DEFENCE SCIENCE AND TECHNOLOGY (DST)

OUTLOOK

DST

2018-2019 EDITION

DST SUPPORT OF AEROSPACE CAPABILITY

INTERVIEW

DR ALEX ZELINSKY
FORMER CHIEF DEFENCE SCIENTIST

DEVELOPING SPACE AND SATELLITE TECHNOLOGY

DISEASE FORECASTING & MEDICAL COUNTERMEASURES

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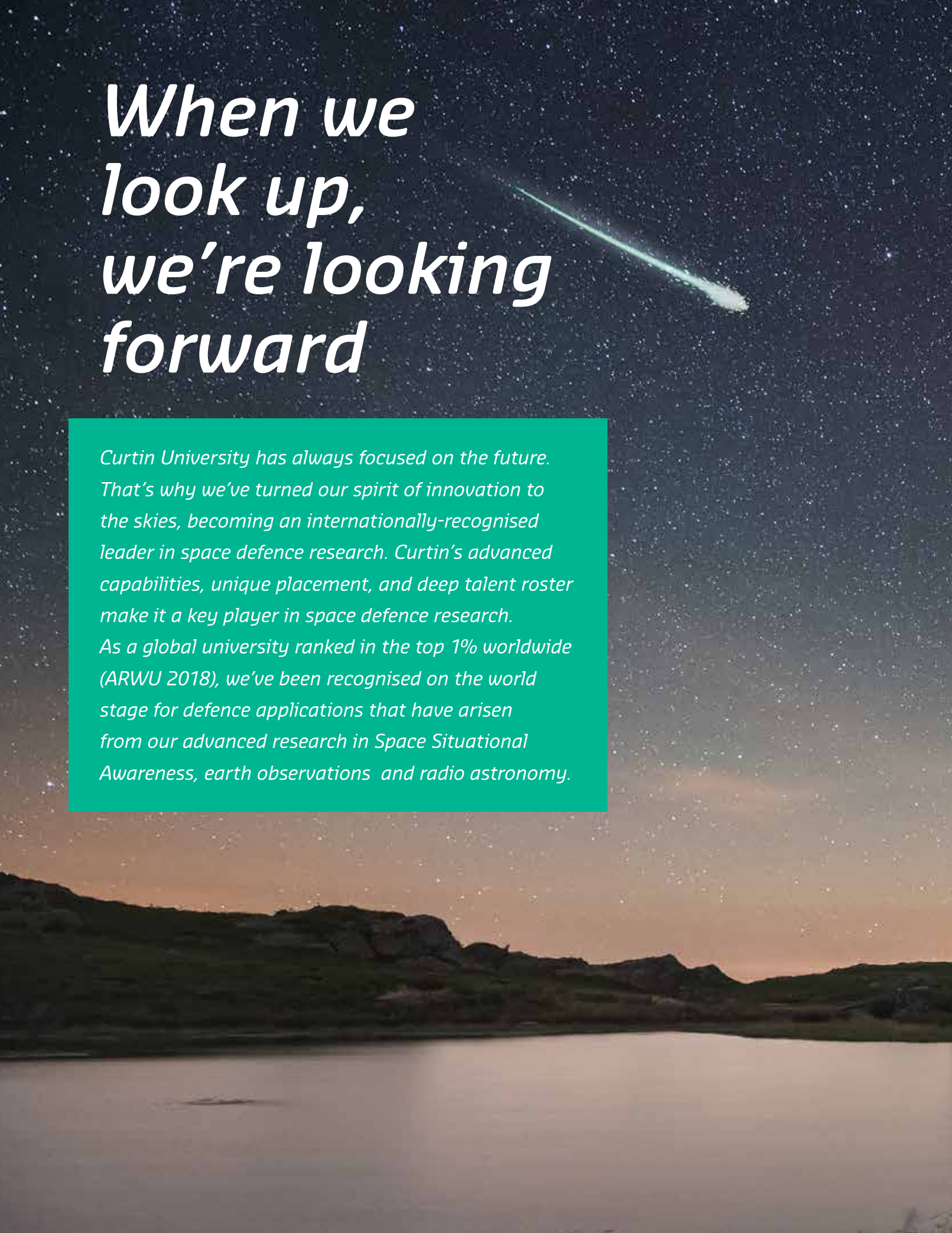

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Phil Bland

Professor Bland is an expert in planetary science, Director of the Desert Fireball Network, and the Australia node of the NASA Solar System Exploration Research Virtual Institute.

Steven Tingay

Professor Tingay is the Executive Director of the Curtin Institute of Radio Astronomy (CIRA) at Curtin University, author or co-author of over 200 papers, and leader of the Murchison Widefield Array project.

David Antoine

Professor Antoine heads the Remote Sensing and Satellite Research Group. His research interests include marine optics, bio-optics, radiative transfer and applications, and satellite ocean colour remote sensing.

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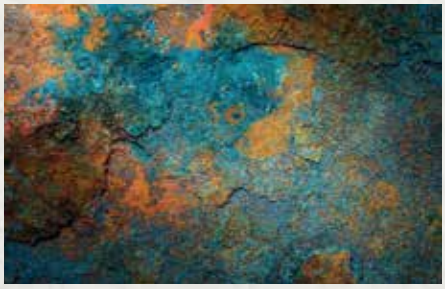

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DEFENCE SCIENCE AND TECHNOLOGY (DST)

OUTLOOK DST

FOREWORD

Welcome to the 2018-2019 edition of *Defence Science and Technology (DST) OUTLOOK*, celebrating the incredible work done by DST.

Faircount is delighted to have worked closely with DST in creating this publication. For the support of the Chief Defence Scientist, Defence Science Communications (DSC), the DST researchers, subject matter experts and DST Chiefs of Divisions who assisted with the content, we are truly thankful.

The work undertaken by DST is without doubt some of the most important in government. Whether it is advising on the desired capability requirements of a new Navy acquisition such as SEA1000 or SEA5000, or finding ways to help troops be more productive through nutrition and human performance, every level of Australia's defence is steered by the scientists behind it.

With the arrival this year of the first of Australia's F-35s, we decided to highlight DST's support of aerospace capability. We look at some of the current aerospace programs and how DST has assisted them, as well as looking back over the past 30 years at some major highlights in DST research and support.

We also report on some major events that took place this year including DST's flagship partner event, SCINDICATE 2018, and Autonomous Warrior 2018, which was developed to demonstrate the potential of uninhabited systems to transform Defence capability.

Finally, we have included articles on a number of other topics including autonomous systems, how drones are being used for security and humanitarian relief, security, expanding research networks, space and satellite technology, disease forecasting and medical countermeasures, and game-changing technologies to name a few.

We hope you enjoy these insights into DST.

David Sanis
Managing Director & Publisher

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DEFENCE SCIENCE AND TECHNOLOGY (DST)

OUTLOOK DST

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Constrained living spaces, shift work, social pressure, months away from home and long working-hours create an environment that not only makes sleep difficult but can also impair cognitive performance.

Engaged by Defence Science and Technology (DST) to look at these problems, the University of South Australia (UniSA) conducted research into onboard living conditions aimed at improving the welfare and raising the endurance and performance of submariners.

UniSA's industrial design team worked closely with the Royal Australian Navy's (RAN) Submarine Force to understand the daily activities, habits, physical requirements and psycho-social needs of the crew.

The team also engaged experts to understand the impact of fatigue and what factors would contribute to the most effective sleep environment.

The design team drew on data from an anthropometric survey of RAN personnel.

The survey helped to create digital human mannequins that were used in a virtual reality environment to develop and evaluate design proposals. Full sized physical models were also made to demonstrate the proposed designs to submariners.

The result of UniSA's research is a new design methodology to build sleeping berths and cabins that makes better use of space and, most importantly, improve the living conditions for serving crew on future submarines.

For more information about our defence capabilities visit

unisa.edu.au/defence

University of South Australia

Image: Associate Professor Siobhan Banks, with Jared Heenen, conducting cognitive testing in a submarine sleeping berth redesigned by UniSA's industrial design team led by Dr Peter Schumacher.

UNISA'S DEFENCE INDUSTRY EXPERTISE AND ENGAGEMENT

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Our defence personnel could soon drive vehicles with adaptive camouflage thanks to world-leading research conducted at UniSA's Future Industries Institute in collaboration with the DST. Powered by a AA battery, the flexible plastic cells covering the vehicle can change colour to blend into the background environment.

WHAT YOU WEAR CAN TELL US WHETHER YOU'RE WORN.

UniSA is developing the next generation of wearable sensors that monitor a soldier's stress and cognitive workload during operations. This data is especially useful for improving human-machine interfaces to reduce operator fatigue and optimise decision-making by changing the information displayed or the team composition.

For more information about how our research is making a valuable contribution to the defence industry visit ***unisa.edu.au/defence***

Image: UniSA's industrial design team are also working on more efficient and effective operator console design on submarines and surface naval platforms.

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INTERVIEW WITH FORMER CHIEF DEFENCE SCIENTIST AND HEAD OF DEFENCE SCIENCE AND TECHNOLOGY (DST)

DR ALEX ZELINSKY

Dr Alex Zelinsky stepped down as Chief Defence Scientist in November 2018 after more than six years in the role, to take up the position of Vice Chancellor at the University of Newcastle. By **Nigel Pittaway.**

Dr Alex Zelinsky was appointed CDS in March 2012 and during his tenure has overseen the transformation of the science and technology organisation he has led, from the Defence Science and Technology Organisation (DSTO) to the present Defence Science and Technology (DST).

This important transformation recognises DST as one of the Australian Defence Organisation's Fundamental Inputs to Capability (FIC) and was foreshadowed in April 2013 by the release of a new strategic plan, which identified a need to more effectively address the longer-term science and technology needs of Defence and be more agile in its response to those changing needs. It also highlighted the need for the organisation to collaborate more effectively with external organisations, particularly with industry and academia.

When he announced Zelinsky's impending departure in June 2018, Minister for Defence Christopher Pyne paid tribute to the work he had accomplished during his tenure, saying that he had transformed DST into a highly successful and valued enabler of Defence capability and the scientific lead for Australia's national security.

"During his tenure as Chief Defence Scientist, Dr Zelinsky has overseen the realignment of DST's research priorities to meet future Australian Defence Force requirements with the application of leading edge science and technology," Minister Pyne said. "Dr Zelinsky's leadership of the $730 million Next Generation Technologies Fund has led to new alliances being forged, and partnerships with Australian industry and academia strengthened. The opportunities afforded by the Next Generation Technologies Fund are enormous for Defence as well as the Australian research and innovation sector in the foreseeable future."

FROM DSTO TO DST

Zelinsky credits the Defence First Principles Review, commissioned in 2014, and the 2016 Defence White Paper for providing a 'reset' for the organisation.

"Under the previous government, Defence spending had been reduced and there was also a sense that the Australian Public Service was being reduced and there were questions about the future, but I think the First Principles Review was a reset for the Department of Defence," he says. "There was a question about whether DSTO belongs outside Defence, or inside it, but in the end the Government took the view that DSTO should really be a part of the strategic centre, and one of the core capabilities."

Zelinsky says the First Principles Review talks about the three individual services (Army, Navy and Air Force) and the joint element, with capability sustainment and science and technology as part of the overall capability. "It was understood that science and technology were an important element of capability – giving Defence the capability edge it was seeking, and then maintaining it. It also took a more strategic view that, if Australia was to either create or prevent strategic surprise, we needed to conduct research into the development of new, game-changing, technologies," he says.

At the same time, Zelinsky says that the move from DSTO to DST was an important step in the process, which in turn led to the White Paper and the re-emphasised role innovation will play in the development of these game-changing technologies.

"We argued that for Defence to be able to create and prevent

"It is impossible to predict at this stage which of those we are partnering together on are going to be a runaway success, but I'm hoping that some of those programs will yield important and useful results that can be adopted by Defence to give us that capability edge."

strategic surprise, we had to make sure all the best scientists, engineers and technologists in Australia were working with us and that we had access to them," Zelinsky continues. "That meant we had to have a new engagement mechanism and that's where the Next Generation Technologies Fund and the Defence Innovation Hub and the Centre for Defence Industry Capability (CDIC) portal were developed. We have moved from the single transactional interactions that DSTO used to have with the innovation sector within industry and academia, to a much more structured program that is part of the First Principles Review."

MEASURING PROGRESS

A study carried out in conjunction with the First Principles Review identified that over a 10-year period, DST created between $20 billion and $25 billion of value for Defence. In addition to that, the current Next Generation Technologies Fund is spending $1.6 billion to create new technologies, while the Defence Innovation Hub seeks to mature those technologies. But how is progress measured?

"We have stood up a whole range of new engagement mechanisms with academia and industry. For example, there are seven new programs in the Next Generation Technologies Fund and one of those is the Grand Challenges program," Zelinsky explains. "The first of those is looking to counter improvised threats and we've also set up a program which is looking at Trusted Autonomous Systems, under a Defence Co-operative Research Centre (Defence CRC) construct. We want a CRC in Trusted Autonomous Systems and we're asking Australian industry and academia to come forward and tell us about their capabilities, so we can organise them into a team. That is an exciting new program."

Another recent initiative has been the Small Business Innovation Research program for Defence (SBIRD), which focuses on Australian small to medium enterprises (SMEs) which can develop technologies valuable to Defence. One example of success so far includes Myriota, which has developed a recording device for soldiers called the Fight Recorder. Another is a start-up company formed by two former DST scientists called Silentium Defence, which is working to develop new technologies in the area of passive radar.

"We are also forming research networks where we bring the best people in Australia to work together in the university sector. Previously DST would work with a particular

university on a particular problem, but we have realised that there are many other universities that may be able to contribute to the same problem," Zelinsky adds.

"So, we are forming networks, including one in human performance research where we've brought in seven universities around the country to work together."

This co-operation has recently been extended to universities in the United States, under the Multi-disciplinary University Research Initiative (MURI), where each country provides funding for its own universities to form partnerships with one another to solve Defence problems. Zelinsky says one example of this is a partnership formed between the University of Tasmania's Australian Maritime College, Massachusetts Institute of Technology (MIT), University of California – Berkeley, and Johns Hopkins University to work together on hydrodynamics.

"What that means is Australians are getting access to the best researchers and at the same time we are actually learning best practices and we can bring that technology back to Australia," he says. "It is impossible to predict at this stage which of those we are partnering together on are going to be a runaway success, but I'm hoping that some of those programs will yield important and useful results that can be adopted by Defence to give us that capability edge."

A PERSONAL RETROSPECTIVE

Zelinsky says that every CEO or chief executive has a 'use-by' date and after almost seven years in the role, it is important to know when to step away and move on.

"Defence has now changed over its leadership; we have a new Secretary, a new Chief of Defence Force (CDF), two out of the three Chiefs of the services are new, and many Deputy Secretaries have changed over as well," he muses. "It is a new team coming in and I think it is a really good time for a new Chief Defence Scientist to join the bigger Defence team as well. That is the reason for he timing."

Looking back upon his tenure, Zelinsky says that his achievements include the establishment of DST as a valued member of the Department of Defence's strategic centre, which is producing results Defence needs, underpinned by world-class research and development.

"We have measured against external benchmarking and I'm pleased to see that a great deal of our work is world-class and in fact in some areas, absolutely world-leading." He adds: "What we are doing now is taking that work and then applying it, to make sure that everyone knows about it and the organisation becomes known as one which is more valued and more valuable. But to do that, we've also had to be more collaborative and work more closely with industry and academia, both nationally and internationally."

He says that the organisation has also become more agile, recognising the fact that good ideas can actually come from anywhere. He also points to new, world-class facilities that are being built around the country, albeit against a backdrop of a workforce reduction in the order of 20%, in line with the Department of Defence's targets. "But our output has actually gone up, and that's because we have formed more partnerships and there's more outreach going on, we're more collaborative," he details.

"I'm also proud of the facilities we have been able to invest in, given the fact that we went through a pretty tough financial period. We've been able to invest in the right facilities and enablers for our people."

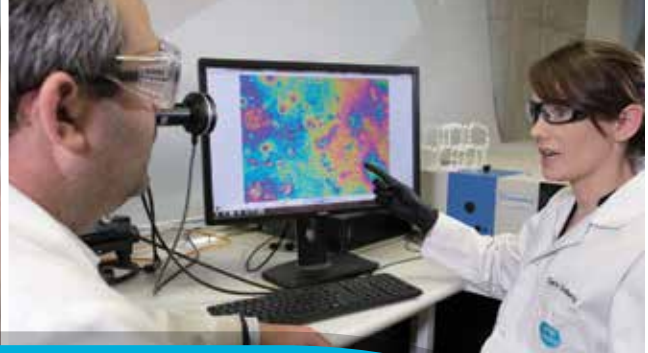
ATTRIBUTES OF DST TODAY

Zelinsky says that the biggest strength of DST today is the calibre of the scientists and researchers who work within the organisation, whom he describes as world-class at what they do. However, he adds that they cannot work effectively without support and pays tribute to the supporting team and the environment established within the workplace.

"Another thing I'm pleased about is that we have removed some layers of management. We have cut a lot of red tape out, removed some layers of bureaucracy and reduced the number of business units down to seven core research divisions and three corporate divisions to support them," he explains. "We previously had 14 divisions, but now we are organised for success and it's all about our people."

This success has also meant a



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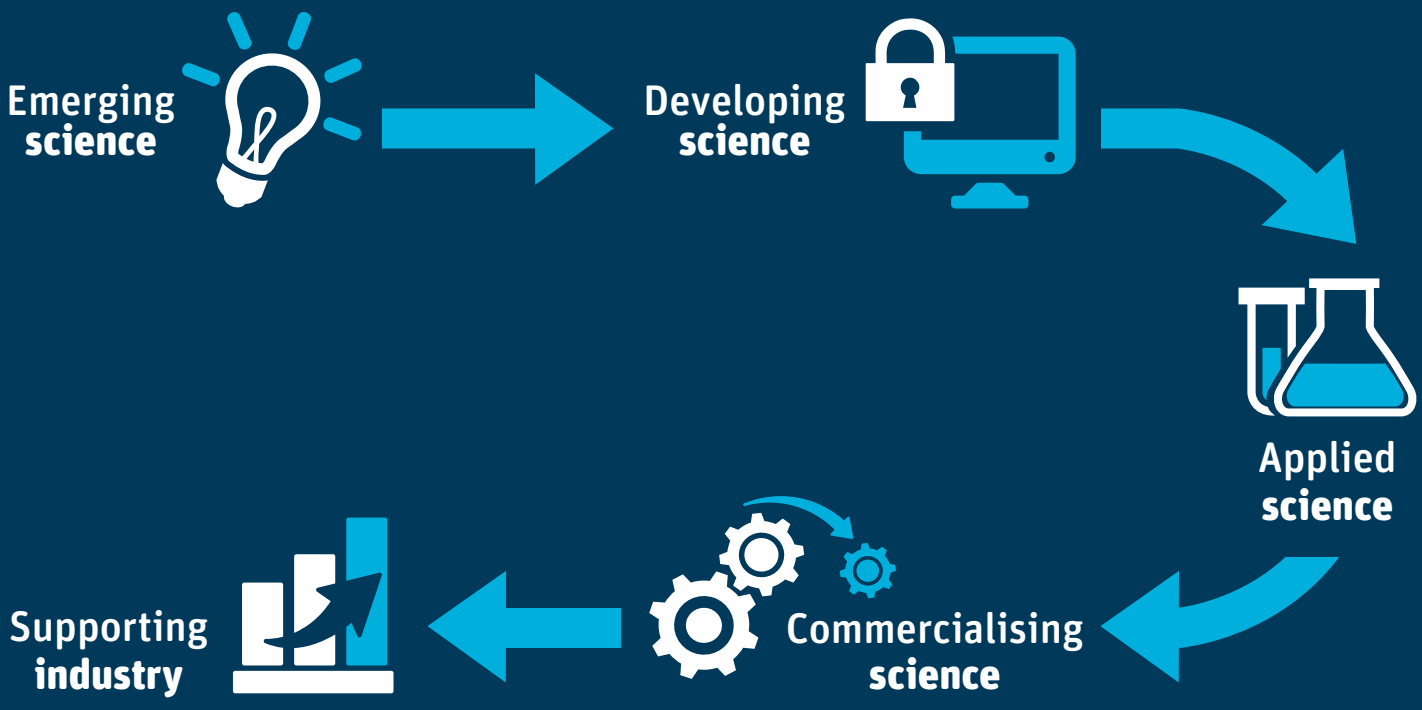

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EMERGING SCIENCE

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CSIRO's Data61, Australia's largest data innovation group, is supporting the Federal Government's Cyber Security Strategy by developing home-grown cyber security capabilities and promoting international co-operation. We have more than 70 cyber security research initiatives active across the network of universities, research institutions and government sectors.

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CSIRO develops fully integrated systems that can sense and provide next generation communication capability. We have researchers working on new broadband antennas and magnetic sensors. CSIRO works with the latest in advanced materials and additive manufacturing, not only combining functionality with strength, but also powering next generation defence capability.

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COMMERCIALISING SCIENCE

We have a number of programs for engaging with industry and supporting innovation.

Our ON Prime:Defence is a part-time pre-accelerator experience designed for science and technology that has the potential to deliver real impact for Australia's national security and defence. Powered by CSIRO, and delivered in partnership with DST, ON Prime:Defence gives researchers a unique opportunity to fast-track their science or technology proposition with expert guidance from those who've been there and done it before.

Main Sequence Ventures is the manager of the CSIRO Innovation Fund which invests in start-up and spin off companies, and small to medium sized enterprises (SMEs) engaged in the translation of research generated in the publicly funded research sector. The CSIRO Innovation Fund is intended to help improve the translation of publicly funded research into commercial outcomes and stimulate innovation in Australia. This will help successful business to grow – boosting Australia's productivity and exports, and generating jobs through increased commercialisation of research outcomes, particularly in priority sectors of the Australian economy.

SUPPORTING INDUSTRY

We partner with a wide range of organisations – from multi-nationals to SMEs, government, research institutes, industry associations and universities – to drive the change Australia and the world needs.

Our national SME Connect team connects Australian SMEs businesses with Australia's research sector, facilitating and enabling innovation-driven partnerships through funding, support and resources. The program is designed to help Australian SMEs overcome potential barriers to innovation through a series of dollar-matched funding and support programs that link those businesses with the expertise and facilities of Australia's best research organisations.

By linking up with key defence initiatives CSIRO helps boost the Australian economy by getting SMEs to be part of the supply chain.

Dr Andrew Piotrowski, winner of the 2018 Minister's Achievement Award, with the former Chief Defence Scientist Dr Alex Zelinsky and Senator David Fawcett who presented the award.

"Today it's very much around multi-disciplinary science, where you might have a material scientist working with a computer scientist and an engineer to build autonomous systems. Teams of people working on complicated technology is how the modern world works. I think we have to be able to work that way too and we're on a journey."

cultural change within DST to embrace collaboration and innovation. "Five or six years ago our people were sitting there working by themselves or within a small team and although some people are still working that way today, I would argue that it isn't the way 21st century science and technology is being conducted," he adds. "Today it's very much around multi-disciplinary science, where you might have a material scientist working with a computer scientist and an engineer to build autonomous systems. Teams of people working on complicated technology is how the modern world works. I think we have to be able to work that way too and we're on a journey."

Although progress has been made on this journey over the past two or so years, Zelinsky says there is still some work to do in terms of collaborating and partnering with other organisations in the future. "It won't be about individuals anymore, it's going to be about teams which are geographically distributed: they will be distributed across divisional boundaries and then maybe across organisational boundaries and possibly even international boundaries," he predicts. "So, we could be working with our partners in the UK, the US, Canada and New Zealand, and we're increasingly working with partners in the Asia-Pacific area such as Singapore, Korea and Japan."

ENGAGING WITH INDUSTRY AND ACADEMIA

One of the tributes paid to Zelinsky by Minister for Defence Christopher Pyne when his impending departure was announced, was acknowledgment of the fact that under his leadership, DST has established long-term bilateral research and development relationships with 17 Australian companies and research agencies and 33 universities in areas of strategic significance to Defence.

"One of the good things that's come out of our work is that we used to engage with each particular university or particular company. We would negotiate and write a contract with each partner," he details. "We have now moved to standardised agreements, so all our university partners operate under the same agreement."

Zelinsky adds that intellectual property is treated in the same way for each partner, as is the way projects are funded and the way the organisation pays for services. "We have made the commitment that we don't necessarily have to own the IP, as long as we have access to it on fair commercial terms," he says.

Similarly, DST has simplified contracts through which it engages

with industry – both the primes and the SMEs. "The SBIRD program, for example, is specifically for SMEs and they are exciting to work with," Zelinsky adds. "We're actually spinning off SMEs as well, but we don't do that to compete with Australian industries, we do it to grow industry where there's a capability gap."

LOOKING TO THE FUTURE

Looking forward, Zelinsky says one of the key priorities for DST will be to draft the next strategy document which will build on current capabilities and direction.

"There are a number of programs in various stages of the approval process with Government, in terms of supercomputing capabilities, and it's important to make sure they continue through the process in good shape," he says. "We also need to ensure that the Next Generation Technologies Fund is actually moving forward with this engagement."

In terms of advice for his successor, Zelinsky says that leaders need to be ambitious and should not be afraid to 'think big'.

"I say to my staff that we should think big – start small but move quickly. Sometimes as new leaders we want to do big things, but it takes time to get initiatives moving and we tend to make the system complicated and that makes it hard to change things," he offers. "But I think it's better to be agile while doing this and thinking big – starting small, but moving quickly."

THE FINAL WORD

Zelinsky says that the future of DST is aligned with the Government's national security policy and priorities. "The 2016 White Paper was very clear about what Australia's national defence priorities were. The country is going through the biggest recapitalisation of its Defence platforms – maritime, land and air – since the Second World War," he states. "Science and technology is a core part of realising that capability. That means that we can help the department de-risk as it acquires these new platforms, but also how they are maintained and sustained."

He says that the rate of change of technological innovation is rapidly increasing, but this presents real opportunities for DST to engage with the innovation that is occurring in the commercial world, and to bring it into Defence and national security. "I think it is an enormous opportunity – a challenge, but an exciting one," he offers.

Finally, Zelinsky's closing words pay tribute to the people within the DST organisation.

"I am really proud of our people and it is really great to see that they are starting to be recognised for their work. Many of these people are relatively young and they are being recognised as some of the best in the world," he concludes. "That tells me that the pipeline is good and if we support them, they will produce these fantastic innovations for Australia's Defence and national security needs for decades to come."

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Stimulating Research Through Collaboration

Recently, conversations about South Australia's defence industry have centred on naval shipbuilding.

Defence SA's Chief Executive Richard Price says that while there needs to be a very strong focus on naval shipbuilding in the state, other sectors are as important to South Australia's economic growth. "Obviously naval shipbuilding is huge for Australia, and much of the new technology that will be developed for our defence industry will be in this area; however, defence industry policy is also stimulating other key areas such as ISREW, cyber and space," Price says.

Price adds that South Australia's Defence Innovation Partnership is acting as a catalyst for new conversations between industry and research institutes.

Established in January 2018, the Defence Innovation Partnership is a collaborative initiative of Defence SA, Defence Science and Technology, and South Australia's three universities. It connects government, industry and researchers with the right partners and fosters the formation of new projects.

"A key activity of the Defence Innovation Partnership is the Collaborative Research Fund program, which provides up to $150,000 to support collaborative research and development activities.

"We've recently selected five successful projects as part of the second round of the program. The projects were selected from a pool of high-quality applications and we were pleased to see some robust collaborations.

"It was also terrific to see South Australian researchers teaming up with national and international partners," Price says.

"In April this year, the Defence Innovation Partnership provided $600,000 to support four projects through its inaugural Collaborative Research Fund round, and these projects are progressing well."

In order to be considered for funding, projects must demonstrate genuine collaboration between South Australian researchers and partners from industry and government, while also being desirable for Defence.

"The Defence Innovation Partnership is also unique because the funding opportunity is open to researchers from both university and industry – something which isn't currently available in similar programs.

"The work of the Defence Innovation Partnership is done in collaboration with the industry expertise of Defence SA and there is also a permanent Defence Science and Technology staff member in the office to provide that strong link to researchers," Price says.

The five funded projects for round two of the fund program include:

- $150,000 for Human-Machine interfaces for detecting, monitoring and managing psychological stress, led by the University of Adelaide with partners the University of South Australia, Flinders University, ElectroAutoMedics and Defence Science and Technology.

- $94,700 for identifying combat and combat-related stigma through the language of a deployed Australian military population, led by the University of South Australia with partners The University of Adelaide, Defence Science and Technology, and The Road Home.

- $150,000 for AI Enabling Australia's Future Submarine, led by Acacia Systems Pty Ltd with partners The University of Adelaide, Flinders University, Defence Science and Technology and Lockheed Martin.

- $150,000 for Miniaturised Orbital Electronic Warfare Sensor System (MOESS) - Phase 1, led by DEWC Systems with partners Defence Science and Technology, Flinders University, The University of Adelaide and University of South Australia.

- $150,000 for engineering, design and lab based testing a whole of vehicle Health Usage Monitoring System (vHUMS) for defence vehicles, led by Dynamic Engineering Solution Pty Ltd with partners Defence Science and Technology, The University of Adelaide, University of South Australia and Flinders University.

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DST SUPPORT OF AEROSPACE CAPABILITY

DST continues to play an important role in support of the introduction and ongoing operation of all the Australian Defence Force's new aerospace platforms and capabilities. By **Nigel Pittaway.**

A range of new platforms have been either recently introduced, or are in the process of being acquired, including the Lockheed Martin F-35A Joint Strike Fighter, Boeing P-8A Poseidon and EA-18G Growler, Leonardo C-27J Spartan, Northrop Grumman MQ-4C Triton and Sikorsky MH-60R Seahawk 'Romeo' helicopter. DST has already played an integral role in each of these major acquisition programs and will continue to support them throughout their service lives.

DST's involvement in Aerospace capability literally extends from the cradle to the grave, encompassing everything from research and development work in emerging technologies through to the early planning and definition studies and acquisition process, to the sustainment phase.

AEROSPACE DIVISION

Although support to aerospace capability is provided across the organisation, DST's Aerospace Division at Fishermans Bend in Melbourne is where most of the efforts are focused.

"DST provides Science and Technology support to the ADF to ensure informed acquisition decisions are made and executed, intended capabilities needed for the modern, high-tech battlespaces are met, and the cost of ownership of these capabilities is minimised," explains Chief of

Aerospace Division, Dr Dong Yang Wu.

Fishermans Bend is home to around 99% of the 240 people who work for the division, with a small number at DST's facility in Edinburgh, South Australia, mainly engaged in unmanned aerial vehicle (UAV)-related work.

The scientific expertise in the Aerospace Division includes propulsion systems, aircraft structures, flight dynamics, advanced aircraft materials, human factors, simulation and extreme environment materials. It supports all aspects of the operation and maintenance of the ADF's aircraft fleet, including airframes and engines, weapons and stores, electromagnetic environmental effects, signature management and platform information systems.

The organisation is world-leading in many areas of this expertise and DST staff have recently been recognised by high office in the United States for their achievements. "In September for example, a DST scientist was presented the US Secretary of Defense medal for Exceptional Public Service. This medal is the highest award for non-Defence staff bestowed by the Office of the Secretary of Defense (James Mattis) and recognised the scientist's efforts during his posting into the Joint Strike Fighter's F-35 Joint Program Office (JPO), in the Prognostics and Health Management Integrated Project Team (IPT). That saved the JSF Program millions of dollars and improved efficiency – thereby helping Australia's F-35A program to be more affordable and sustainable," Wu says. "This is the third such award presented to DST Group by the US Government in support of F-35; the first was awarded in 2014, the second in 2016 and the third this year (and) all recipients are from the Aerospace Division."

SUPPORTING THE JOINT STRIKE FIGHTER

Australia is buying 72 Lockheed Martin F-35A Joint Strike Fighters under Project AIR6000 (New Air Combat Capability) to replace the ageing fleet of F/A-18 Hornets in service with the RAAF and the first two aircraft are due to arrive in Australia in December 2019.

Australia has been a Tier 3 partner in the international F-35 program since 2002 and DST's involvement stretches back to that time. Its current roles in the JSF include the provision of critical Science and Technology (S&T) aspects of the program throughout the acquisition, introduction to service and sustainment phases of AIR6000. Specifically, the organisation supports the Australian JSF IPT by providing technical risk assessments, operational analysis, modelling and simulation, research in key technology areas and assistance to Australian defence industry engaged in the program. As noted, it also has S&T staff embedded within the F-35 JPO in the United States.

"DST has staff working on the JSF program at research facilities in Australia and at various locations in the US," Wu details. "The work performed by these scientific and project personnel has been recognised at some of the highest levels possible, including their pivotal role in providing enhanced fatigue data for analyses of the platform."

Wu says the improved fatigue analysis methodologies were developed in-house by DST in a collaboration between its Aerospace and Maritime Divisions and the placement of personnel within the JPO reflects the organisation's expertise and international reputation.

"The S&T advice provided by DST has led to improved confidence that the JSF program will deliver high-technology capabilities for the ADF with significantly lower risk and lower through-life costs," she adds.

DST has also supported the JSF program through its advocacy of a third full-scale lifetime durability test, which will provide enhanced structural assurance to complement the work already done by Lockheed Martin as the original equipment manufacturer (OEM).

"The work we are proposing is based on our expertise in this area," Wu explains. "We will be performing some smaller-scale testing at Fishermans Bend, but the full-scale tests were conducted in the US and UK."

Further work with a focus on enhanced structural assurance being undertaken by DST includes the development of new fatigue design curves, made possible by characterisation of metallic surface treatments and the application of the in-house thermoelastic stress analysis in the verification of the OEM's design stresses during fatigue testing.

Other aspects of the organisation's engagement with the international program relate to tactical and operational simulation, interoperability studies and Intelligence and Mission Data (IMD), which are all strongly linked to Plan Jericho, the RAAF's fifth-generation roadmap for the future. The full integration of F-35 capability with the broader Australian Defence Organisation and DST's world-leading Live, Virtual and Constructive (LVC) simulation research and capabilities are also contributing to the introduction integration of the fifth-generation capability.

"We have also been working on weapons release and stores clearances, different properties of materials and a whole range of things. We do a lot of work on the F-35 program," Wu says. "The work undertaken by DST to date and into the future ensures that the intended capability of the F-35A as a fifth-generation air combat capability is met and that it can operate safely and effectively in the Australian-specific context, with a minimised cost of ownership."

MH-60R 'ROMEO' SUPPORT

The Royal Australian Navy has recently completed the introduction of the Sikorsky MH-60R Seahawk naval combat helicopter to replace its earlier S-70B-2 Seahawk fleet. Colloquially known as the 'Romeo' in service with the Fleet Air Arm, 24 helicopters have been acquired, primarily for use aboard the Navy's major surface combatants – the Hobart class DDGs and Anzac and (future) Hunter class frigates.

DST involvement in the Romeo program, under the aegis of Project AIR9000 Phase 8, began back in 2010 and the organisation will continue to be extensively involved through to life of type, some decades from now. Major examples of this ongoing work include research into infra-red signature management, powerplant improvements and studies into the operational limits of the helicopter when operating aboard RAN warships.

