THE UNIVERSITY of ADELAIDE

Defence and Security Institute Profile

make history.

Mission

In partnership with government, industry, and other academic institutions, apply our academic expertise to solve defence and national security challenges.

Commitment

The Defence and Security Institute will continue to build and maintain world-class research, knowledge, infrastructure, and commercialisation pathways required to support the defence and security of our nation.

Goals

We aim to:

- Accelerate the delivery of research outcomes and growth in sovereign capability
- Build national capacity and excellence in Defence research by attracting and retaining high calibre academic and post-doctoral talent
- Maintain an appropriate and strong security posture.

Enablers

Contents

Key R&D Expertise – Asymmetric Advantage

Advanced Cyber	Autonomy	Artificial Intelligence
Photonics & Advanced Sensing	Radar & High Frequency Technologies	Quantum Materials & Technologies
Radiation	High Energy Lasers	Human Bio Technologies
Information & Influence	International Security, Politics, Policy, Law	Human AI Teaming

Message from the Executive Director

Vital contributions to sovereign capability in Defence research

DSI was established in July 2021 to provide a strategic framework for Defence or National Security focussed research and innovation at the University of Adelaide. DSI, headquartered at Lot Fourteen, South Australia's high-tech hub for innovation and entrepreneurship, plays a key role in ensuring the University's capabilities are relevant, identifiable, and accessible to external parties, and in developing educational programs for an evolving workforce.

A defining characteristic of much of our research is its transdisciplinary nature. The complex nature of the challenges we address often demands contributions from multiple perspectives, combined in new and innovative ways. This is key to building technology-enabled Asymmetric Advantage for Defence, as highlighted in the 2023 Defence Strategic Review (DSR).

The "engine room" of academic research comprises predominantly postdoctoral fellows and PhD students. Attracting and retaining our best young talent into this ecosystem has been a long-term challenge. Without multi-year contracts, our best postdocs and PhD graduates leave this ecosystem for more reliable work, often overseas. DSI has been working to address this challenge in a number of ways. Firstly, in partnership with the Defence Science and Technology Group (DSTG), we have identified the cyber and electronic warfare domains as two where the University has core strengths while being highly aligned with Defence priorities and are working together and co-investing to grow national capability and capacity in these areas. The DSR has underlined their importance for National Defence.

Secondly, in partnership with DSTG, DSI has established the first two Centres for Advanced Defence Research (CADR) in Australia. These Centres are established for a minimum of 5 years, enabling the University to attract and retain our best and brightest academics and postdocs in the fields covered by each CADR. In one CADR, this ability to transcend the short-termism of normal research agreements has been shared with many other universities in Australia, and so has significantly enriched the National Defence innovation community. Two more CADRs are under development, one led by the University of Melbourne covering operations in environments compromised by chemical, biological, radiological or nuclear attacks; and the other led by the University of Adelaide in High Frequency Technologies, principally in support of our nation's sovereign Over-The-Horizon-Radar capability, JORN.

Thirdly, DSI worked in close partnership with the University of New South Wales to establish the Defence Trailblazer Program, funded by Department of Education, Skills and Employment for four-years. Together, these partnerships have introduced a measure of sustainability into the ecosystem.

The announcement in the DSR of the Australian Strategic Capabilities Accelerator (ASCA) is timely and a welcome evolution with its enhanced clarity of purpose and sense of urgency. Transitioning will require deliberate planning to preserve and strengthen the steady growth in defence-led academic research across the nation in priority areas to identify solutions to key national problems.

DSI Statistics 2021-2024

150 security cleared staff & students

$65M research program

12 university partners

50 Defence industry partners

circa $250M Defence Trailblazer translation program

DSI's purpose is to be a long-term strategic asset for research and development in key areas of importance for Defence and National Security. DSI is committed to providing previously unimaginable solutions to the nation's most complex defence and security challenges. This DSI profile highlights key areas of research, key research leaders, and specific education and leadership development activities undertaken at the University of Adelaide.

Professor Michael R Webb BE(Hons) MMedSc PhD FIEAust
Executive Director,
Defence & Security Institute
The University of Adelaide

Message from the Chief Security Officer

First in security and compliance

By almost any measure, The University of Adelaide is one of the most Defence-engaged universities in Australia. Our Defence partners expect us to maintain an active security-aware posture and take our compliance obligations seriously.

Ours was the first university to become a member of the Defence Industry Security Program (DISP, August 2016), and continues to retain membership in the revised DISP (2021). At the time of writing, we are the only university in Australia entitled to sponsor "Negative Vetting 2" security clearances for our staff. This enables our best and brightest to have the necessary conversations with Defence partners to truly understand the impact our research may have on Australia's defence and national security.

We face a vastly different geopolitical environment than we did just five years ago. The Australian Government has recognised the world-class performance and reputation of its university system. This success comes from the globally engaged and open nature of Australia's universities and our development of new knowledge and technological innovation, which is vital to Australia's prosperity, economic growth and international engagement.

The Guidelines to counter foreign interference in the Australian university sector have uplifted the foundations for building awareness and resilience to foreign interference within a university. Our response to the original Guidelines has been heralded as exemplar within the sector, and also by Government in conversation with their counterparts internationally.

My office, in coordination with the Division of External Engagement, is tasked with ensuring we adapt to the newly revised Guidelines. Indeed, I was on the Enhanced Due Diligence Working Group of the University Foreign Interference Taskforce (UFIT) tasked with revision of one section of the Guidelines.

Federal regulations place additional compliance measures on the university sector:

- International sanctions derived from UN Sanctions and from the Autonomous Sanctions Act (2010)
- Defence Trade Controls Act (2012)
- Foreign Influence Transparency Scheme (2018)
- Foreign Arrangements Scheme (2020).

My office manages a Foreign Engagement Compliance Review (FECR) process that evaluates all proposed University activity with foreign entities (and their Australian subsidiaries) for compliance to these regulations, and considers the potential risks of the activity, for example to the reputation of the University as perceived by our Defence partners.

Recently the Critical Technologies Policy Coordination Office (CTPCO) was established in the Department of the Prime Minister and Cabinet to provide coordinated, whole-of-government advice on technology developments, opportunities and risks, and to recommend actions to promote and protect critical technologies. Unsurprisingly, several critical technologies identified by CTPCO relate to research undertaken by our Defence and Security Institute (DSI) members.

The DSI team and my office are here to support members in navigating the compliance and regulatory landscape and enable their research to continue contributing to Australia's defence and national security.

Prof Bruce Northcote
Pro Vice-Chancellor Research Operations & CSO
The University of Adelaide

Information, influence and cyber

The increasingly complex information landscape creates many diverse and complex security challenges for Australia.

As the world becomes more connected and we increasingly rely on information, we face a growing threat from the misuse of the digital technology driving these connections and the 'weaponisation' of information. Mass influence campaigns and deep fakes intensify mistrust between society, business and governments, and opportunities for state and non-state actors to attack critical infrastructure continue to grow. The use of artificial intelligence and automation have greatly increased our vulnerability.

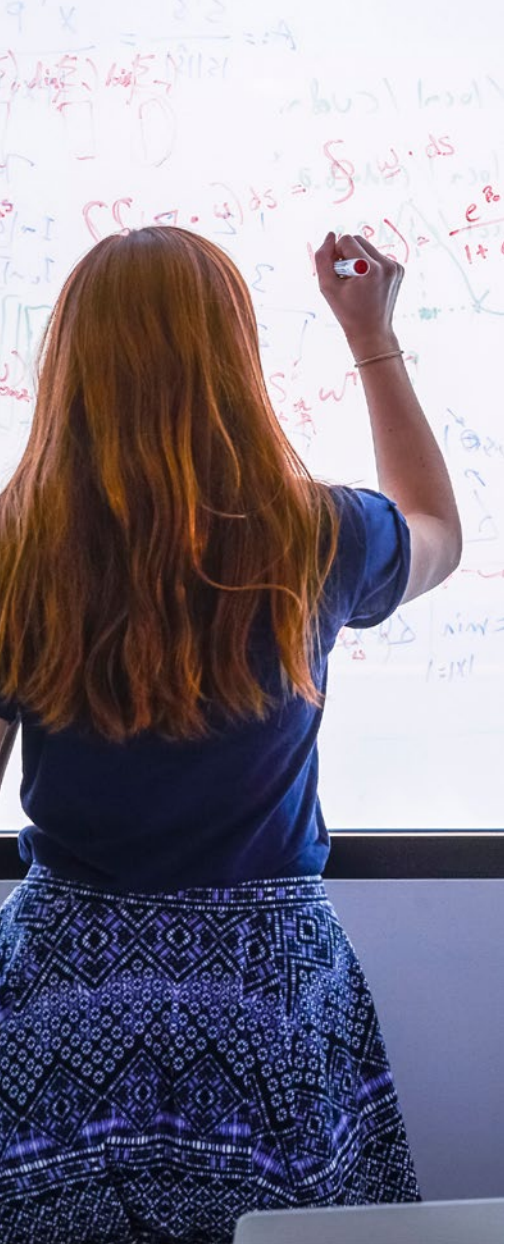
To respond effectively to "attacks" in this grey zone, all below the threshold of armed conflict, Australia needs to fully understand the social, economic, and technological impacts of these threats across defence, critical infrastructure, agriculture, health and energy and also how these impacts are experienced by our regional partners.

