Development
- Reverse Engineering
- Wireless, Mobile and Internet of Things Security

Undersea Warfare

- Introduction to Naval Combat and Weapons Systems

Enabling concepts – Modelling and Simulation

- Designing a Simulation-Based Training Environment
- Building a Case for Immersive Training Technology
- Simulation Practices for Immersive Environments
- Modelling and Analysis of Non-Kinetic Effects in Live, Virtual and Constructive (LVC) Exercises
- Data Engineering and Architecture in LVC Environments
- Open Architectures and LVC Integration

Enabling concepts – Capability Development

- Breakthrough Performance in Design for Successful Systems
- Capability Life Cycle (CLC) Management
- Function and Performance Specification Development Workshop
- JCNS and OCD Development Course
- Need Statement Development Workshop
- Operational Concept Document Development Workshop
- Scope Development Workshop

Enabling concepts – Military Systems

- GPS and its Military Application
- Introduction to Electronic Warfare
- Introduction to Guided Weapons
- Modern Military Navigation Systems
- Optical Surveillance Systems
- Radar Fundamentals

Enabling concepts – Operations and Decision Analysis

- Introduction to Decision Analytics
- Introduction to Evidence-Based Decision Making
- Introduction to Spreadsheet Based Data Analytics
- Introduction to Spreadsheet Based Decision Analytics
- Spreadsheet Based Decision Analytics

Nuclear Education and Training

- Introduction to Nuclear Engineering
- Ionising Radiation Protection

UNSW

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