In addition to this work, then Minister for Defence Industry (now Defence Minister) Christopher Pyne announced in April that DST will use a retired US Navy Seahawk airframe to develop fatigue testing technologies which have the potential to transform how military helicopters are managed throughout their service lives.

"The Australian operating environment is different and, because we only have a small fleet of MH-60R helicopters compared with the US Navy, our missions are very different. We need to be lean and efficient and we need to multi-task."

The airframe, donated by the US Navy for the work, is a former prototype MH-60R airframe which was converted from an earlier SH-60B and dubbed 'Bromeo'. It is part of the Helicopter Advanced Fatigue Test – Technology Demonstrator (HATD-TD) program, a joint US Navy and DST project being undertaken at Fishermans Bend, which will apply novel techniques to demonstrate the feasibility of significantly shorter helicopter fatigue load testing projects.

"The airframe has been donated by the US Navy because the United States recognises that DST has a world-leading capability in this particular area," Wu explains.

In the case of the Romeo helicopter, DST has estimated that to test all the complex load behaviours peculiar to a helicopter by current methods would take upwards of 250 years, so HAFT-TD is exploring means by which this can be reduced to just 2.5 years. The Australian Government has invested $5 million over the next five years in the trial program, which will last until 2022.

"This will allow timely fleet sustainment decisions to be made," Wu adds. "If successful, the technology developed from the HAFT-TD when applied to a life extension of the Romeo should lead to a significant increase in the Flight Hours limit and the operational availability of this aircraft."

The technology will be initially used to inform the service lives of the Romeo in RAN and US Navy service,

"DST has staff working on the JSF program at research facilities in Australia and at various locations in the US. The work performed by these scientific and project personnel has been recognised at some of the highest levels possible, including their pivotal role in implementing improved fatigue analysis methodologies for the platform."

but in the future it could also be adapted for testing other helicopters, such as the ADF's MRH-90 Taipan multi-role helicopter (MRH) and even for the US Government's ambitious Future Vertical Lift (FVL) program. In a statement following the launch of HAFT-TD, Minister Pyne said that, if successful, the program could also represent "considerable opportunities" for the defence industry in Australia.

Some programs which began as research and development project during the time the S-70B-2 was in service have equal application to the Romeo, including the Small Engine Test House (SETH) at Fishermans Bend. The test facility is being upgraded – with work set for completion in June 2019 – and will use a General Electric T700 donated by a retired Seahawk to test a series of different technologies, including IR signature suppression, alternative fuel technologies and prognostic and health management systems and components, such as wear debris sensors and vibration algorithm development and validation.

A further example is the DST-developed low emissivity coatings which were initially tested on the earlier Seahawk and are now also in use on the Romeo. The coatings are a very effective, low weight alternative to heavy and drag-inducing IR suppression systems and the technology is also one which the organisation can offer to the US Government FVL program.

Expertise in airframe corrosion and corrosion monitoring technology is yet another example of value DST brings to the Romeo program. The organisation has developed a sensor which is able to measure not only temperature and humidity, but a range of parameters, which will allow corrosion to be addressed even before it manifests itself. The Corrosion Sensor Mk.2 unit is a DST development of an earlier sensor originally developed by the US Navy.

"Aircrew training and operational analysis is another key area where DST has provided specialist support for the ADF for the Romeo platform. The Aviation Training Health Evaluation and Analysis (ATHENA) tool is a dynamically reconfigurable decision support tool, for management of aircrew training," Wu adds.

"It contributes to the delivery of stable and robust solutions, avoiding a shortage or surplus of personnel, thus providing significant cost savings."

The RAN's crew model for the Romeo is different to that of the US Navy and Wu explains that DST also performs mission and task analysis for MH-60R aircrew. This work looks at different scenarios, models aircrew workload and task-sharing in different crew configurations and the organisation has also conducted simulations, using human-in-the-loop methodology, to validate the models.

"The Australian operating environment is different and, because we only have a small fleet of MH-60R helicopters compared with the US Navy, our missions are very different," Wu explains. "We need to be lean and efficient and we need to multi-task."

During the Romeo's recent First of Class Flight Trials (FoCFT) aboard the RAN's new Hobart class DDGs, the ship's air wake data gathered by DST was used to model the effect on the helicopter during the critical launch and recoveries phases of operations and therefore significantly reduce risk.

"Work is also being undertaken to study the operational effectiveness of the MH-60R in challenging environments, along with assessment of its Anti-Submarine Warfare (ASW) and Anti-Surface Warfare (ASuW)

capabilities," Wu continues. "For ASW acoustic systems for example, an understanding of how the platform will be employed in an Australian task-level context as well as operational boundaries, are essential to the RAN's future ASW capability. DST is undertaking research aimed at better understanding this capability – involving performance analysis, modelling and simulation and mission planning."

SUPPORT FOR POSEIDON

The RAAF is about mid-way through delivery of 12 Boeing P-8A Poseidon multi-mission maritime aircraft and DST support includes work which helped enable the early declaration of Initial Operational Capability (IOC) in January this year as well as support for the P-8A collaborative program with the US Navy.

To date this work has included providing technical advice to the Commonwealth on ASW and ASuW capabilities and the embedding of DST personnel within the US Navy project office to support assessments of current capability and the prioritisation of future upgrades in the US spiral development pathway.

This work is being undertaken under the auspices of the P-8 Production, Sustainment and Follow-on Development Memorandum of Understanding (PFFD MoU) signed between the Commonwealth and the US Navy in 2012.

"The work includes research and advice in the areas of radar performance and trials, image data management, acoustics modelling and simulation, operations analysis, operational loads and electronic support systems," Wu details. "DST also participates in, and contributes to, the annual P-8A S&T Co-ordination meeting and in other forums, such as the International Aircraft Structural Integrity, Joint Acoustics and Joint Radar Technical Working Groups."

Wu says the organisation has also been heavily involved in the specification, development and verification of the RAAF-unique operational loads monitoring system. "All the work we are doing is linked to how to effectively utilise the P-8A," she adds. "Those areas that we have identified are not only critical to Australia's Poseidon operations, but it also means that Australia has a strong capability to bring to the table through DST."

The DST staff embedded in the US project office have also made key contributions in areas including software architecture, fatigue testing, satellite communications and aircraft tracking, interoperability, crew workload and human machine interface development. "Those areas we have identified are also the areas where DST has world-class expertise to bring to the table," Wu says.

INTRODUCING THE GROWLER

The RAAF is the only operator of the Boeing EA-18G Growler Airborne Electronic Attack (AEA) capability outside the US Navy and unsurprisingly, DST is fundamental to its introduction to service and continued development.

In collaboration with the US Navy, DST is working to improve the geolocation capabilities of the aircraft, a vital functional aspect of an electronic warfare capability.

Other work includes contributions to other co-operative research activities, such as the development of an advanced Electromagnetic Warfare Battle Management capability, advanced approached to Electronic Warfare (EW) modelling, simulation and analysis, and research into future EW technologies.

"The Australian Government is acquiring the Growler in recognition of the importance of winning the electromagnetic battle and it is capable

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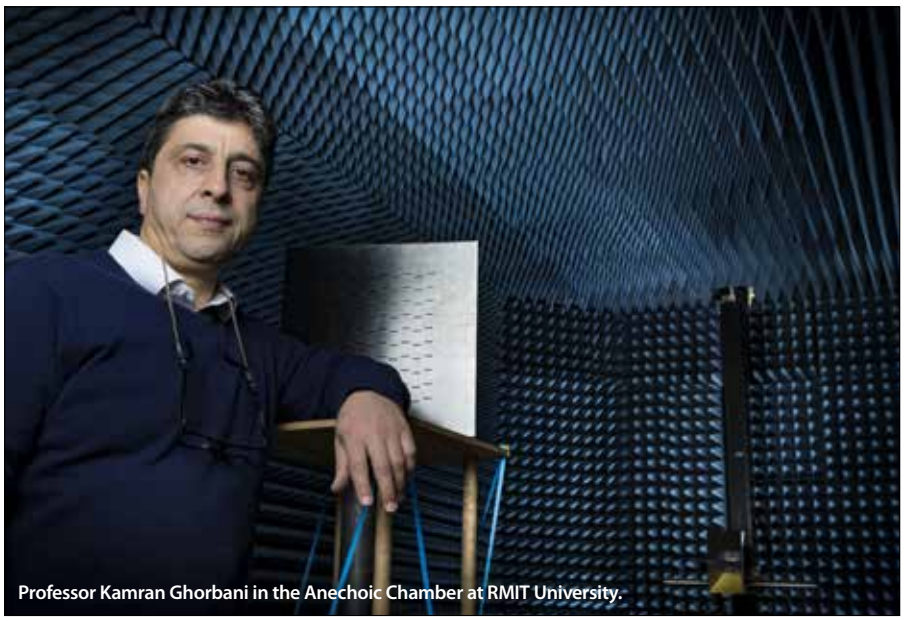


Professor Kamran Ghorbani in the Anechoic Chamber at RMIT University.

Smarter, faster, stronger is the aim of the game for vehicles of the future with new technology radically transforming planes, trains and automobiles as we know them.

The study of multifunctional structure is at the heart of futuristic change. By investigating ways materials can be of more use than one, researchers are discovering mechanical and electrical shortcuts to make vehicles slicker and more efficient.

Professor Kamran Ghorbani at RMIT University's School of Engineering has been analysing multifunctional structure for the past decade. His work aims to refine best practices for aircraft by developing new methods of structure.

It all started with integrating antenna into the body of the plane. To do this, Ghorbani and his team began investigating the electromagnetic properties of carbon fibre reinforced polymer (CFRP) – a strong and lightweight alternative to aluminium.

"We spent two years analysing the electromagnetic or electrical property of the carbon fibre and found that although its conductivity was not great, we could use it as the conductive material," he says. "We designed some antennas built from this carbon fibre and came up with a few typologies and tested the gain of antenna. The efficiency wasn't as good as the metallic one, but it was acceptable as a radiating element."

At first, Ghorbani used slotted waveguide antenna structures that guide electromagnetic waves, and trialled rectangular and spiral slots. Combined with hat stiffener, a common tool used in aerospace design, the antenna could be used for various applications in the aircraft.

"We built quite different antenna structures until we found one that was suitable and mechanically and electrically sufficient.

"However, the antenna patterns for the slotted waveguide array (combined with the hat stiffener) were not uniform, so we realised that the waveguide was not really the optimum solution."

The alternative was found in embroidery techniques using conductive threads.

"We sewed conductive threads directly into a grade of composites called 'preimpregnated' (pre-preg) materials. So we were able to integrate the entire metal strip line and antenna, into the carbon fibre structure."

Mechanical testing revealed the electrical properties on the static loading were being affected by the movement of the plane. Ghorbani and his team countered this by introducing carbon fibre veil instead of the embroidery techniques. The veils were used as a conductive material layer to build antenna and transmission lines. The electrical performances under both static and cyclic loading were improved.

The end result spells a new look for tomorrow's aircraft. Instead of external antenna mounted on a plane, they will be integrated into the body of the plane making for a lighter, less air resistant and more fuel efficient model.

The next step for Ghorbani and his team lies in embedding transceivers into carbon fibre so these can be incorporated into the body of the plane.

"We're trying to integrate the entire transceiver and we've done some preliminary work. This is significant because you reduce the need for having external equipment as well as so many cables connecting various devices, so everything can be integrated into the structure.

"In the future this will greatly reduce the weight of planes and other vehicles and improve their efficiency," says Ghorbani.

of disrupting, deceiving or denying a broad range of military electronics systems, including radars and communications (but) this also means they can disrupt civilian systems," Wu explains. "Live training for Growler operations is therefore subject to a variety of restrictions and unique difficulties."

To help in this regard, Wu says DST is bringing its world-leading LVC capabilities to bear to assist the ADF with the development of effective training programs.

"We are also working closely with our US partners and we have established a Spectrum Dominance Working Group with the US Navy to provide a formal mechanism for information exchange related to EW Science and Technology activities," she adds.

SUPPORT FOR SPARTAN

The RAAF's Leonardo C-27J Spartan battlefield airlift capability is working towards Final Operational Capability (FOC), which is expected to occur by the end of 2018.

DST support for the 10-strong Spartan fleet will include full scale fatigue testing of the airframe under the C-27J Structural Substantiation Program (SSP), which will provide the structural airworthiness and life of type outcomes for the aircraft in RAAF service.

C-27J test specimen is being funded through the Project AIR8000 Phase 2 budget and will be installed at Fishermans Bend in the near future, where DST is the lead Commonwealth agency in the structural test program. "The SSP, consisting of flight loads testing, loads development, full scale testing and analysis is necessary because the intended use of the aircraft in RAAF operations has role usage mix and mission profiles that are different to the original intent," Wu explains. "DST typically works with Australian industry to deliver the projects and the C-27J will be no exception." She said industry is expected to be included in planning activities for the SSP in 2019.

PREPARING FOR TRITON

The Northrop Grumman MQ-4C Triton Remotely Piloted Aircraft System (RPAS) is being acquired through Project AIR7000 Phase 1B as the unmanned complement to the Poseidon for Australia's future maritime surveillance capability.

The Triton will arrive early in the next decade and to date DST has supported the Commonwealth's consideration of the platform through technical assessment and analysis of operational and technical factors to determine the number of aircraft required to meet Australia's future Maritime Intelligence, Surveillance, Reconnaissance and Response (MISRR) requirements.

"DST has also contributed in the areas of radar, electronic support systems, motion imagery, satellite communications, Australian-specific training and system integration, human-system interaction, operational considerations (including the effect of weather), airworthiness and certification, composite structure life estimating, prognostic health management and attrition estimates," Wu details.

With the aid of the Northrop Grumman mission system trainer, DST has also contributed to risk-reduction initiatives associated with introducing the Triton into service with the ADF. This mission system trainer also assists the Triton's effectiveness in terms of full exploitation and integration of gathered data.

Wu says that some of the benefits of DST's work on Triton includes the accumulation of knowledge which will help to minimise through-life costs and help to prioritise capability proposals for future upgrades and the research into technology options for capability upgrades in the future.

"We need to consider that Australia will use Triton in a different way to the US Navy, based on local scenarios," Wu concludes. "But we will also look at such things as data fusion and how we will operate with other platforms."

DEVELOPING SPACE AND SATELLITE TECHNOLOGY

With the flawless launch of its Buccaneer cube satellite in November 2017 and the subsequent successful communications with the vehicle now in low earth orbit, DST is looking to future space and satellite technologies. By **Nigel Pittaway.**

The Buccaneer CubeSat program is a partnership between DST and the University of NSW Canberra and the vehicle now in space is the pathfinder for a second satellite which is expected to be launched in the 2020 timeframe. The second CubeSat will be used to assist with the calibration of Defence's Jindalee Operational Radar Network (JORN).

The initial launch coincided with the 50th anniversary of Australia's first (and until now, only) Defence satellite, the Weapons Research Establishment satellite (WRESAT), in 1967. With the initial success of Buccaneer now behind it, DST is now turning its collective mind to the development of a space research and development strategy which will provide a roadmap for future work in the domain.

At the time of the Buccaneer launch, Defence Minister Marise Payne flagged increased government investment in space-related projects for Defence over the next two decades and the related establishment of a national space agency to further drive commercial involvement in the domain.

The 2018 Federal Budget allocated $41 million over three years to fund the establishment of the Australian Space Agency and the document also foreshadowed a further $260 million to develop core satellite infrastructure and technologies, including enhanced Global Positioning System (GPS) capabilities and easier access to satellite imagery.

BUCCANEER PROGRAM

Buccaneer is a 3U satellite, which is a capacity of three 'U class' CubeSat standard units, where one unit represents one litre of internal volume and no more than 1.33 kg weight. The concept behind CubeSat technology is that many small satellites can be loaded into the payload bay of a launch rocket in what would otherwise be empty space around the main payload.

Buccaneer was launched from Vandenburg Air Force Base in California on November 18 last year aboard a US Delta 2 rocket, whose main payload was the Joint Polar Satellite for the US National Oceanic and Atmospheric Administration (NOAA).

The Buccaneer missions will study the effects of the Earth's ionosphere on high frequency radar emissions and the data gathered will then be

used to inform future development of the JORN over the horizon radar system. The UNSW Canberra team will also use Buccaneer to perform Space Situational Awareness experiments.

"Small, low cost satellites like Buccaneer provide a unique opportunity to support Australian Defence Force capabilities and to rejuvenate Australian space research," Minister Payne said, after the successful launch of the first satellite. "Buccaneer is designed to improve understanding of the outer atmosphere, in particular the Ionosphere, which plays a key role in Australia's over the horizon radar capability."

DST Team Leader for Small Satellite Experimentation, Dr David Lingard said the first mission is being used to test some of the key technologies required for the second mission in that 2020 timeframe, primarily the ability to capture signals transmitted by the JORN array.

Dr Lingard said that to receive JORN radar energy in the HF range, a large antenna is required and given the small size of the Buccaneer CubeSat (about the size of a two-litre milk container), the antenna had to be stowed in a small volume for launch and then deployed once the vehicle was established in low earth orbit. Because of the frequencies involved, once deployed, the antenna needed to be a cruciform shape, three metres wide.

This was successfully achieved in late April 2018, some five months after launch, as Dr. Lingard explains. "It was wound into a small volume for launch and we were able to successfully deploy it in a twelve-stage process," he says. "The next big question was whether it would keep its shape in low earth orbit microgravity, but we have been able to take a series of images of a particular element of the antenna and downlink them to our ground network, which shows it is always in the same position in the field of view."

DST has a ground station at its facility in Edinburgh, South Australia, which has been communicating with Buccaneer since November last year. UNSW Canberra supports the mission with another two ground stations in the Canberra region.

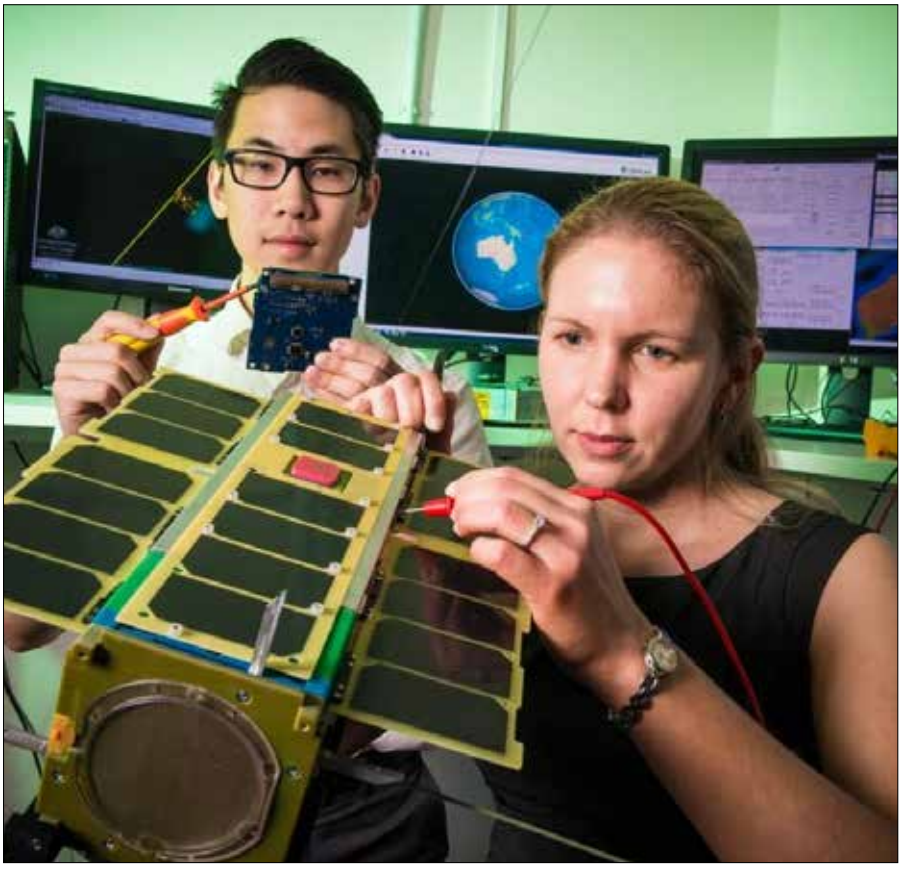
"This is the first mission in DST since WRESAT in the late 1960s, so we have been able to demonstrate the ability to perform command and control of the Buccaneer satellite since November. So, demonstrating that we can get everything to function as a system, including the space segment, the satellite, and of course the ground segment," Dr Lingard adds. "That has been a fantastic learning experience for us and over the next couple of months we will be documenting all of the lessons learned so that we can capture them and take that knowledge into account for our future missions."

RAAF MISSIONS

UNSW Canberra is also collaborating with the Royal Australian Air Force on two further CubeSat missions, known as M1 and M2, which are due to be launched in November this year and the middle of 2019 respectively.

The M1 spacecraft will carry out a variety of technology demonstration/ research roles in the areas of

"We think that small satellites definitely have a role to play in that ecosystem and have a real benefit for the Australian Defence Force and our allies, so we want to explore that and demonstrate their utility for the ADF."



Looking to the future, Dr Lingard says that the plan will be to grow the size of the satellites over the next decade or so, to around 100kg and to explore the development of constellations of small satellites with a level of artificial intelligence embedded within them.

Space Situational Awareness, RF Communications and maritime/aviation surveillance.

The M2 mission consists of two larger and more capable 6U spacecraft flying in a Low Earth Orbit constellation. The payload consists of two Software Defined Radios and a pan-chromatic, visible spectrum imager. Advanced on-board processing of the payload telemetry will be used to incorporate autonomy functions into the spacecraft operations for surveillance applications.

Secondary payloads are also used to carry out communications, Space Situational Awareness and space environment research and capability demonstrations.

The design of both missions is influenced by the university's teaching and academic roles and, in turn, the missions are used to deliver teaching, training and research outcomes.

"There are some educational benefits as well, because they will be controlling those satellites from the UNSW Canberra ground station, which is co-located with the Australian Defence Force Academy (ADFA), Dr Lingard adds. "So, there will be opportunities for the students at ADFA to learn about operating a spacecraft."

LOOKING TO THE FUTURE

One of the key goals of the DST roadmap for space and satellite systems now under development will be to demonstrate that satellite missions have an important military utility for the Australian Defence Organisation.

Dr Lingard said that he believes that small satellites will have an ongoing role to play in the overall ecosystem of space assets, due to their relative low cost.

"We think that small satellites definitely have a role to play in that ecosystem and have a real benefit for the Australian Defence Force and our allies, so we want to explore that

and demonstrate their utility for the ADF," he says. "The Buccaneer only weighs four kilogrammes, but that's a terrific place to start, because it is relatively easy to launch and relatively inexpensive as well."

The increased commercial interest in developing launch facilities in Australia and elsewhere around the world also has a potential benefit to future DST space and satellite programs. Included in these are Equatorial Launch Australia (ELA), which is looking to develop a launch site at Nhulunbuy in Arnhem Land, and Southern Launch in South Australia, who are considering a number of sites along Australia's southern coastline – from Albany in Western Australia to Ceduna and even Adelaide in South Australia and the eastern Victorian and south-eastern coastlines of New South Wales.

"It will be interesting to see over the next ten or fifteen years whether there will be a greater capacity developed in Australia to launch small satellites in a responsive manner." Dr Lingard says.

Looking to the future, Dr Lingard says that the plan will be to grow the size of the satellites over the next decade or so, to around 100kg and to explore the development of constellations of small satellites with a level of artificial intelligence embedded within them.

"Part of the vision is to look at the whole paradigm of constellations of small satellites. With smaller satellites you are able to have a larger constellation, which means you can look at a certain point on the Earth more often," he says. "There is a trade-off in that larger satellites will always give you more detailed information, but they will be more challenged in the temporal domain – they won't be able to see a spot on the Earth as often."

Over the next five to ten years DST will also consider increasing the level of intelligent processing that is able to be carried out on board the satellite itself, so that they will be able to operate in a much more autonomous manner.

"Instead of receiving very detailed instructions from the Ground Control Station on Earth, they will be able to autonomously decide what the next move might be, in terms of an Intelligence Surveillance and Reconnaissance mission," Dr Lingard explains. "Of course, these constellations also have to have military utility and be capable of achieving something that's worthwhile for the Australian Defence Organisation."

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UNSW Canberra Space – More Than Ever, Australia's Leading Space Program

Interest in the Australian space industry hit new heights this year with the formation of the Australian Space Agency, but the country's largest team of space scientists and engineers, UNSW Canberra Space, was already hard at work on a number of exciting projects.

One cubesat was orbiting the earth (Buccaneer, in partnership with DST), another was being prepared for launch, and three more were in the pipeline. International partnerships were formed with the French Space Agency and Airbus. Collaboration with the University of Colorado (funded by USAF) and the National University of Singapore continued to grow. Meanwhile, the university maintained its commitment to securing the future of Australia's space efforts through its specialised degree programs.

At the same time, UNSW Canberra Space has spawned the commercial space company Skykraft Pty Ltd, part owned by the university, to commercialise and provide operational capabilities from the R&D of the group, and to play a role as industry partner to help drive the research.

Skykraft will also help guide the development of education content as the company seeks employees with the disruptive skills needed for Australia to be a leader in the global space sector of the future.

It is a huge accomplishment for a program that was created just four years ago, but UNSW Canberra Space Director Professor Russell Boyce says it speaks to the heritage and expertise of the team. "All combined, the team brings together well over a century of experience in space research and satellite design, manufacturing, testing, launching and ongoing operations, to develop new knowledge and meet challenges and opportunities on the ground," Boyce says.

Some of these highly skilled space professionals left the country to work in the global space sector, but they have since been lured back to Australia by the program that has a strong vision for a sustainable, homegrown space industry.

UNSW Canberra has invested more than $10 million in the development of the program, which is at the forefront of Australia's space capabilities.

Boyce says Australia's opportunities in space lie in combining our growing expertise in 'Space 2.0' with disruptive technologies that we are world leaders in. "Space 2.0 is about the clever use of constellations of miniature satellites, such as cubesats, that are agile, affordable and can be reprogrammed while they are in orbit to deliver new outcomes on the ground," he says.

"By combining rigorous space engineering with disruptive technologies such as on-board processing, artificial intelligence, autonomous systems and even quantum technologies, constellations of small spacecraft can deliver game-changing outcomes.

"That's what UNSW Canberra Space is about, and we're the largest and leading Australian space mission capability."

The creation of the Australian

Space Agency demonstrates the government's commitment to growing the sector. "Space for Australia is not just about what's going up – far more importantly, it's about meeting needs and opportunities on the ground. The government now realises how dependent we are on space-derived information, and how we have become too reliant on the capabilities of other countries," Boyce says.

The national conversation has evolved and there is an understanding that Australia must operate in space for both economic and security reasons.

Australia relies on space technologies for communications, position, navigation and timing, environmental monitoring, improving emergency management for extreme weather events and bushfires, on meeting the needs of Defence and national security, and more. The mission for UNSW Canberra Space is to develop and provide space research and technology that provides actionable information to help meet these needs and opportunities.

The science of space situational awareness, which underpins our understanding of the way space objects interact with their environments, is at the core of the research efforts at UNSW Canberra Space and demonstrated by aspects of the program's first cubesat mission.

The Buccaneer cubesat, a joint mission with DST, is doing laps of the Earth every 90 minutes in low earth orbit, several hundred kilometres above the ground. It is playing a role in growing Australian experience in space, contributing to Defence's ability to improve Australia's over-horizon radar network, and supporting Australia's contribution to international efforts to understand and mitigate space congestion – the problem of space debris.

A further $9.69 million from the Royal Australian Air Force is enabling UNSW Canberra Space to fly another cubesat packed with sophisticated radio technologies. Set to launch very soon, it will demonstrate technologies for space-based maritime and aviation surveillance. The satellite, known simply as M1, will be followed in mid-2019 by a pair of larger satellites, each equipped with not just advanced radios but also telescopes, to take the art of the possible one step further.

These space missions are underpinned by the ground-based R&D required for fully in-house spacecraft and payloads, as well as further SSA research, and are building UNSW Canberra's capability to train the future Defence space talent pool.

In 2017, with the support of the ACT Government and in a close partnership with the French Space Agency CNES, UNSW Canberra has established a state-of-the-art national asset for the rapid and efficient design and development of world-class space missions – the Australian National Concurrent

Design Facility (ANCDF).

This facility complements the Australian National University's spacecraft test facilities on Mt Stromlo, and together they position Canberra to be a key technology hub as the national space sector gains momentum.

"We have the in-house ability and capacity to conceive, develop and fly innovative space missions with our own hands, supported by world-class space research, rather than relying on others," Boyce says. "It's about building a sustainable domestic space capability with affordable methods of delivery."

These facilities allow UNSW Canberra Space to pursue projects with international agencies and organisations, such as CNES and Airbus. Two separate projects will study breakthrough hyperspectral remote-sensing micro satellites, about the size of a washing machine.

Such technologies can serve applications such as monitoring fresh and marine water quality and enabling precision farming practices.

"After two years of working with CNES toward the development of joint space missions between Australia and France, it's fantastic to see our first project come into being," Boyce says.

"The capabilities we are studying and which ourselves and our partners have expertise in include hyperspectral remote sensing and the on-board processing needed to turn measurements into useful information with real-world application."

UNSW Canberra Space is also collaborating with the National University of Singapore on a project to develop the world's first in-orbit scientific demonstration of satellite-to-satellite quantum (ultra-secure) communications.

These missions demonstrate a few of the diverse fields in which space technology is being utilised. They position Australia as a key partner in this rapidly growing global industry.

Not only is UNSW Canberra strengthening ties with its international partners – it is helping to build a local sector capable of pursuing independent missions.

A self-reliant space industry will create new jobs and research opportunities in Australia. Some of these will be 'upstream' activities that provide space technology, while others will be "downstream" activities that utilise the upstream technology in a range of different applications.

UNSW Canberra's space missions will also deliver research and educational outcomes for Defence and civilian students studying engineering at UNSW Canberra, forming an important part of building our space capability for the future.

The university offers two unique intensive delivery and online education Master's programs – the Master of Space Engineering and the Master of Space Operations. It is looking to offer undergrad space engineering subjects to both Defence and civilian students in the near future.

UNSW Canberra Space research students have the unique opportunity to engage in the activities of the flight team.

Courtney Bright is completing her PhD in mechanical engineering but she is also the Flight Operations Lead at UNSW Canberra Space. "It's my role to plan, test and execute the flight activities from launch to end-of-mission – there's never a dull day at work when you're flying a spacecraft," Bright says.

"I'm proud to be part of a team that is pushing the boundaries of Australia's space capability and I can't wait to see the opportunities that are forged in the coming years."

Finally, UNSW Canberra Space's commitment to growing the Australian space sector goes even further than research, teaching and contributing to industry. On behalf of the Australian Academy of Science, UNSW Canberra Space is hosting the world's largest space research conference COSPAR in Sydney in National Science Week 2020. Some 3,000 delegates from across the globe will gather to discuss space research set in a context of disruptive technologies such as artificial intelligence, and a nation-wide STEM outreach and celebration of science via the theme of space. The eyes of the world will continue to focus on the growth of space in Australia, and UNSW Canberra Space is proud to be a major change agent stimulating that growth.

"We have the in-house ability and capacity to conceive, develop and fly innovative space missions with our own hands, supported by world-class space research, rather than relying on others."

SCINDICATE 2018

SCINDICATE has already become a key engagement and partnering mechanism that allows DST to target higher-risk, higher-impact outcomes on behalf of the ADF. By **Gregor Ferguson.**

DST's Partnership Week has a new identity: SCINDICATE. The inaugural SCINDICATE event was held at DST's Fishermans Bend laboratory on 29 and 30 August and the increasing number and variety of attendees, from the ADF, industry and academia, was testimony to the success of DST's advocacy and outreach: some 650 people attended SCINDICATE 2018.

The old Partnerships Week was launched by DST in 2015 as a mechanism for promoting and stimulating closer partnerships and collaboration. The concept was turbocharged by the 2016 Defence White Paper.

The Minister for Defence, The Hon. Christopher Pyne, MP, said in his SCINDICATE 2018 keynote address, "The work being done to advance innovation and science and technology in support of Defence capability is something that is not spoken about enough. In 2016, when the Defence White Paper was released, we outlined two basic principles – that industry was a Fundamental Input to defence Capability (FIC), and science and technology were key enablers in achieving a capability edge. Bringing these two elements together was a no-brainer."

The importance of that external engagement, partnering and collaboration is a repeated theme throughout this edition of *DST OUTLOOK*. As Dr Ian Dagley, Chief of DST's Science Partnerships and Engagement Division explains (see p.xxx), DST does not have the internal resources to do everything asked of it, so needs trusted external partners. "It's essential that DST collaborates with the wider research community and industry to make sure that we maximise the capability edge that we deliver to Defence."

In her own keynote address, former NASA astronaut Colonel Pamela Melroy, who now works in Adelaide as Director of Space Policy and Technology for Nova Systems Pty Limited, outlined the changes in the world's security and technology environment that are driving this increased collaboration. Government is no longer the traditional 'big' customer for many new technologies, she said. And the government no longer drives R&D in the US. Development of new technologies is driven largely nowadays by commercial needs.

Meanwhile, fast-paced threats have emerged to national security, she warns: drones, hypersonics, ballistic missiles, cyber technology, and the mis-use of space. Furthermore, our adversaries do not worry about process: they do not care about protecting IP, they do not care about contracting or about detailed, validated user requirements. They go for speed – they innovate inside governments' own innovation loops.

That is why bodies such as DST need commercial partnerships: industry has great technology, says Melroy, and IP ownership cannot be allowed to be a barrier to exploiting it. She added that the defence community needs to focus on transition: new technology must get into the war fighters' hands as soon as possible; partnerships facilitate that, and help build utility and buy-in, which strengthens the partners' efforts further; and importantly, the war fighters, acquisition, technical exports and industry players must act as a team – there cannot be stovepipes.

The role of the government's technology experts is important, she says: Defence must be a sophisticated consumer of commercial capability; this in turn requires experts who can understand and define the key technology investments needed to achieve defence outcomes, and these experts need to stay close to the war fighters so they can both understand their needs and monitor the contribution of new innovations on actual operations.

This reality was on show at SCINDICATE 2018: Australian SMEs are stepping up to commercialise DST innovations, having also assisted in the development process. Adelaide-based Consilium Technology has enhanced DST's visualisation simulation software for Defence applications and is marketing it under the brand name Infinite Studio for commercial markets; and Sydney-based SME Clearbox Systems will commercialise the CORTEX military satellite communications monitoring and control system, designed by DST. This was developed to provide enhanced situational awareness of Defence's satellite networks.

During his walkaround at SCINDICATE 2018, Minister Pyne met these companies and also presided over the presentation by a Melbourne SME, Defence Innovations, of the NIFTI (Non-Intrusive Flight Test Instrumentation) system to the RAAF. It is compact and wireless, which means flight tests can be carried out without time-consuming aircraft modifications The IP for this was also developed by DST and commercialised by Defence Innovations.

"Our adversaries do not worry about process: they do not care about protecting IP, they do not care about contracting or about detailed, validated user requirements. They go for speed – they innovate inside governments' own innovation loops."