At DSI, we collaborate closely with research partners from the Defence Science and Technology Group (DSTG) to integrate information and cyber artificial intelligence (AI) insights with psychology and social science. This allows us to develop tools and techniques to assist with monitoring and guarding the public information environment by better understanding how influence strategies work, and what makes a system or society susceptible or resilient to these influences.

We are also able to identify strengths and weaknesses in both the technology and its human operators and develop evidence-based approaches using graph theory, game theory and AI/machine learning to support integration of deception technologies into networks and help human operators deal with the complex, fast paced and deceptive nature of cyber environments.

Each aspect of this collection of projects and activities is deliberately aligned with DSTG's Information Warfare (IW) STaR Shot, with funding from various sources including: the IW STaR Shot, Next Generation Technologies Fund (NGTF) cyber, the Australian Research Council (ARC), the South Australian State Government's Defence Innovation Partnership (DIP), and industry.

Translating research in this area relies on the availability of qualified and experienced cyber professionals. DSI supports development of a highly skilled and specialised workforce by providing existing and emerging researchers with an environment which benefits from large-scale investment and has strong connections to the defence industry, allowing them to create solutions with immediate and practical impacts.



Autonomous cyber defence tools
Associate Professor Hung Nguyen

The digital networks we use every day for business, recreation and security have become so complex that it's impossible for anyone to understand and eliminate all the vulnerabilities in a given system, even with the most advanced tools. In addition, our defence is often designed to be static, so the information and how you access it stays the same and you know where you need to go to find what you need.

The problem is that people who wish to attack our systems are not static. They can, for example, run multiple attempts to access networks until they find a weakness. Attackers need to be right only once whereas defenders need to be right all the time. Human network engineers struggle to keep networks safe and spend much of their time patching weaknesses once they have been exposed by attacks.

In partnership with DSTG and with funding from NGTF cyber, ARC and industry, A/Prof Hung Nguyen and his team are solving this problem using mathematics, AI and machine learning. He explains "We can create a graph which models all the key components in a complex system and their relationships, then teach a machine to interpret the graph, identifying possible pathways that an attacker could use to get into and move around the system. This creates an 'active defence' which means, for example, that we modify weaker areas to change at intervals. When an attacker tries to enter the system, they don't find static information but a new variable each time which they need to try and overcome.

"We can also create algorithms using well-known computer science models such as 'context-free grammar' to train AI agents to effectively interpret the methods of the attackers, allowing us to better understand and anticipate what they may try next.

"These techniques have already been tested in the real-world and have been very successful in identifying chokepoints which need actively defending in large, multi-user networks.

As our work evolves however, so do the attackers, making it vital that we continue to investigate new ways to defend our networks."

Advanced cyber deception techniques
Professor Debi Ashenden

Cyber attacks are increasingly automated, however at their core are people, no matter how remote they are. Prof Debi Ashenden and her team use a behavioural science perspective to develop new cyber deception techniques designed to deceive attackers and potentially change their behaviour.

She explains "Cyber deception measures are usually designed to entice would-be attackers to a specific place on the network which then triggers an alert and lets us know there is an active threat. Advanced cyber defence will see future cyber deception technology leverage behavioural science. The goal is to gain intelligence about an attacker's tactics, techniques and procedures, whilst also shaping their behaviour and decision-making while they are inside our networks. The key is to create confusion in the attacker's mind and, by extension, the automated algorithms that may be used against us.

"We gather knowledge of how security analysts and network defenders make decisions on potential responses during an attack. We then use information about these human cognitive processes to build a process to disrupt the attacker's decision-making and make them waste time and resources. This allows our defence systems more time to respond to a threat, but also may cause enough doubt that the attacker thinks twice before attempting again."

The next steps are to look at automating parts of this system and developing an online tool to allow organisations to be more proactive with their own cyber security.

Prof Ashenden is the inaugural joint chair with DSTG in cybersecurity, a position that is co-funded by the University and DSTG. This work on cyber deception is funded under the NGTF cyber program and is closely aligned with DSTG's Information Warfare STaR Shot.

Understanding mass influence campaigns
Associate Professor Carolyn Semmler

Cyber-based attacks are not just limited to security networks. They often take the form of sophisticated mass influence campaigns, usually via social media platforms, designed to change the thoughts and behaviours of the larger population.

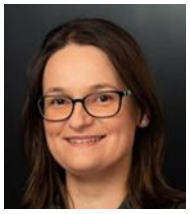
A/Prof Carolyn Semmler's team (including Dr Matteo Farina and Prof Lewis Mitchell) are developing a deeper understanding of the types of conversation that happen during these campaigns and where they are likely to turn from words into actions.

"Social media is integrated into the fabric of our society and a powerful tool for shaping beliefs and action in large numbers of people. It is optimised to keep us engaged and the best way to do that is to generate strong emotions, whether positive or negative.

"Our research looks at the specific types of content which change people's beliefs and encourage them to coalesce around an issue they may not have been aware of or interested in previously. We are developing models that help us understand how groups form, what type of content is more likely to be shared and how misinformation can build to the point where these groups act, in the form of protests or other direct actions.

"The biggest challenge is the volume of data. We analysed 7 days' worth of content related to COVID-19 lockdowns, for example, and ended up with 73,000 conversations to analyse. Part of our research, therefore, is also working out how to provide security analysts with powerful AI algorithms which help to make sense of content, without introducing bias."

The scope of this research requires experts from a wide range of disciplines including not only behavioural science, psychology, maths, data science and engineering, but also politics and ethics.



Creating resilience against mass influence campaigns
Dr Rachel Stephens

With the volume of information – whether genuine or misinformation – available, how can we help people develop their critical thinking skills and build resilience against mass influence campaigns?

Dr Rachel Stephens is part of the Monitoring and Guarding the Public Information Environment (MAGPIE) project with Dr Keith Ransom and collaborators from the Universities of Melbourne, Western Australia, and South Australia, as well as DSTG and industry. Key aspects of the work are funded by DSTG's IW STaR Shot program and the SA Government's Defence Innovation Partnership (DIP). MAGPIE is looking at how people interact with social media and what cues they use to make decisions on the authenticity or intent of content. She explains "We know that one way people decide whether to believe a particular claim or not is by looking at consensus. If the claim has been supported in multiple messages, or shared by lots of people in their social circle, the likelihood of it being accepted as truth is much higher. The problem is that many people do not look at the quality of that consensus. Are the messages from credible, independent sources? Is there evidence to support the idea or activity outlined in a given message, and how reliable is the source of that evidence?

"There are a range of techniques to help people navigate the public information environment. Fact checking tags and automated fact checkers have appeared throughout the various platforms in recent times, but our MAGPIE project aims to provide a transdisciplinary solution which not only looks at the computer and data science aspects of this environment but also considers individual cognition and how people communicate or influence each other."

The aim is to develop an automated, interactive tool which can help people critically assess the consensus behind a claim, which will result in a healthier, more resilient and better-informed online environment.

Influencing regional security

Professor Joanne Wallis

Australia's relationships in the Pacific Islands region have always been important to successive governments but never more so than in these times of global upheaval. Traditional partnerships are being tested and new alliances are being formed.

The Regional Perspectives Project is led by Prof Joanne Wallis and undertaken in collaboration with researchers from DSTG with funding from Defence. This project is looking at our relationships in this region and how we can ensure Australia is the partner of choice for the various island nations into the future. Joanne explains "We have previously assumed that Australia's military, economic power, and trade resources would ensure our level of influence over the Pacific Islands such as the Solomon Islands and Vanuatu. As illustrated with the signing of an agreement between the Solomon Islands and China, this can no longer be taken for granted.