"Defence benefits when its in-house innovations are licensed to industry," the Minister commented.

The SCINDICATE 2018 program included an exhibition area where attendees could meet subject matter experts from all of DST's research divisions as well as its Technology Partnerships Office and other Commonwealth government stakeholders including the Centre for Defence Industry Capability (CDIC) and Defence Innovation Hub.

However, the meat of the event was the program of presentations and panel discussions in the David Warren Auditorium, the Mini Theatre, Marquee and Theatre 2. These ranged from Pamela Melroy's keynote to a presentation by the recently appointed CEO of the Trusted Autonomous Systems CRC, Rob Sale, to a presentation on the commercialisation path for Adelaide SME Myriota's nano-satellite Internet of Things (IoT) technology by CEO Dr Alex Grant. Myriota was selected, along with another start-up, IMeasureU, to develop DST's ' Fight recorder', which was announced in 2017.

Of equal interest was a program of 36 one-minute technology 'pitches' by researchers from DST's research divisions which took place in the David Warren Auditorium and Mini Theatre each day. These were designed to expose the work of these researchers to potential industry and research partners, with an eye on further development and possible commercialisation.

The program was rounded off with a series of laboratory tours of DST's principal facilities at Fishermans Bend, ranging from the new Helicopter Advanced Fatigue Test rig, and the Metamaterials Manufacturing laboratory, to showcasing DST's Energy Usage Optimisation Research capability.

SCINDICATE 2018 was busy and popular with DST's engagement targets, says Dagley. This was evident from the intimate involvement of both industry and academia."That interest you're seeing really reflects what's happening out there more broadly. We're engaging much more heavily with universities and with industry, and the ADF is very excited about our forward-looking work in various areas like Trusted Autonomy and the Grand Challenges and so on."

NGTF: A SOLID TRACK RECORD

The welcome novelty of Defence's Next Generation Technologies Fund (NGTF) has worn off and two years of solid track record has emerged. By **Gregor Ferguson.**

The underlying thinking behind the NGTF, and its supporting activities, has not been challenged: how do you prepare for the next war? How do you 'future proof' the Australian Defence Force (ADF)? How do you exploit an emerging technology in innovative ways to put an adversary at an unexpected disadvantage, and prevent the same thing happening to you?

This is a serious concern for the ADF and therefore also for its science & technology (S&T) authority, DST. To help avoid what it calls 'Strategic Surprise' in today's rapidly evolving technology environment, Defence has invested some $730 million over a decade in R&D under the NGTF. This is part of a $1.5 billion Defence-wide construct that also encompases the Defence Innovation Hub (resident within Defence's Strategic Policy & Intelligence Division) and the Centre for Defence Industry Capability (CDIC) which is funded by Defence but administered by the Department of Industry, Innovation and Science from a new headquarters in Adelaide.

The NGTF is administered by DST and is by far the largest element of this new construct. Its purpose is to 'future proof' Defence and the ADF: to enable research at previously unfunded levels into game-changing technologies that have the potential to fundamentally shape the ADF and its capabilities. It had nine (now 11) technology priority areas (see Table).

IMPRESSIVE STEPS FORWARD

The CDIC, NGTF and Defence Innovation Hub opened for business at the end of 2016 and nearly two years on, the outgoing Chief of DST's Science Strategy and Program Division, Dr Janis Cocking, PSM, explained to *DST OUTLOOK* what

the NGTF has achieved. The ramp-up in spending has been deliberately measured: $17 million in 2016-17 and $29 million in 2017-18; but that funding has been directed into every state and territory in Australia, except the NT. Even the baby steps have been impressive, says Dr Roger Neill, DST's Program Leader, Grand Challenges: "Our very first call in 2017 was to the universities, for them to suggest relevant seedling research projects. We had 428 responses of which we were able to fund 59."

The priority through 2017 and early 2018 was on achieving some of the priorities announced for the NGTF: getting its program of Grand Challenges under way, establishing the Small Business Innovation Research for Defence (SBIRD) program and establishing the first of a new portfolio of Defence CRCs. These have been done, Cocking tells *DST OUTLOOK.*

GRAND CHALLENGE

The first Grand Challenge was to Counter Improvised Threats (CIT), says Neill. A DST national roadshow in early 2017 attracted no less than 600 attendees from industry, the universities and other research organisations, and 215 applications for the first stage call for proposals; "We didn't know what to expect but we thought if we get 80 we'll be excited. We got 215 – we were very excited, but also very daunted."

DST had to work hard to meet its own deadlines, but down-selected to 40 proposals and from there ended up with 14 priority projects.

The lessons learned will be carried into the next Grand Challenge, including the desire of the ADF to become more involved, says Cocking: "The services are now interested in using this as a potential way of tackling some difficult issues and problems. We know the RAAF is busily thinking about how they might host a Grand Challenge. Navy, similarly, is really interested in being a sponsor to a Grand Challenge which will take maritime technology into the future."

The level of interest from across Defence and industry has been high enough that DST will select the topic for the next Grand Challenge using a different process, says Neill. "Our ambition is that over the remainder of this financial year we will undertake a competitive process whereby we identify what our next Grand Challenge theme might be." That is the first priority: to ensure a specific topic is of interest and value to Defence. And, secondly, do DST and Defence's eco system have the resources to both manage the program and engage successfully as well?

"We don't see any point in inventing something for the sake of being different if there's a model there that works. I think over many years the CRC system has been really successful."

In this regard, the NGTF supports the aims of many of DST's Strategic Research Programs (SRP) including those that are focused specifically on major ADF capital equipment projects such as SEA1000 and SEA5000 (see p.61). Much of the 'future proofing' of the capabilities being produced by these projects will be done under NGTF-funded programs (For example examining things like future sensors, material sciences and autonomous systems).

"One of the reasons we want to take six months over this process is that some folk, like the RAAF's Plan Jericho team, have really taken the ball and are running with it," Neill tells *DST OUTLOOK.* "But we don't want to exclude anybody, we want everybody to have the opportunity to state their case. The aim is to be announcing the topic mid next year. That then allows us to plan the logistics of how and when we actually leverage the program."

Meanwhile, the CIT Grand Challenge is creating a new template for this kind of work, he says: "We've got 13 research streams and 14 contracts. These were all signed by the end of March and we held the first workshop in April. We've appointed a CIT Grand Challenge Associate Director, Olaf Reinhold. We've also established a Technical Working Group that is like an expert advisory panel. It has a representative from DSTL in the UK, Nick Farrar, Dr Cathy Foley from CSIRO, an ex-DST Division Chief, Dr Simon Oldfield, and we've got representation from the ADF's CIT Task Force. The idea is that it keeps a guiding eye over the program as it unfolds.

"We really want to apply the 'fail fast' principle. At the end of the first year we'll be reviewing the CIT program and identifying which streams are proceeding to plan and which ones either need a little guidance, or perhaps we can make the decision that it was a great idea but perhaps it's time to try something else." The focus is on exploring these technologies to understand their potential to deliver military utility within a useful timeframe, so framing the research question correctly has been critical.

SBIRD

Something else that the NGTF program launched during 2017 was the Small Business Innovation Research for Defence (SBIRD) initiative. The first SBIRD project was for the Fight Recorder, a small transducer mounted on a soldier's uniform that provides a means of locating casualties on the

battlefield as well as reconstructing complex and confusing events for subsequent analysis. From a field of 47 Australian and New Zealand industry and university applicants, the team selected for this $700,000 commercialisation project consists of an Australian wearable technology company, IMeasureU, and an Adelaide satellite communications start-up, Myriota. This was announced in September 2017.

The SBIRD program is explicitly focused on the small to medium enterprise (SME) sector, so is slightly less structured than a Grand Challenge and more open to 'left field' proposals from creative start-ups. It creates an environment in which young businesses and freethinkers can explore and experiment. This includes those at the DST research 'coal face' and who are already engaged with external partnerships. However, discipline still underlies the approach. Stage 1 of an SBIRD project (which is where Myriota and IMeasureU are at present) studies the feasibility of a low Technology Readiness Level (TRL) concept; if successful, further funding becomes available under Stage 2, possibly leading to advanced acceleration via the Defence Innovation Hub.

Submissions closed on 9 July for DST's second SBIRD program, which is about enhancing stealth for Unmanned Aerial Systems in the surveillance role. An announcement of shortlisted proposals is expected soon.

NEXT GENERATION TECHNOLOGIES FUND PRIORITIES

Integrated intelligence, surveillance and reconnaissance – effective enterprise intelligence, surveillance, reconnaissance integration and interoperability with our allies will provide a capability edge through superior battlespace awareness.

Space capabilities – de-risking Defence's dependence on space-based systems through technical expertise and enhanced capability agility.

Enhanced human performance – including enhancing soldiers' resilience and ability to interpret and use data in the battlefield.

Medical countermeasure products – establishing and coordinating a national infrastructure for the rapid development of medical countermeasure products to provide effective protection of Defence personnel from a range of chemical, biological and radiological threats, pandemics and emerging infectious diseases.

Multidisciplinary material sciences – investigating technological advances to reduce detection of ADF platforms and improve ballistic and shock protection. Exploring materials and processes that support advanced manufacturing.

Quantum technologies – increasing the security of military and government communications and computing through strengthened encryption and exploring new types of sensors based on quantum systems.

Trusted autonomous systems – researching developments in trusted autonomous systems that may have the potential to support ADF capability in the future, such as the use of autonomous vehicles for resupply.

Cyber – establishing a research and development capability to address the threats presented by information and communications technology dependencies and vulnerabilities within military systems.

Hypersonics – understanding the science behind hypersonic flight, including propulsion, flight dynamics, control surfaces and materials that support flight systems.

Advanced sensors, hypersonics and directed energy – investigating the use of smart, intelligent sensor technology for surveillance, intelligence and combat operations; understanding the science behind high-speed flight at more than 5 times the speed of sound; and developing concentrated electromagnetic energy sources as countermeasures.

DEFENCE CRC

An important third initiative launched under and funded through the NGTF is the Defence CRC (Cooperative Research Centre) program. The first, for Trusted Autonomous Systems, was announced in 2017 and was established at the end of the year. The Defence CRC program is based on the Department of Industry Innovation and Science's well-known CRC model, says Cocking, though with a difference.

"We don't see any point in inventing something for the sake of being different if there's a model there that works. I think over many years the CRC system has been really successful. It spins off really good solutions and good companies and the framework works, so long as it's properly led. What we're really doing with the Defence CRC is a minor tweak by identifying the specific technology area and then asking the community what they might bring to it," Cocking says.

The CRC for Trusted Autonomous Systems is a limited company; with an independent Board and a DST secondee, Dr Jason Scholz, as Lead Scientist. The CRC has been established in Queensland, whose government effectively matched DST's investment dollar for dollar to create significant leverage and

increase its momentum.

The critical difference with a Defence CRC is that it is what DST calls 'mission driven' – it focuses specifically on the ADF's operational needs. The first fruits of the Trusted Autonomous Systems CRC will be on display in November 2018 during the Five Eyes Exercise Autonomous Warrior 2018 in Jervis Bay. "The aim is to have a demonstrated activity in Jervis Bay over a three-week period," says Cocking. "It will be looking at the littoral environment, looking at surveillance and force protection and Human In The Loop (HITL) control of multiple autonomous systems, some maritime and some airborne."

The Five Eyes involvement in this RAN led EX Autonomous Warrior 2018 leverages DST's broader relationships and also provides a trusted international platform for Australian companies and research institutions that participate.

"We really want to apply the 'fail fast' principle. At the end of the first year we'll be reviewing the CIT program and identifying which streams are proceeding to plan and which ones either need a little guidance, or perhaps we can make the decision that it was a great idea but perhaps it's time to try something else."

So, what is the next CRC going to address? "We'll have to run a competition because we have so many possibilities for what the next defence CRC will be," says Cocking. "In parallel with running the selection process for the next Grand Challenge we'll also run the selection process for the next defence CRC and, again, it really needs to be mission-driven by Defence but something where the broader defence community, including industry, can work together to demonstrate outcomes."

Her role is now filled by Dr Todd Mansell who assures *DST OUTLOOK* that continuity remains unbroken programs across all NGTF programs.

ENGAGEMENT WITH ACADEMIA AND INDUSTRY

The Grand Challenges, SBIRD and Defence CRC projects have stimulated engagement with academia and industry at a scale that has taken

"We're being watched really closely by some of our overseas partners because, for example with the Grand Challenge model, with the level of partnership that we're trying to generate across the board, that's something that's unique."

outsiders by surprise. The CDIC's Defence Innovation Portal is the formal mechanism for much of this engagement, and has proven effective, says Neill with growing usage and acceptance on both sides of the Defence-industry transaction. "I think it'll become quite a jewel actually. I'm very upbeat about the portal."

Just as important has been the flow of insights in both directions as a result of this new and more open environment, he says. "We've learned that industry and the universities need a little bit of coaching. Some of the universities submitted essentially an Australian Research Council (ARC) application, but they've been working on subject X for the past 20 years and want to keep on doing that. We've had to teach the universities that, no it really doesn't work that way and you need to address what we're looking for: the message is 'Read the criteria'.

"Sometimes industry gave us the answer: 'We'll do this for you, you don't need to worry about getting anybody else to do it. We've got the answers.' So we've had to tell industry that this is a collaborative partnership and you'll be working with DST."

The appetite within academia and industry for this level of engagement is huge, says Neill. This is attested to by the number of responses to each call DST has put out and by the even spread of responses across universities, prime contractors and SMEs, so he is confident DST is hitting the right mark. It is also learning a great deal about the capacity and capabilities of industry and academia that it did not know before.

"But the other thing that was really interesting was, for example, at the Perth Grand Challenge Workshop we actually had two teams, from a university and a company, come together who'd had no previous knowledge of each other. And they ended up jointly submitting one of the successful Grand Challenge bids. That was really good – we acted as a marriage broker if you like."

Selecting the right engagement mechanism is important, says Cocking. DST has looked carefully at the engagement mechanisms adopted by counterparts overseas such as DARPA, DSTL and DGA. "We've cherry picked some of the partnering mechanisms that are used around the world to create something that's uniquely Australian, to create our own special beast that has a high probably of producing really good results."

Says Neill, "We're being watched really closely by some of our overseas partners because, for example with the Grand Challenge model, with the level of partnership that we're trying to generate across the board, that's something that's unique."

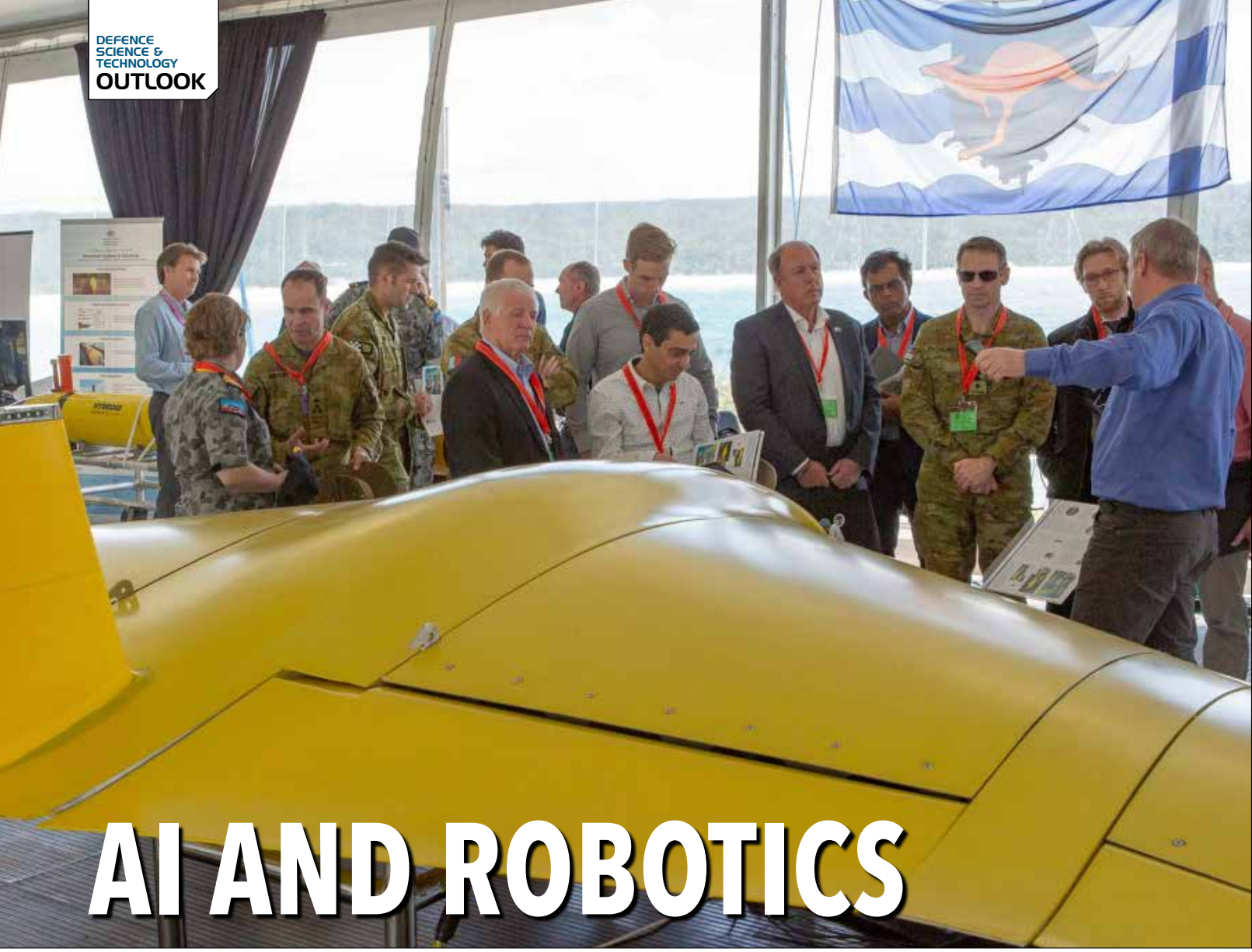
"So we have people from both the US and the UK asking if they can be engaged, could they perhaps be involved in things that we have been unable to fund but are still very interested in," adds Cocking.

"That's an advance – for Australian academia and for industry, too, to get that exposure. It's happened with the Grand Challenge and it's happened now with some of the other areas that we're building up, in quantum technologies for example, and in cyber, for some of our close allies to talk about perhaps having complimentary activities so that again we all leverage and benefit from each other."

One of the mechanisms by which Australian universities gain access to this insight and exposure is the three state-based networks DST has stablished with NGTF funding. The first, set up nearly a decade ago in Melbourne, was the Defence Science Institute (DSI); although it predates the NGTF, DST's funding for it is now from that source. Over the past 18 months the Adelaide-based Defence Innovation Partnership and Sydney-based Defence Innovation Network (DIN) have followed and recently the University of Tasmania (and especially its Australian Maritime College) has elected to join the DSI. They are all funded jointly by DST and the state government concerned and have a DST-appointed full-time Associate Director to create and nurture the defence research networks with universities and industry in those states. It has been a very successful model, says Cocking: "I fully expect that in due course there will be others."

The downside to this success is that expectations can sometimes outstrip this still-maturing system's ability to satisfy everybody, acknowledges Neill. "That's actually been one of our challenges: managing expectations, because we've hit the road running but with, initially, a very modest budget." However, one fallacy he is keen to correct is that most of the NGTF money has been allocated or spent already. It has not, he emphasises – the NGTF is less than two years into a 10-year program and less than $80 million of the $730 million allocated will have been spent by the end of 2018-19.

The annual NGTF budget will grow and, importantly, both industry and academia have hard evidence of DST's willingness to fund research that matters. Through DST they are also learning about Defence's operational needs as well as its culture and processes. That knowledge is the basis of successful innovation and successful research and commercialisation partnerships – and that, ultimately, is what the NGTF seeks to deliver.



AI AND ROBOTICS

The EX Autonomous Warrior showcased some recent work by DST in robotics AI and future research directions. By **Gregor Ferguson.**

This year's EX Autonomous Warrior 2018, which was held at Jervis Bay NSW from 5 to 23 November (see p.80), was an important platform for DST's work on robotics and artificial intelligence (AI). As the first such event since the establishment, in early 2018, of the Defence Cooperative Research Centre (CRC) for Trusted Autonomous Systems (TAS), it showcased some recent work as well as highlighting some (though not all) of DST's research directions.

These include human-machine interfaces, control interactions, control of multiple vehicles and the evolution of swarm behaviours, according to the Chief of DST's Science Strategy and Program Division, Dr Todd Mansell.

"Artificial Intelligence plays into that, and plays into things like cyber security as well," he tells DST OUTLOOK. "We are looking at how AI might be used for threat analysis, for data security, network control, and making sure cyber systems are really resilient."

DST has been working in the AI and robotics space for a long time. Nearly 20 years ago it was leading the 'Automation of the Battle Space' initiative, examining autonomous systems and swarming behaviours. Now the TAS CRC is a reality, launched by then-Minister for Defence Industry, The Hon. Christopher Pyne MP, in May 2018 at the International Conference on Robotics and Automation.

The founding industry members of the TAS CRC include BAE Systems Australia, DefendTex, RMIT University, and Defence Science and Technology. The CRC will initially carry out three research projects in the maritime, air and land domains led respectively by Thales Australia,

Lockheed Martin and BAE Systems.

The ABS initiative was way ahead of its time, believes Dr Mansell; the advent of the Next Generation Technologies Fund (NGTF) has transformed the prospects for collaborative research of the type undertaken by the TAS CRC, he believes: "The transition pathway and getting the buy-in from everyone was more difficult then than it is now. I think we're much more mature."

However, it is important to understand what AI and robotics can deliver, says Dr Nigel McGinty, Program Leader Integrated Force in DST's Joint and Operational Analysis Division and the organiser of the EDTAS (Emerging Disruptive Technology Assessment Symposium) which considered Trusted Autonomous Systems back in 2015, long before the idea of a TAS CRC took flight. "They're both independent technologies, but they're both transformational across the Department, across the warfighting areas and probably broader – AI particularly so in the command and control areas."

Already AI is being used in some areas of logistics resupply, says McGinty, "but there's more that could be done to help the decision-makers have the right information at the right time".

BEWARE THE AI HYPE

However, McGinty warns against the hype surrounding what AI promises. "An AI system still can't use cognition to make judgements from disparate information, and that's something really important that humans can do." He cites the example of a domestic robot: if instructed to wash the clothes, would it put them in the washing machine or the dish-washer? It's a simple example, he says, "but that context awareness is critical for us in Defence as well, so there's still a way to go".

"The thing to move forward with is a white box solution. This is where you understand what's inside and how it's making decisions. And that's another fundamental breakthrough that's needed. When that happens, I think you'll see a real explosion in terms of adoption of AI."

The other area for caution is that, in an age of so-called 'big data' which AI depends upon to train its algorithms, for example, Defence does not necessarily have that big data. "Google and Facebook do but we're relatively small in comparison," says McGinty. "I think that's going to be one of the research problems: how do you do learning and gain insights from small data?"

There is also a philosophical problem here, says McGinty. Humans train AI systems and unconsciously impart their biases, insights and frames of reference. One of the challenges for Defence is acceptance: how do you put your trust in a system which may embody unintended but subtle biases?

"This is the difference between black boxes and white boxes," he explains. "A black box is one in which you don't know what happens inside, but you know what you put in and what comes out, and you're happy with what comes out. So that's what a deep neural network is – it's a black box, you're not really sure how it's doing its business but it's making some insights." Where the context allows it, black box solutions are still useful, he says. A Google personal assistant that tells you what time to leave for the airport or what time you need to order dinner is helpful but non-critical. But where it's a harder decision – do you launch an operation – then you need to understand the process within the box.

"The thing to move forward with is a white box solution. This is where you understand what's inside and how it's making decisions. And that's another fundamental breakthrough that's needed. When that happens, I think you'll see a real explosion in terms of adoption of AI."

Much of the research into AI and the algorithms is being driven by big companies such as Facebook, Google, Amazon and IBM, which are developing it for marketing and personal experience purposes, says McGinty. "So, this is why defence research establishments are important, to look at the context that's relevant for us. Because Google's not going to do that."

ROBOTICS

Robotics development will focus on better sensors and actuators; better batteries mean you can fly further or for longer, and improvements in communications – IoT and 5G, for example – will allow them to become smarter. But essentially, says McGinty, robotics is "the physical substantiation of the command and control elements that AI can give you. We've been able to do robotics for years. So, what is the difference now? I think it's the AI, cheaper computing power, and that's how it's going to be game-changing".

One of Defence's challenges remains the leverage of all that robotics can deliver. At present, it takes about 300 people to run a single military UAV unit which might have only one UAV aloft at any time, says McGinty. Ideally, you'd have the same workforce operating tens or even hundreds of platforms simultaneously, instead of just one. "Defence doesn't have much in the way of robotic or fully autonomous systems at this point in time. Certainly, if we can work at those leveraging pieces where you don't have one operator for one robot, that's when it will become transformational."

The Institute for Intelligent Systems Research and Innovation

There is little doubt that robots and autonomous systems will have a widespread impact in Australia's future defence operations. The extent to which people can control or collaborate with a robotic system, or purely observe an autonomous system complete a critical task, can determine the success of an operation. The implications of these roles are wide ranging, especially as robots operate as medical support or surgical tools, and large autonomous mobile systems lead a convoy to deliver important supplies.

The Institute for Intelligent Systems Research and Innovation (IISRI) at Deakin University is at the forefront of the accelerating pace of robotics and autonomous systems research and technology. Professor Saeid Nahavandi, who is the Director of IISRI and first Australian University appointed Pro Vice-Chancellor for Defence Technologies, is one of Australia's leading researchers in intelligent systems. Since 2004 the institute has made key contributions in the defence and security domains with over 20 research projects covering robotics, universal motion simulation, virtual/mixed reality and autonomous systems. These projects were funded through the Defence Capability and Technology Demonstrator program, Defence Innovation Hub, Defence Science and Technology, Army Minors program and the Defence Science Institute. The success of these projects is through the ongoing collaboration between the Australian Defence Force, defence industry representatives and academia, says Professor Nahavandi.

It is long accepted that robots can be used to aid humans in completing tasks that are difficult, monotonous, and especially dangerous. The ability to remotely control a robot and feel what the robot touches or interacts with in its environment is a technology developed by IISRI through the

Defence Capability and Technology Demonstrator program.

IISRI has since extended this research into the tele-medicine space with the haptically enabled robotics system (HaptiScan). This system utilises advanced haptic (force feedback) and stereovision capability for remote ultrasound procedures. HaptiScan aims to increase the availability of a sonographer and physician in remote or smaller medical facilities, and also minimise the potential for error and the time taken for a patient to be re-scanned.

IISRI has developed a robust system capable of being controlled over Australia's telecommunication network. A number of remote communities could be supplied with an ultrasound 'robot' for medical diagnosis requirements. When needed, a skilled sonographer or doctor could log onto the system from their home location and perform the diagnosis with haptic feedback, stereovision and full two-way audio visual communications.

A principal advantage of this system is the ability to translate the sense of touch to an operator, leading to reduced operator fatigue and the ability to lower the number of potential musculoskeletal disorders which the operator is exposed to. The addition of stereovision and force feedback to tele-diagnostic medicine can improve operator situational awareness by giving the operator depth perception, which also contributes to the accuracy and efficiency of manipulation tasks.

The system has been successfully demonstrated using data links to represent network latency existing between Melbourne and several regional and rural cities within Australia. Recent testing of the upcoming 5G network has demonstrated the proven technology can successfully scale to allow surgeons and sonographers to control the system at even greater distances.

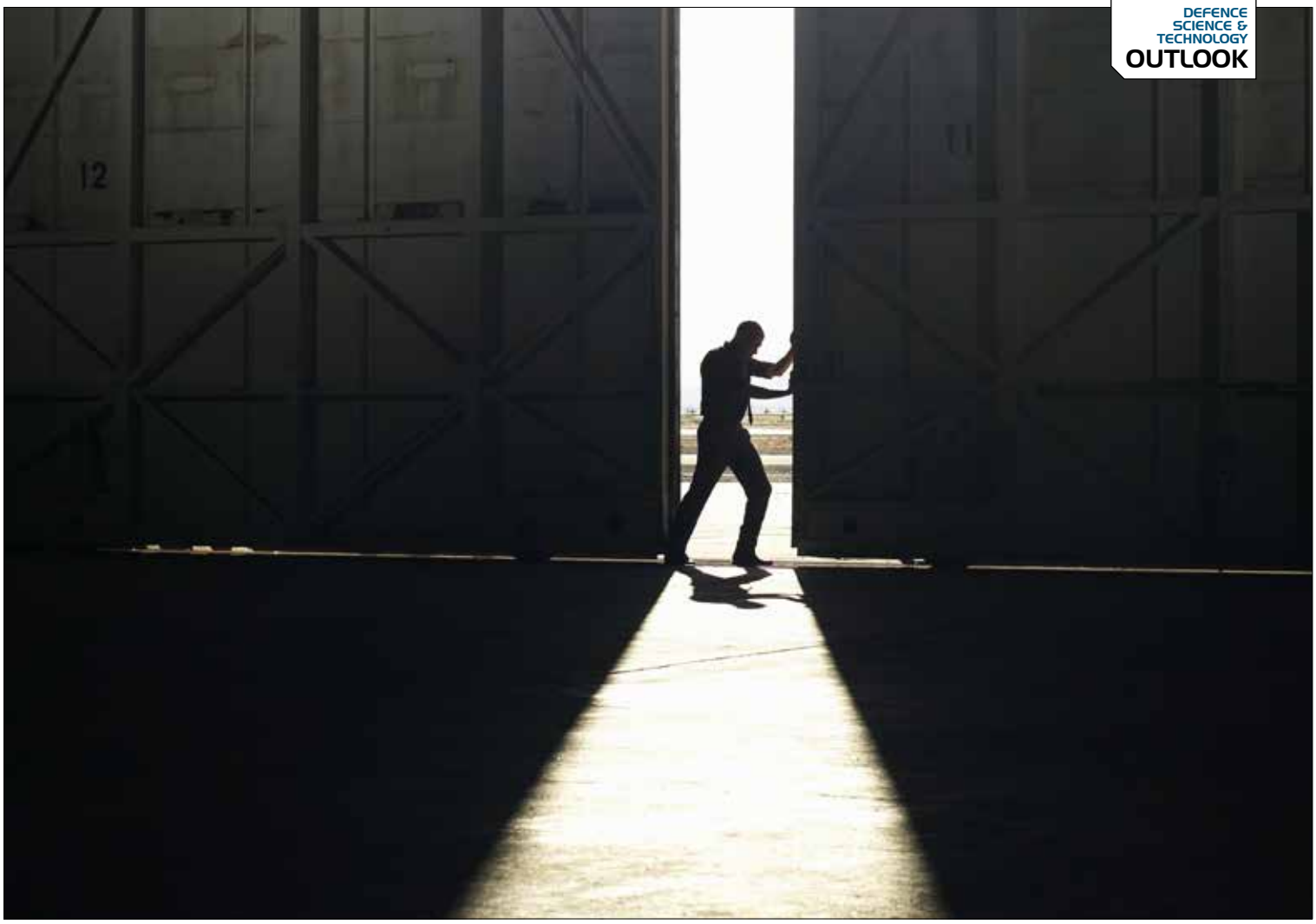
IISRI is also placing a great emphasis on autonomous navigation, focusing on defence applications in a GPS denied, map-less environment. This combines expertise from traditional robotics, deep learning, intent prediction for humans and animals, and uncertainty aware prediction. IISRI has already achieved success in obstacle avoidance and autonomous goal reaching where no maps are available through the use of state-of-the-art LIDAR technology and information fusion.

IISRI's research on intention predictions spans a wide range of predicting long-term behaviour of self-conscience targets such as animals, humans as well as autonomous vehicles in different scenarios. The research harnesses the uprising power of artificial intelligence and deep learning to derive a mathematical model for the behaviour of the targets being monitored. The derived models take into consideration two major factors, that is, social effects and kinematic limitations that may affect the behaviour of the observed target.

Observing the kinematic limitations of the observed target allows the machine learning models to narrow down the search space of the next step the target might take which in return allows faster prediction. In order to do this for human and animal targets, IISRI's machine vision and deep learning solutions are employed to derive biomechanic models of the observed target.

Modelling intent in social contexts increases the accuracy of long-term prediction of observed targets. Social contexts, such as crossing the street with a loved one in contrast to crossing alone, impose different behaviours. Similar discrepancies in behaviour also appear with wild animals and autonomous vehicles running as part of a group as opposed to running alone. IISRI's crowd simulation serves an important role in identifying the different scenarios for machine learning models to learn from.

IISRI has developed smart machine learning models that learn from synthetic scenarios and generalise on real ones. The synthetic scenarios are generated using IISRI's anthropometrically and biomechanically sound data generation pipeline. This addresses the data scarcity problem and allows tailoring different solutions for different scenarios and thus steering the learning capacity of machine learning models to focus on the critical aspects of the problem.



MOBILISING THE INTELLIGENT MILITARY: 5 TECHNOLOGY TRENDS TRANSFORMING THE DEFENCE COMMUNITY

By **Chris Otley-Doe**, Accenture Australia

Digital change is accelerating at an unprecedented pace, dramatically disrupting industries and touching every aspect of defence organisations. Those that equip their personnel with new skillsets will have unparalleled ability to create fresh ideas, develop cutting-edge products and services, and disrupt the status quo.

Getting past the digital culture shock that many organisations in the defence community are experiencing today may sound daunting. Defence agencies are particularly being challenged by non-traditional actors, cyberattacks and state-sponsored subversion seeking to disturb democratic governance and create an increasingly volatile operational and security environment. To address these threats, military organisations must be able to operate seamlessly, intelligently and with agility across a network of local and multinational partners.

Accenture's annual Technology Vision report, which surveyed more than 6,000 business and government leaders worldwide to pinpoint the emerging technologies that will have the greatest impact in the next three to five years, identifies five trends that are essential to success in an increasingly digital security environment: Private Artificial Intelligence (AI), Extended Reality, Data Veracity, Frictionless Defence and Internet of Thinking.

PRIVATE AI: TRAINING AI AS AN EFFECTIVE SOLDIER

Harnessing AI's potential is no longer just about training it to perform a specific task – AI will increasingly function alongside people as a full-fledged member of a team. In the high-stakes world of defence, it is especially important that AI systems act as trustworthy, responsible and efficient colleagues.

AI could have a major impact for military organisations, including defence logistics and cybersecurity. An adversary equipped with advanced AI capabilities will not wait for its enemies to catch up technologically before launching an offensive. AI's ability to process and analyse vast amounts of data has significant implications across the 'observe, orient, decide, act' (OODA) loop. From augmenting our ability to detect new threats to analysing countless variables, AI could transform surveillance and situational awareness.

EXTENDED REALITY: THE END OF DISTANCE

Extended reality (XR), which includes virtual reality (VR) and augmented reality (AR), is the first technology to relocate people in both time and place – effectively eliminating distance.

For the defence sector, the ability to simulate and share a common view of an operational theatre is immensely powerful. Recently, Accenture created a mixed reality proof of concept using Microsoft HoloLens and gaming engine Unity that provides military personnel with an interactive map showing real-time location and status data for troops and resources on the ground. With a simple command, a user can order reinforcements or supplies, or create and test different scenarios through a mixed reality interface.

XR technology can also enhance operational command capabilities in the field. For example, AR goggles could provide dashboards and data visualisations where and when they are needed – such as at an operating base. XR also will have major implications for training, allowing soldiers and pilots to engage in highly realistic combat simulations.

DATA VERACITY: THE IMPORTANCE OF TRUST

As defence organisations become increasingly data-driven, inaccurate and manipulated information is

a persistent and serious threat. Agencies can address this vulnerability by building confidence in three key data-focused tenets: provenance or verifying data from its origin throughout its life cycle; context, or considering the circumstances around its use; and integrity, or securing and maintaining data.

The ability to trust and verify the data that flows between multinational partners is critically important. Organisations must be capable of delivering the right data to the right recipient, at the right time – which can only be accomplished by radically reorienting how data is shared across today's armed forces. Today's vertical approach involves passing information up and down the command stack of a nation's military. In contrast, multinational military operations demand that information is also shared horizontally across the forces of different nations and partners. This shift requires a profound change in technology, mindset and culture within agencies.

FRICTIONLESS DEFENCE: BUILT TO PARTNER AT SCALE

Our recent survey found that 36% of public service leaders report working with twice as many strategic partners than two years ago. And when partnerships between industry, academia and military organisations are horizontally integrated and technology-based, they can expand faster and further than ever before. Here in Australia, Accenture recently opened an innovation hub in Canberra, to provide defence and national security agencies in Australia and New Zealand with access to the latest technology innovations and digital solutions to help them innovate and stay ahead of an evolving threat landscape.

Defence organisations must take steps to develop new IT architectures to reduce complexity. Old legacy systems were not built to support new technologies, and soon, outdated systems will be major hindrances to collaboration. Agile IT systems must be built to allow innovation to flourish, unimpeded by internal politics and employee resistance. A modern IT architecture will push organisations to clearly define the services they offer and turn each service into a potential enabler of collaboration. Locally, with significant capital investment planned by the Department of Defence over the next 10 years, the need to build agile IT systems that both enable innovation and support collaboration must be a priority. The role private-sector partners can play in enabling a culture of collaboration and innovation should not be underestimated. Awareness of the benefits associated with increased collaboration between public and private sectors is growing rapidly across the world. Forward-looking defence agencies are taking steps to tap into the skills, technology capabilities and R&D networks of private sector partners to help enhance defence operations both regionally and internationally.

Defence agencies must be bold and harness new technologies to advance mission success. This requires devising a digital strategy for their organisation that includes new rules and operating standards for the digital age.

THE INTERNET OF THINKING: INTELLIGENT DISTRIBUTED DEFENCE CAPABILITIES

Today's technology infrastructures are designed around a few basic assumptions: enough bandwidth to support remote applications, an abundance of computing power in a remote cloud and nearly infinite storage. But the demand for immediate response times defies this approach. Recent projections suggest that by 2020, smart sensors and other Internet of Things devices will generate at least 507.5 zettabytes of data. Trying to manage the computational 'heavy-lifting' offsite will become limiting.

The need for real-time systems puts hardware back in focus: special-purpose and customisable hardware is making devices at the edge of networks more powerful and energy-efficient than ever before. Public service organisations are taking note: our survey indicates 79% of leaders believe it will be very critical over the next two years to leverage custom hardware and accelerators to meet new computing demands.

The next generation of military strategies rides on pushing intelligence into the physical world. Defence organisations have to embrace new operating models to enable high-speed data flows, harness the potential of distributed intelligence and successfully neutralise threats.

CONCLUSION

Defence agencies must be bold and harness new technologies to advance mission success. This requires devising a digital strategy for their organisation that includes new rules and operating standards for the digital age. Those entities that take the lead and innovate will establish their place at the centre of the new digital ecosystem – while those who do not will likely be left behind.

https://www.accenture.com/au-en/insight-defense-technology-vision

THE WORLD NEEDS NEW

Associate Professor Rohan Walker sits at the cross roads of neuroscience and psychology and in collaboration with the Australian Defence Force is developing a Biometric Assessment Platform and a Cognitive Resilience Training tool using virtual reality.

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SEA1000 & SEA5000: DST'S CONTRIBUTION

DST looks at recent technologies and also much further ahead at technology evolution and anticipated development in order to help maintain the RAN's regional superiority well into the future. By **Gregor Ferguson.**

It is impossible to understate the importance of two key acquisition projects to the Royal Australian Navy, and therefore of DST's contribution to their success. Project SEA1000 will deliver a fleet of 12 Future Submarines, to enter service in the 2030s; Project SEA5000 will deliver a fleet of nine Hunter class frigates, with the first scheduled to enter service in the late 2020s.

They are important for several reasons: firstly, Australia's increasingly uncertain strategic circumstances have the potential to change quite significantly, and quite quickly; secondly, the nature of maritime power in our immediate region is changing – by 2030 about half of the world's submarines are expected to be based in our region, making a robust anti-submarine warfare (ASW) capability essential for a country like Australia which depends on the sea for both its security and its prosperity.

And thirdly, the massive investment in these platforms, along with the 12 Offshore Patrol Vessels to be acquired under Project SEA1180, will be the bedrock of Australia's continuous naval shipbuilding program and the vehicle for a massive national investment in both operational and industrial capability. But to be effective and relevant, that emergent industry base needs to master or at least understand multiple technologies.

S&T PLANS

The potential risks in this massive, continuous naval shipbuilding program are obvious and that has driven DST's approach to it, according to Dr David Kershaw, Chief of DST's Maritime Division at Edinburgh, SA. The organisation's Science and Technology (S&T) program has been built around risk analysis and focuses on three principal goals: Design Assurance and Acceptance; Sustainment of Regional Superiority; and Design Development.

The SEA1000 S&T Plan addresses capability and technology modelling and analysis; power and energy studies, including advanced battery technologies – a program that began

six years earlier; signatures and stealth; hydrodynamics and propulsors; submarine structural integrity; and sensors and combat systems.

'Signatures and stealth' describes the noise radiated or reflected by the submarine. DST has been working to ensure that it and the RAN understand all of its platforms' signatures and how to keep them as discreet as possible, and in the case of the Future Submarine and Hunter class frigates, understand the design decisions and the operational thinking behind them in order to be able both to manage signatures and keep those platforms safe and effective throughout their lives.

This is part of DST's role in helping Defence behave as a 'smart buyer', Kershaw explains. On Project SEA5000 this began as long ago as 2012 with development of the SEA5000 Initial Pass Studies and Analysis Plan, then included supporting the Competitive Evaluation Process (CEP) that resulted in the selection of the BAE Systems Global Combat Ship – Australia design. Importantly also, DST helped examine Combat Management System (CMS) options, a process which led to the selection of Lockheed Martin and Saab as CMS providers within a new Navy CMS Enterprise, of which DST will be an active member.

DST's S&T plans for these projects are worked out in close collaboration with Navy and CASG, says Kershaw, and become embedded into the projects' master schedules. They begin by identifying the key technical risks to be addressed, and then the key project decision points, whether government approval points, design reviews or other early stage decisions. DST, Navy and CASG then identify the S&T deliverables required to support these critical early stage decisions.

Meanwhile DST also looks much further ahead at technology evolution and anticipated development in order to help maintain the RAN's regional superiority well into the future. The continuous build philosophy for surface combatants and the rolling acquisition of submarines provides potential insertion points for a new or improved technology, says Kershaw, and therefore provides guidance on when technology needs to be sufficiently mature in order to be inserted into the design process. This helps prioritise DST's work but requires it to scan the technology horizon many years ahead in order to help 'future-proof' the Navy.

Some technologies give you little flexibility. You do not get many chances to change the steel used in a ship or submarine hull, for example, so long-lead research needs to begin very early in the project in order to get

this vital element right. Conversely, he points out, "in something like the cyber domain [the horizon for] long-lead research can be in the order of weeks, at times".

This is a balancing act that DST negotiates with the Navy and CASG, and it underlines the importance of sovereignty in science, he tells *DST OUTLOOK*: "Australia and Defence need to be conscious of those forward technologies in which we need to be world-leading, vice those technologies where we can afford to just be aware of what the state of the technology is, and monitor it. We can't do everything."

A sovereign S&T capability includes the expertise and capacity to analyse and understand signatures and stealth as well as key technologies such as submarine propulsion and sonar systems; and to keep refreshing that analytical capability as technology changes and evolves. "That is where a lot of our effort is, having the models and assessment tools to undertake that sort of analysis and provide that advice into the decision-making," Kershaw says.

"By 2030 about half of the world's submarines are expected to be based in our region, making a robust anti-submarine warfare capability essential for a country like Australia which depends on the sea for both its security and its prosperity."

The pursuit of sovereignty in science has implications for the Next Generation Technologies Fund (NGTF), he says, and ensuring Australia has the practices in place to protect emergent technologies that really are sovereign.

PARTNERSHIPS

Which raises the issue of partnerships, both nationally and internationally. DST's thinking is clear, says Kershaw: "There's more work to be done than we have the internal resources to do. We also are in a world where in some cases the demand is variable."

Twenty years ago DST helped to establish key facilities at the University of Tasmania's Australian Maritime College in Launceston (see side bar); DST can use these as required but does not need to own them. DST also has good research links with the universities through its Defence Science Partnerships program. DST plans to augment these by a number of University Research Networks that will support the establishment of a long-term sovereign capability in

>> Continued on page 67

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The Saab and DST Alliance: A Partnership for Innovation

Thirty years ago, Saab established its Australian headquarters and local company, Saab Australia, at Technology Park, South Australia to support and build Australia's defence capability, building and integrating Australia's unique combat system for the Anzac class frigates. Now employing more than 400 Australians, the company is one of the country's most respected defence and security system integrators. It is leading research and development for Australia's future combat power and rolling out technology to protect Australia's critical infrastructure to keep its people and society safe. In line with the company's orientation towards research and development, Saab allocates a total of around 20% of revenue to R&D.

Our strategic research and development alliance with Defence Science and Technology (DST) has been critical in supporting our R&D program and provides mechanisms for the exchange of intellectual property, access to facilities, staff exchange and engagement in collaborative research. The parties have jointly and successfully operated a strategic alliance since October 1995.

The latest work in this long-running alliance has been focused on maritime combat systems and includes activities that cover:

- Cyber vulnerabilities
- Maritime command and control
- Force protection
- Combat system modelling
- MFC prototyping
- ASW interface development

These are all key elements of the development work around SEA5000 Future Frigate and the Tactical Interface for Air Warfare Destroyers. Saab has also been a key industry participant in the DST Virtual Maritime Architecture and has assisted the development of the architecture and command and control federate for inclusion in the DST Virtual Ship. Together with DST, Saab is utilising the Virtual Ship to explore future warfighting concepts including integration of new sensor and weapon systems, optimised allocation of weapons and countermeasures, implementation of new operational concepts such as NCW, and investigation of HMI factors.

Ongoing R&D activity includes the areas of sensor management and sensor scheduling; non-cooperative target classification and identification; dynamic weapon-target allocation for the coordination of hard kill and soft kill weapons; interoperability data models; strategic systems interoperability; training and simulation system interaction; simulation and modelling to support experimentation; message routing for tactical environments; and real-time systems for the tactical environment.

Saab also competes for work with DST under the DST Research Engineering & Technical (ReSET) panel arrangement. Working in partnership with DST, Saab has had the opportunity to benefit from their research and investigation resources and is better equipped to respond to ADF requests. In return, DST gains an insight into industrial capability and the flexibility of industrial programs. By focusing efforts on areas of common interest and open communication, both parties are able to benefit greatly. Rigorous research and development into the future of Combat Management and Command Support Systems, in conjunction with DST, will ensure the long-term operational viability of these systems within the ADF.

UNIVERSITY of TASMANIA | AMC Australian Maritime College

Training Maritime Researchers

Australian Maritime College Associate Professor Jonathan Binns

By **Gregor Ferguson**

One of DST's key external partnerships is with a specialist institute of the University of Tasmania. The Australian Maritime College (AMC) in Launceston hosts the Australian Research Council's (ARC) Research Training Centre for Naval Design and Manufacturing, or RTCNDM.

Established in 2014 to meet the already-emerging submarine and surface ship design and construction challenges associated with Australia's Naval Shipbuilding Plan, the RTCNDM has multiple partners, all of them with skin in the game: the University of Tasmania, the University of Wollongong and Flinders University in Adelaide, and seven industry partners that represent the backbone of the future industry: ASC, Babcock, Thales Australia, PMB Defence Engineering, Serco Defence, Austal, and the Defence Materials Technology Centre (DMTC). It also has a key government partner, DST.

The thinking behind the RTCNDM is simple, according to its Director, Associate Professor Jonathan Binns. Industry, academia and Defence will all need trained researchers to support their design and manufacturing operations. Australia has too few of them and it takes several years to train them. Hence the investment in the RTCNDM.

In a remarkable piece of foresight, the RTCNDM actually predates many recent defence industry and innovation policy milestones such as the 2015 National Innovation and Science Agenda and the 2016 Defence White Paper. It was launched in 2014 and inducted its first PhD students in June 2015.

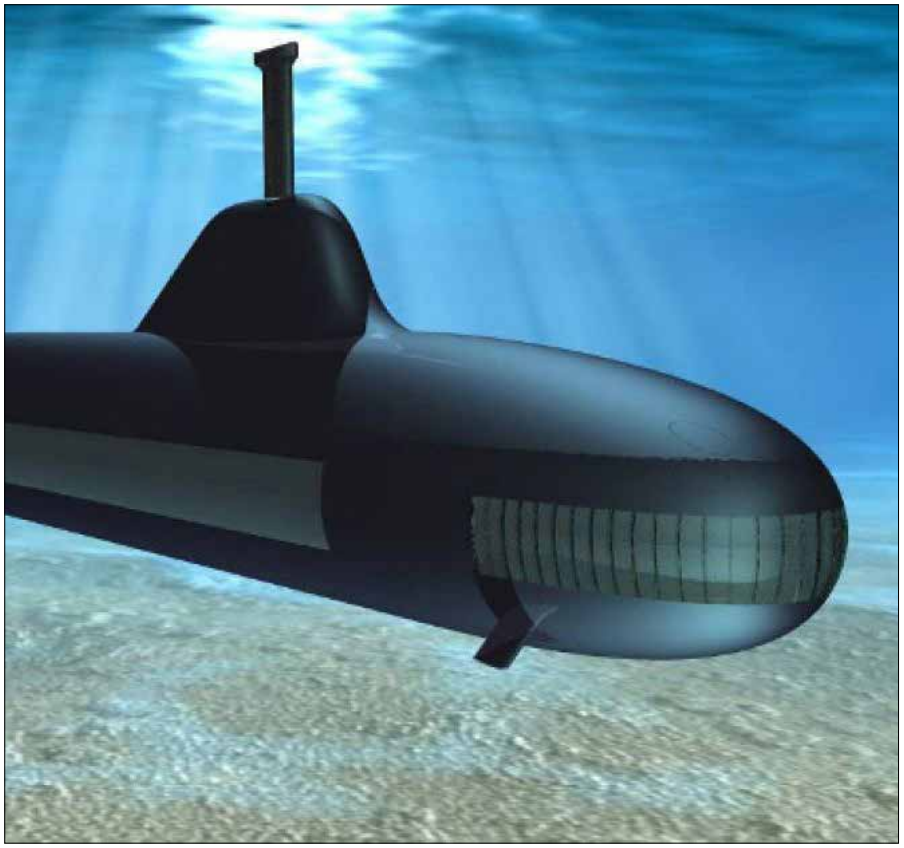
Every research topic is suggested by industry, so ensuring the relevance of the RTCNDM; there must be a transition path to industry for the resulting IP, and each PhD student and post-doctoral fellow must spend at least 12 months during the program with either DST or an industry partner. Initially, industry proposed 30 different research topics – a few were combined, others were rejected as not being PhD-appropriate, some were refined to make them more PhD-friendly, and to address security and commercial confidentiality requirements, and the final result was 10 PhD projects, with three post-doctoral fellows recruited to supervise and mentor the PhD candidates undertaking the research.

DST benefits in many ways from the RTCNDM, says Binns. It creates a supply of research-trained engineers for both DST and its external partners; it facilitates industry engagement at the educational level; the RTCNDM helps both DST and industry pursue specific R&D goals; and, importantly, it helps create confidence in the capacity of external R&D and industry partners who employ graduates. While the research undertaken at RTCNDM is closely aligned to the manufacturing needs of industry and Defence, it is also applicable to other areas of the advanced manufacturing sector and wider economy.

Australian industry needs around 5,000 people to make the Naval Shipbuilding Plan work, Binns tells DST OUTLOOK. Much of the initial STEM focus has been on vocational skills, but there is an increasing demand for professional engineering skills as well as higher research qualifications, so the system needs to be producing such individuals now.

The RTCNDM's far-sighted response to this need, says Binns, makes it a small but vital component in Australia's emerging defence and naval industry innovation system and an important component in Australia's science sovereignty.

Photo: Quentin Jones / AMC



The basic hull forms of ships and submarines have largely stabilised, he reckons, so the big risks facing submariners are associated with step changes in propulsion technology, particularly batteries and electric motors.

submarine S&T. The first candidate is a Research Network for Undersea Decision Superiority. This aims to build the capability and capacity of Australian universities to conduct research in support of decision-making on Australian submarines.

"Harnessing the full S&T eco-system is something that we're always trying to improve on because there are lots of bright ideas elsewhere," says Kershaw. "And that's one area where DST can assist the broader community, because of that key word: Defence. We actually understand our partners, which in my case is the Navy and the Maritime domain. We understand the timelines and limitations, and in many cases the opportunities. So it's beholden on us to build a network such that we can bring people in."

Internationally, DST also maintains close relationships with governments and the companies involved in these projects, though it manages the probity issue carefully. "We as the lead defence S&T organisation do have connections at various levels to both our international counterparts [such as DSTL]; and we also have our alliance links with most of the Australian primes – with BAE Systems and with Lockheed Martin, for example. We are very careful in the arrangements to keep it clear when we are working in the project space, which means we are working very closely with Navy and CASG, vice when we are having discussions with our international partners and industry on broader, non-project specific technology trends and issues."

Of course, ASW is more than just a tactical battle fought at the platform level by the individual ships and submarines. Quoting a former Chief of Navy, Kershaw says ASW is a team sport, requiring a highly skilled team of players both in the water and in the air. One of the priority areas in DST's Maritime S&T strategy is Theatre Level ASW – wide area surveillance, detection, tracking, reporting and, if required, prosecution. Whether at Task Group level or higher, successful Theatre Level ASW needs a combination of national and even multi-national assets, from teams of submarines, ships and helicopters to more exotic intelligence, surveillance and reconnaissance (ISR) assets.

This is where DST's mastery of airborne and space sensors, communications, combat management systems and command support technologies in all three environmental domains is important. It can bring all of these to bear on the challenge of ASW, says Kershaw, and provide a wider context in which platform-specific decisions can be made with higher confidence.

Technology does not stand still, Kershaw says, even if some areas evolve faster than others. The basic hull forms of ships and submarines have largely stabilised, he reckons, so the big risks facing submariners are associated with step changes in propulsion technology, particularly batteries and electric motors. Robotics and autonomous technologies are on the radar also. The technical possibilities are fascinating, but the operational focus is vital: lives, even the future of nations, can depend on these deeply technical decisions, hence DST's focus on helping get the decisions, and their timing, right.

FORCE MULTIPLIERS: AUTONOMOUS SYSTEMS RESEARCH FOR AIR, LAND AND SEA

The recent Defence Integrated Investment Program (IIP) foreshadowed $195 billion of investment in Defence equipment acquisition and sustainment in the decade up to 2026. By **Nigel Pittaway.**

Included in the major acquisition programs within the IIP are F-35A Joint Strike Fighters and MQ-4C Triton unmanned maritime surveillance aircraft for Air Force; submarines, frigates and Offshore Patrol Vessels (OPVs) for Navy; and new armoured fighting vehicles, trucks and protected mobility vehicles for Army.

These are all cutting edge capabilities and the Australian Defence Force is the envy of many armed forces around the world today, but how can these capabilities continue at the cutting edge over the years to come? Australia arguably cannot afford to embark on major defence acquisition programs every decade or thereabouts, so is there a cost-effective way of maintaining a regional advantage? One way is to combine manned platforms with trusted autonomous systems, so that together they are able to operate as a cohesive unit. In the battlespace of the future, such relatively low-cost autonomous systems are intended to enhance, but not replace, Joint Strike Fighters, submarines, armoured vehicles and the like, to provide a force multiplier effect for the ADF while maintaining important human oversight of their operation.

This is a major focus for DST which, among other research initiatives in the unmanned space, has recently established a Defence Co-operative Research Centre (CRC) to develop

trusted autonomous systems for the air, land, sea, intelligence surveillance and reconnaissance (ISR) and cyber/electronic warfare domains.

TRUSTING AUTONOMOUS SYSTEMS

One of the problems regarding the use of unmanned systems today is that it is estimated to require on average, four humans to command and control every single, complex robotic system. Given that autonomous systems are more accurately semi-autonomous systems – because there is always human involvement, DST's research is aimed at developing trusted autonomy which will enable each operator to manage up to 10 semi-autonomous vehicle systems: so those four operators can manage 40 vehicles, a 40-times force multiplier.

"It is about the 'smarts' in those particular platforms, and the combat systems that help to provide control and reduce operator cognitive effort," explains Professor Jason Scholz, Chief Scientist and Engineer, Trusted Autonomous Defence CRC. "In the loop you have a human operator in direct control of the vehicle, on the loop a human is undertaking a monitoring or supervisory role."

Control of autonomous systems in each domain also comes with its own unique challenges; maintaining continuous communications with vehicles underwater for example is a problem that is unsolved, and across the various domains there is the ever-present threat of communications and navigation systems being jammed by an enemy. So, the aim is to develop machines which can autonomously fulfil its mission to the degree possible, without having to forfeit the mission and return to base when either communication is lost, or it is otherwise unable to complete its primary mission.

"We have a focus on ensuring that we have an adequate systems of controls, which addresses everything including policy, doctrine, training, evaluation and certification," Scholz adds. "All of those things are around trust in the autonomous system. It's multi-dimensional."

Maintaining continuous communications with vehicles underwater is a problem that is unsolved, and across the various domains there is the ever-present threat of communications and navigation systems being jammed by an enemy.

In this regard, the work undertaken by DST is not so much about the development of new platforms or a better sensor, but rather, finding ways to make machines 'smarter', to provide a game-changing edge over an adversary.

"Overall I think it's going well, but we have some difficult problems to solve and this is the reason this technology is still very much in the research domain," Scholz explains.

"When we think about trusted autonomous systems there are many useful applications which could involve the integration of current systems or innovation, but we are seeking things that will either create surprise or protect ourselves from surprise. Australia is a big country, our force numbers are relatively small, and we may need a bigger ADF in the future, so we want autonomy to enhance, not replace, our human-centred capability.

"It is also critically important for the ADF to maintain human oversight, so we want our relatively small force to manage large scale autonomous systems as a force multiplier, extending the reach and potency of manned platforms."

DEFENCE CRC AND OTHER INITIATIVES

The Trusted Autonomous Systems Defence CRC is a component of the overarching $730 million Next Generation Technologies Fund, which is administered by DST on behalf of Defence. The $50 million Defence CRC Centre was announced by the then Minister for Defence Industry Chris Pyne in December 2017. "The Defence CRC model was developed by Professor Rob Sale, interim CEO for the Centre, by keeping the best of the National academic CRC model and based on industry feedback, making changes to put Industry in the driving seat."

"It was decided some time ago that the particular mechanism to take research into trusted autonomous systems forward would be a CRC-like approach. The Defence CRC has a new set of guidelines," Scholz explains. "It is a series of industry-led projects that are focused on those game-changing technologies. It is about seeding, shaping and building new national capabilities."

DST is engaged in the Technical Co-operation Program (TTCP) Autonomy Strategic Challenge, a 'Five Eyes' initiative specifically addressing the force multiplier concept.

The Autonomy Strategic Challenge achieved a world first in July with the successful interoperability test of simultaneously-operated unmanned vehicles on land, in the sea, under the sea and in the air. Scholz says the interoperability of a range of different vehicles, systems and payloads as demonstrated in the recent trial permits adaptable payloads to be employed to suit the individual mission. The trial was one of a series of five over 3 years performed in several of the 'Five Eyes' countries.

The Autonomy Strategic Challenge will culminate in November during the Autonomous Warrior 2018 demonstration and exercise in Jervis Bay, with a demonstration of a future allied combat system for the control of multiple trusted autonomous systems across the sea, air, land and underwater domains. "It will show how a single operator can manage 10 or more autonomous vehicles at the same time with variable control, from human in- to on- the loop," Scholz says.

Other than the aforementioned Defence CRC and TTCP Autonomy Strategic Challenge, DST is also pursuing a national Trusted Autonomous Systems Strategy under the Strategic Research Initiatives (SRI) scheme, which will build the group's

capability and capacity to support development of new Science and Technology across all domains.

"There are quite a range of things happening in the trusted autonomous systems area and it isn't just under the 'Five Eyes' purview," Scholz adds. "We have bilateral and multilateral activities with the United States and United Kingdom, we have a trial program underway with Singapore and we are scoping programs with South Korea and Japan, so we're quite active regionally and are looking to further extend those agreements and do more in that space as well."

ON LAND, AT SEA AND IN THE AIR

As a strategy that spans all domains, DST's work in the trusted autonomous systems field has several active programs, including undersea gliders, unmanned aerial systems (UAS) and unmanned ground vehicles.

One example of work being conducted in the maritime domain is the partnership with Australian small and medium enterprise Ron Allum Deepsea Services, to further development of the Sun Ray and Deep Ray underwater gliders. The Sun Ray and Deep Ray unmanned underwater vehicles (UUVs) have no mechanical propulsion systems and use a variable ballast engine, which is flooded with water and then pumped out to change the vehicle's buoyancy. The subsequent movement of water over the 'wing' of the vehicle generates lift in a similar manner to that of an aircraft's aerofoil and results in forward motion.

Testing of the Sun Ray vehicle began earlier this year at Woronora Dam, south of Sydney, "This type of UUV has a very long range and underwater persistence and we are looking at it as a potential surveillance capability for the ADF. The part that I'm focused on is how to make that machine smart, looking at how it plans to travel and navigate over a long range and manage its own energy budget, for example," Scholz explains. "These are significant challenges and it is only the first step to have a platform or systems that are self-sustaining, or at least more sustaining, on their own. We are now focused on building the 'smarts' into them to give them greater autonomy."

The underwater glider program so far has seen only limited testing carried out, but this will continue over the coming months, under what Scholz describes as a "learning by doing" process.

"The trial is looking at that force multiplication goal and how we can reverse the ratio of the number of people to machines. At the moment a large UAV, for example, might require four humans to operate it, so instead of four operators for one machine, we want a 10 to one machine to human ratio, or even higher."

"We have three research themes and a series of goals, which are about how we get up to the level of autonomy that we're looking for in a way that is still controlled and is comfortable for operators, but is trusted and certifiable," he explains.

In the land domain, Scholz says a further example of DST forming partnerships with Australian industry is its association with the Australian Centre for Field Robotics (ACFR), based in Sydney, to develop the Ground Hog unmanned ground vehicle (UGV).

"The Ground Hog is designed to be able to traverse over uneven ground very quickly, with the ability to carry some useful sensor equipment and it is one of the concepts that we will be demonstrating during Autonomous Warrior 2018 in November," he says. "It has what we term 'active perception'. So, if it 'sees' something, rather than just passively trying to identify what it is, it might actually change its location autonomously in an attempt to gather further information. An active perception system is one of the features of that capability and that gives you greater confidence in what it is that is being looked at by the vehicle."

The active perception system is one that has dual utility and there is significant potential for the use of such vehicles outside Defence. In agriculture, for example, robots may be capable of identifying fruit on a tree and then accurately count the number of fruit by moving its position around the tree.

The air domain has already seen extensive use of unmanned vehicles and such systems have been developed in Australia since the Government Aircraft Factories' Jindivik remotely piloted aircraft of the early 1950s.

An example of partnerships between DST and industry in this domain include work with Sydney-based Silvertone Electronics, which has recently been accepted into the Centre for Defence Industry Capability (CDIC) program. Silvertone has developed the Flamingo Mk.3 remotely piloted aircraft system (RPAS), which is a high altitude, long endurance platform that will also be demonstrated during Autonomous Warrior 2018.

"The unmanned aerial vehicle (UAV) space is really quite rich," Scholz explains. "There are so many innovative and interesting platforms out there and we're looking at everything from quad rotors up to the larger fixed wing capability such as the Flamingo."

"When we think about trusted autonomous systems there are many applications which could involve the integration of current systems, but we are seeking things that will either create surprise or protect ourselves from surprise. Australia is a big country, our force numbers are relatively small, and we may need a bigger ADF in the future, so we want autonomy to enhance, not replace, capability."

COUNTERMEASURES AND CHALLENGES

Countermeasures for autonomous systems is understandably a sensitive topic, but it is also an extremely important one to consider. Countermeasures may include other autonomous vehicles, in a 'robot wars' scenario, or directed energy weapons which are able to destroy machines at some distances. But these countermeasures are just as likely to include some means of hijacking or disrupting the communication link to a vehicle, or perhaps corrupting the software within it, in order to prevent it from functioning as intended.

"There's no single panacea or solution to this problem," Scholz adds. "There's a countermeasures game that will play out in this area, as it does with many things. The range of countermeasures is very wide and we're not closing ourselves off to any options, but I'm more focused on bringing the autonomy about rather than countermeasures at this stage."

Countermeasures aside, there are still some challenges ahead in the development of trusted autonomous systems, not least of which is the problem of a single operator simultaneously managing a large fleet of unmanned vehicles in the air, on the ground, on the surface and under the water.

"We already have systems that industry is designing and building, but they have a degree of piloting and navigation built in to the design," Scholz says. "What we are looking at is in effect a combat system that will help to manage and control those assets and co-ordinate their movement and activity with much

lower cognitive load on operators. We are continuing to encourage industry and academia to build more autonomy into their platforms to make them that bit smarter as well."

AUTONOMOUS WARRIOR 2018

The next major trial of the work done with regard to the control of multiple autonomous systems by a single operator will be during the aforementioned Autonomous Warrior 2018 (AW18) demonstration and exercise (see article on page 80).

A major component of the AW18 activity will be a trial led by DST to test command and control and artificial intelligence systems that the 'Five Eyes' partners have been developing, but there will also be an exercise component and industry demonstrations. The objective is to understand how autonomous systems can be used in the littoral environment – i.e. across several domains simultaneously.

"The littoral environment is the interface between the land and the sea, so it is a very complex environment and it involves capabilities that have to co-operate and work across all those domains. We saw this as a really interesting application space for autonomy, to see what the art of the possible might be and what might have a military relevance that would help future operations in that space," Scholz explains.

Another major objective is to explore the interoperability of the systems, to determine how they can be mixed in mission packages to achieve an outcome in the littoral arena. The exercise aspect of AW18 will involve 10 different scenarios that will be run end to end and include counter submarine incursion, sea defence, counter piracy, counter arms smuggling, critical infrastructure defence, fleet base attack and defence, support for land forces, clandestine operations from the sea and civil unrest management.

"The trial is looking at that force multiplication goal and how we can reverse the ratio of the number of people to machines." Scholz concludes. "The goal is to see if we can do that, and what the issues might be with maintaining control of multiple trusted autonomous systems in a contested and complex littoral environment."

OUR DEFENCE RESEARCH A FORCE FOR INNOVATION

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SUB CRUCE LUMEN

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UNMANNED AND AUTONOMOUS SYSTEMS FOR NATIONAL SECURITY AND DISASTER RELIEF

The use of unmanned systems to assist in national security and humanitarian aid and disaster relief (HADR) operations is not a new phenomenon and such vehicles and systems have been in use for more than a decade. By **Nigel Pittaway.**

As the capabilities of unmanned systems develop, and technology moves towards the deployment of more autonomous platforms, the potential for their use in such circumstances stands to become commonplace.

According to the Royal Australian Navy's definition, an unmanned (or uninhabited) system is one in which a human operator is always in full control of the vehicle. An autonomous system can be pre-programmed to carry out a series of tasks and therefore not always in contact with a human controller.

In the future, autonomous systems may provide rapid assessment of buildings or large and complex structures after a fire or other natural disaster, such as an earthquake. They might fly into noxious fumes or radioactive plumes to measure toxicity, or assess structural damage and search for and then direct rescuers to injured people. But while autonomous systems are arguably critically important to the future of such operations, they remain a means to a human end.

Defence Science and Technology is conducting research into two broad areas in this regard: the first is the deployment of uninhabited systems

into complex environments for the purposes of collecting intelligence, surveillance and reconnaissance (ISR) information; and the second is looking to solve long-range navigation problems for uninhabited vehicles which may be required to operate in an environment where communication or navigation aids (such as global positioning system, or GPS) are denied or degraded.

DEPLOYMENT IN BUILT-UP AREAS

One of the challenges with operating uninhabited and autonomous systems in a complex urban environment, whether inside a building or outside, in what is often termed an 'urban canyon', following a natural disaster is that the environment itself has likely suffered significant damage.

A key aim of sending one or more such vehicles into such environments is to rapidly build up an intelligence picture and identify injured people, but there may be risks to these vehicles along their travel route, or unstable infrastructure, or perhaps even gas leaks.

Dr Simon Ng, Group Leader, Unmanned Aerial Systems within DST's Aerospace Division, explains that the work being undertaken in this area is focused on enabling small robotic systems to enter a complex environment and map that area independently of an external human controller, or a navigation aid.

"Often in HADR cases the environment might have a lot of obstructions, such as smoke or debris, so we have been focused on developing technology that will allow a system to detect and avoid those sorts of obstructions and continue to collect information and map the environment," Ng says, "whether there's smoke or it is inside a darkened building, where you cannot necessarily rely on traditional electro-optical sensors to do the job."

DST is now looking at how multiple systems can be deployed into such environments and then work co-operatively within it without direct human control.

"One of the challenges that we're now exploring is whether we can deploy several of these systems into an urban environment, to map that environment, but also to find a target of interest – or to locate a particular area which might be of importance during a search and rescue operation," Ng adds.

LONG-RANGE NAVIGATION

In times of natural disaster, as well as warfare, navigation systems available to uninhabited vehicles may become denied or degraded, either by damage or by malicious intent, and another area of research DST is looking at is how vehicles can identify where they are and then navigate accurately in accordance with their briefed mission.

"This is an area of interest both here in Australia and around the world and there is a lot of work going on with regard to solving problems with mapping and collecting intelligence and navigating in areas where you don't have GPS and communications," Ng explains.

The work is looking at combining a range of sensor systems, and biologically-inspired techniques which include, celestial navigation, navigation using light polarisation, visual navigation and optical flow, which looks at how objects move past the vehicle's optical field of view when it is in motion.

"We are also looking at identifying critical features in the environment, so a vehicle can reference where it is and how it is moving relative

to that environment," Ng adds. "Those can be visual features, such as buildings or roads, but they can be electromagnetic features – for example the RF signals emitted in urban environments. Each of those signals represents a point in space that you can use to track where the vehicles are and therefore use that to track where they are moving.