"Our project aims to get a better understanding of how people in the region perceive stability, security, and resilience and what makes them feel vulnerable. In the past we have viewed their perspectives through our own Australian lens but for this project we are trying to find out what these concepts mean to Pacific people, not going in with preconceived ideas of what we will find.

"Obviously, there is a significant security and defence element to this work but we need to appreciate that with existential threats such as climate change, security may actually mean something very different to the people who live in the Pacific Islands. It's about analysing security but defined in a local context.

"Finding out how they understand security and what they need in order to feel and be resilient to future changes, will help us better support them and in turn help Australia to deepen its relationships in the region."

Quantum technologies

Quantum technologies is a fast-moving field at the boundary of condensed matter physics, quantum physics, material sciences, chemical engineering and optoelectronics.

Quantum technologies make use of the extraordinary effects of quantum mechanics to give rise to exotic and often incredible properties.

While all materials exhibit quantum mechanical properties at some level, 'quantum materials' exhibit anomalously strong and unique properties such as quantum entanglement, quantum coherence, and topological behaviour. These strange properties can be exploited to deliver devices that have new capability in telecommunications, defence and medical sciences.

Quantum technologies will be at the core of Australia's future industries, which will need a workforce with advanced knowledge and skill to help us understand the full range of benefits they offer, and place Australia at the forefront of quantum technological innovation.

Advanced research in quantum sensors

Dr Giuseppe Tettamanzi

We pursue quantum technology solutions because they allow us to create sensors which can sense electro-magnetic signals to a degree that classical technologies would never achieve.

Dr Giuseppe Tettamanzi explains "Using the principles of quantum mechanics, we developed a sensor which can detect electromagnetic (EM) signals across the widest range of frequencies ever achieved in a single device.

"This is possible because we can design and operate our structures in the most optimal way so they are limited only by quantum noise, with all other sources of noise suppressed. The technology is of great interest to the defence sector, but it is also important for medical purposes because we can detect tiny electromagnetic signals in the heart, brain or spine using the same technology, allowing for more precise diagnoses and therefore more targeted treatments."

Being able to pick up signals this precisely is also valuable for the space industry. As we venture further from Earth, these devices are prime candidates for enabling reception of EM signals to and from the Moon, Mars and further. "Our project is now working to determine the sensor's limits and identify ways to scale the technology up or down for use in other ways," says Giuseppe. "A limitation is that the sensor needs to be operated in a low temperature environment. In the past, low temperature operation created problems as the cryogenic setups needed were large, heavy, noisy, invasive, and difficult to operate. These cryo-setups are now scaled to tens of centimetres sizes and need very little power to operate, making DSI's approach extremely appealing for a wide range of critical applications."

Portable quantum clock technology

Professor Andre Luiten

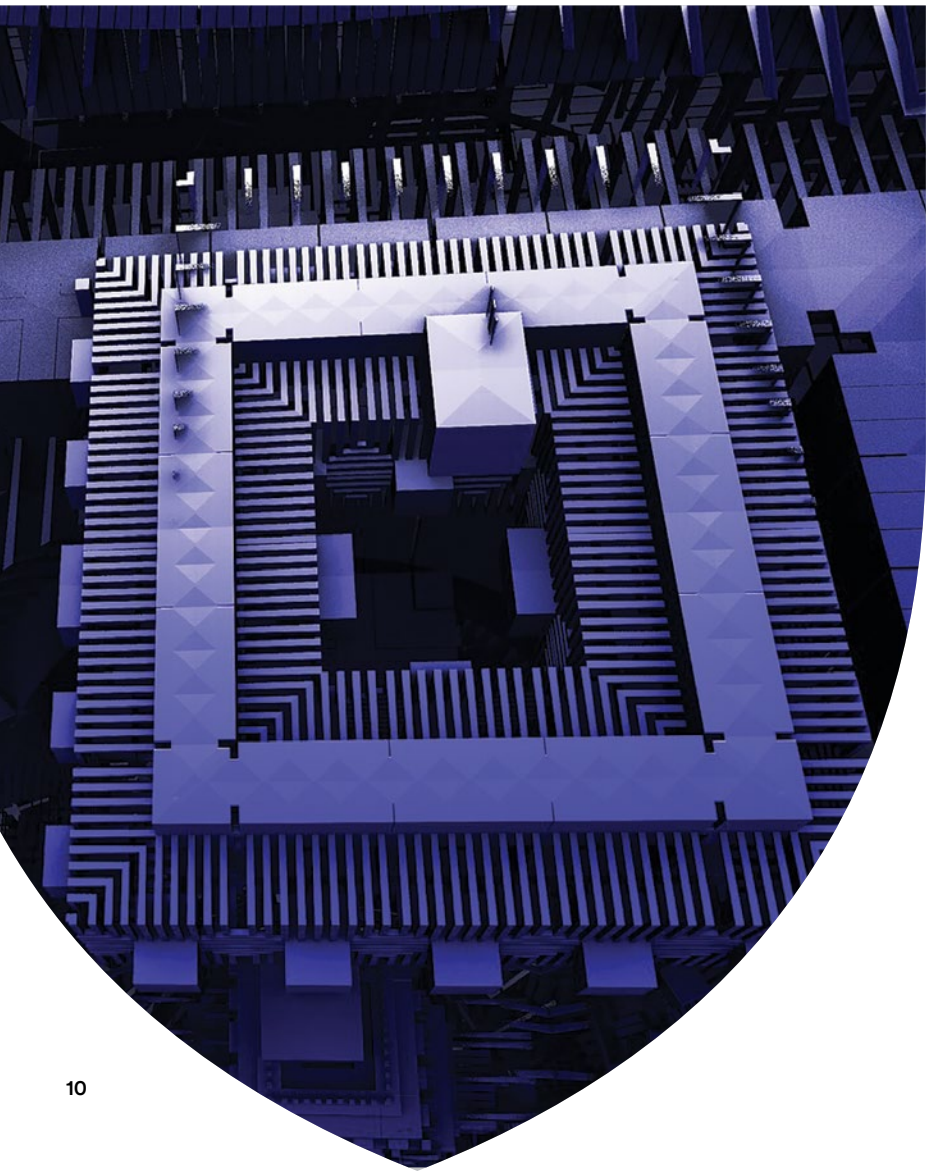
Accurate and assured timing is critical to numerous defence and civilian operations including computing, communications and navigation. The best of these systems typically depend on access to Global Positioning Systems (GPS).

However, in contested environments, where GPS may be jammed or deceived, this access will be denied, with the resulting loss of synchronisation between multiple locations stopping these critical systems from working effectively. A solution is to develop a sovereign, portable and independent clock, deployable in the field.

The University of Adelaide and the Defence Science and Technology Group (DSTG) have developed not one but two separate portable quantum clock technologies. Both clocks are optical quantum clocks that can provide incredibly pure timing signals that outperform GPS by many orders of magnitude.

Director of the Institute for Photonics and Advanced Sensing (IPAS) and Research Group leader, Prof Andre Luiten, said "These clocks are performing at a level which formerly could only be obtained by the best laboratory clocks. The incredible team has created fundamentally new approaches to embed this performance into a portable package.

"The clocks were demonstrated and tested against other quantum sensing technologies in a field trial representing real-world conditions. This successful collaboration is proudly coupled with DSTG's Quantum Assured Position Navigating and Timing (QAPNT) STaR Shot, which delivers new capabilities to ensure the Australian Defence Force and our coalition partners can operate in complex and contested environments with uninterrupted access to position, navigation and timing information."



The University of Adelaide and the Defence Science and Technology Group (DSTG) have developed not one but two separate portable quantum clock technologies.

Harnessing quantum materials for magnetic field sensing
Professor Heike Ebendorff-Heidepriem

Advanced research into quantum materials has allowed us to harness quantum effects on well-known materials and introduce properties which provide sensing abilities far beyond what has been possible previously.

Professor Heike Ebendorff-Heidepriem and her team are working on using diamonds with quantum properties, embedded in more conventional glass fibres, to very precisely sense changes in magnetic fields.

Heike explains "Glass fibre networks are used all over the world to carry information as they allow signals to go in one end, travel great distances without being impacted by external environments, and be accurately detected and interpreted at the other end.