"But the challenge is actually how you can combine all those together in that environment, because no one technique will give you a perfect solution."

There are different challenges with navigation inside a building or other such confined space and traditional sensors such as electro-optical cameras may not work effectively in a space that is dark or filled with smoke or other obscurant. Solutions under consideration by DST for such problems include the evaluation of very high frequency radar, Lidar (light detection and ranging) and infra-red sensing systems.

"The real challenge is putting these systems on uninhabited vehicles which are small enough to manoeuvre and operate effectively in tight spaces and they are the areas we are working on," Ng says.

SELF-HEALING SYSTEMS

Within the wider DST organisation, work is also being undertaken into developing self-healing networks of drones, which can maintain communications between each other and other end users in an environment, without assistance from outside.

Communication in urban or cluttered environments may be blocked or restricted by obfuscation of communications, or by 'terrain' such as high-rise buildings, or even by accidental or deliberate jamming of signals. In response, the work now being undertaken within the organisation is looking at how unmanned and autonomous systems can detect a loss of communications and are then able to relocate themselves to ensure there is still a communications pathway available.

"The ability to maintain coherent networks is a critical part of being able to co-ordinate any sort of effort, whether it is search and rescue (SAR), HADR or a military operation," Ng says. "The clever part about the work we are doing is that the drones themselves are able to determine when communications are breaking down and they are then able to manoeuvre themselves to maintain communications in an environment where they need to also determine where they are and where they need to go, while avoiding obstacles. When you put all those pieces together the challenge becomes quite complex."

CHALLENGES

Ng says while there are a number of challenges in this area, a significant example is that of miniaturisation. Large autonomous vehicles, such as Google's (now Waymo's) self-driving cars, are capable of carrying equipment payloads weighing several kilograms, but small autonomous systems such as UAVs designed to operate in confined environments do not have the same luxury. And even when miniaturisation can be achieved, the fidelity of the information is often reduced, so the challenge is to find ways to exploit and interpret the information to mitigate the problem.

"The second fundamental challenge is that the more you operate these systems in environments that are contested or denied, the more intelligent the systems need to be just to carry out their mission, because there is no human in the loop to control them," Ng explains. "One of the big challenges is to take this perception information and use it to help the system to make sensible decisions about where it needs to go, what it needs to look for and whether it should continue exploring – or whether it needs to get the information quickly back to where it's going to be useful."

Therefore, the challenge is to elevate the intelligence of a system from just perceiving its environment, to a level which enables it to conduct the mission with human oversight, but not direct control.

"In the future, it is hoped that autonomous systems will be capable of mapping the environment, determining areas of risk, locating people and exploring a building or area to build up an understanding of the environment before humans are sent in."

SOLUTIONS

Ng says one of the solutions to these problems is to develop a system which is able to use multiple sensors to characterise and understand the environment.

"If you think about a human team going into that environment, one person might be a specialist in one area and the next person a specialist in something else and we recognise that we're going to have the same issue with unmanned systems," he says. "So, if we deploy a team of unmanned systems, we might have to make a choice about which platforms carry which types of sensors. They will need to make decisions and allocate tasks based on both what they know about their own capabilities and those of their team mates. This is where

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Emulating Nature's Perfect Pursuit

Although its name may not inspire fear and dread in the way of a great white shark, or Bengal tiger, the humble dragonfly is widely considered nature's most effective predator.

This phenomenally talented aerialist is able to target, pursue and capture tiny flying prey in mid-air at speeds of up to 60 km/h – even if that target attempts to disappear within a seething swarm – with an incredible hit-rate of over 95%.

With such abilities having obvious application to human needs in the areas of defence and surveillance, along with health systems, environmental monitoring and manufacturing, researchers at the University of Adelaide set themselves the task of unlocking and harnessing the dragonfly's secrets.

According to lead researcher and neuroscientist Dr Steven Wiederman, from the Adelaide Medical School, they're succeeding.

"We're delighted to say that we've been able to build an autonomous robot that, using computational models bio-inspired by the dragonfly's neuronal processing, can effectively and efficiently pursue targets in unstructured environments," says Wiederman.

The team, which also includes researchers in the fields of mechanical engineering and computer science, first investigated how the dragonfly was able to focus on a single moving target and shut out all else.

"We recorded the activity of dragonfly neurons, and discovered the first identified neuron in any animal that exhibits an 'attentional spotlight'; selecting a single target amidst distracters.

"We also recorded from target-detecting neurons that predictively encode trajectory, enabling the dragonfly to estimate its target's future location and ambush it."

The processes displayed were then adapted into a unique algorithm to emulate the dragonfly's visual tracking capability. When tested in various nature-mimicking virtual reality environments, the algorithm performed every bit as accurately as other state-of-the-art algorithms, but while running up to 20 times faster, so requiring less relative processing power.

"We're very excited to continue our research now," says Wiederman, "and further define the fundamental principles that underlie neuronal processing. Translating these principles into the development of advanced artificial vision systems could result in some incredibly effective autonomous robotics, drones, neuronal prosthetics, and many more applications."

So where is all this going? The University of Adelaide team is working with industry partner DefendTex Pty. Ltd and DST, to develop such bio-inspired algorithms for the DST Grand Challenge in countering improvised threats. The improvised threats in this case are drones carrying packages (improvised explosives) and this dragonfly research will ensure the drones we use to target the threat drones are able to successfully catch and 'kill' the threat.

intelligent co-operation between systems becomes important."

A practical example of this level of intelligence is perhaps where one vehicle is not able to carry out its task due to smoke in the environment – it may autonomously request support from another vehicle which is able to function in that environment and then either exchange or negotiate the tasks to ensure that the whole team can continue with the mission as briefed.

"We think there is a way of exploiting heterogenous capabilities on different platforms and we think it's important therefore for those platforms to be able to co-operatively and dynamically allocate the resources within the team to those resources best matched to the specific tasks of the mission," Ng explains.

MEASURING SUCCESS

According to Ng, there are two core ways of measuring success in DST's endeavours in this area. The first is to establish a series of benchmarks and then undertake the research, trial the solutions and then compare the results against those benchmarks.

"We do that iteratively so, for example, we conducted a long-range navigation experiment where we flew a 200-kilometre round trip without GPS or communications systems which would enable the system to find its way back home," he details. "We demonstrated that we could do that to a level of accuracy that we could get the performance we were seeking using low-cost, lightweight systems without using GPS."

A further way for DST to measure success is when their research work translates into an Australian Defence Force (ADF) acquisition requirement. "We have a technical measure of success where we measure against those benchmarks we set for ourselves, and then we have the operational measure," Ng adds, "which is where we can influence what is specified in a requirement, or transition our technology to an industry partner, so that Defence ends up with a capability that they have not had before."

"Often in HADR cases the environment might have a lot of obstructions, such as smoke or debris, so we have been focused on developing technology that will allow a system to detect and avoid those sorts of obstructions and continue to collect information and map the environment."

TOWARDS THE FUTURE

Unmanned or uninhabited systems can be routinely fielded to support national security and HADR operations today, as noted earlier, but this relies on the vehicle or systems being operated in the traditional manner, by humans directly controlling them from some form of control station.

In the future, it is hoped that autonomous systems will be capable of mapping the environment, determining areas of risk, locating people and exploring a building or area to build up an understanding of the environment before humans are sent in.

"However, we're still a long way from reaching the point where it can be done autonomously by robots and there are still many challenges to be solved before we can do that," Ng says. "But we have made small steps on the way and we have already demonstrated the ability to deploy a very small system into an urban environment and have it find its way around that environment autonomously.

"We are working with international partners through a number of mechanisms, such as The Technical Cooperation Program (TTCP) and others and with academia and industry."


The UK DSTL MAST USV "airborne" at high speed in Jervis Bay.

AUTONOMOUS WARRIOR OUTCOMES

The Autonomous Warrior 2018 activity held in the Jervis Bay area during November provided Defence and industry with a glimpse into future autonomous systems. By **Nigel Pittaway.**

Autonomous Warrior 18 (AW18) was an initiative to demonstrate the current capabilities of unmanned systems and their potential to transform Defence capability in future years. The core activity was a trial led by DST to test command and control (C^2) systems and developments in artificial intelligence (AI), named 'Allied Impact'.

The trials were combined with industry demonstrations and presentations of a range of unmanned systems, in the air, land and sea (surface and sub-surface) domains applied to a wide range of missions.

During the activity, which focused on the littoral environment, 10 different 'end to end' missions were conducted, including counter piracy, fleet base attack and defence, sea defence, anti-submarine incursion, oil terminal and infrastructure defence, clandestine insertion from the sea, support to ground forces, counter arms smuggling and civil unrest management.

The activities were centred on the Royal Australian Naval College, HMAS *Creswell*, including operations of unmanned aerial systems from the adjacent Jervis Bay airfield, maritime operations in the waters of Jervis Bay itself and land activities at the lower sports ground, and on the nearby Beecroft Peninsula.

The multiple goals of AW18 included the military objective of the operational utility of robotic and autonomous technologies, the scientific aim of understanding teaming concepts between humans and autonomous systems, the strategic objective of enhancing the interoperability of such systems, and the industry dimension to promote Australian companies, foster relationships between primes and small to medium enterprises (SMEs) and the important goal of educating the broader public about their use.

"AW18 looked at semi-autonomous vehicles for the littoral: in air, on land, on sea surface and underwater and featured an Australian Industry Dynamic Exhibition (IDE). Around 60 expressions of interest were received and around 80 products were displayed," explains Professor Jason Scholz, Program Leader for Trusted Autonomous Systems with Defence Science and Technology.

"About half of those were for dynamic exhibitions of novel and exciting new technologies from both primes and SMEs with application potential for Defence. It was an opportunity for industry to show what they can do for allied militaries, scientists and regional partners. The Trusted Autonomous Systems Defence Cooperative Research Centre will also be looking to take forward some of the most promising 'game changing' potential technologies."

MAJOR FEATURES

AW18 was divided into three major components: the IDE, a Navy support aspect which included exercise control for safety and an Autonomy Strategic Challenge.

The IDE consisted of static displays and presentations as well as a dynamic component, where companies demonstrated the capabilities of their platforms, sensors and control systems in and around Jervis Bay.

"In the Autonomy Strategic Challenge we brought together

semi-autonomous air, surface and land vehicles from the UK, US and New Zealand with Australian Industry contributions to provide a force multiplier focus, where multiple vehicles were controlled by a single operator," Scholz says.

"We also had a range of underwater activities going on as well. We had Defence-owned Hydroid Remus 600 and Remus 100 unmanned underwater vehicles (UUVs) working an acoustic link with an Australian Ocius BlueBottle surface vessel, which was towing a Thales sonar array and they demonstrated an ability to operate in all sea states out in Jervis Bay."

OUTCOMES

The technology on display at AW18 attracted significant interest from across Defence and its coalition partners and neighbours. Visitors during two VIP days included Chief Defence Scientist Dr Alex Zelinsky, Head of Navy Capability Rear Admiral Peter Quinn and representatives from a number of countries including Singapore and South Korea.

"Part of the huge value has been the conversations and those conversations are great opportunity for industries – large companies looking at what the SMEs are doing and bringing them on board. Communication for me is one of the most valuable outcomes," Scholz continues.

"We also had people from the Defence Innovation Hub, including First Assistant Secretary Andrew Hodgkinson, who got to see the results of their first contracting activities. In my role with the TAS Defence CRC, I was looking at and talking with companies about game-changing technologies in the autonomy space."

"This is also the focus of the Next Generation Technologies Fund, not on what we can logically do next with trusted autonomy, but reaching into the future, choosing things that we know will change the way we fight and bring them into the present."

LOOKING TO THE FUTURE

Scholz thinks there is a need for future activities in the spirit of AW18, particularly to introduce new companies to the existing industry networks, but the decision will be up to Defence.

"I think it has been astoundingly good and I think a lot will come from this activity. It is important to provide opportunities to companies with technologies that look promising, then through the Defence Innovation Hub and the TAS Defence CRC and other means, take specific things through to operational utility," he explains.

Looking at the future of autonomous systems in general, Scholz says it is about the achievable intent of C². systems and expanding the capability using capability-given awareness.

"Autonomy is, in a sense, about C². It's the decision-making part of action that matters and there are three key elements – intent, capability and awareness. Humans are largely responsible for the provision of C² today, but machines are increasingly capable of performing some aspects of this and we need to integrate this with human decision-making," Scholz explains.

"Machines can do some things much better than humans and humans can do some things much better than machines. What we need is integration, to allow the strengths of one to offset the weaknesses of the other and our ultimate goal is fully integrated human and machine decision making. That's the holy grail for us. But to get there, machines will need more C² competence, like the ability to manage goals, comply with Command constraints, develop and analyse course of action options, track not just objects in volumes of time and space, but identify situations and threats."

"The Autonomy Strategic Challenge during AW18 takes us a step forward in a whole range of these areas and I think it's not an unreasonable to think we can get a long way there technologically in the 2035 timeframe."

The IAI LR2 "RoBattle" 7000kg 6 wheel drive UGV

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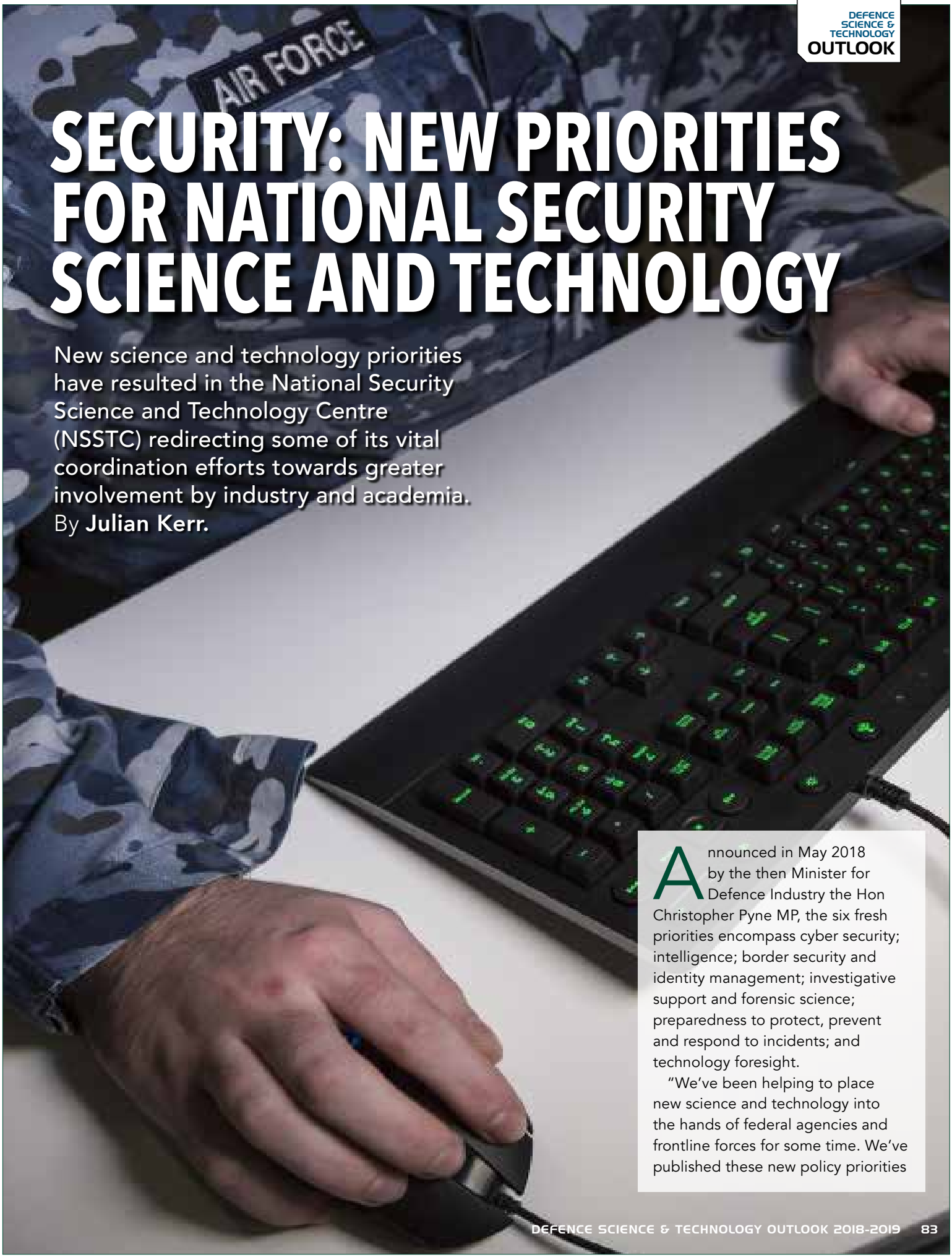
SECURITY: NEW PRIORITIES FOR NATIONAL SECURITY SCIENCE AND TECHNOLOGY

New science and technology priorities have resulted in the National Security Science and Technology Centre (NSSTC) redirecting some of its vital coordination efforts towards greater involvement by industry and academia. By **Julian Kerr.**



Announced in May 2018 by the then Minister for Defence Industry the Hon Christopher Pyne MP, the six fresh priorities encompass cyber security; intelligence; border security and identity management; investigative support and forensic science; preparedness to protect, prevent and respond to incidents; and technology foresight.

"We've been helping to place new science and technology into the hands of federal agencies and frontline forces for some time. We've published these new policy priorities

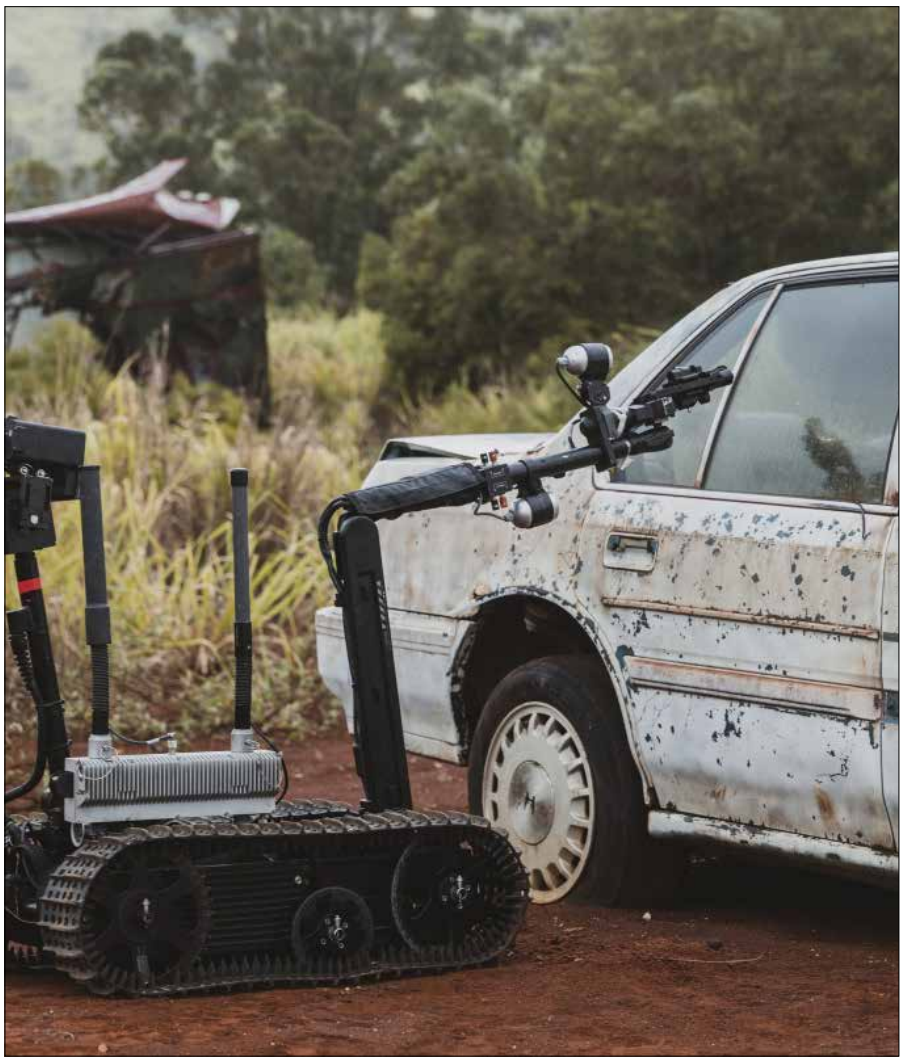
so it will be easier for Australian industry and academia to understand how their capabilities could contribute to Australia's national security," says Dr Richard Davis, Chief Technology Officer National Security.

DST's coordination role, through the National Security Science and Technology Centre (NSSTC), provides cross-agency visibility of the national security science and technology requirements. For example, a number of agencies have similar requirements for biometrics "so there is potential to get a critical mass biometrics program up for all of us rather than individual agencies contracting individual universities to carry out individual projects," Davis comments. "We're trying to raise the game so we can look at bigger programs which are more efficient across the government entities with interests in related areas."

NSSTC

Whole-of-government national security science and technology is coordinated from DST's National Security Science and Technology Centre (NSSTC). The first NSSTC was established in 2006 within the national security division of Prime Minister and Cabinet (PM&C), and in 2012 was moved to Defence and the then-Defence Science and Technology Organisation, now DST.

The current Centre has around ten staff, spread between Canberra, Adelaide and Melbourne, including program managers for priority areas and personnel working on strategy and policy. Some are on secondment from other areas – the program manager for forensic science previously worked in the Australian Federal Police, and that role may subsequently be filled by somebody on rotation from within DST, or from another agency. Another program manager position is filled by an engineer from Home Affairs on a two-year secondment.



As head of the NSSTC, Davis works to the Chief Defence Scientist as chair of a National Security Science and Technology Interdepartmental Committee (IDC). The IDC provides strategic direction, coordinates investment across the sector, enables interdepartmental coordination, and oversees the development and delivery of the science and technology program.

Actively shaping national security science and technology requirements against the agreed priorities is the responsibility of a Band 1 Round Table group which convenes quarterly.

The NSSTC engages with the federal national security agencies through the Interdepartmental Committee and Round Table, and with state and territory governments through the Australia-New Zealand Counter-Terrorism Committee (ANZCTC) in order to understand science and technology requirements.

The NSSTC then seeks an appropriate provider which can address the agency requirement – whether an international partner, a publically funded research agency, industry, or from within DST.

DST'S NATIONAL COORDINATING ROLE

Although the DST coordination remit covers all six priority areas, it

is important to separate the NSSTC coordination role to DST's science and technology capabilities. DST is not the sole provider for national security science and technology. DST has expertise in areas where there are no equivalent capabilities in industry and academia. In the really sensitive classified work in cyber and intelligence, DST have government facilities it would be hard for a university to replicate. DST has exposure to testing capabilities that probably no-one else in Australia has, and it's the same for chemical and biological threats.

"But as we now know, there's a lot of Australian national industrial and economic capability that could be better harnessed for those other priorities."

DST's national coordinating role has not stood on anyone's toes, Davis avows. "When we first set up I wanted to hear directly from the agencies whether they wanted us to do this or not. Every single agency said there's no point in doing this individually, it's clearly inefficient and we don't have the expertise we need, so if Defence is willing to provide this coordinating role, we're very supportive."

"There is potential to get a critical mass biometrics program up for all of us rather than individual agencies contracting individual universities to carry out individual projects."

Other nations have decided to have a central funding of around $50 million a year and most of that is used by putting out calls for proposals in particular areas. "DST now has the Next Gen Tech Fund and can support things like Grand Challenges on counter-improvised threats that obviously have relevance to national security, but nevertheless they're funded by Defence for Defence purposes."

"I think there would be benefits if Australia worked towards a model where we could have that sort of scale of investment for national security. At the moment we're not resourced to that scale but we are looking at other international models and seeking to apply best practice back home".

"We are co-investing with our international partners but that's more on a project basis whereas we could be trying to move to something more program-based – for example aviation security."

"What we're really trying to do is keep ahead so that we are thinking about the future threats and constantly looking at how R&D in science and technology can help us stay ahead of the curve."

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The Modern SOC: Time to Look Beyond Automation

In recent months, we have witnessed a significant increase in the number and severity of cyber attacks, and the ability of cyber attacks to spread in minutes across the globe. The most critical component in fighting these cyber threats is the security operations centre (SOC). An EY 2016 Global Information Security Survey showed that 56% of surveyed organisations have set up a SOC. This number will continue to grow, as more organisations realise the need for centralised cybersecurity incident prevention, detection and response.

Several years ago, organisations considered their security information and event management (SIEM) software products and services as their central SecOps management system. This made sense at the time, when the primary SecOps requirement was to centralise log collection and management, and perform basic correlation and alerting. However, more recently, security organisations are growing to understand that the SIEM is no longer effective for managing incident response.

Today, organisations are threatened by complex attacks from multiple vectors, and responses are required within minutes. On top of this, a massive number of alerts and a growing number of security tools overwhelm organisations. With these burdens, a new layer was required on top of the SIEM – resulting in the birth of SOC Automation and Orchestration platforms. These tools attempt to streamline event management, automate playbooks, coordinate between SOC team members, and integrate the entire portfolio of security tools and feeds. As a result, SOCs can now manage complex campaigns, handle thousands of alerts per day, and align security with IT operations.

And yet SOCs are far from effective. The recent Petya and WannaCry attacks are two examples showing us that organisations hit by malware fail to manage the response effectively, resulting in massive spread and damage. So, what are we still missing?

In 2017, when the 3 June London Bridge terror attack that claimed eight victims was analysed, experts pointed at the overload of intelligence data, and the lack of resources to process it: numerous snippets of information, terabytes of chatter, tipoffs, sightings and wiretaps that cumulatively could have helped form the intelligence picture. The data was there, but the intelligence operation lacked the systems and the human resources to process, decode and contextualise it – resulting in attackers slipping under the radar.

Cybersecurity operations have grown to resemble military and counter-terror operations: it is essential to collect and process large volumes of data collected by sensors we have deployed in our networks and endpoints, in order to detect malware before it causes massive damage.

So, the next stage in the evolution of the modern SOC is in becoming proactive – not only to respond, but to detect cyber campaigns before they turn into active attacks. In order to get there, we must add an investigation layer to our SOCs, just like the tools and capabilities that are common practice in the Intelligence community such as correlation engines, advanced dashboards, link analysis, BI and timelines. These must become a substantial part of our day-to-day cybersecurity operations, a necessity that I am sure, two years from now, will be a basic capability for every SOC analyst. We need to enable our SOCs to: automate, orchestrate and investigate.

Adi Dar is the CEO of Cyberbit. As a major subsidiary of Elbit Systems, Cyberbit's solutions span the entire range of cybersecurity and intelligence capabilities.

"What we're really trying to do is keep ahead so that we are thinking about the threats we have to consider and constantly looking at, in particular, how R&D in science and technology can help us stay ahead of the curve."

the individual agency requirements, the NSSTC aims to place science counsellors in Home Affairs and the Office of National Intelligence, an undertaking in which a relationship must be built between the policy and operational community and the science community.

"There are really two ways of doing that – the science counsellor is us putting one of our scientists into one of those agencies, and encouraging the reverse where they second someone in to take on one of the program manager roles," says Davis. "Between all our departments and portfolios we should be trying to share our resources and capabilities for best national effect."

INTERNATIONAL PARTNERSHIPS

Harnessing Australian science and technology also helps bring to Australia the best of breed from the four other Five Eyes members.

The UK, Canada and the US all have large organisations undertaking the same sort of work as NSSTC; New Zealand does not have a formal centre for national security science and technology and is not resourced to the same extent.

Of two entities in the US with which DST deals, one is the Combatting Terrorism Technical Support Office, part of the Department of Defence, which is seeking fairly high technical readiness of capabilities it can then develop or co-develop to provide a physical capability within six to 18 months.

By contrast, the US Department of Homeland Security is dealing with more enduring challenges such as aviation security and tends to take a longer-term view.

"They, like us, want to provide a safe but also efficient arrangement for aviation security so the public is kept safe from threats but doesn't have to queue up for four hours for screening," says Davis. "These threats are constantly evolving, we may find a solution to one set of threats and then

adversaries understand the limitations that we have and will be constantly seeking to find ways around it."

One recent but hitherto unreported advance in international cooperation emerged from a Five Eyes meeting in Melbourne in May with the launch of a Five Eyes Research and Development sharing arrangement. Dubbed the Five RD Council, this augments bilateral arrangements which each partner holds with each of the four other countries.

"Rather than just sharing bilaterally, we can now share multilaterally," says Davis. "So if the Canadians have done something really good in cooperation with the US, we can share outcomes directly through this Five RD Council. That's an important improvement, and a real enhancement to our

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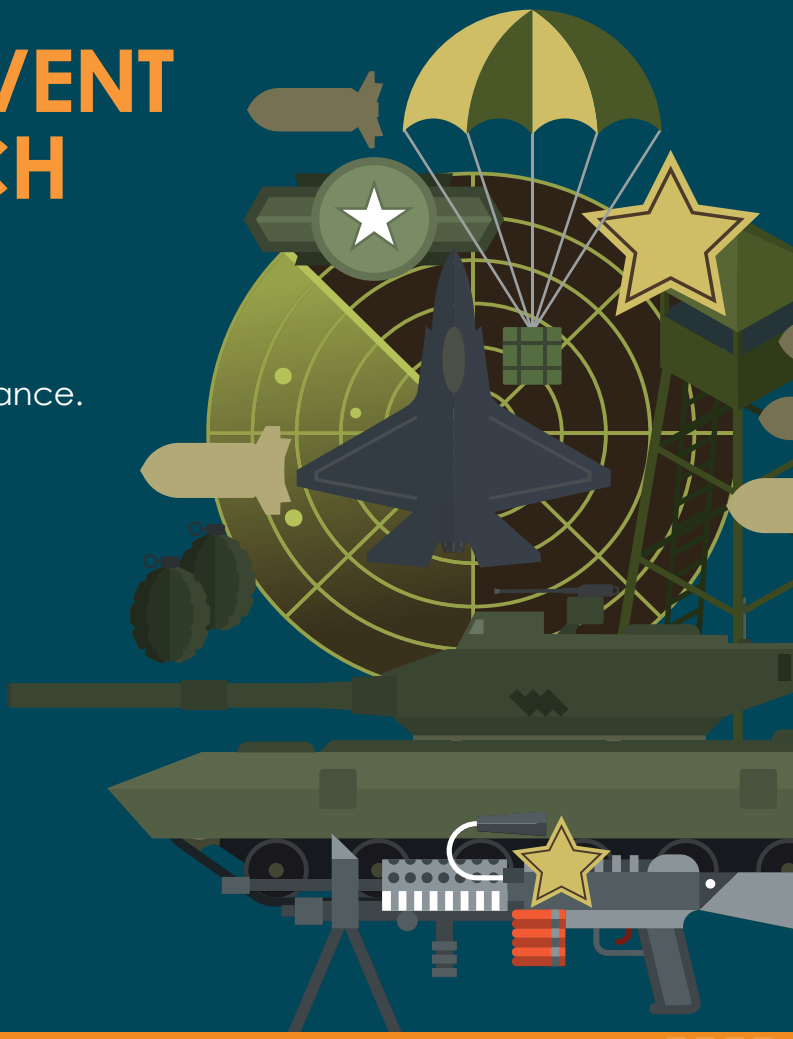

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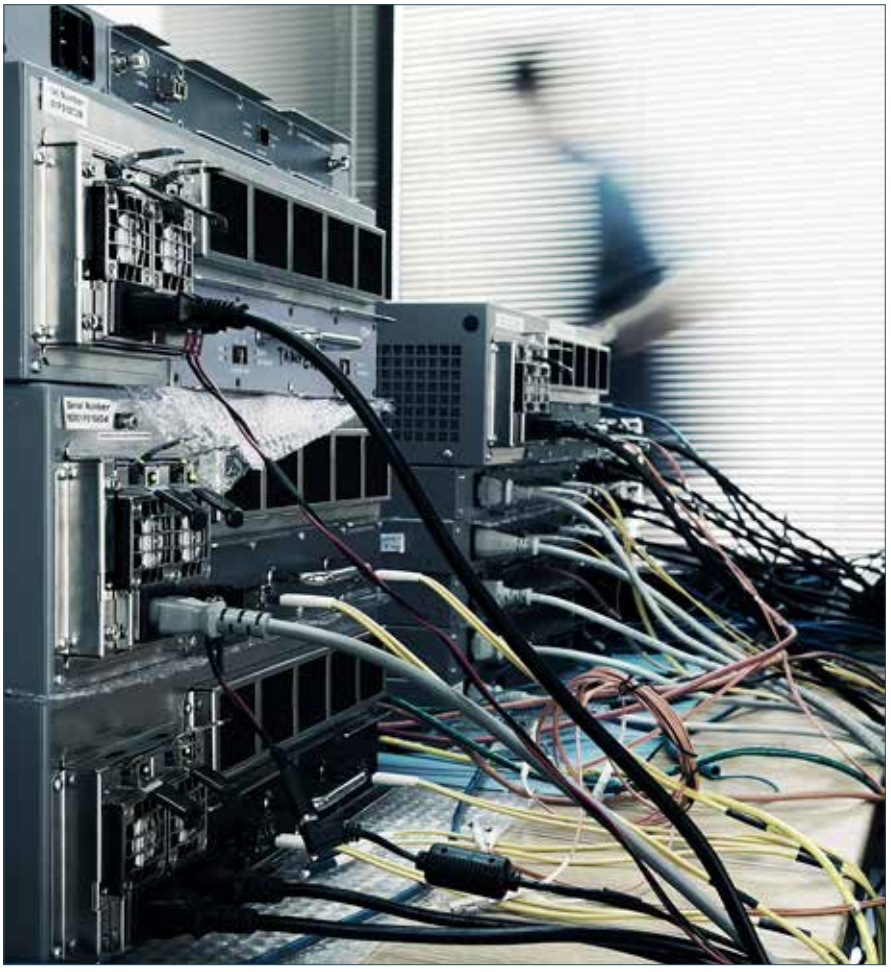
BE CAREFUL OF WHAT YOU WISH FOR:
NEW TECHNOLOGIES CAN BE TRAPS FOR THE TRUSTING

By **Simon Galbally, Senetas Corporation**



The wide-spread development and adoption of new Cloud-based business technologies continue to accelerate, leading to multi-Cloud environments and more complex data networks that enable them. In short, they lead to increased security attack vectors. Consequently, among new technologies' business benefits lie serious "traps for the trusting". These traps require robust data security to protect business technologies' network data and their connected assets. And, there is the issue of the emerging quantum computing! Failure to treat cyber-security as a core business technology, rather than a side issue, will lead to self-defeating adoption of new business technologies. They demand better security planning – "designed-in security"."Be careful what you wish for, lest it come true."

The defence industry, like most, has embraced new business technologies that promise reduced costs, better performance and competitive advantages. However, in their quest for improved business efficiencies, too many organisations have a single-minded focus on the benefits whilst ignoring the cyber security risks. This is evidenced by the increasing rates of data breaches and successful malware attacks.