"We are working on an interdisciplinary project, with collaborators at RMIT, University of Melbourne, UniSA and Defence, which marries the capabilities of glass fibres with the magnetic field sensing abilities of specially adapted diamonds. If you alter diamond by incorporating nitrogen atoms and vacancies (spaces where the carbon atoms have been removed) in the diamond's structure, it can fluoresce red light when illuminated with green light. As the brightness of the fluorescence changes with varying magnetic field strengths, glass fibres with embedded diamond can be used for magnetic field sensing.

"This method of detection is so sensitive, it can measure small changes even against the ever-present background magnetic field of the Earth and can identify the presence and movement of large metal objects even when placed underwater or underground.

"The tricky part is putting the adapted diamond inside the glass fibre as if you heat the diamond too much it can damage the sensing properties. We have developed a process whereby it can be embedded into the glass before it is 'stretched' out into a fibre, allowing the diamond and its properties to survive the process whilst keeping the optical properties of the fibre accurate and consistent.

"Next, we will look at improving how we analyse the fluorescence to achieve higher levels of sensitivity and determining which type of glass is most robust under real world conditions. We will also look at whether there are differences in accuracy depending on where in the fibre the diamond is situated and whether operation changes the properties of the defect in the diamond which we are relying on for sensing."

Glass fibres embedded with diamonds in this way can be used to develop underwater fibre networks which can detect marine vessels in areas such as ports, or underground networks which can be used in contested spaces to detect vehicle movements. They also have potentially exciting applications in bio-medical thermometry and imaging.

Creating quantum light sources and light source detectors
Professor Glenn Solomon

The University of Adelaide has a world-class quantum materials program which brings together physicists, engineers, material scientists, and key industry partners, including Silanna and DSTG, to identify where quantum materials and solid-state quantum devices can affect impactful change. Research areas are founded on semiconductor and superconductor quantum materials, including high-power semiconductor lasers, superconducting nanowire single photon detectors, and quantum light sources.

As part of this program, Professor Glenn Solomon and his team are working on developing quantum light sources, and the equipment to detect them, as they have the potential to provide ultimate secure communications, even between Earth-based systems via satellites. Glenn explains "We have been investigating how light interacts with materials that are engineered to accentuate their quantum properties, and how the resultant devices can be used to create very secure communication channels. We create a quantum dot which contains somewhere between 50,000 and 100,000 atoms that all act like just one atom, but produce much brighter light. We make the quantum dot inside a specially designed crystal where the light builds up as it bounces off different layers in the crystal, further enhancing the brightness of the quantum light.

"We can then use this light to send messages, and due to the quantum nature of the light (a single photon), there is no way to listen in to, or interrupt, this message as the photon would flicker and the sender/receiver would be aware.

"We also need to be able to detect this light, so our team is looking at creating highly efficient superconducting detectors which can be integrated into a robust photonic chip, easily used in real-world conditions. Ideally, we will ultimately have the light source and detector on one chip.

"This type of ultimately secure communication is critical for defence as their current classical methods will reduce in security over the next decade as quantum options become more widely available.

"Our next steps are to increase the efficiency and integration of the light source. We are also looking to deeply understand the physics behind these reactions as this is the key to future improvements in this exciting field of quantum materials."

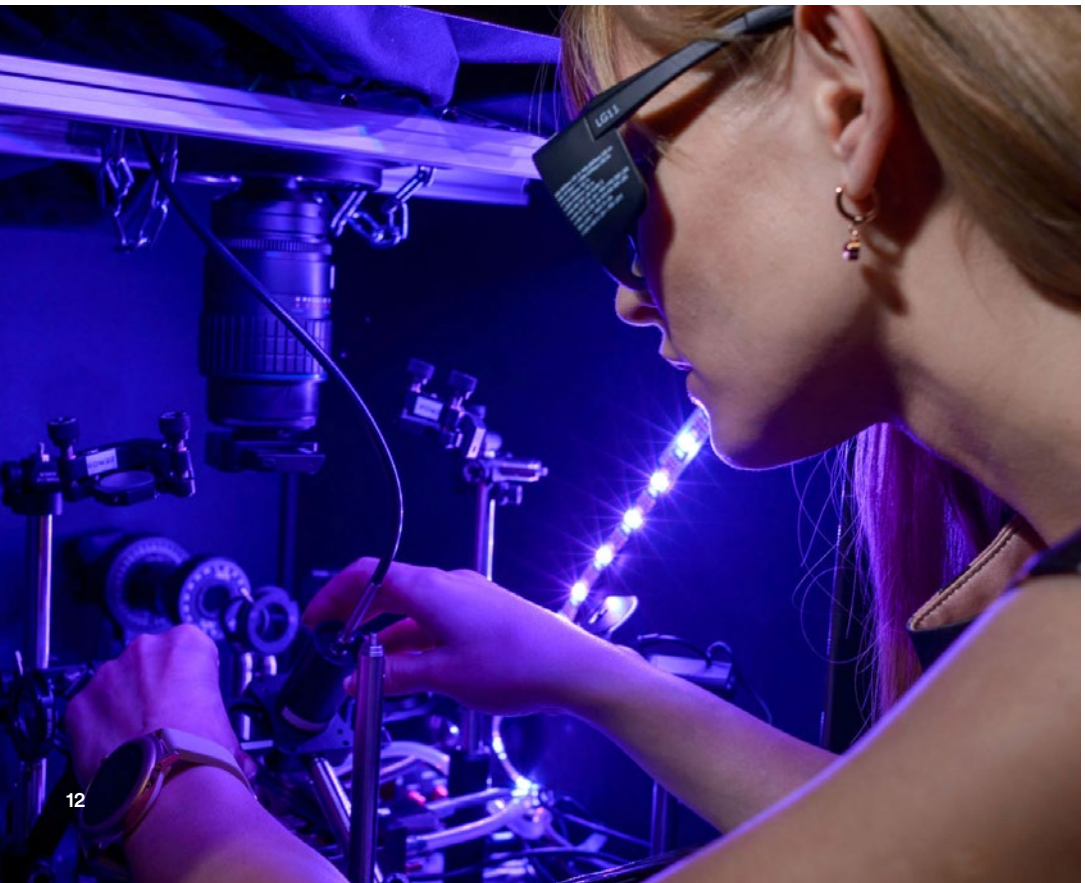
Ultrashort and short pulsed lasers

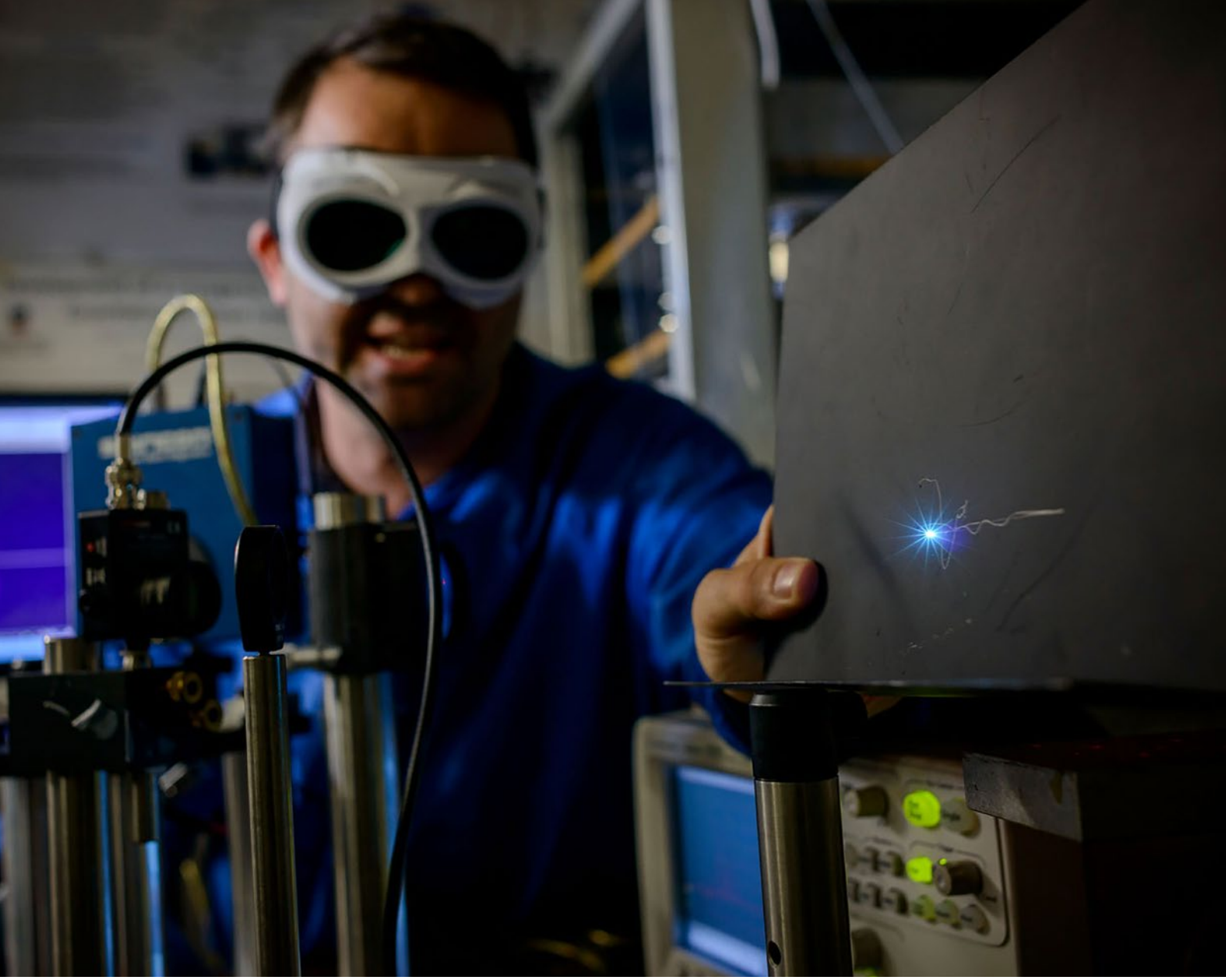
Ultrashort and short pulsed lasers (USPL) provide game-changing benefits across multiple applications.

The high-energy light of ultrashort and short pulsed lasers makes them orders of magnitude more powerful than standard lasers. In medicine, this means they can improve the precision of surgical procedures with minimal scarring and they are also being explored for use in nuclear fusion.

In the defence sector, USPLs have applications in the next generation of laser sensors and effectors. USPLs can neutralise threats by 'blinding' a target or overloading their electronic systems, rendering them inoperable. Our Centre for Advanced Defence Research in Ultrashort and Short Pulsed Lasers (CADR-USPL) further develops these lasers and provides cutting-edge research into potential applications with a focus on creating a world-class sovereign defence capability.

To realise the potential of USPL technology, Australia needs a skilled workforce able to understand and apply USPL technology. One of CADR-USPL's core objectives is to build this workforce through its extensive postgraduate research program. It owns and operates specialised laboratories where students get hands-on experience in meeting the challenges of USPL activity. Defence personnel also have the opportunity for on-site education and upskilling, ensuring the Centre is Defence-oriented and meeting Defence needs.





Next generation high energy, high repetition lasers

Professor Miftar Ganija

Ultrashort and short-pulse lasers (USPL) are driving substantial innovations in a range of sectors including defence, medicine and remote sensing. But they require new technology to stay at the forefront of engineering and scientific advancement.

DSI's CADR-USPL is supporting development of this new technology by delivering lasers which transmit pulses of high-energy light as brief as one trillionth of a second and 100 times brighter than sunlight.

Prof Miftar Ganija explains why this is important. "When you shine our high energy, high repetition lasers onto a material, the laser bursts create extremely high temperatures and pressures that could otherwise only be created by a small nuclear bomb. This turns the target material into 'plasma' and as the laser bursts are extremely short, there isn't time for the plasma to spread or to increase temperatures in, or damage, surrounding areas. This makes our lasers incredibly accurate and effective. It also means they can liquidise or even vapourise objects, making them much more powerful than conventional technologies and an extremely exciting area to be involved with."

From a defence perspective, these lasers have the potential to detect, track, illuminate and engage the latest generation of advanced air, maritime or land-based threats. They can also be used to improve precision and accuracy in a wide range of industries including medical, cutting-edge x-ray technology and manufacturing of microchips.

Robotics and autonomous systems, artificial intelligence and space

Australia is a large landmass with a relatively small population and so capabilities that deliver asymmetric advantage are vital.

Robotics and autonomous systems (RAS) capability and the ability to use artificial intelligence (AI) to operate these are critical to defending our nation in the land, maritime, air and space domains.

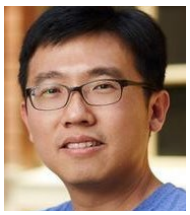
To ensure these capabilities are used to maximum effect, we need a deeper understanding of how these systems work, both autonomously and in teaming arrangements with other autonomous systems and human operators.

Our CADR in Robotics and Autonomous Systems (CADR-RAS) allows us to develop a deeper understanding of autonomous systems, how we can make them more robust by identifying how we can help them develop and demonstrate spatial and contextual awareness, and ways we can interrogate and display the information they gather to create the required level of trust between the system and its human operator.

CADR-RAS is directly linked with the Defence Trailblazer, a University of Adelaide-led initiative, and the Trusted Autonomous Systems Defence Cooperative Research Centre (TAS-DCRC). Both accelerate research outcomes into prototypes, products and services, and ultimately, defence capability.

This CADR also facilitated the Robotics and Autonomous Systems Lab at the Australian Defence Force Academy (ADFA) to ensure our future military leaders understand their capabilities, strengths and weaknesses.

With a current investment by the Department of Defence of $6.8m, and 19 projects partnering with 9 universities across Australia, CADR-RAS brings to bear the collective experience and knowledge of the national academic RAS research community.



Increasing Space Domain Awareness

Professor Tat-Jun Chin

There are thousands of satellites operating in the Earth's orbit, some of which provide communications, navigation and other critical functions to our defence and security forces.

However, there are even more resident space objects (RSOs) orbiting the Earth which include functioning satellites and spacecraft, but also debris from launches, space flight or malfunction/destruction of decommissioned assets.

Operating satellites colliding with RSOs is a growing concern, and with space increasingly becoming a contested domain, it is becoming more vital that we develop space domain awareness which is essentially knowing what is where and when in the orbital regions, much like how air traffic control on Earth keeps track of all aircraft.

Currently, most monitoring of RSOs is done from ground-based facilities but Professor Tat-Jun Chin's team is looking at how we can conduct this monitoring from space itself. He explains "Ground-based sensors can be limited by clouds or windows of time when an object is visible from the sensor's location. We want to do the monitoring in space so there are no visual restrictions and longer observation windows. It is demonstrable that cameras mounted on satellites could detect and track objects much more effectively than ground-based facilities.

"We are developing algorithms which can make decisions about where to point the camera. With so many objects to watch, how do you choose which to track at any given time? How do you maximise the chances of spotting something which isn't already known about? We need to be able to make observations at scale and use artificial intelligence to sift through the data and create space domain awareness for analysts back on Earth. This awareness can be used to ensure newly launched rockets aren't headed straight into the path of existing debris but it is also vital for our defence and security industry as understanding what is where is crucial before any operational decisions are made.

"The space-based surveillance system has been concept-tested on Earth and we are working towards testing on a live satellite hopefully in upcoming missions."

Simultaneous location and mapping in autonomous vehicles

Professor Ian Reid

Robotic and autonomous vehicles are valuable defence assets as they can undertake operations which present increased risks to personnel, such as entering contested or contaminated areas where they can gather information, or act as relay points for communication systems.

Key to their use is trust. Operators of these vehicles need to be sure that the information both they and the vehicle are using is accurate, and that it can be interpreted quickly and effectively. Information on the environment around a vehicle can be gathered using a range of sensors including radar, lidar and global positioning (GPS). These sensors are used in autonomous vehicles to provide information about where the vehicle is and, to some extent, the state of the dynamic, uncertain environment in which it is operating. But current methods do not make this picture more complete by determining things like object identities, whether they are fixed or moving, threats or benign; whether regions are navigable or traversable; and how to make effective decisions using this more complete – but still uncertain – picture of the world.

Professor Ian Reid's team are combining data from these sensors with images and video from vehicle-mounted cameras to help create a much more detailed picture of the environment. This will allow an autonomous vehicle to make much better decisions itself, but also provides its operator with a much clearer picture of what is around the vehicle so they can understand the rationale for any decisions the vehicle makes and provide additional guidance based on this more comprehensive data.