Organisations finding cyber security a challenge today, need to consider what it will be like tomorrow. New business technologies promise greater challenges as the Internet of Things (IoT), Machine Learning (ML), Software as a Service (SaaS), Platform as a Service (PaaS) and Internet as a Service (IaaS) solutions lead an explosion in Cloud and data network dependent technologies. "Prevention" security (firewalls etc.) are not sufficient security as seen by continued shocking data breach statistics. "Protection" security (encryption) is now essential to ensure breached data is useless, and injected rogue/malware data has no impact.

The defence industry differs to others in its high profile and appeal to rogue state and other bad actors. No defence organisation is immune! Defence services and supply organisations risk the loss of business secrets and intellectual property (IP) that have the potential for catastrophic national security outcomes. Such a risk was highlighted on 10 Oct 2017, when it was revealed that a breach of a defence supply contractor's systems led to the theft of many gigabytes of sensitive data - "The intruders had access to the IT network for a long period of time and stole large amounts of the defence supplier's data". It was also reported the breach, "included information on the [F-35] joint strike fighter, C130 [Hercules aircraft], the P-8 Poseidon [surveillance aircraft], joint direct attack munition [JDAM smart bomb kits] and a few naval vessels." More seriously, this data was not encrypted!

The most serious issue was not that a breach was successful (being difficult to prevent any cyber-attack). What was unacceptable and preventable was that the data itself was not encrypted. Had the data been encrypted the breach would not have been a successful breach (a standard applied by Europe's General

Data Protection Regulation - GDPR)

It's essential to keep in mind that the defence industry's deep involvement in high-value innovation, and science and technology development makes it an obvious high priority target for cyber-attacks from a variety of bad actors - cyber-activists, organised crime syndicates, terrorists and rogue states.

NEW TECHNOLOGIES AND DATA-IN-MOTION CYBER SECURITY VULNERABILITIES

We live in exciting times with rapidly developing new technologies adding value to business performance as well as our lives. These new technologies are dependent upon data networks that enable them. But data networks are unsecure and an ideal attack vector, especially when the many technologies used by organisations significantly increase the size of the attack vector. As McKinsey & Company's James Caplan puts it, "The larger the data volume, the greater the risk."

Whilst it is not uncommon for organisations to encrypt their "data-at-rest" – stored data – it is worrying that too few commercial organisations encrypt their network transmitted data (data-in-motion), even in the knowledge that their data is travelling over public infrastructure and outside their control and security boundaries!

The new and emerging technologies that promise future benefits, all conspire to increase data's exposure to greater cyber security risks. These risks occur at a number of entry points, from the devices themselves, end-points and the networks, including network devices (routers and switches) that enable them. Statistics reveal that in recent years no more than 4% of breached data was encrypted, making 96% of breaches successful! Typically, the breached data included personal identity, business secrets, financial records, IP, and other sensitive data.

Today, new Cloud-based IoT and ML technologies have turned houses into dream homes through automated and intelligent floor cleaning, video security, automated shopping and entertainment

systems, to name just a few. In businesses like defence supply, ML and IoT and their end-point devices are becoming commonplace in manufacturing, logistics, supply chains and other functions.

Testing of IoT solutions, where devices from general business products to specialist products used in specific industries, has highlighted the increased security vulnerabilities being introduced into organisations and their data networks. They provide an entry-point for hackers. The Register also reported in its article "Internet of Things" in April 2018, how an IoT device, "…leaks its own identity in URLs, they found: any request from the device to its server, and any response from the server, included its brand. This is sufficient, the paper said, to tell an attacker that someone is using the device and how often they're using it…". Additionally, common IoT security risks are the device's own inherent vulnerabilities to the injection of malware.

IoT and ML are playing an increasingly active role in the defence sector's human activities, systems and processes. It is seeing increasingly high connectivity of what are referred to as intelligent devices leading to cyber security challenges.

In the case of ML technologies, the CERT Division of Carnegie Mellon University's Software Engineering Institute published a list of technologies that provide headaches in the security department. Its report "Emerging Technology Domains Risk Survey" highlighted ML as the second highest new technology's risk to cyber security.

Although Gartner estimates that ML is two to three years from achieving mainstream adoption, it is nonetheless an increasingly important technology. The aspects of ML in active use today include Big Data analytics, typically dealing with sensitive information; and sensors used in learning activities and that inform and perform actions in reality (e.g. factory robotics and self-driving vehicles).

The question is, what security is integrated within the IoT and ML technologies? Because IoT and ML are connected to data networks they provide bad actors opportunities to exploit. The security problems for access control (access to and control of the systems) and processes in which these intelligent devices are involved. These may range from manufacturing to critical national infrastructure. The bad actor can "take control" of the system or process as has occurred in the energy sector. On July 19, 2018 S&P Global reported, "Every day the energy sector faces a barrage of cyber-attacks…"

While IoT and ML technologies are new and maturing, there is a bigger issue of the business services and applications delivered by, Software as a Service (SaaS), Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Internet as a Service (IaaS). These Cloud-based business solutions are data network dependent, leading to multi-Cloud environments by organisations adopting multiple vendor services. When

Image: Senetas Corporation Limited.

these business solutions are considered "mission critical", the cyber security risks faced are more serious.

The cyber security issues are not limited to vendor customers' environments, but also the vendors' environments and the public network infrastructures they use – from data centre interconnects to within their data centres. Typically, vendors use multiple data centres as data is backed up and updated, some of which are in multiple countries.

Whilst Cloud-based services customers need to ensure their data is protected by the provider, the use of Cloud services raises an increasingly important risk issue of "data sovereignty". Does the customer have control over where its data is located? What jurisdictional (legal) issues arise when its data is stored in a foreign country? Some service providers report that they lose deals for this single reason – it is impractical to provide customers with certainty about their data sovereignty.

New technologies' cyber security issues are not limited to theft of sensitive information and eavesdropping, but the potential for serious business disruption and asset access control and injection of malware. Bad actors may be motivated by serious harm - to the organisation and its production, the public, or other nefarious purpose.

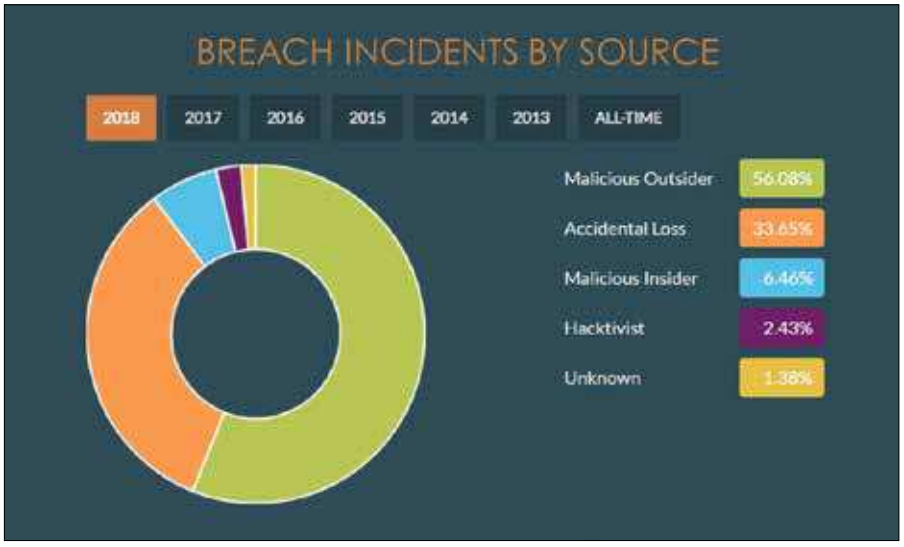
A "DESIGNED-IN" APPROACH TO CYBER SECURITY

The Australian Signals Directorate (ASD) and other nations' security organisations have recently revealed specific state sponsored bad actors identified in cyber-attacks and that these were not confined to industrial espionage and financial gain, but included acts to cause serious harm by injecting malware and obtaining control of industrial control systems. The defence industry must take these revelations as an alert to the need to do more than use security prevention tools and ensure data protection through encryption – protection from both theft and injection of malware.

In an environment of significant change towards Cloud-based technologies and IoT and ML hardware components, risk assessments/analysis must be alerted to the new reality of unsecure data-in-motion - data networks – whether they be public or private and whatever vendor. Everything from the Cloud-based solution provider's data centres, en route to customers' locations, and connected devices. All are attack vectors.

Ideally the Cloud-based solution will offer "designed-in" strong encryption security. But, customer organisations' networks are often neglected in their cyber-security plans. The implementation plan for these new technology solutions also require a designed-in approach. Simply, one that runs with the solution's implementation and is not an after-thought.

To be able to supply the Australian government and the Department of Defence, it is necessary for Australian defence industry organisations to comply with cyber-security regulations defined in the Protection Security Policy Framework (PSPF). These standards are set out in the Australian Signals Directorate's (ASD) Information Security Manual (ISM), and provide the "standards that govern the security of the government's ICT systems". However, whilst a key component of broader business risk management and due diligence, PSPF compliance is simply where best practice cyber-security begins. It is a minimal requirement.



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QUANTUM COMPUTING – A QUANTUM SECURITY THREAT

Whether quantum computing is three, five or ten years away, it will be highly disruptive. Quantum computers that draw their computational capabilities from quantum mechanics/physics will turn cyber security upside down. Because large number factoring is the basis of today's encryption standards, and quantum computers are able to factor large numbers more efficiently than classical computers, classical encryption algorithms will be rendered ineffective due to the extraordinary computing power that quantum computing will apply to decryption. Today's encryption algorithms provide extraordinarily long-life data security, well beyond the useful life of any data – from many hundreds to many thousands of years.

However, in a "post-quantum" world that will change. Cyber security will require "quantum-resistant" algorithms. Fortunately, the US-based National Institute of Standards and Technology (NIST), has already begun working with the industry to develop a quantum-resistant algorithm standard. What is important today, is that cyber security solutions include the agility to enable upgrade to post-quantum era algorithms without rendering a current solution redundant.

The rise and adoption of new technologies are certainly "traps for the trusting"!

CROSS DOMAIN DESKTOP COMPOSITOR

DST's Trustworthy Systems team has already earned many plaudits from its collaboration with CSIRO's Data61 Group on the technically advanced Cross Domain Desktop Compositor (CDDC). By **Julian Kerr.**

These include three National awards from the Australian Information Industry Association, one of which was for the 2017 Research and Development Project of the Year.

Now the team is continuing to develop applications for the CDDC while Data61 moves ahead with plans to commercialise the new multi-network user interface.

As systems grow increasingly interconnected, vulnerabilities multiply and solving the problem of accessing and transferring information across multiple and segregated networks becomes increasingly important.

Enter the CDDC, which gives users access via a single interface to multiple networks that have different security levels.

CDDC does the same thing as several other solutions but it does it in a new way and does it better, explains Trustworthy Systems researcher Mark Beaumont.

"The standard Defence approach to security is to keep networks very separate. You have an office with a number of different classification computers in it and it can be quite difficult to work in that environment.

"One of the ways that this is currently addressed is by using a keyboard-video-mouse (KVM) switchbox that allows you to hook up multiple computers to a single monitor but this prevents simultaneous access.

"CDDC takes the standard KVM switchbox to the next level, it's smart enough to be able to combine windows at different classification on the monitor at the same time, and you can switch by simply clicking on a window of different classification rather than hitting a button and waiting for the switchbox to switch to the other computer.

"Ongoing collaborative research between DST and Data61 is investigating more advanced features, for example how the CDDC can securely provide a controlled copy-and-paste facility between separate networks and also enable true cross domain applications such as email, chat and wiki.

"There's a small software component that provides the data CDDC needs and then that's it; there is no networking required, it's literally plug and play."

The CDDC uses secure hardware developed by DST and is powered by Data61's mathematically proven-

secure seL4 microkernel; a trustworthy operating system, which has also been used in autonomous helicopters and trucks. The seL4 microkernel underpins the integrated CDDC experience and guarantees that security policies are properly enforced across each connected network.

A successful five-month usability trial ending in mid-2017 saw the CDDC work across the Defence Protected Network and the operational Defence Secret Network in Headquarters Joint Operations Command, in 462 Squadron (part of the Information Warfare Directorate in the RAAF's Air Warfare Centre), in Defence's Chief Information Officer Group, and in the Defence Network Operations Centre.

The device was also demonstrated successfully in September 2017 to US, UK and Canadian defence specialists, "all of whom saw the value in both the device and the extended applications.", comments Beaumont.

Commercialisation of the CDDC is being handled by Data61, assisted by a $441,000 grant from the Defence Innovation Hub to produce a technology transition plan laying out the cost and time required to move the CDDC to a commercial product. This includes security and design advice from West Australian company Expert Knowledge Group, who have experience with the Australian Signals Directorate's high assurance evaluation process through involvement with the successful certification for the Silicon Data Vault High Assurance (SDV-HA) product.

"It's a real challenge taking an idea from a bench-top concept to a commercial product, and the difficulty increases when you are building a High Assurance product that then needs to undergo a rigorous evaluation process before it can be used; that's what this commercialisation process is addressing," says Beaumont.

"Instead of having to move all your data to a classified domain in order to work on it you can keep the data where it is and show the data all at once."

"Last year's trial on Defence enterprise networks went well, there's interest from Project ICT2273 Maritime Fleet Information Environment Modernisation, and the CDDC has broad applications across government and enterprise as well as critical infrastructure, banking and health.

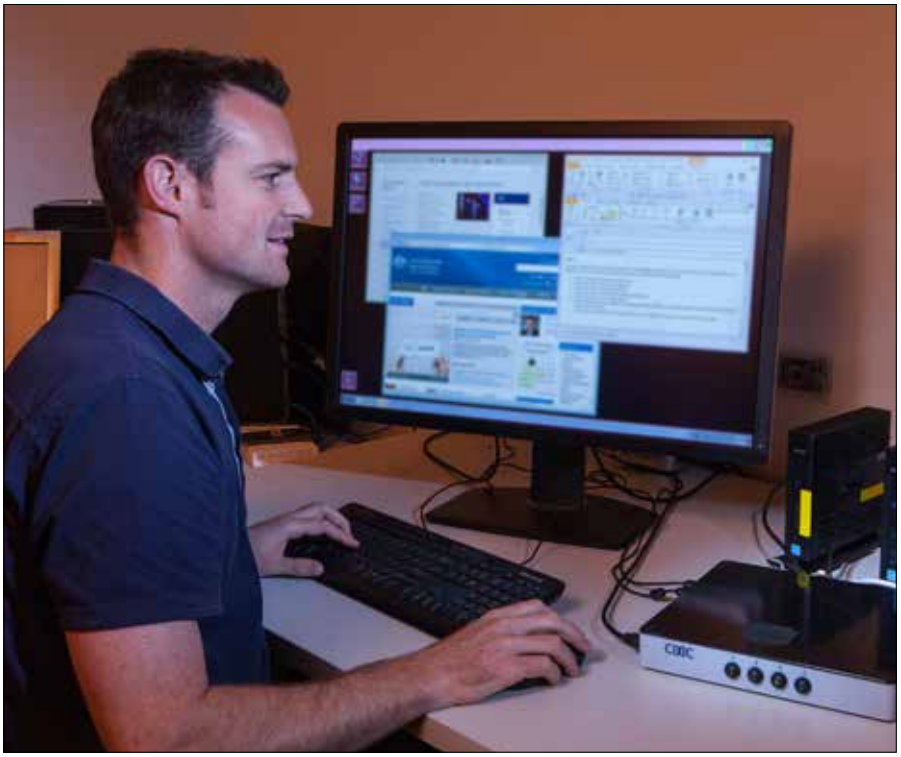
"Data61 and DST are confident in the technology and the opportunities for commercialisation. The path to market is a balancing act between achieving value for the two organisations, and ultimately resulting in a new capability for Australian Defence."

Meanwhile the DST team has focused on the development of several new multi-level secure applications that can be run on top of the CDDC, including a proof of concept Common Operating Picture.

The team also believes the CDDC operating model has the potential to be rebridged in the future for more interesting ways to work.

"Instead of having to move all your data to a classified domain in order to work on it you can keep the data where it is and still access the data all at once," explains DST's Simon Windows. "You don't have to copy it across different classification domains which is potentially a security risk, you can instead show it in side-by-side windows. With a more advanced visualisation you can interleave applications so that it looks like you're running a single application but you're actually running two at once.

"Some of our more advanced research on top of the CDDC is looking into how we can leverage this concept and move forward in five or 10 years' time."



FOOD FOR THE TROOPS

DST's involvement in the cutting edge of food processing technology is set to produce significant improvements in the texture and taste of the combat rations supplied to Australian warfighters on deployment. By **Julian Kerr.**

Not only is this technology enhancing the nutritional profile of the food to which it is being applied, it is also extending its shelf life and proving effective with foodstuffs such as seafood and fragile vegetables for which traditional technologies such as canning and retort sterilisation have been unsatisfactory.

The recipe for success lies in the process known as microwave-assisted thermal sterilisation (MATS), R&D on which is being undertaken at DST's nutrition research facility at Scottsdale, Tasmania.

Recently refurbished at a cost of $18.7 million, the Scottsdale facility has been providing expertise on food science to the Australian Defence Force for more than 60 years.

This capability was boosted with the arrival in early 2017 of a MATS-B pilot-scale device, the first of its type in the Southern Hemisphere.

"Army, Navy, less so Air Force, are often involved in situations where it's very difficult for them to provide high-quality food to meet nutritional requirements," explains Dr Nick Beagley, Research Leader – Land Human Systems.

"It's not just getting in those nutritional requirements – the way the food looks and tastes and its variety has an impact on the degree to which it's consumed. Tried and tested technologies like canning and retort pouches allow us to provide safe and edible foods after long periods of high temperatures without refrigeration but finding ways to increase their quality and acceptability is an ongoing challenge for food and nutrition research.

"With retort pouches and tins, you've got to apply a lot of heat, a lot of energy to kill the bacteria and make them self-stable. You add the foods to the tin and to the pouch and energy is then applied in a very general way so when you heat the centre sufficiently to kill any bacteria and viruses the edges tend to get overprocessed.

"The resultant product lacks the texture of fresh food. It will do for a period but if we can improve on it we stand a chance of enhancing the nutritional value of the food and also the level of its consumption. And there's also the morale aspect."

MICROWAVE-ASSISTED THERMAL STERILISATION

Enter MATS, a technology developed by Washington State University in the US, with which DST has been working as a research partner since 2016.

During MATS processing, packaged food is simultaneously heated from the outside in a pressurised hot water bath and heated internally with carefully

targeted 915MHz microwaves, using the precise amount of energy necessary to eliminate pathogens and spoilage microorganisms.

The food is then rapidly cooled to minimise heat damage, resulting in a meal to either eat, or heat and eat, or be stored on a shelf.

"The quality of the products that we've been able to produce in our early commissioning of the MATS equipment really shows to us that we're on the right track, we're producing the sort of food you wouldn't be surprised to get in a restaurant," comments Beagley.

"It really is of much better quality than we can provide with any other food-processing technologies and the ability to do it in a shelf-stable way has all sorts of opportunities for the ADF, everything from feeding on ships and submarines to mass-feeding in remote locations and potentially operations."

One element that MATS does not provide is browning – "you won't get a roast dinner out of this that looks like a roast dinner unless it has been pre-roasted; MATS is applying heat for sterilisation but it's not applying grilling," says Beagley. "But it will keep the food longer and the fundamental components of the meal are less denatured.

"Some of that is still to be demonstrated within the laboratory – there's a research program of testing that will validate much of the fundamentals we've been working on up to this point."

This research is being undertaken by the Centre for Food Innovation, a collaborative partnership between DST, the University of Tasmania and CSIRO originally launched in 2013. It was a cost-benefit analysis by the Centre working with industry that identified potential applications for the MATS technology beyond Defence's requirements and cleared the way for the MATS-B acquisition.

It is this acquisition that will provide the ability for industry to work with DST and its partners to explore the development of products that will be suitable for both commercialisation and application in a range of Defence contexts – "if you like, the type of meals that industry might produce to Defence specifications and Defence could then acquire", comments Beagley.

RESEARCH AND TESTING TIMELINE

Setting a timeline for this depends on industry partners as well as ongoing work to optimise the MATS-B device and the processes to refine what he emphasises is a brand-new technology.

"We're not here to manufacture those meals, we're here to advance the technologies so that Australian capability, both commercial and Defence, can all get a leg-up in this area.

"We're talking over a year, probably two or three years before you might see anything being acquired by Defence but I would imagine we'd see the testing of some of these concepts with Defence users much sooner than that."

These tests will also help pave the way for the wider commercialisation of the MATS technology, potentially opening up significant opportunities for the development of ready meals for export.

Centre Director Professor Roger Stanley points out that Defence research will not focus only on content and packaging, but also on the enhancements that the new technology could provide to operational flexibility, performance and logistics including the ability to provide personnel at short notice with nutritious, other than fresh but fresh-tasting food without having to establish large field kitchens.

While this will help provide a route to commercial production, initial research is concentrating on adapting the MATS technology to Australian requirements including meeting stringent food safety regulations that differ from those in the US.

"The guarantee of food safety against quality is a research area – this is not like standard canning where you boost the flavour with salt. It's a trade-off between overprocessing which kills the flavour and the nutrition, and underprocessing where you risk food safety," says Stanley.

"The quality of the products that we've been able to produce in our early commissioning of the MATS equipment really shows to us that we're on the right track, we're producing the sort of food you wouldn't be surprised to get in a restaurant."

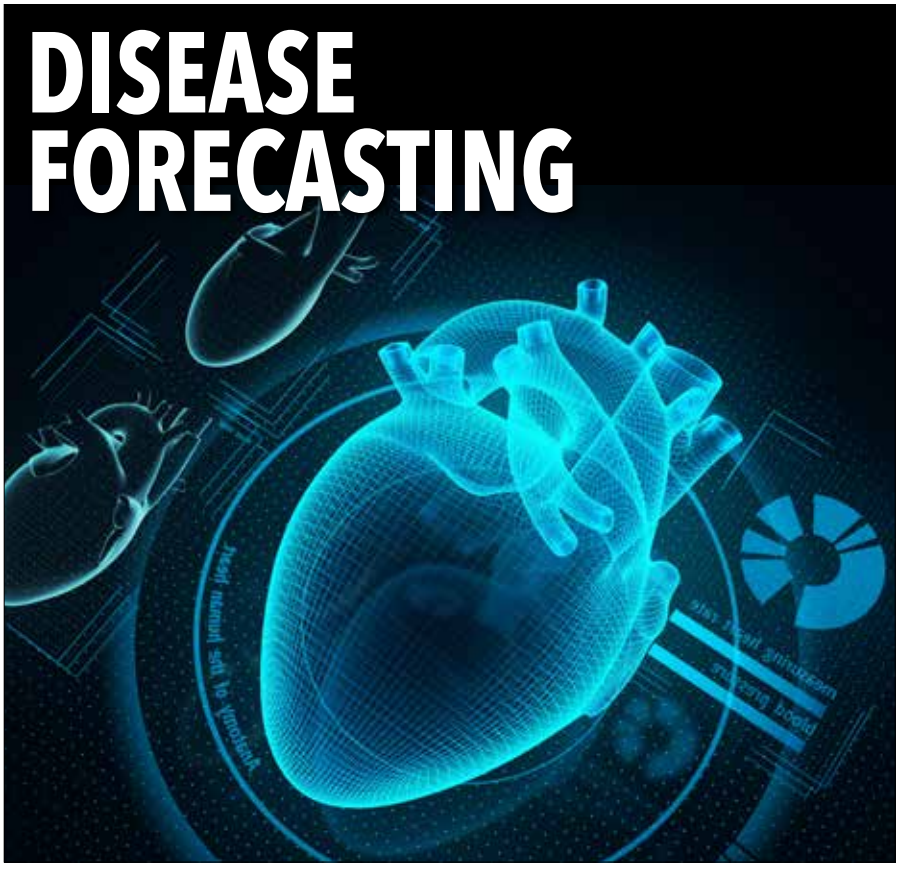
A further complexity involves the parallel development with MATS of barrier packaging plastics that replace the standard packaging technology of foil or plastic with aluminium coating that cannot be used in a microwave.

"This is at the very forefront of packaging. We won't be developing our own, our research program is to work with the leading international players in that area and we have links back to the US and Japan where we are sourcing for trial the latest packaging, initially for single meals," Stanley explains.

Work is now underway on a proposed collaborative program in which industry would set up and operate as a commercial concern, a production facility in Launceston, about 60km south-west of Scottsdale.

The capability of such a proposed facility has yet to be determined – the MATS-150 system now in commercial use in the US produces 150 food packages a minute.

DISEASE FORECASTING



DST has developed software modelling tools to provide early detection of disease outbreaks and to predict outbreaks of influenza up to eight weeks in advance. But while some diseases such as influenza are endemic and seasonal, there is a persistent risk of a deliberate attack using a hazardous biological agent. By **Gregor Ferguson.**

If Australia's 2016 Defence White Paper broke new ground in making Medical Counter-Measures an explicit focus of defence policy and research, it was merely acknowledging the expertise of DST researchers who have been working in this area for much longer.

One of these is Dr Tony Lau of DST's Land Division at Fishermans Bend. He leads the research team that won a prestigious Innovation Award in 2018 for its work developing tools to identify the outbreak of an epidemic, and then predict its spread.

The recent episodes of epidemic and pandemic diseases such as SARS, Ebola, and swine flu demonstrated the devastating impact of infectious disease outbreaks to the global communities. Even the recurring seasonal outbreaks of influenza generate catastrophic consequences. They can claim thousands of lives and result in major economic damage, making them as much a danger to the nation's security as a more overt armed threat. With new strains and species regularly discovered, health and relevant authorities all around the world have grave concerns on improving their preparedness for management and control of outbreaks.

DST has developed software modelling tools to provide early detection of disease outbreaks and to predict outbreaks of influenza up to eight weeks in advance. The World Health Organization (WHO) estimates that influenza alone kills between 250,000 and 500,000 people globally every year. Australia suffers an estimated 1,500-3,500 influenza-related deaths annually, with a further 18,000 hospitalisations, and over 300,000 GP consultations. This all costs some $85 million a year so the ability to predict the spread of a seasonal influenza epidemic will provide public health authorities an earlier window of opportunity to deploy appropriate measures to contain and mitigate the spread of the disease.

But while some diseases such as influenza are endemic and seasonal, there is a persistent risk of a deliberate attack using a hazardous biological agent. In both cases, says Lau, an outbreak can start quietly without being identified as such. By the time the outbreak is confirmed it may be too late to prevent widespread infection. Terrorists and our adversaries know this and there have been reports alleging that the knowledge, skills, equipment and facilities needed to culture, weaponise and stockpile biological agents are being acquired.

Australian Defence and its partners recognise the threats and have actively engaged to set up collaborative biodefence programs to improve our readiness to respond to such an attack, says Lau.

Within Australia, DST's Bioterrorism Preparedness Strategic Research Initiative (SRI) team was tasked with the development of disease detection and forecasting tools capable of providing

early warning to the ADF in the event of a biological attack. The team leveraged DST's existing world-leading expertise in target tracking based on data fusion algorithms, and has adopted some of these algorithms for epidemic model development.

Towards the end of 2014, the West African Ebola pandemic attracted worldwide attention. Lau's colleagues used the team's nascent capability to conduct epidemic modelling and provide outbreak forecast advice to the Chief Defence Scientist in anticipation of a parliamentary enquiry. Retrospective evaluation showed that DST's live prediction closely matched the actual number of victims reported by the WHO.

A slightly modified version of the forecasting model was developed for a different application. DST collaborated with the University of Melbourne's School of Population and Global Health (MSPGH) and developed the EpiFX model which utilises confirmed case notification data to predict the timing and peak impact of seasonal flu outbreaks five to eight weeks in advance. Outputs from EpiFX are used operationally in Victoria, and as an advanced prototype in NSW, QLD and WA, to aid health departments in the management and control of seasonal flu. This flu forecast capability is now getting more and more recognition and support from health authorities across the nation to the point that a national flu forecasting capability should soon be established. This development can potentially shape the Australian Health Management Plan for Pandemic Influenza. "The development of a cohesive national network for disease surveillance and prediction is highly important, and is one of the primary goals of our research," Lau tells *DST OUTLOOK*.

However, as he points out, the accuracy and readiness of DST's detection and forecasting technology is heavily dependent on the completeness and timeliness of the data collected and analysed. This represents a real challenge in particular when the ADF deploys into remote areas or in countries where health/patient information systems are not as well developed as those in wealthier countries.

A deeper understanding of the dynamics and progression of flu infection can facilitate a more robust and confident detection and forecast of outbreaks from bio-attack agents, as symptoms of pathogens such as anthrax and pneumonic plague are very similar to influenza in the early stages of infection. Using advances in Bayesian probability approaches, EpiDefend – a disease detection model capable of early alert of an outbreak – was developed.

"It took the combined efforts of a multidisciplinary DST and university team of mathematicians, epidemiologists and medical practitioners to develop the tools and techniques to enhance our situation awareness of disease outbreaks and improve our readiness to respond."

Lau's team found that, compared with ESSENCE, a benchmark syndromic surveillance system used by the US military and public health services, EpiDefend has a much lower false alarm rate. It can be configured to monitor other specific diseases simultaneously and raise a red flag for outbreaks of unspecified diseases. This capability is not just benefitting Defence but has a much wider implication in national security and public health.

These disease detection and forecast capability developments have won international recognition, and recently, Lau and his colleague Dr Peter Dawson worked with the US Defence Threat Reduction Agency (DTRA) and the Universities of Melbourne and Adelaide under a Coalition Warfare Program (CWP) worth US$1.2 million to jointly develop epidemic models to account for severity and transmissivity of disease infection and decision support tools for epidemic/pandemic control. Lau's team plans to evaluate prototypes of these capabilities in the Joint US-Australian Talisman Sabre Exercise in 2019 and later conduct a fully-fledged test in 2021 when the tools and techniques become mature. These epidemic models will eventually integrate into the US developed Global Biosurveillance Portal (BSP) and Biosurveillance Ecosystem (BSVE) when they are professionally developed.

Developing disease outbreak detection and forecast capabilities was not a trivial exercise and became feasible only due to DST advances in data fusion techniques, says Lau. It took the combined efforts of a multidisciplinary DST and university team of mathematicians, epidemiologists and medical practitioners to develop the tools and techniques to enhance our situation awareness of disease outbreaks and improve our readiness to respond. The results speak for themselves: EpiFX is now an operational tool for flu outbreak management and together with EpiDefend will be integrated into the global biosurveillance network. It is envisaged that UK's DSTL will join force with DST to fast-track EpiDefend development for operational support to both the AUS and UK militaries, for the purpose of detection of a biological attack.

For Lau and his far-flung team, the research work is starting to result in a satisfying outcome with an impact far beyond Australia: "Our collaborative team have delivered pioneering epidemiological surveillance and forecasting models that have the potential to become operational tools for a national and global bio-surveillance network."

Make Life Matter

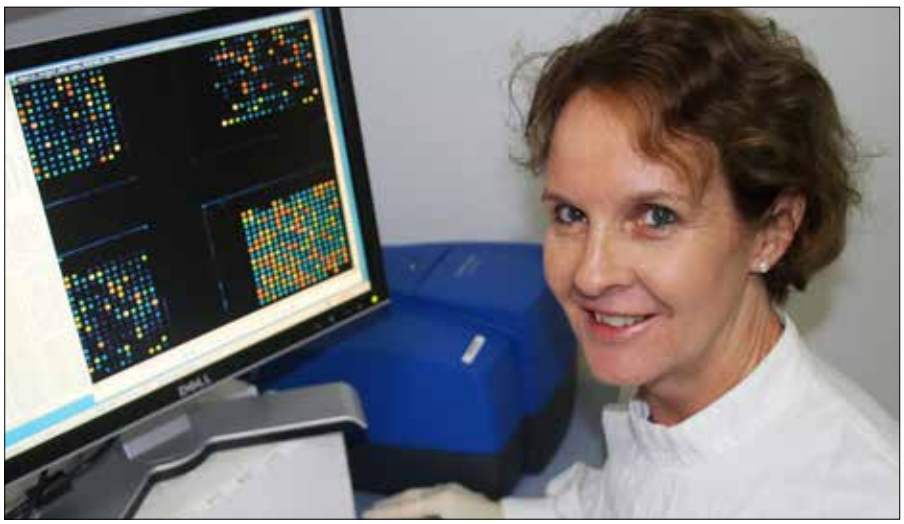
JCU: Research that makes a difference

The Australian Institute of Tropical Health and Medicine (AITHM) at James Cook University is a leading malarial research group in Australia and is a significant global player in malarial research, with strong ties to field sites and collaborating institutions world-wide. AITHM researchers are tackling the complex challenges posed by the disease, including the mosquitoes that transmit it and the five species of parasite that infect humans.

jcu.edu.au/aithm

JAMES COOK UNIVERSITY
AUSTRALIA

Fighting On All Fronts Against Malaria's Casualties Of War



James Cook University's Australian Institute of Tropical Health and Medicine (AITHM) is a leading national and international malarial research group in Northern Australia. AITHM researchers are tackling the complex challenges posed by the disease, including the mosquitoes that transmit malaria, and the parasite that infect humans with the disease. This multidisciplinary approach to malaria research includes work on several promising malaria vaccine candidates.

FIGHTING ON ALL FRONTS AGAINST MALARIA'S CASUALTIES OF WAR

Malaria is not usually the first word that springs to mind when one hears the words 'casualty of war'. But the disease has been a significant cause of wartime casualties since the First World War. The Australian Institute of Tropical Health and Medicine (AITHM) at James Cook University (JCU) houses a number of leading malarial research groups that are tackling the disease on several fronts. Its researchers are working on improved methods of prevention using expertise in entomology and vector biology; others are developing vaccines.

The Institute's research outputs are focused on the most pressing health issues facing tropical Australia and the Indo-Pacific. One of the strengths of AITHM and JCU is its multi-pronged approach to health and medicine, as well its disease-specific research in areas such as tuberculosis and malaria. AITHM brings together experts in many fields such as science, big data, economics, epideomiology, public health and ecology. The Institute's activities thus span the spectrum across products, practice and policy. Malaria remains a major public health threat throughout the Tropics and is the cause of significant mortality, and morbidity.

Currently, AITHM is working on three vaccines at various stages of development: fundamental proof-of-concept, pre-clinical development and clinical trials. These projects are aligned with the global Malaria Eradication Research Agenda (malERA) initiative.

Led by Professor Denise Doolan, one research group is taking advantage of the possibilities opened up by new vaccine technologies. Professor Doolan's team is exploring the genetic blueprint of the malaria parasite, Plasmodium, with a view to providing a comprehensive picture of the interactions between the parasite and its human host. To progress this work towards clinical testing, Professor Doolan is involved in a collaboration with the international OptiMalVax consortium, which is engaged in an innovative programme of antigen discovery science linked to rapid clinical development of new vaccine candidates.

In a second vaccine development project, AITHM, led by its Director, Louis Schofield, has developed a prototype vaccine aimed at overcoming the complexity and challenges presented by a disease with a multi-stage life cycle that can be spread by several different species of a parasite. The project is innovative on several fronts. The saccharide-conjugate vaccine attacks a universally conserved target present on the surface of most stages and all species of malaria parasite. Such broad-spectrum action is not found in other vaccine candidates. The work is funded by the Bill and Melinda Gates Foundation, the Australian Government Department of Industry, Innovation and Science, and the National Health and Medical Research Council (NHMRC).