Ian explains "We're looking at gathering information from a broader range of sensors on an autonomous vehicle, whether the vehicle is land, sea or air-based, and creating software which takes that information and creates a geometric and semantically meaningful, dynamic map of the world which can be understood by the vehicle and the human operator. Using machine learning, we can sift through huge quantities of data (too much for a human to process) and distil it into a detailed and easily recognisable map of the surrounding environment. This can then be used for path planning, for example identifying if the flat area in front of the vehicle is a road or a river, or for determining if the area is safe from other potential threats which may damage the equipment.

"This technology can also be useful in areas where GPS is unavailable, by using simultaneous localisation and mapping. The software uses the sensor data to create a detailed map of the surrounding environment and, from that, work out where the vehicle is.

"A significant element of trust in such a sensor suite is proven robustness. A significant focus of our current work is to look at how the software performs when it loses an input. If a camera gets mud on the lens and can no longer provide suitable images, how should other inputs respond and what changes does the software need to make to adapt to the new information, so outputs can still be trusted? We know that theoretically the mathematics of probability provide us with ways to fuse disparate sensor data robustly, but new methods in machine learning are needed to build models which will enable us to do so. We are currently investigating machine learning models, such as those used at the heart of ChatGPT for instance, as a powerful new way to fuse all sensor data."

Contextual awareness training for autonomous systems

Associate Professor Claudia Szabo

Many algorithms used to train autonomous systems are based on variations of existing thresholds rather than truly unexpected new data. Obviously, it is hard to know all the situations a system may encounter. Systems are also mostly trained in a laboratory environment where parameters can be easily controlled and maintained.

In the real-world however, the systems may find themselves under attack during operation, or simply encounter battery or connectivity issues which impact their ability to function effectively. To build complex, robust and resilient autonomous systems, we need to be able to train them to determine which course of action to take when the unexpected happens.

A/Prof Claudia Szabo and her team are looking at how we can create these increasingly resilient systems. Claudia explains "We need to be able to create algorithms which allow autonomous systems to determine what to do next even when this is outside what they have previously learned or experienced. My team is working to understand how we build these systems so they can effectively decide what information is relevant in a given situation and offer a quick and accurate response.

"It may be that the correct and only response is to bring the human operator in to the decision-making process, in which case we need to ensure the autonomous system can provide a quick, comprehensive, relevant and accurate understanding of what's happening, and ideally a suggested response based on this analysis.

"We also need to make these learning and decision-making paths transparent and understandable to human operators. Trust between them and their autonomous counterparts is vital and you can't trust what you can't understand."

Claudia's work not only has huge implications for the use of autonomous systems in the defence sector, but also offers huge benefits for emergency services who are increasingly using these systems in response to natural or man-made disasters.

Building successful hybrid human/AI teams

Professor Anna Ma-Wyatt

As we increasingly embed Artificial Intelligence (AI) into defence capabilities, we must understand how AI agents and humans can work together. For example, how can humans work with, and trust, AI agents and develop AI systems that "understand" and respond to changes in human behaviour and performance. A key part of this problem is how to quantify human performance so that an AI algorithm can monitor it, and how to develop AI algorithms that represent this performance. We also need to establish a 'common ground' where an AI system can process human performance, and equally human operators can see how the AI has gathered and analysed the information they provide about a particular scenario.

Under the umbrella of CADR-RAS, Prof Anna Ma-Wyatt and her team, work with renowned Prof Lang White (Electrical and Electronic Engineering) and DSTG collaborator Dr Justin Fidock, on a Defence AI Research Network (DAIRNet) project aiming to develop human performance metrics that can be used with an AI agent to establish such common ground. Anna explains "Our project looks at how humans gather and process information considering factors such as training, experience and how they use a given interface. We use geopolitical information analysis as our starting point. In other projects, we work with DSTG and the Australian Army to understand how humans use information systems while walking.

"In our DAIRNet project, we are developing a modelling framework that enables a representation of how the human operator gathers this crucial information and establishing a common way to represent this information to the AI agent. The next stage is to support dialogue between the AI agent and the human to support effective and resilient decision-making by the human.

"It is a truly multi-disciplinary team working on this project including researchers with strong research capabilities in computer science, maths, psychology and behavioural science.

We have also recruited great postdoctoral fellows, including Dr Heidi Long, Dr Abdul Chowdhury and Dr Kelli Francis-Staite."

Operating in environments compromised by chemical, biological, radiological or nuclear agents

Safeguarding Australia against chemical, biological, radiological and nuclear (CBRN) attacks, requires an increase in the speed and flexibility with which our defence forces can respond.

DSI researchers are innovating and introducing systems which rapidly alert defence personnel when they have been exposed to chemical or biological contaminants. The systems provide real-time actionable data so personnel and mission-related countermeasures can be deployed, improving mission and personnel health outcomes. Advanced sensors are being developed which can be mounted on drones to check for radiation with an accuracy not currently available and in areas where conventional detection methods are not possible.

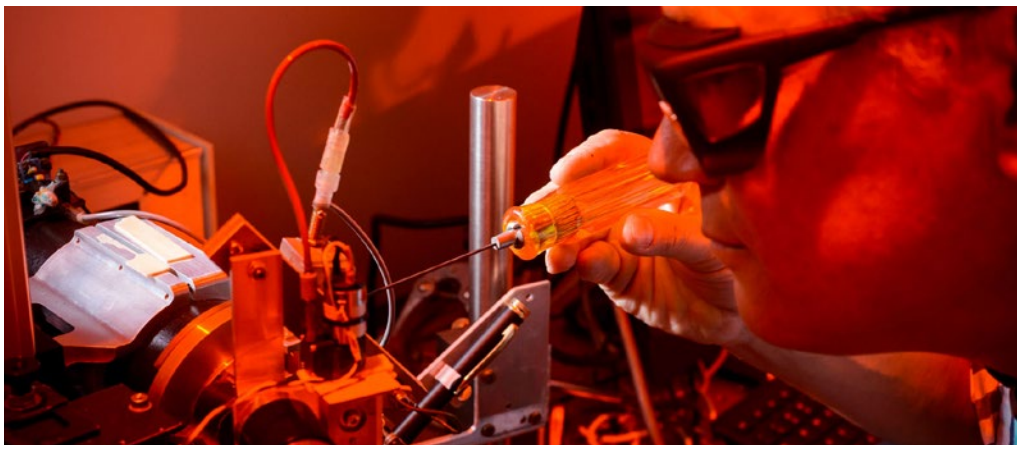
These and other CBRN-related projects help our forces avoid contamination, or when avoidance is not an option provide intelligence on the length of time personnel can be exposed without serious risk and what protective equipment will keep them safe and allow operations to continue.

Our focus is on supporting Australia's defence capability. However, this research also has implications for other environments including contaminated mine sites, emergency search and rescue, and for medical radiation therapy.

DSI also works with the Centre for Radiation Research, Education and Innovation (CRREI) to create and support the next generation of highly skilled researchers to work in this complex and uncertain space. Find out about CRREI on page 21.

Drone-borne gamma ray sensors
Professor Nigel Spooner

In a CBRN attack, our defence forces must be able to accurately assess a battle space for radiation and other toxic substances. Prof Nigel Spooner is leading a team at the Prescott Environmental Luminescence Laboratory (PELL) developing a radiation field intensity sensor which can be mounted on to a defence drone. This sensor will be capable of being flown over contentious spaces where there may be nuclear activity to detect whether radiation is present and if so, the strength and exact location of the source.



Nigel explains "Using cost-effective, robust materials, the drone-borne sensor will be able to detect radiation in all terrains and subtract naturally occurring background radiation, providing operators with a highly accurate analysis of the landscape. We use robust plastics rather than crystals as are used currently, so if the platform is damaged during operations the sensor can be recovered and used again.

"Understanding the level of radiation present and where the source is situated allows our forces to make better informed decisions on whether to move into an area, and whether it is safe to move civilians out through the area. The next steps in our research are continuing to refine the geometry of the sensor so the shape offers the most accurate detection efficiency possible and looking at other potential materials to increase usability."

This technology also has implications for routine monitoring, detecting leaks at industrial sites and mines, and for emergency management personnel dealing with potential radiation-related incidents.

Human Integrated Sensor System Program
Professor Mark Hutchinson

Sometimes it is not possible to identify in advance if there are chemical or biological agents present in an area. This might be due to time constraints or the need for personnel to enter an area not accessible by drones, such as tunnels. Even when advance knowledge is possible, the effects of exposure on an individual can be markedly different depending on their personal biological markers. Existing systems for alerting defence personnel when exposed to a chemical or biological threat rely on time-intensive procedures, such as blood tests. This can mean significant delays for deploying countermeasures, risking mission and personnel health outcomes.