AITHM's third malaria vaccine candidate, also led by Professor Schofield has recently completed Phase 1 clinical trials in Queensland In collaboration with Professor James McCarthy from QIMR Berghofer. The vaccine is a genetically attenuated live blood-stage malaria vaccine in which pathogen virulence factors have been ablated.

James McCaw, a Professor in Mathematical Biology at the University of Melbourne, has been working at the forefront of infectious diseases modelling.

Modelling for Flu Outbreaks on Front Line in Bioterrorism Defence

International interest is growing in disease forecasting with the capacity to move from public health to defence applications. By Liz Wells.

A forecasting tool developed using routinely collected surveillance data during the annual winter influenza season is being augmented to model the spread of a host of viral outbreaks so appropriate responses can be put into place across Australia and beyond.

Known as EpiFX and developed by a research team at the University of Melbourne, the influenza forecasting tool is now being assessed by a number of state governments across Australia.

Its spin-off, EpiDefend, has drawn the attention of the US Government, which is working with DST, the University of Melbourne and the University of Adelaide to develop an even more robust modelling tool that can identify the level of threat from a bioterrorism attack to enable an appropriate response to be deployed as quickly as possible.

Under an agreement between the US and Australian departments of defence, DST will be working on a two-year program from September 2017 to bolster the capabilities of both these epidemiological surveillance systems.

Dr Tony Lau, the task leader in DST's epidemic detection and forecasting program, says modelling capabilities were born out of the concept of probability inference combined with Susceptible, Exposed, Infected and Recovered (SEIR) compartmental disease models. These would also be on the front line in mitigating the risk of a deliberate and covert release of hazardous biological agents with malicious intent.

"While the work has implications for national security, a lot of its benefit will lie in its ability to support public health and to gear towards a national forecasting system for viruses," Lau says.

"What we are aiming for is the development of robust and powerful software that can tell us within 24 to 48 hours the extent of what we are dealing with in terms of a virus."

Lau says such modelling had the potential to predict the rate of spread of an epidemic, and to identify those most at risk so preventive action could be taken through measures such as targeted vaccination. "In general, it is the young, the old and the weak who are most at risk from viruses like influenza; better forecasting means we can better use state or national resources

with those people in mind."

James McCaw, a Professor in Mathematical Biology at the University of Melbourne, has been working at the forefront of infectious diseases modelling since it began in Australia about 12 years ago and was a key developer of EpiFX.

Viruses such as ebola and influenza and emerging diseases such as zika and SARS have governments around the world considering the threats posed by communicable diseases. Professor McCaw says all of these viruses were being looked at as EpiDefend evolved.

"We have to start with what we know about these pathogens and how they might spread," he says. "Projections and planning are based on modelling and extrapolation."

Professor McCaw says when an outbreak occurred, either naturally or through an act of bioterrorism, the forecasting tool provided the crucial link between pre-pandemic scenario modelling and real-time data analysis.

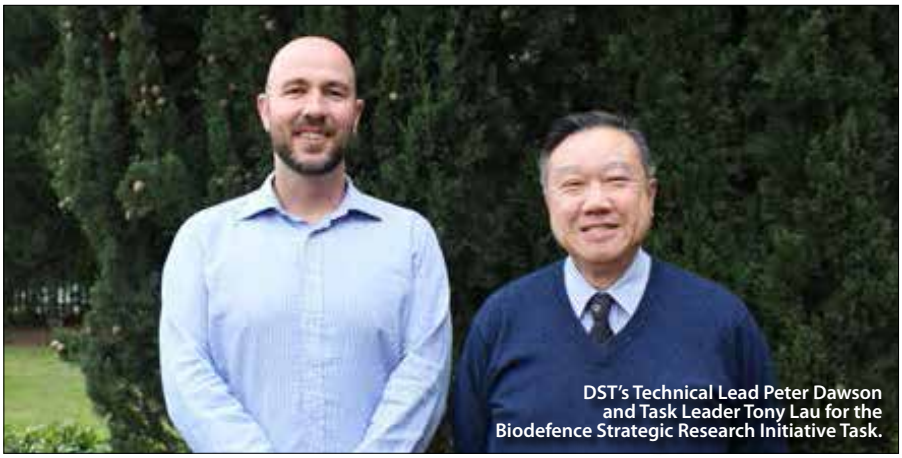
"That kicks in when people affected by the virus start to arrive at emergency departments, or when in a particular environment, such as a barracks, soldiers start displaying symptoms such as coughing.

"Analysis of that data shows us how quickly a virus is spreading and points us to initiating an appropriate and proportionate response."

In extreme cases, that could mean interventions such as closing schools or shutting down public transport to minimise opportunities for the virus to spread.

"If you did that for a mild virus, you may do more harm than good by imposing an unnecessary logistical and economic burden on the population, so it's important that the modelling leads us to a proportionate and not an over-reactive response," Professor McCaw says.

DST began working with the University of Melbourne research team on disease modelling four years ago. "We are still developing and refining our forecasting, but in the event of a health emergency, we are in a better position to respond than we have ever been as we improve our ability to integrate forecasting with our scenario analyses," he says.



DST's Technical Lead Peter Dawson and Task Leader Tony Lau for the Biodefence Strategic Research Initiative Task.

He felt the fit between the University of Melbourne and the Department of Defence objectives was a good one. "Their scientists are all about putting in place systems to deal with bioterrorism, and we have developed our system by working with the public health sector to deal with this naturally occurring phenomenon.

"While the cause of the outbreak might be different, the response required is similar, and we find it's been a very compatible match between defence and civilian academics."

EpiFX and EpiDefend differ from other epidemiological surveillance systems by using Bayesian approaches that can process statistics to accommodate competing probabilities caused by different viruses.

In the Victorian context, EpiFX has accurately predicted flu outbreaks up to five weeks in advance, and weekly forecasts of the incidence of flu are made available to the health sector.

The success of the forecasting tools has come about through the commitment of researchers and public servants working in fields including computer science, physics, mathematical biology, electronic and software engineering, epidemiology and medicine.

While a healthy human immune system will build up resistance to a virus in two to three weeks, the research team is well aware that communities can suffer widespread illness or even deaths from an unforeseen outbreak.

Lau says for this reason, several of Australia's allies including the United Kingdom were in discussions with DST about using its epidemic modelling capabilities. "We want to engage regionally, too, and a delegation from South Korea is exploring collaborative possibilities in this area. Singapore has also shown interest in what we are doing," Lau says.

This collaborative project between DST and the University of Melbourne is made possible by ongoing assistance from, and engagement with, data custodians and public health staff. The active participation of three government branches – Health Protection Branch, Victorian Department of Health and Human Services; Health Protection NSW; and the Communicable Diseases Branch, Queensland Department of Health – has been an essential part of this.

MEDICAL COUNTERMEASURES

The inclusion of medical countermeasures in the 2016 Defence White Paper was official acknowledgement that these were a critical defence requirement; and funding from the NGTF will help develop this national capability. By **Gregor Ferguson.**

The 2016 Defence White Paper was significant for a number of reasons but for Dr Felicia Pradera, Program Manager Medical Countermeasures within DST's Land Division at Fishermans Bend, it was ground-breaking. For the first time its inclusion reflected both an official acknowledgement that medical countermeasures were a critical defence requirement, and funding from the Next Generation Technology Fund (NGTF) would be allocated to develop this national capability.

Medical countermeasures (MCM) are vaccines, therapeutics and diagnostics against chemical, biological and radiological (CBR) threats, emerging infectious diseases and pandemics. It has been said that a CBR threat does not care whether you are wearing a military uniform or not. Therefore, MCM are relevant to both civilian and military personnel, making it a national security issue.

This is the day-to-day focus of Dr Pradera who works for both DST and, on secondment, at the Defence Materials Technology Centre (DMTC) where she is the MCM Program Leader. DMTC plays an important role in the Defence Innovation System. In relation to MCM alone, it is facilitating a body of R&D activity in collaboration with some 17 industry and research partners that is designed to deliver enhanced capability for the Australian Defence Force (ADF). DST is a key partner of the DMTC program.

The Australian Government has an obligation to protect its military and civilian population here and abroad from natural and man-made threats. The DMTC program is an important step in reducing Australia's historic reliance on imported MCM products. This is significant in the face of two scenarios – firstly, a global event which may result in closed international borders or, secondly, a specific threat in our region for which there may not be an available international solution.

DST is part of the Australian delegation to the quadrilateral MCM Consortium that includes the UK, US and Canada. The aim is to burden-share MCM R&D across the four countries to work in areas that highlight each region's strength and which meets the global requirement. For Australia, our first step was to understand our capability and capacity to support MCM development through National Capability Audits (NCA). The first NCA in 2012 identified the nation's strengths and gaps and a second NCA in 2017 highlighted the changes in the ecosystem since 2012. Dr Pradera was a co-author of both of the audits and now leads the DMTC work to reduce the gaps and improve national MCM capability.

DMTC's MCM program is designed to position Australia to become a regional leader and centre of expertise, harnessing skills and resources from civil and military domains to develop an effective domestic MCM capability. Dr Pradera reinforced to *DST OUTLOOK* that the focus of the government has shifted significantly from a responsive strategy to CBR threats, to one of developing a national preparedness strategy.

Australia has world-class bio-medical researchers and manufacturers in this specialist domain, she points out, but

not enough of them. And the linkages between them are not sufficiently robust that they amount to a cohesive national capability to respond in an integrated way to a sudden event. The unique and challenging characteristics of MCMs, with national governments as the sole customer, add to this imperative to nurture and mobilise researchers and manufacturers with the right mix of skills.

The DMTC program aims to tackle this persistent shortage of expertise by injecting funding and strategic guidance into what is currently a fragile but important eco-system. The goal is to be able to harness a disparate team of researchers, development laboratories and manufacturers across the country to develop and deliver a suitable response as quickly as possible, depending on the threat.

Australia benefits from a world-class medical and scientific regulatory environment, so research and manufacturing standards are high. They are policed conscientiously, and they contribute in turn to the international attractiveness of either buying from Australia or doing business here. One priority for the MCM community in Australia is to help more researchers and manufacturers achieve internationally recognised ISO accreditation in research and management systems as well as in three critical areas, the so-called 'GXPs': Good Laboratory Practice, Good Clinical Practice and Good Manufacturing Practice. Without these internationally recognised accreditations, Australian organisations lack the credibility to deliver viable results required for regulatory approval of vaccines, therapeutics or diagnostics.

As Dr Pradera acknowledges, this activity requires effective collaboration across a broad range of government stakeholders including the Department of Defence represented by both DST and Joint Health Command; the Department of Health; the Department of Industry, Innovation and Science; and the Department of Foreign Affairs and Trade. Health security is a key component of national security.

Why work with DMTC? For several reasons, Dr Pradera explains to *DST OUTLOOK*. Firstly, the strengths of its existing collaborative model speak for themselves. While MCM is a step away from DMTC's traditional focus on materials such as steel, titanium, composites and body armour, the DMTC has some critical research strengths that no other organisation in Australia can match in this context. It understands Defence intimately; it understands applied research and commercialisation; CSIRO and DST, who drive the MCM program, are already partners of DMTC, so they are familiar with its organisation and methods; it has the program management, governance and co-investment models that support commercialisation and commercial relationships; it understands industry as well as academia, and therefore commercialisation pathways. Most importantly, says Dr Pradera, it has ISO9001 accreditation which is vital for international credibility in medical R&D. This cannot be over-emphasised and is part of the reason why the research program is attractive to national and international organisations with expertise in MCM.

DMTC's R&D program attracted $5 million initially from CSIRO and then a further $5 million from DST under the NGTF. Industrial and research partners have also co-invested in the program such that there is at least three dollars of sector activity for every dollar of government investment. Currently, seven R&D projects have been launched during the first two funding rounds, each of them undertaken by an industry-led consortium whose aim is to develop relevant MCM product outcomes. A recent solicitation for a third round is expected to add another three or four projects to the program. For the MCM community, successful R&D projects will start to close the gaps identified in the audits of Australia's MCM capability.

As the program grows, the DMTC will also undertake smaller scoping projects designed to de-risk technology proposals before they grow into large R&D projects. In addition, it will work alongside other organisations to deliver fellowships designed to help researchers develop the requisite product development skills, with a more commercial outlook and mindset.

An example of the success of the program is highlighted through the DMTC collaboration led by Planet Innovation which is developing mobile, high precision diagnostic test to enable medical professionals to rapidly identify and treat life-threatening diseases. The project addresses the specific need to diagnose military and civilian personnel infected with security-sensitive biological agents. This project recently won a National Innovation Award for Combat Equipment and Mobility at Land Forces 2018.

DST in partnership with CSIRO and DMTC are advancing MCM technologies and workforce capabilities in line with the national preparedness strategy. The current program is exercising the muscles of collaboration which is essential for Australia's MCM capability, says Dr Pradera. Whereas Australia once had what could have been described as A-class components but D-class wiring, this integrated approach is allowing the collaborative mechanisms to work effectively and efficiently so that in the event of a CBR threat the right team can be triggered to deliver a quick and effective MCM response that protects Australian lives.

More information:
https://dmtc.com.au/our-activities/medical-countermeasures/
https://www.dst.defence.gov.au/publication/medical-countermeasures-initiative-national-capability-audit-2017-summary

NETWORKING REVOLUTION

In a new initiative to boost its collaboration with universities, DST is expanding its use of research networks to address future-looking Defence problems. By **Julian Kerr.**

Utilising the Human Performance Research network or HPRnet, introduced by DST and Army in 2017, researchers in DST's Land Division and seven Australian universities are focusing their efforts on improving soldiers' performance, both physically and cognitively.

A second such network – the Operations Research Network or ORnet – is set for launch in December 2018 to facilitate a strategic research investment (SRI) program on Modelling Complex Warfighting (MCW) launched in 2017 by the Joint and Operations Analysis Division; in essence supporting the design of the Australian Defence Force of the future.

Such strategic research initiatives focus on high-impact priority areas for future Defence capabilities.

The genesis of HPRnet was the recognition by Army of the warfighter's performance being central to its capability, says Dr Nick Beagley, Research Leader – Land Human

Systems. "Army's requirements far outstripped our ability to undertake all the research into human performance that they required, so they allocated funding of $4 million over four years for us to expand our program by partnering with universities.

"It wasn't to be in isolation to the research we were doing in DST but a supplement to address those priorities we didn't have the resources or the specific expertise to address."

A call for expressions of interest from Australian universities for studies based on research questions agreed upon by DST and Army resulted in 67 study proposals. These were then down-selected to seven funded studies, chosen for innovation, feasibility and impact, to be delivered by the University of Western Australia, the University of New South Wales, the University of South Australia and the University of Canberra, Victoria University, Deakin University and Curtin University.

"Rather than go out for a series of projects to be delivered in parallel by these universities we decided to set them up as a network, but not one where everyone has to talk to everyone else all of the time," explains Beagley. "We saw benefit in connecting a multidisciplinary community and exploring their willingness to work collaboratively with DST and with each other. The seven that were selected were asked to identify an academic chair for their studies who is their point of contact for the HPRnet."

Each of the academic chairs and their research teams meet the other study groups in an annual symposium, and a part-time co-ordinator tracks the progress of the studies and looks for opportunities to bring teams together for research benefits and efficiencies – for example, two universities combining to gather human performance data at the time with the same group of soldiers.

"It's very much a virtual construct with the seven universities, the DST scientists and the closely involved Army partners distributed widely across Australia. We use software which allows partners to access shared information but there's no access to Defence intranets," says Beagley.

HPRNET: AN INVESTMENT IN PERFORMANCE

The studies are focused on opportunities to physically and cognitively prepare and augment personnel to achieve an enhanced level of operational performance and resilience, and are described by Beagley as more on the research horizon than trying to deliver a near-term implementable product for Army.

"We were really looking to stimulate studies on which universities would like to put a PhD student. We decided the best approach would be to offer each of the seven partners funding of around $450,000 over those four years; that was also the seed for a larger activity where they could bring on post-Docs and undergraduate students as a co-contribution.

"This isn't us giving them money and coming back in four years with a product – this is demonstrating a long-term commitment to human performance research and co-investing in that area.

"Another important aspect of the

"This isn't us giving them money and coming back in four years with a product – this is demonstrating a long-term commitment to human performance research and co-investing in that area."

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approach is establishing partnerships in depth, so to each of the studies we have assigned a DST researcher; these are not governance positions to track contract progress, these are researchers who are providing a scientific contribution to the study and also improving their own research capability by partnering with excellent research teams around Australia."

Notwithstanding the longer-term nature of the research being undertaken – or possibly because of it – Beagley is optimistic that new HPRnet backing will be secured, possibly from the Next Generation Technologies Fund, well before Army's funding ends in 2020. "We're only scratching the surface and there are enduring questions around physical and team resilience and performance," he comments.

"If we're going to keep Army's Human Performance Centres operating at the edge of research using the latest understanding of what we mean by performance and resilience and how you enhance that, then access to the community we're building here of research across a wide range of disciplines is vital to them maintaining that cognitive and physical edge.

"That's really why Army is investing their own money in this; on the future battlefield they see that technological overmatch can't be guaranteed and that it could come down to the quality of its people and decision-making in difficult situations."

ORnet

While final details are still being formulated, the ORnet represents a different approach, utilising a hub and spoke research model with integrated project teams from different universities being built several research nodes or themes.

"The nodes could initially align with the current seven project areas involved in the Modelling Complex Warfighting SRI (MCW SRI) – machine discovered behaviour; simulation for future operating concept development; data-driven defence operational analysis; modelling complex human systems under uncertainty; force effectiveness modelling; concepts for complexity-enabled warfare; and transdisciplinary approaches to modelling unknowns,"

explains Dr Tim McKay, Research Leader - Land Capability Analysis.

"Defence faces difficult decisions on the best way to make choices on both future force structures and current employment where the consequences of these actions will be realised in future scenarios that the decision-makers cannot fully control nor know at the time of the decision."

Hence, the SRI "expressly seeks to revolutionise how DST undertakes operations analysis so as to better handle the interaction of complex geopolitical, social, technological, economic and cultural factors for employment of the current force and design of the future force. Such decisions are often made under conditions of high uncertainty, and without assumptions on predictability or stability of the system".

"Historically, Operations Research has tended to focus on mathematical methods and be rather quantitative – we said that's not going to be sufficient to deal with future Defence challenges and what is required is a new generation of techniques that bring together a range of social sciences and other disciplines that don't normally play in this space, and we want them to be part of a collaborative network," comments McKay.

"For whatever reason, our approach has excited people and they've said Tim, if you didn't have that aim to 'revolutionise', it would just be DST doing incremental improvements. Last September we received 70 expressions of interest from Australian academics which we whittled down to 40 and then decided we wouldn't accept any in totality, but combine elements of several in collaborative projects."

The first 12 months of academic engagement across the seven areas of the MCW SRI were funded by DST on the basis of credibility in the selected areas; a particular commitment to innovative and novel research addressing the theme; a co-contribution of >30% made up of academic resources; and a readiness for multilateral collaboration.

With the intent that the approved one-year collaborative research agreements on MCW will be replaced with contracts of up to three years, a firm base has been created for the creation of ORnet.

"The first 12 months from launch in December will basically be piggybacking on what is already in existence for MCW, but my view is that over time, ORnet will outgrow MCW and its current seven-year time span," says McKay.

"What we want to do is transition from the existing seven project areas into some enduring problem sets and build the project teams around them on the basis of bringing together academics to work on transdisciplinary difficult problems that could not have been tackled otherwise by any of them working in isolation.

"What we're trying to do is establish a network where the universities are all on the same research agreement and they have to work collaboratively around a problem. New problems will come in and out of the nodes rather than expressions of interest going out for independent proposals from separate universities."

ORNET MEMBERSHIP

Although ORnet governance is still a work in progress, McKay suggests that some of the 15 universities, that is almost half the number of Australian universities, currently partnering with MCW are likely to partner with ORnet, and it is equally likely that more universities will join. DST is yet to finalise the ORnet business model. Both MCW and ORnet conduct unclassified research.

One option would be multi-level

>> Continued on page 113

Meeting global challenges through translational research

At Murdoch University, our approach to research is simple; meeting global challenges through translational research.

Located 15 minutes south of Perth, in Western Australia, and with campuses in Dubai and Singapore, Murdoch has been a research-led University since its inception in 1973.

Our focus on research has been a catalyst for collaboration with governments, the defence sector and private industry, in Australia and overseas.

Discovering solutions to global challenges has been the driving force behind the University's support for our globally-recognised scientists and their world-class research.

Today, Murdoch leads the way across a wide range of research fields which have the potential to establish industry-setting standards in the international defence sector.

As the global population increases, so too does the complexity of challenges facing countries around the world, as they look at ways of improving defence capability.

An international research collaborator, Murdoch University is helping our partners face and meet these challenges.

EXPLOSIVES

- Researchers at Murdoch are developing formulations of new, intrinsically-safe, nitrogen oxide-free explosives
- Current research partners include industrial and mining explosives manufacturer, Dyno Nobel Asia Pacific

The Fire Safety and Combustion Kinetics Laboratory at Murdoch University has been collaborating with Dyno Nobel Asia Pacific for more than a decade on ammonium-nitrate emulsion explosives.

Their investigations gain insights into the performance of mining explosives and develop new explosives formulations. The most recent studies focus on developing explosives that do not contribute to atmospheric pollution, for example, oxides of nitrogen, generally termed as NOx, during detonation.

Professor Bogdan Dlugogorski, Dean of Engineering and Information Technology, explained: "Murdoch researchers conduct experiments and molecular simulations to tackle practical problems, especially those relating to mitigation of toxic pollutants that form in explosions.

"These include the application of sustainable ingredients, development of new sensitising mechanisms, and novel synthesis of explosives that eliminate noxious burning.

"This work has led to the development of innovative materials with excellent performance, with applications to explosive blasting and aviation propellants.

"Murdoch and Dyno Nobel Asia Pacific have developed fully instrumented, experimental facilities to study explosives."

Murdoch and Dyno Nobel Asia Pacific have worked together to develop these facilities to study explosives that can support the scientific interest of high energy materials in the Australian defence sector.

The team at Murdoch develops methodologies for sampling post-detonation soil and atmosphere to help minimise the environmental impacts of military activities.

HUMAN PERFORMANCE

- MindBody Lab is located adjacent to the Human Performance Lab at Murdoch's Perth Campus in Western Australia
- The facility enables physiological, biomechanical, cognitive and psychological factors to be integrated, assessed and trained to advance human performance

Our research to enhance training efficiency and optimise performance can readily be applied to defence applications. Work within the Lab includes:

- Perceptual-cognitive (decision making) expertise and skill learning work aims to optimise learning and enable rapid transfer of skills to the field. We work with a variety of services and organisations, including Australian police and elite sports organisations such as Tampa Bay Rays, Western Australian Cricket Association and Hockey Australia, We help them to adopt multiple strategies to achieve these stated aims.
- Research to identify the biomarkers of fatigue and pain, using a variety of physiological and psychophysiological protocols. Our research team mapped eight unique chemicals in the blood which herald the onset of fatigue during sustained and strenuous physical activity.
- We aim to understand and enhance the neurological networks within the brain, using non-invasive,

neurostimulation techniques. We are particularly focused and interested in how modulation of the brain's neural system can enhance performance across a diverse population.
- We have expertise in tracking physical activity and field-based capacity using a variety of accelerometers, GPS sensors, body-temperature sensors and heart rate monitors.
- Our labs simulate various environmental conditions, including temperature and elevation, allowing us to tailor training regimens to extremes. Our research team is internationally-renowned for training and performance-deficits associated with low-level oxygen conditions (hypoxia).

Timothy Fairchild, Associate Professor in Exercise Science said: "Murdoch has a unique perceptual and exercise laboratory facility, MindBody Lab.

"The facility was built adjacent to our existing human performance testing and training facility - spanning nearly 500 square metres - and is designed to explore and advance human performance.

"We collaborate with a wide range of partners in elite sports and industry, including air traffic control, forensics and the police, to understand how stress and performance can be adapted to optimise critical decision making.

"Our research has direct application to the defence services, in supporting personnel and the specific requirements of their role."

BIOSECURITY AND MILITARY

- Researchers work with military on biosecurity strategies for land, sea and air deployments of personnel and equipment
- We work to establish new standards for military equipment to reduce risk from infection and transfer of invasive species
- We develop decontamination options that are effective, environmentally friendly and meet health and safety requirements
- New systems will ensure military remains in a state of operational readiness for rapid deployment

Biosecurity and decontamination strategies are critical issues for operating military, especially overseas.

The military must maintain a balance of operational readiness for rapid deployment and advance compliance with biosecurity regulations, particularly for exercises, peace-keeping and aid-related missions.

To achieve this, comprehensive biosecurity and decontamination strategies must be established and operationalised for personnel and equipment in all aspects of force requirements.

Professor Simon McKirdy, Director of the Harry Butler Institute, has expertise in biosecurity strategies.

"The military operate in some of the world's most extreme environments," said Professor McKirdy.

"Time is one of the greatest challenges facing armed forces, particularly in live operations. Therefore, strategy and planning are critical to maintaining operational readiness.

"Our research teams are working on developing protocols to mitigate risk from infection and transfer of invasive species, including environmentally sensitive decontamination procedures and the future design of equipment for faster cleaning and disinfestation.

"We are looking at systems to effectively manage everything from the overseas transfer of boots and uniforms, to the use of toxic chemicals during the cleaning process.

"Biosecurity researchers at Murdoch have worked with military agencies to build biosecurity and decontamination strategies into their forward plans in Australia and the USA.

"These collaborative research activities are being undertaken with partners at Kansas State University and the Smithsonian Environmental Research Centre."

ABOUT MURDOCH UNIVERSITY

With campuses in Perth, Dubai and Singapore, Murdoch University is a globally-recognised institute of learning and research.

We have more than 23,000 students and 1,700 staff from across 90 different countries.

Murdoch is proud to be recognised for the impact that our free-thinking graduates, life-changing research and innovative campus and industry developments have made – both in Western Australia and around the world.

We believe in engaging with global challenges and in the translation of new knowledge into practice. Murdoch finds inspiration through collaboration. Our research is focused on Health Futures, Food Security and Sustainable Development. We are proud to be a research-led University, committed to meeting global challenges through innovation and inspired thinking.

For more information on Murdoch University's real-world research, or if you're interested in collaborating with us, please contact:

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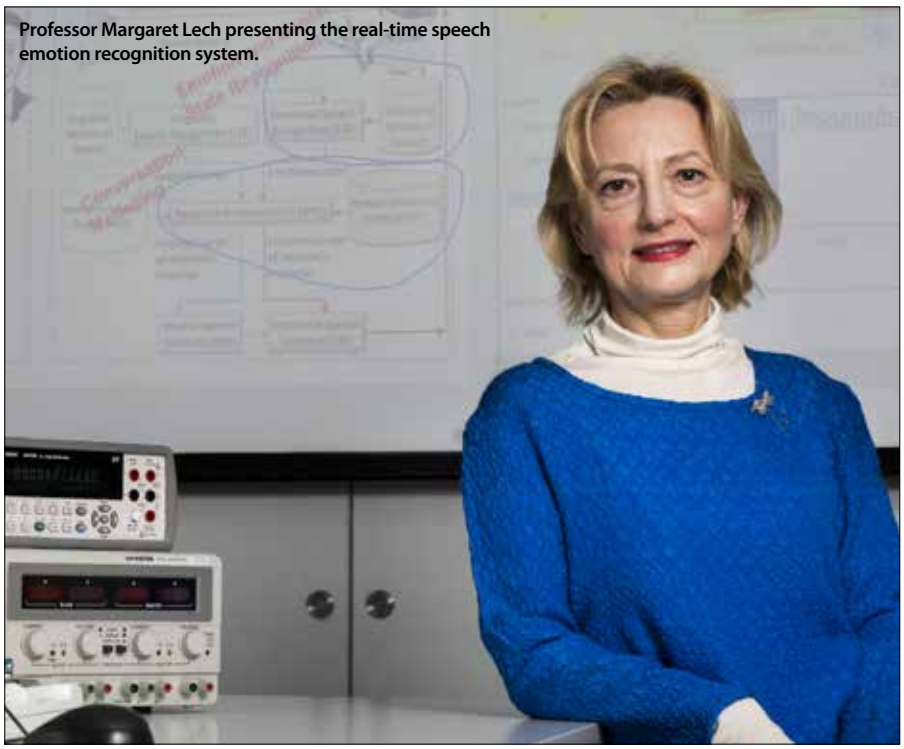
RMIT UNIVERSITY

Machines That Speak Our Language



Professor Margaret Lech presenting the real-time speech emotion recognition system.

If you are familiar with the frustration caused by the robotic limitations of virtual assistants, you can breathe a sigh of relief.

Researchers have developed technology that can detect emotion in human speech. It promises to boost the power of voice-activated technology, which is playing an ever-increasing role in our everyday lives. We use it in our cars to navigate, on our phones to do the banking and in our homes as voice assistants. Yet current voice devices can only go so far. The inability of technology to decipher human emotions renders it stunted and less intuitive than if it were able to read human expression.

A team of researchers from RMIT University's School of Engineering led by Associate Professor Margaret Lech has discovered how to add emotional capabilities to machines to make communication more natural and more socially acceptable.

"There's always an emotional context when we talk to people and we understand it, but machines don't understand this," says Lech. "When we call an automatic call centre, for example, people get very frustrated because they talk to the machine and it does not understand that they are sad, they are anxious, that they want things to be done quickly.

"They don't understand the emotion associated with the task and we can hear from many recordings people saying, 'I want to talk to a person, not a machine'.

"There is no way to explain certain things to a machine, including those subtle cues that we can express through emotions when we talk to each other."

Lech and her team have spent 11 years creating new machine learning techniques that allow technology to understand human emotions from speech signals, and to analyse and predict patterns of emotional interactions in human conversations.

Equipped with these capabilities, voice-activated devices can understand both the linguistic and emotional contents of speech, and provide appropriate responses. They can read seven human emotions: anger, boredom, disgust, fear, happiness, sadness and neutral.

The challenge of making machines read human emotions lay in measuring the unspoken commands in voices such as subtle changes in tone, volume and speed.

Enhanced by the power of emotion recognition, voice-activated technology has many more applications and wider benefits, Lech says. "People will accept machines more, they will trust machines, they will have the feeling that the machine really understands them and can help them better.

"People, especially the elderly, will not be so reluctant to use automatic call centres. Then we can employ machines, for example, robots as companions. An older person may like actually talking to a machine and hear that the machine can laugh with her, can sympathise, and understand her feelings.

"It could also be good if used for kids' toys. Children will interact with robotic toys that can talk emotionally, so children will learn more about emotions."

Lifelike artificial intelligence may have once been a futuristic dream. But with developments like this making human-machine interactions simpler and smoother, the future has seemingly arrived.

partnership model where lower-tier ORnet membership is essentially a community of interest, with a list maintained of people or networks whose skills could be drawn on as required, and whose attendance would be welcome at ORnet symposia.

A second tier could comprise academics and universities involved in ORnet-linked projects, while a third level could consist of strategic or foundational partners focused on long-term research, and making substantial contributions.

"I'd imagine our strategic partners would contribute to the governance board of ORnet and play a role in shaping the direction of fundamental research," notes McKay.

"Once you're on the ORnet everyone is equal; being a strategic partner may just help you get on the team."

As of late 2017 some 40 academics from 15 universities were involved in multi-disciplinary MCW work across all seven program areas.

"I suspect there's a group of people on the periphery of MCW who will want to be involved in ORnet, then once we advertise ORnet there will be a broader group of people unconnected with MCW who will want to join it as well," comments McKay. "When that's completed we want to be able to say not only did we develop new tools and techniques, we also created this ORnet which is enhancing the national capability of our operations research."

"That's really why Army is investing their own money in this; on the future battlefield they see that technological overmatch can't be guaranteed and that it could come down to the quality of its people and decision-making in difficult situations."

ORNET OBJECTIVES

While development and self-sustainment of the ORnet is an objective of the MCW program, the primary objective for DST and its research partners is to create an Australian capability in OR to deliver methods and tools to improve force design.

"That's challenging because we're not talking about producing an autonomous vehicle, we're talking about something which is a bit more general and abstract in terms of analysis and decision support, it's about enabling better decisions around the capabilities that the Defence Force will acquire in the future," explains McKay. "We're contending that new techniques in the Operations Research area will enable better decision-making. The current challenge is we're so focused on solving short-term defence issues that we're not looking at how we could do that more efficiently the next time.

"This Strategic Research Investment is about prepositioning DST and Defence so that in five years' time when we're undertaking the annual force design process, we'll have improved the manner in which complex problems are handled, thereby improving outcomes for Defence."

Biomechanical Laboratory on the Front Line of Human Movement

The capacity to measure, and potentially eliminate, load-bearing forces that cause or exacerbate injury when under heightened mental and physical strain – such as those incurred during military combat – has become possible with the installation at the University of Melbourne of one of the world's most advanced human movement biomechanics laboratories.

Called CAREN – Computer Assisted Rehabilitation Environment – the laboratory is a multi-sensor and multi-sensory simulator that can replicate loads on a person during a range of human movement activities.

To look at, CAREN is a large dual belt treadmill partially surrounded by a large screen that provides a virtual reality overlay. The treadmill spans a deep pit, allowing it to be tilted, jolted, even dropped, in concert with the virtual reality scenario being applied.

Professor Peter Lee, Deputy Head of Research at the Department of Biomedical Engineering, says CAREN can replicate, and fully measure in a laboratory setting, real life movement within a near limitless range of applied scenarios, including physical, cognitive, visual, auditory and vestibular perturbations.

Its unique capability is that it brings together biomechanics and neuroscience to create an unprecedented tool for analysing human movement.

As well as measuring the effects

of load on the human body, virtual reality scenarios can apply sensory stresses – visual and aural – and the compounding effects that these have on complex human movement such as recovery from falls or carrying heavy loads.

"In other words, we can observe and measure the different activities that influence the body's movement under load," says Lee.

A simple analogy showing the importance of visual and aural (i.e. sensory stresses) is the difference in risk between purposefully jumping onto the ground or unexpectedly falling/ landing from the same height – the latter being riskier due to the lack of both neural and muscle control.

Lee says CAREN gives researchers the chance now to measure in real time all of the sensory inputs and outputs preceding both intended and unexpected movement, and the physical consequences.

This becomes even more significant when you place additional physical and cognitive stress on soldiers. This is where researchers at the university see particular value for defence forces and defence equipment manufacturers.

"We can see the effects of equipment on the soldier's physical performance and then take this a step further using virtual reality to add in heightened brain activity – shock, fear, noise," says Lee.

"We can analyse both the cognitive and physical impacts of the equipment design on soldiers and where improvements can be made and injuries avoided."

Dr David Ackland, Deputy Head of the Department of Biomedical Engineering, says the initial research has two particular objectives – injury prevention and enhanced human performance: "We are introducing an immersive virtual reality-based environment for simulating and assessing the influence of physical and cognitive loading, while simultaneously measuring a range of bio-signals from electromyography (EMG), electroencephalography (EEG) and functional near-infrared spectroscopy (FNIR).