Professor Mark Hutchinson and his team are developing the 'Human Integrated Sensor System (HISS) Program which identifies changes in an individual's biology within 15 minutes of exposure. This is the earliest ever warning, allowing people to immediately change their location, protective equipment or behaviour.

Mark explains "We integrate information from the individual's immune system, changes in their cognitive functions, right through to their specific biomechanical markers, to identify when they have been exposed to a threat and evaluate how likely that individual is to be functionally impaired by the exposure.

"This level and speed of detection allows the team to make better informed decisions about whether to persist with the mission and if so, the precautions needed to reduce the threat or impacts of further exposure.

"The technology we use is based on the precision medicine techniques already used in areas like oncology where they can determine exactly what cancer they're dealing with and therefore exactly what chemo will work," continues Prof Hutchinson. "You put the two together and recovery rates improve drastically. We're building on that to provide precision awareness of CBRN exposure. We have experts from immunology, psychology, maths and engineering working on various aspects of this program and the intention is to put the sensor in a wearable device like a smartwatch to allow for maximum usability in the field."

The technology will also be of great value to sectors where workers are regularly exposed to potentially harmful chemicals such as emergency services, mining and agriculture.

Strengthening the workforce

At DSI, we not only support our defence and security rising stars with the knowledge and skills to contribute to our nation's security, but also inspire and empower them to disrupt the way things are done and develop new and innovative approaches to improving Australia's defence capability.

Picture: Russell Millard/*The Advertiser*

We encourage talented students to consider defence as a career path and provide engaging, fulfilling, and rewarding reasons to stay in this sector, with the goal of boosting retention rates and addressing the critical global shortage of highly skilled and specialised professionals needed to meet Australia's future security challenges.

The University of Adelaide provides highly specialised training in chemical, biological, nuclear and radiation research, information warfare and cybersecurity and cutting-edge technologies such as quantum materials and photonics, alongside a range of internships and other development programs. DSI helps link Faculties and Schools with the defence industry, through initiatives such as the CADRs, so they can ensure this training focuses on real-world issues. Our goal is to build on the University of Adelaide's outstanding reputation for industry-oriented education, producing high-quality, work-ready graduates with broad, applied knowledge of the defence and security sectors.

AUKUS Foundations

With the AUKUS Submarine agreement now in place, the University of Adelaide is working closely with the Department of Defence to identify specific gaps in our current foundational programs and develop new course content to address these gaps. Australia now faces the challenge of building the knowledge and experience that will enable us to achieve and maintain the sovereign Technical Authority essential for operating a nuclear-powered submarine capability.

While the discipline of nuclear engineering is of course vital to this AUKUS enterprise, in terms of the number of jobs required, it is relatively small. Core disciplines that will be required in substantial numbers include electrical and electronic engineering, mechanical engineering, systems engineering, and computer science.

The University of Adelaide's Schools offering degrees in these disciplines are very highly regarded, nationally and internationally. The University also has specific capabilities in nuclear chemistry and radiation safety, both areas that a sovereign nuclear-powered submarine capability will need.

The best educational offerings from universities are underpinned by research excellence. Where there are national gaps in research and education, the University of Adelaide will be working closely with Defence to fill those gaps with highly capable research and the best educational offerings possible.

Master of Marine Engineering

This Master course is unique due to its specific Defence context. It is taught in partnership with local defence shipbuilder ASC along with guest lectures from other local industry leaders including SAAB Australia, so course content is aligned to the latest industry knowledge and practices.

Associate Professor Eric Fusil leads the Maritime Engineering course. With over 20 years' experience in the submarine industry including 2,000 hours on board nuclear submarines, he is uniquely qualified. He says "We need to not only create a workforce of diverse, smart engineers who can put things together, but also of aware engineers who can see the bigger picture and make well-informed decisions about how to act before things go wrong. We teach world-wide technologies and design philosophies to create a broad perspective but with the end goal being a sovereign capability which can be deployed quickly and effectively in the event of a threat."

A core part of the Master qualification is a Systems Engineering course. Lecturer Dr Kim Harvey says "The course is very practical in terms of providing students with the building blocks to successfully design and develop a submarine. They are responsible for all aspects including identifying what is needed, designing a solution, and testing this with the end user. Students learn how different components and systems work together and how to deal with unexpected consequences from design choices."

Kim and Eric are also creating a hub to connect learning and research with local companies called the Shipbuilding Hub for Integrated Engineering and Local Design (SHIELD) which will connect learning and research with local companies. They also created an experimental project known as ARES which involved designing and developing an experimental unmanned submarine, reconfigurable to allow for maximum flexibility under testing.

Eric adds "We will be increasing our capacity to teach future researchers and workers to support growing nuclear engineering requirements and to ensure they meet the needs of Australia's changing defence needs."

Centre for Radiation Research, Education and Innovation

The Centre for Radiation Research, Education and Innovation (CRREI) provides tertiary level education to the next generation of radiation professionals, facilitates international and national radiation research collaborations, uses the latest technology for its radioanalytical service and provides a focal point for information on radiation and related issues.

Associate Professor and Director of CRREI Tony Hooker explains "The risk of encountering radiation is a real possibility to defence personnel. It is vital we understand the potential long- and short-term impacts and how to mitigate these.

"Our researchers have specialised research experience looking into the biological effects of radiation in individuals and are currently looking to investigate the identification of personnel who may be resilient or susceptible to radiation exposure damage. We know that there is a protective effect from low doses of radiation, so we are investigating to see whether there are factors which change this effect for each individual.

"We are also looking to develop a non-invasive field test of radiation exposure which could provide the individuals with quick intel of their radiation exposure.

"We currently offer a Graduate Certificate in Radiation Management and can develop short courses in the areas of radiation. We are also offering a defence PhD program on select projects for those who wish to pursue a career in defence science and technology."

Internship programs

Designed to develop our world-class defence workforce, internship programs provide opportunities to explore defence as a career path while working on solutions for real-world problems.

Our annual summer Cyber Internship program is run in collaboration with DSTG. The 12-week program provides paid 'work experience' to undergraduate students whilst they research various aspects of cyber, electronic warfare, and related electronic communication systems including exploratory analysis of such systems with machine learning and artificial intelligence concepts.

The University of Adelaide sponsors Australian Government Security Applications for all students which enables access to the Cyber Innovation and Research Centre (CIRC) established jointly by the University of Adelaide and DSTG. Located at Lot Fourteen in the heart of Adelaide, one of the world's safest and most liveable cities, CIRC is part of a precinct that is making a global impact by accelerating innovation, entrepreneurship, research, education, and culture.

Testimonials

Karolina Dawidowski – KPMG

"I first heard about the Internship program at a networking event at Lot Fourteen. Before that I assumed I would use my Master of Cyber Security to consult for small businesses, but defence sounded like an interesting field so I applied and was lucky enough to be successful.

"I spent the summer working on a project which had two components, allowing me to partner my Visual Basic coding skills with a colleague who specialised in machine learning. The program gave me a much better overall understanding of cyber security within the defence sector which I now use in my work assessing defence-related security systems for risk and compliance."

Matt Rodda – DSTG

"Experience on real projects as a student is valuable, so when I heard about the Internship from my Uni lecturer I couldn't pass it up. The project I worked on related to machine learning on network traffic, basically teaching a computer to understand and take part in a 'conversation' when it hasn't been involved from the beginning. We were given full autonomy to choose the models, programs and components we thought may work and as I was working with people from backgrounds in physics, maths and computer science, we all had different experiences to bring to those decisions.

"At the end of the project we presented our research to the Uni, DSTG, and the wider defence community through the Defence Industry Skilling and STEM program. I am now working for DSTG on extending the work and writing a research paper so I can share the findings with the rest of academia."

Matthew Rehbein – SRC Aus

"I had completed an internship with DSTG before, so I knew the summer program would be a great way to get more experience in this interesting field. I worked on a project looking at improving machine learning algorithms which classify electromagnetic spectrum data, by incorporating an element of human guidance to speed up the training process and overcome the large data requirements of existing methods. Defence is heavily reliant on the electromagnetic spectrum and wireless communication channels, so anything we can do to improve speed and accuracy is hugely valuable.

"The program structure allowed us to work alongside other team members including on other defence-related projects, increasing our awareness of the broader defence ecosystem. I now use the technical skills I learned, and the networks I built, in my current role at SRC Aus."

Young Leadership Dialogue 2022-2023

This program brings together a group of outstanding young leaders (aged 27 – 37) from Australia and the United States to discuss areas of mutual interest and strategic importance, advancing understanding and cooperation between our two nations.

DSI sponsored participants in the two-year program, which provides a 'life changing experience' as it explores significant and timely issues facing the two countries, giving the participants a global perspective whilst collaborating and networking with their peers. DSI encourages early and mid-career researchers to apply for the program to develop their skills, expertise, and collaborative networks.

Applicants to the program need to demonstrate excellence in their field, whether in academia, business, government, defence, media, space or technology. If successful, they are expected to engage in meaningful and productive discussions to promote ties between Australia and the US, in particular where this involves innovative research endeavours in areas of mutual benefit.

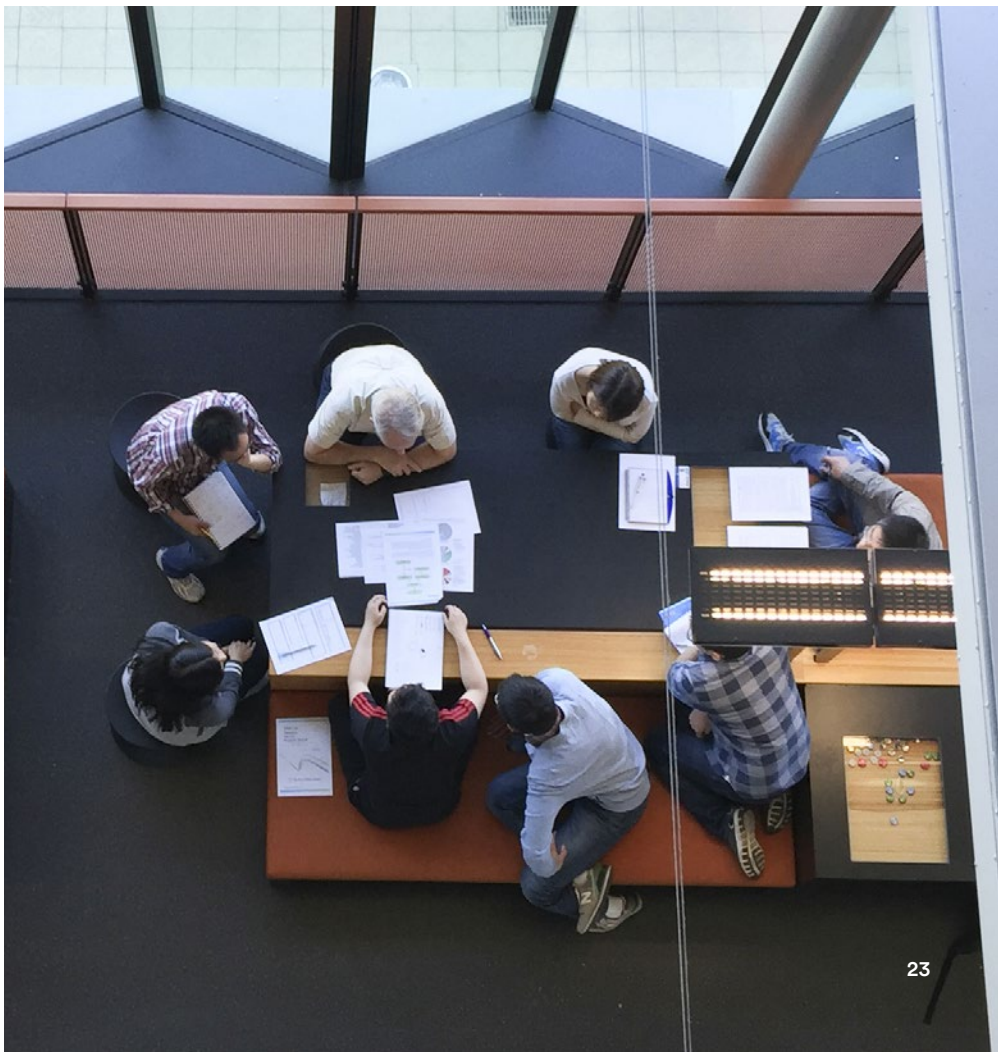
Testimonial

Professor Lewis Mitchell – University of Adelaide

"Being nominated for the Young Leadership Dialogue was an honour and I was curious to see outside the 'academic bubble', see what a range of people from industry and politics, serving members of the armed forces and defence analysts for example, could come up with when put together.

"As a Professor of Data Science, I could comfortably share in the understanding and mapping of how misinformation spreads and modelling ways to counter. Discussions in broader issues like the resilience of global supply chains, what the world looks like post-pandemic and the rise of economic coercion were not my areas, but my critical academic lens and quantitative way of thinking were beneficial to the conversation. The experience broadened the range of topics I am comfortable getting involved with and opened my eyes to the range of global issues that maths and data research can provide valuable input into.

"It also allowed me to represent the University of Adelaide and DSI at this strategic and global forum, positioning us as leaders in the defence sector."



Leadership Profiles

Michael Webb
Executive Director

Michael joined the University of Adelaide in 2008 following a long and illustrious career spanning more than 2 decades with the Defence Science and Technology Group.

Michael has a PhD in physics from the University of St Andrews, a Masters' degree in mathematical psychology, and Bachelors' degree in Electrical and Electronic Engineering from the University of Adelaide.

As Executive Director, Michael provides a single point of contact within the University for all defence and security related research and education whilst leading a diverse range of defence related applied research.

With awards for leadership and contributions to the sector including the Australian Operational Service Medal (Iraq and ICAT), his knowledge, dedication and experience make him a natural fit for the role of Director, Defence and Security Institute.

Lieutenant General (Retired) Rick Burr AO DSC MVO, Strategic Advisor to DSI

Rick retired as Chief of the Australian Army in 2022 after a distinguished career in prominent leadership appointments, in strategic roles and on operational service.

He has deep experience and unique strategic insights from leading complex organisations, engaging throughout Australia and across the Indo-Pacific region, and transforming organisations and capabilities to meet future needs. He is passionate about investment in future leaders and the centrality of people, leadership and culture.

Rick is an Officer of the Order of Australia, recipient of the Distinguished Service Cross and Member of the Royal Victorian Order. His leadership has also been recognised with numerous foreign honours.

Rick is a graduate of the Harvard Business School Advanced Management Program, the Cranlana Centre for Ethical Leadership, the United States Marine Corps' Command and Staff College and School of Advanced Warfighting, and of the Royal Military College, Duntroon. He holds a Master degree from US Marine Corps University and Bachelor degree from the UNSW.

In January 2023, Rick joined the University of Adelaide as a strategic adviser. His in-depth, real-world understanding of the complex challenges facing our nation will support DSI in developing innovative strategies and technologies to prepare for a future defined by the effects of disruptive technology across multiple domains.

Jennifer Burgess
Assistant Director and Institute Manager

Jennifer joined DSI in June 2021 bringing with her more than 20 years' experience in the defence sector including senior roles in areas including defence strategy, capability development, policy, and modernisation.

With qualifications in engineering, capability and project management, and awards for leadership, dedication, courage, outstanding teamwork and military operational service, she is well placed to lead the development and implementation of the Institute governance and operations, including intersections with other University departments, functions, and activities and external parties.

Jennifer oversees all operational areas of DSI including research development, funding schemes, and marketing and communications, in addition to developing the strategic direction of the Institute, managing major projects and supporting the development of major program funding applications.

Jennifer guides change towards higher performance by working with stakeholders, understanding, and analysing perspectives, to inform problem-solving and decision. Her vision is to create an environment that energises people, fosters collaboration and activity, to do phenomenal work in support of the defence of Australia and its national interests.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Kaurna acknowledgement
We acknowledge and pay our respects to the Kaurna people, the original custodians of the Adelaide Plains and the land on which the University of Adelaide's campuses at North Terrace, Waite, and Roseworthy are built. We acknowledge the deep feelings of attachment and relationship of the Kaurna people to country and we respect and value their past, present and ongoing connection to the land and cultural beliefs. The University continues to develop respectful and reciprocal relationships with all Indigenous peoples in Australia, and with other Indigenous peoples throughout the world.