"We can see the effects of equipment on the soldier's physical performance and then take this a step further using virtual reality to add in heightened brain activity – shock, fear, noise."

These have obvious benefits for military personnel, but also for sportspeople. And as the name suggests, CAREN takes rehabilitation and clinical analysis of rehabilitation to a new level.

It has been described as providing a safe, controlled environment where patients interact with a virtual world to work on balance and gait, develop stress coping skills, and in the case of limb loss, learning to use prosthetics.

Infrared cameras placed at every angle capture the patient's movements and gait and corrections are suggested in real time. Technicians see a 3D representation of the patient's musculature on-screen as they move, and use visuals and data to pinpoint problems and identify degenerative conditions.

The American Society of Engineers has reported the potential use of CAREN for the development of adaptive driving simulators (for the control of steering, acceleration and braking) for people who have suffered spinal injuries. CAREN would allow people with such impairment to learn to drive adapted vehicles without the dangers of being on the road.

Ackland says researchers in Canada are already looking at using CAREN technology to help people recover from head injuries by, in effect, 're-calibrating' brain signals with body movement.

Psychologists in The Netherlands are reporting promising results using CAREN to help service personnel with combat-related PTSD. Current therapies often include exposing sufferers to some degree of re-imagining the traumatic event, which often leads people to abandon treatment. The psychologists have found the CAREN treadmill, allowing a person to walk into a virtual reality event related to their trauma, provides a sense of physical control and release, compared to seated therapy sessions.

Ackland says that for the university, this capacity to combine biomechanical and neurosciences presents the most exciting opportunities for cognitive and neuromuscular research, and subsequent applications in real world activities – particularly those that often entail extreme physical and mental fatigue. "What we bring to the table is an integrated measurement of motion and loading under different conditions. With our computational modelling of the human body we are able to glean a lot more information than ever before about human responses to physical and cognitive loads."

CAREN was developed in The Netherlands by Motekforce Link and its installation at the University of Melbourne is a first in Australia.

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ARTIFICIAL INTELLIGENCE
AUTONOMOUS ROBOTICS
INTELLIGENT AGENTS
MACHINE LEARNING

Autonomous vehicle development for RAAF.

AOS specialises in operational autonomous robotics and software, covering the full spectrum, from "intelligent assistants" supporting experts in solving mission-critical problems, to autonomous systems performing tasks delegated by humans.

Established in 1997, AOS is responsible for many of the advances in intelligent, or intentional, agents – leading to the science of Beliefs, Desires and Intentions, or BDI agents.

AOS's approach combines BDI agents with machine learning, thus enabling a new generation of intelligent robotics. The BDI paradigm, with its goal-based, context dependent knowledge representation, addresses key objectives of the current goal of producing Explainable AI, and Trusted Autonomous Systems.

– Dr Andrew Lucas. Andrew.lucas@aosgrp.com

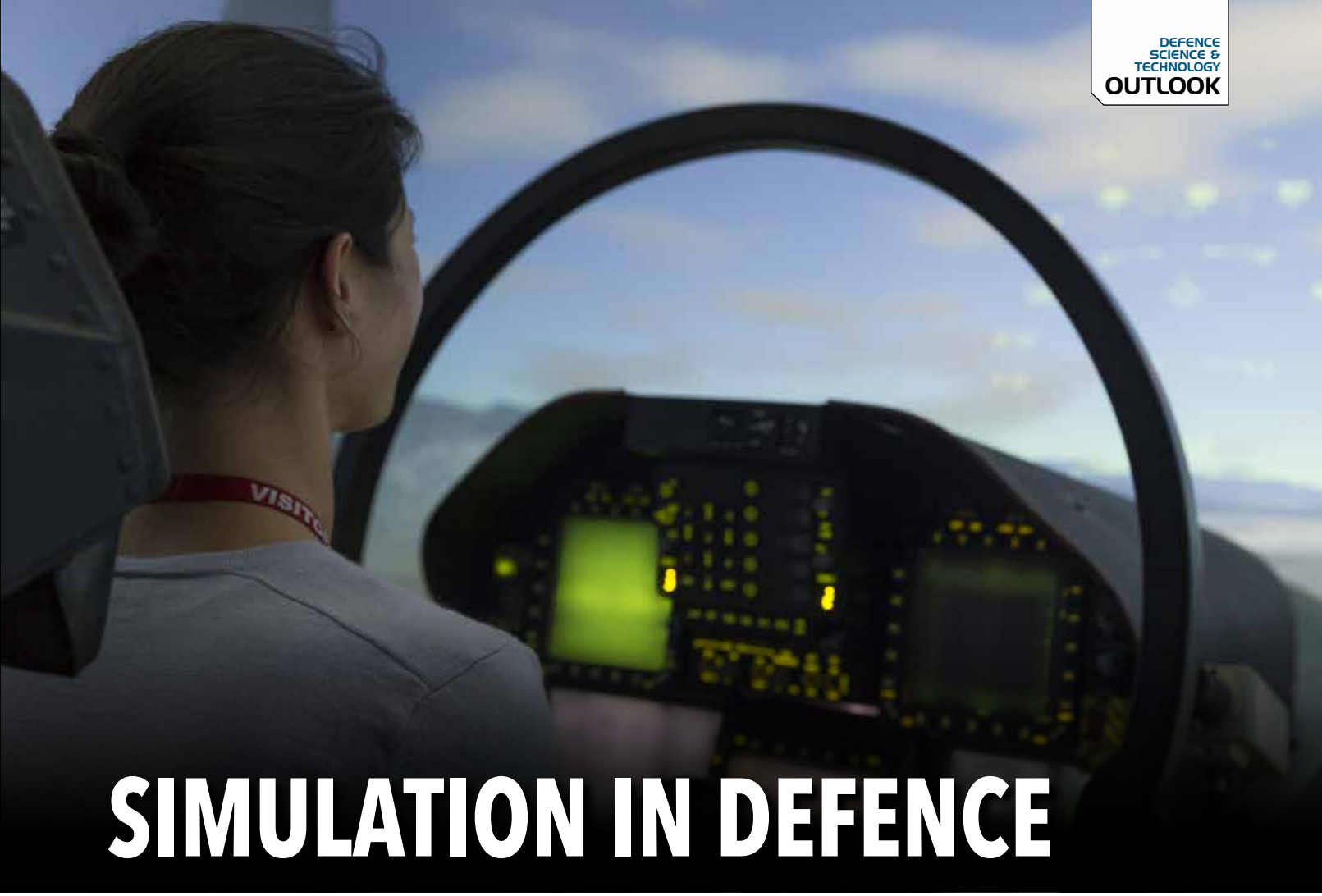
"Today's machine learning systems are more advanced than ever... however, a critical component of Artificial Intelligence (AI) remains just out of reach – machine common sense...

> **"The absence of common sense prevents an intelligent system from understanding its world, communicating naturally with people, behaving reasonably in unforeseen situations, and learning from new experiences," said Dave Gunning of DARPA.**
> **"This absence is perhaps the most significant barrier between the narrowly focused AI applications we have today and the more general AI applications we would like to create in the future."**

To focus this new effort, DARPA's Machine Common Sense program will pursue approaches for developing and evaluating different machine common sense services... This includes the domains of objects (intuitive physics), places (spatial navigation), and agents (intentional actors)."

– DARPA, Defense Advanced Research Projects Agency; www.darpa.mil.

www.aosgrp.com.au



SIMULATION IN DEFENCE

The use of simulation in Defence has evolved significantly in the past two decades to be where it is now: a vital part of the Defence capability life cycle and key component of Defence training and exercises. By **Nigel Pittaway.**

The wider Defence Organisation has long viewed simulation through the prism of support training –a synthetic environment in which forces and platforms move. For the Defence Science and Technology (DST) Group, however, "simulation is far broader and can include everything from working step by step through a complex feedback model on a whiteboard, to task-specific simulations, through to bespoke simulation engines".

DST AND SIMULATION

For DST, simulation is an integral part of the scientific arsenal, routinely used to understand and explore the behaviour and properties of equipment, forces and the physical and information environments.

DST researcher, Dr Richard Fleming, commented that "DST simulation for a wide range of applications, everything from how a ship moves through the water to the propagation of radio or radar energy, to what happens to a vehicle when it is moving off-road under different weather conditions – because, for example, the behaviour of soil when it gets wet is different to that when it is drying off, even at the same levels of wetness – and so you have to model things like that."

Dr Fleming is currently Director Science Strategy and Engagement – Joint, engaging with DST's joint domain stakeholders and the parts of DST supporting their science and technology needs in order to ensure DST's Joint domain work aligns with both the stakeholders strategic needs and DST's resourcing, sustainment demands and scientific standards. He also represents DST on the Defence Simulation Product Working Group (DSPWG) and is Project Science and Technology Advisor for the Defence Core Simulation Services Capability project (JP9711).

DEFENCE SIMULATION STRATEGY AND POLICY

At the working level, the governance and strategies for use of simulation in Defence is developed by the DSPWG which is hosted and led by the Australian

Defence Simulation and Training Centre (ADSTC - part of Defence's Joint Operations Command). As well as providing a scientific perspective, Dr Fleming sees a key aspect of DST's representation on the working group as "ensuring that Defence Simulation strategy and governance is cognisant of, and does not obstruct, the myriad ways in which DST uses simulation to understand and explore the behaviour and properties of equipment, forces and the physical and information environments".

According to Dr Fleming "broader Defence is overwhelmingly a consumer of simulation whereas DST's use of simulation ranges from researching simulation approaches, through developing new simulations to applying simulation as a scientific tool." This divergence gives rise to very different needs and expectations for the utilisation and governance of simulation. As a consumer, simulation in Defence is best managed centrally to ensure both efficiency and interoperability. "For DST this would represent an unworkable constraint on a key analytical approach. Central control of such a ubiquitous research tool - used in so many ways by scientists across DST's range of disciplines - would be the enemy of innovation and deny its use for much of our research."

CORE SIMULATION CAPABILITY

Simulation is seen as the core technology through which an integrated Defence training, exercise and (eventually) experimentation capability will be achieved. Defence's Core Simulation Services Capability Project, Joint Project 9711, is tasked with delivering this "persistent (available on demand), integrated and distributed core simulation capability through a system of services and products, collectively referred to as the Defence Synthetic Environment".

The focus of Phase 1 of the project is on the core simulation services to support training outcomes in both single-service and joint domain, rather than procurement of simulators for specific Defence platforms.

Phase 1 is at the post-Gate 2 stage and two industry groupings have

been shortlisted as final contenders for delivery of the capability. The two teams are Lockheed Martin, with NEC and Calytrix; and Northrop Grumman with DXC Technology, Cubic and CAE. The current timeline is for the successful bidder's acquisition contract to be in place early in the new year.

The project is being driven by the ADSTC , and will be capable of supporting exercises across the entire spectrum of ADF operations, from Command Post Exercises to large bilateral and multi-lateral exercises such as the Talisman Sabre series of amphibious warfare serials.
The Chief Information Officer Group (CIOG) is responsible for managing JP9711's delivery.

Dr Fleming explained "It will be a large computing facility which will schedule training for all of the Australian Defence Force (ADF) and integrate the different packages and simulations and other resources that are required for each exercise. When that training is scheduled to occur, the Chief Information Officer Group (CIOG) will stand up servers and infrastructure and provide the bandwidth to support those exercises, potentially at multiple remote sites. At the completion of an event, the servers, infrastructure and bandwidth will be dissolved back into the CIOG pool for reuse in subsequent simulation events"

Dr Fleming says that although the project does not currently address virtual reality (VR) technologies, working groups under the DSPWG are, among other things, looking at VR requirements, strategies and policies for anticipated future Defence needs.

SIMULATING COMPLEX WARFIGHTING

Dr Fleming cited DST's Modelling Complex Warfighting Strategic Research Investment (MCW SRI) as a good example of the application of DST simulation research to Defence challenges, with outcomes of this work potentially being applied in areas as diverse as force design evaluation, capability development, information warfare training and operational planning.

The MCW SRI program is a five-year program which the organisation says is seeking to "revolutionise how DST undertakes operations analysis to better handle the interaction of complex geopolitical, social, technological, economic and cultural factors impacting the capability of the current force and design of the future force".

DST notes that modern Defence operations are intrinsically complex and becoming more so as technology rapidly advances and, as a result, it is becoming increasingly problematic to rely on intuition, experience and common sense for complex decisions in areas such as Force Design.

An area of focus for the MCW SRI is in applying high performance computing (HPC) to data farming simulation for exploring and developing complex whole of force operating concepts.

The data farming involves executing very large numbers of simulation runs of experiments in which the force being modelled will be faced with simulated threats. Data farming techniques are then used to identify the critical factors which dominate the simulation results and allow scientists to focus on the elements which make the most difference. There are, however, significant science and technology challenges to be overcome, including the complexity of future forces – both friendly and enemy – the computational difficulties involved with large-scale simulation, the development of strategies for analysis of high-level concepts and the development of modelling strategies to represent these high-level concepts.

As a result, DST is seeking to engage with partners from academia to solve these complex simulation problems.

Electrical Grid Research is Changing the Landscape of Electrical Platforms on Navy Vessels

As navies worldwide look to counter future threats and increase capability, the overall layout and energy balance of the platforms is a major challenge for the future warship.

Research is playing a critical role in this space by helping realise solutions that are directly beneficial to the challenge of meeting rapidly evolving electrical generation and load share grid concepts.

A major initiative in Germany, the Forschungscampus Flexible Electrical Networks (FEN) Research Campus, which Siemens is a partner of, is leading the research in this space.

Siemens as an FEN partner and, being active in all areas of this evolving technology both within the consumer grid and maritime platforms, is realising that the challenges in both domains are similar and that present research is directly applicable to naval platforms. The company sees the evolving nature of direct current (DC) networks as a solution to the historical challenges of electrical systems on ship.

The joint research at FEN Research Campus with academia and industry under one roof facilitates the efficient exchange of knowledge between the partners to successfully research the challenges of future energy supply. The research interests range from grid planning and operation to automation and control, standards and norms, cloud platforms for smart energy services, components and power electronics. Industrial partners such as Siemens benefit from being able to translate the research into innovative products and services – such as the application of DC technologies into maritime applications. A key focus of the transdisciplinary research is on the development and integration of DC technologies.

Siemens' expertise in both consumer grid and maritime platforms makes the company a key industry partner for this research.

THE CHALLENGES OF ELECTRIFICATION ON NAVAL PLATFORMS

In maritime operations, although electrically driven platform concepts provide advantages in operation profiles, even in view of redundancy and battle damage tolerance, the share within naval surface vessels today is still at a low level.

Several naval applications today do not benefit from the advantages of electrical platform as the 'conventional' electrical propulsion plants are considered to be too bulky and heavy to be integrated within naval platforms.

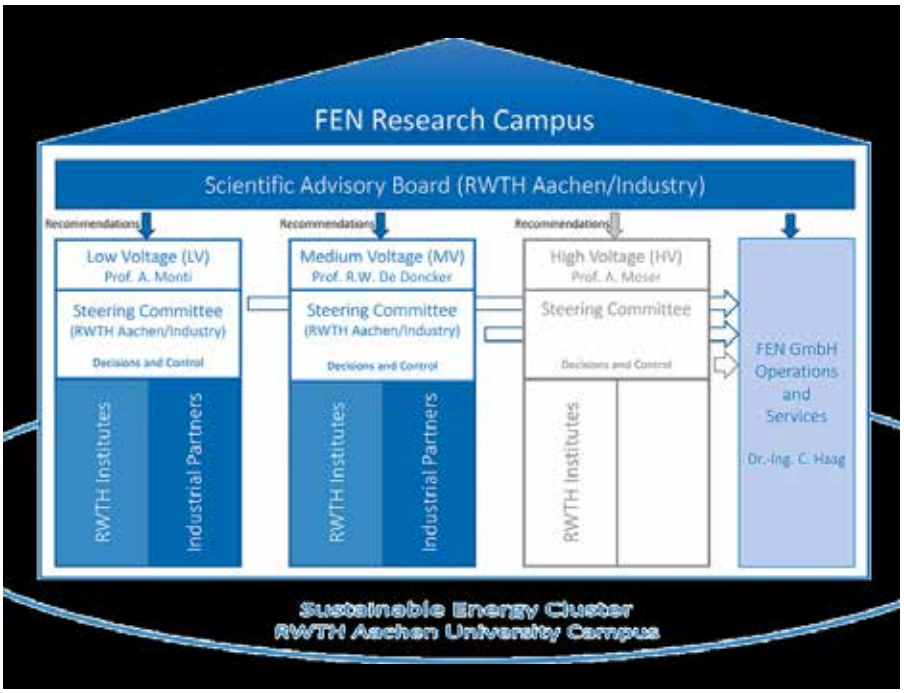
The benefits in volume and weight – which are already considerably related to developments in the electrical machinery components themselves – do not close the gap to today's mechanical-driven vessel concepts, hence completely new philosophies are needed for electrification.

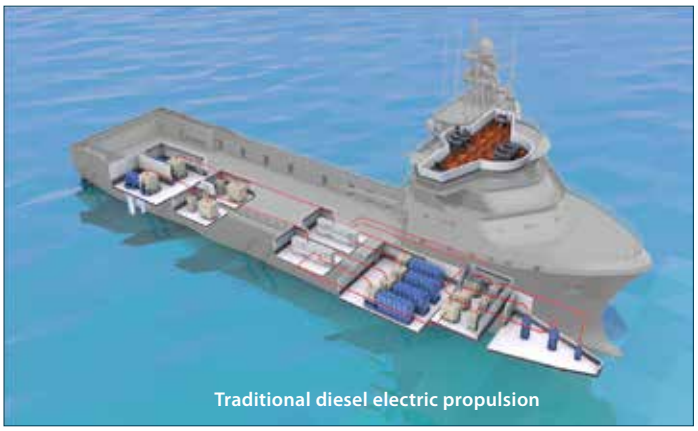
The challenge is even bigger as future platforms need to comply not only with the acceptable weights demanded on a naval platform, but also with the evolving power requirements throughout a vessel's lifetime. Not only will the overall installed power be impacted by new and increasing demand on the ship for electrical power, but the dynamics will be completely different from what we see today.

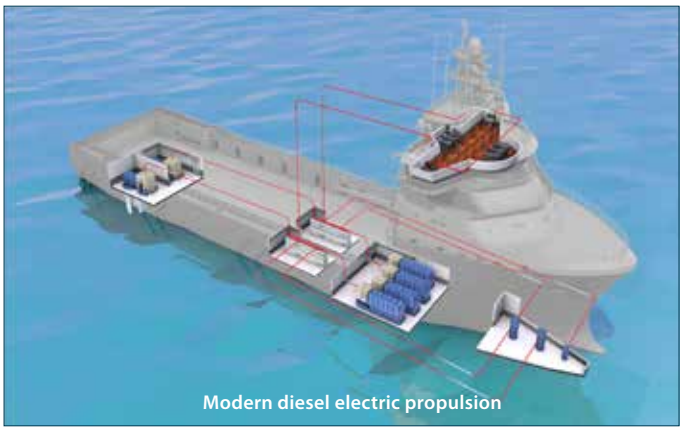
DC ARCHITECTURE IS THE SOLUTION TO MARITIME APPLICATIONS

For power stability in AC-grid systems, both voltage and frequency must be monitored and controlled to ensure stable situations with fast switching on-off of consumers or pulsed loads. Today, this is already very hard to maintain on some of the newer naval vessels.

The DC busbar system is one of the best solutions here – there are no reactive power interactions, ensuring the system control is oriented to the voltage only and




Traditional diesel electric propulsion


Modern diesel electric propulsion

helping keep the power stability to that of an AC grid. It is important to mention here that DC will only be controlled within the main switchboards. The connected units, like generators, loads and/or electrical motors, will be of AC type and the cabling between the main switchboard and these units can stay as it is today with AC technology. The incoming rectifiers AC/DC and the outgoing DC/AC inverters are all integrated with the DC power unit.

With DC, the synchronisation of generators is simpler than the AC grid, where it is necessary to consider the voltage, frequency and phase angle during the synchronisation of more than two generators. During operation these parallel running generators must be controlled to be kept stable. However, in the DC busbar system, as the voltage is the only crucial factor, there is no need to keep the generators at the same speed. This means each generator can be allowed to run at its individual speed as the synchronisation of the generators is not required; also, blackout situations from synchronisation failures are removed.

Compared to the same AC-grid solution, the optimised DC busbar solution reduces the weight and space required within a vessel significantly, mainly due to removal of drive transformers and conventional switchboards/converters. And although the drive transformers are removed, there is no possibility of common mode effects, like those that the AFE AC-grid solutions are faced with, and no filtering is needed. The fundamental principle of a safe and reliable power plant is to segregate the power distribution equipment into self-sustained autonomous groups in the case of failure.

In the AC-grid solution the circuit breakers are used to ensure the separation and safety features within the plant. For the DC busbar, the usage of DC breakers and the alternative usage of fuses are not the best and most user-friendly solutions as, after an incident, these units have to be replaced and the separation is not guaranteed. Therefore a new solution is needed for DC options.

The Siemens solutions consists of an ultra-fast, fuse-less solid-state breaker (ILC) used as a bus tie and/or consumer feeder breaker segregating the power sections in case of a short circuit fault in 7-30µs range. This ultra-fast tripping ensures that the other sections are unaffected by the short circuit fault.

The next generation of navy vessels will have higher electrical power demands with high load changes in ship systems and weaponry. Advanced lithium-ion battery-based solutions, such as the Siemens BlueVault, are suited for both all-electric and hybrid energy storage applications. They are designed to operate on a vessel and to ensure continuity of power, performance and safety to meet these upcoming challenges.

Energy storage solutions are scalable in design and when installed into the DC grid solution:

- Reduce and/or remove the risk of blackouts
- Assist with extended recovery time (hours to seconds) to enable safe restart of diesel engines and safe operation with only one engine online or even running for defined time on batteries only
- Support the handling of pulse loads and peak shaving with fast charging and discharging rates that are customised to the vessel's demands
- To meet the market demands of the commercial maritime sector, Siemens developed the BlueDrive PlusC DC power solution to achieve the implementation of these decentralised energy storage systems.

This solution, combined with suitable-sized energy storage systems, further enhances the operation, safety, maintenance, fuel efficiency and emissions of the vessel. It allows the full freedom to connect power generation without the boundary of 50/60Hz and higher generator frequencies or variating generator frequencies are possible. Variating the generator frequency, depending on the power demand, has the capability of fuel reduction increasing the operating time and/or range of the vessel.

Since 2013, Siemens has been supplying the marine industry with the BlueDrive PlusC Diesel-Electric Propulsion (DEP) system, combined with battery storage systems. More than 60 vessels have now been delivered with DC busbar technology in various marine segments and differing operation profiles.

This achievement aligns well to the future research already underway by DST, Siemens and QUT on High Temperature Superconducting propulsion and generation technology ongoing since 2015.

Managing uncertainty and complexity are key features of future warfare

Queensland University of Technology (QUT) is working in partnership with different divisions of the Australian Government's Defence Science and Technology (DST) on fundamental aspects of future complex warfare.

QUT is contributing key research into:

- Uncertainty quantification in modelling, simulation and analysis of complex systems
- Characterisation of adversarial behaviours of interacting complex networks

This research has the potential to assist DST develop new tools to inform decisions of the Australian Defence Force in asset acquisitions, tactical decisions and future force design.

QUANTIFYING AND COMMUNICATING THE IMPACT OF UNCERTAINTY IN MODELLING, SIMULATIONS AND ANALYSIS OF COMPLEX SYSTEMS

Today, scenario-based computer simulations are a fundamental tool for informing decision making at different levels of a defence organisation. When decisions concern the potential behaviour of complex systems, uncertainty quantification is paramount to provide appropriate levels of information for effective decision making.

Complex systems are characterised by a high number of interacting entities with non-linear behaviours, interactions among entities and with externalities, high levels of uncertainty in what we can know about these systems, and constraints on information flows between different parts of the system. This results in challenging problems when it comes to the characterisation and communication of the uncertainty associated with outcomes that are intended to inform decision making.

Understanding uncertainty and complexity in abstract situations derived from defence context and analysing how they interact is important for defence decision makers when developing and shaping future capability. QUT researchers are working in partnership with DST on methods and tools to model, manage

and communicate the impact of uncertainty in complex systems modelling, simulations and analysis.

QUT has assembled a transdisciplinary research team with expertise in applied mathematics and engineering to work on the fundamentals of modelling dynamical complex systems, uncertainty quantification, and computer simulators and emulators. As part of this research, an unclassified scenario is being used to demonstrate the methodology and tools within a realistic simulation environment. This research could eventually lead to new methods of analysing the impact of uncertainty quantification and its communication of particular decisions.

CHARACTERISATION OF ADVERSARIAL NETWORK BEHAVIOURS IN COMPLEX WARFARE SITUATIONS

The network-centric characteristics of modern warfare scenarios require an understanding of situations in which the complexity arising from the behaviours of interacting networks can be exploited in different ways at different times.

The research being conducted at QUT in collaboration with DST aligns with the challenge of contextualising dynamical models in adversarial situations into the framework of optimisation theory. QUT is assessing the applicability of newly developed theory related to nonlinear-inverse dynamical games and adversarial networks. We are posing the interaction of the networks as a problem in which they seek to optimise different objectives, and we use data from the observed interactions to select the objective that best describes their behaviours.

Our researchers, in collaboration with DST, are also posing problems with increasing levels of difficulty involving restrictions on information access and behaviours related to the adversarial networks.

The research seeks to investigate how the new tools can be developed and applied to tactical warfare scenarios relevant to DST. This work forms part of DST's Strategic Response in Concepts for Complexity-enabled Warfare.

RESEARCH CAPABILITIES

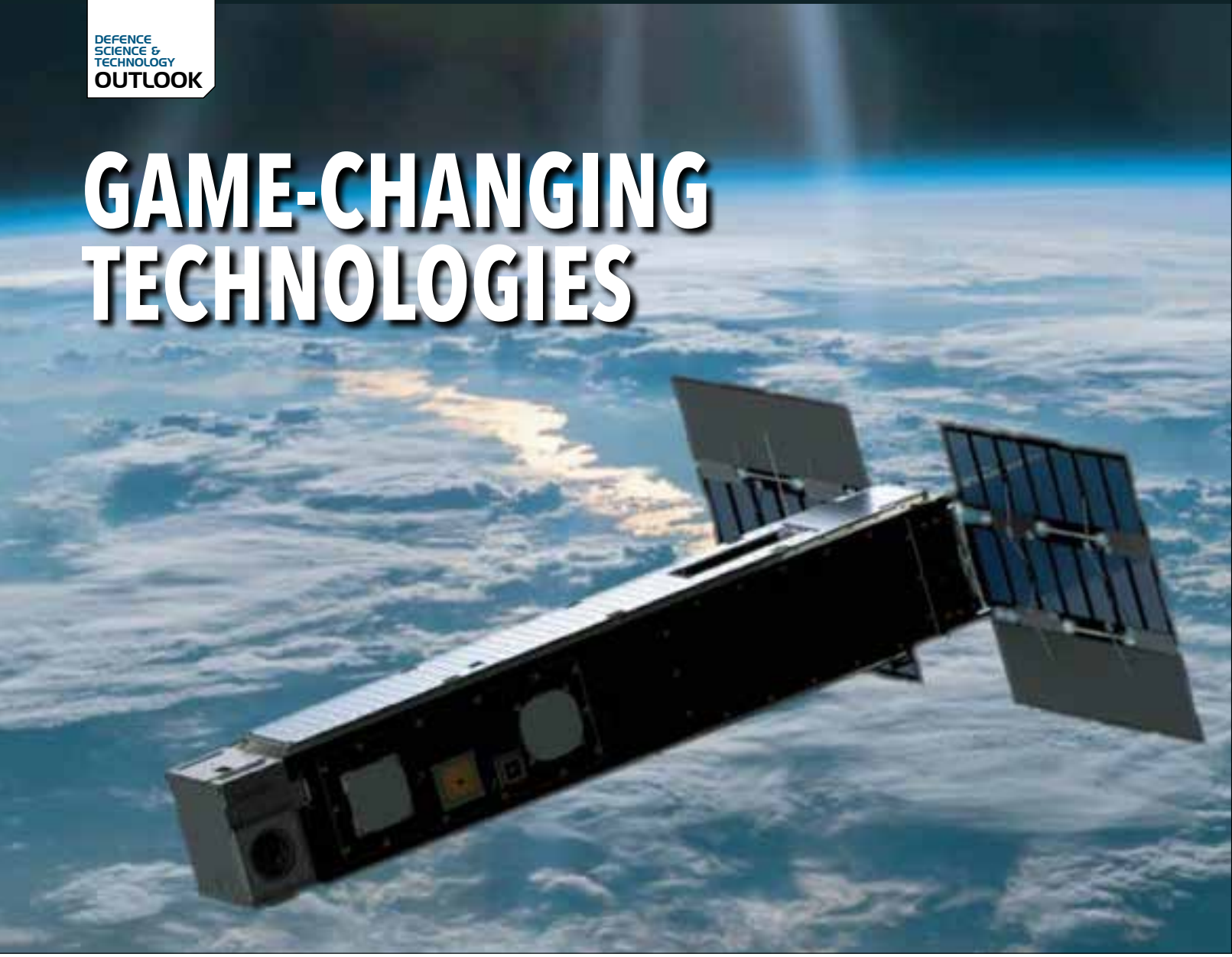
The research team at QUT combines resources from QUT's Institute for Future Environments and from QUT's node of The Australian Research Council (ARC) Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS).

Researchers at QUT's Institute for Future Environments study how our natural, built and virtual environments interact, change and converge, to find ways to make them more sustainable, secure and resilient. Through our partnerships with national and international industry, government and community organisations, our researchers seek to make a lasting impact on the real world.

The Australian Research Council (ARC) Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) brings together a critical mass of Australia's best researchers in applied mathematics, statistics, mathematical physics and machine learning. With partner researchers, ACEMS engages in research programs that combine innovative methods for the analysis of data with theoretical, methodological and computational foundations, provided by advanced mathematical and statistical modelling.

Find out more
For more information, please contact QUT's Institute for Future Environments by emailing ife@qut.edu.au or calling 07 3138 9500.

GAME-CHANGING TECHNOLOGIES



One of DST's roles is to help 'future proof' the ADF by identifying what it calls 'game-changing' technologies that can either give the ADF an operational edge or represent a new and unexpected threat. By **Gregor Ferguson.**

Defence Science and Technology (DST) has been patrolling the leading edges of defence science and technology for more than a century. One of its roles is to help 'future proof' the Australian Defence Force, its biggest stakeholder, by identifying what it calls 'game-changing' technologies that can either give the ADF an operational edge or represent a new and unexpected threat. The trick is to achieve this early – especially if there are lives at stake or a significant 'first mover' advantage from reaching the high ground first.

One of the mechanisms by which DST scans for game-changing technologies is the Next Generation Technologies Fund (NGTF) whose 11 technology investment priorities (see p.xxx) provide a framework for analysis and experimentation. However, this is informed by (and in turn informs) DST's recently instituted program of Emerging Disruptive Technology Assessment Symposia (EDTAS), which deliberately puts difficult questions to an eclectic mix of war fighters, researchers and industry players.

WHAT IS A GAME-CHANGING TECHNOLOGY?

One of the DST researchers charged with imagining and contextualising an uncertain future is Dr Nigel McGinty, Program Leader Integrated Force in DST's Joint and Operations Analysis

Division and the EDTAS organiser. Nothing is simple in this game, he says, not even the definition of a game-changing technology.

"If you asked a whole bunch of people you'd get a whole bunch of answers as to what a game-changing technology is," he tells *DST OUTLOOK*. "You probably don't know quite what a game-changing technology is until it has eventuated, and you're using hindsight. But of course, we're trying to anticipate and look forwards. So the game-changing technologies that we're looking for are those that are going to create an asymmetric advantage for Defence, for national security."

A game-changing technology can be either transformational or disruptive. Dr McGinty uses the OODA loop – Observe, Orient, Decide, Act – as a simple reference. "If it's something that we can observe, orient, decide and act upon within that decision cycle, it's a transformational technology." It's a *disruptive* technology if it's happening much quicker in that cycle.

Whichever it turns out to be, "We're trying to make sure that it's an advantage to us, and that's why we do all the foresighting work as a systematic program," he explains. A lot of that systematic work consists of trying to anticipate the impact and the implications for Defence of that technology.

The structure and rigour that DST brings to this foresighting work is designed to protect the ADF against both people with narrow obsessions and, occasionally, mad inventors. So DST looks at new technologies and their impacts and implications from multiple perspectives, Dr McGinty says. "It's not just taking one look at something and, *tick*, it's a transformational piece. We look at it from different elements and considerations."

Digital disruption is an example. Early in 2017, Dr McGinty ran an EDTAS on digital disruption. This brought together the ADF, Defence and DST, industry and academia to do some blue-sky thinking on a technology environment that has the power to disrupt every aspect of daily life. It threw up plenty of food for military thought, he tells *DST OUTLOOK*: "We probably want to do that again, or something like it, taking a different focus, different scenarios, what have you, to help really understand those technologies."

As an illustration he uses the iPhone, the first so-called smartphone, which Apple released in 2007 and is now practically ubiquitous, with a transformational effect on human communications. "If you look back, the UK's Department of Trade and Industry released a publication in 1989, called 'Phones on the Move', and this laid out the road map, essentially, for what became the iPhone." In the quarter century that followed, plenty of manufacturers failed to achieve an iPhone-like result before Apple succeeded, he says: Apple caught the "confluence of social need, of time, coming in at the right costs and all these other factors which essentially needed to converge at the right time for the technology to be adopted and achieve a broad scale impact".

There is probably something else out there, just waiting for the right combination of technological, cost and social factors before it can become transformational or even disruptive. So partly via the EDTAS events, DST, says Dr McGinty, looks at good ideas not just from the technology point of view but from a multi-displinary perspective: "legal, ethical, economic, social construct. There's a whole host of methods and approaches you can use to examine emerging technologies."

SYSTEMATIC FORESIGHT

But given how serendipitous technology development can be, how far is it possible to be systematic in foresighting? Dr McGinty acknowledges the difficulties: innovation and research usually lead people and companies in unexpected directions, so accurate forecasting is virtually impossible. He suggests a different approach.

"You probably don't know quite what a game-changing technology is until it has eventuated, and you're using hindsight. But of course, we're trying to anticipate and look forwards. So the game-changing technologies that we're looking for are those that are going to create an asymmetric advantage for Defence, for national security."

"I think actually we need to talk about concepts. Little-c concepts, not the traditional military concepts: things that are like a vision statement of what we might want to be able to do, and that's what we're testing. And that can actually drive research programs."

The most famous concept, in this construct, was President Kennedy's call in the early 1960s to put a man on the moon and return him safely to earth within less than a decade. "Google's grabbed this – they do these things called 'moon shots', and we've adopted similar terminology for our work.

"So what are those audacious things that we might want to do? And if we could do that how would it be transformational?" Different technology sectors have different rates of evolution and development, he says. "Everyone talks about exponential change of technology where, actually, that's probably not a fair statement. I think there are some sectors where there is unquestionably exponential growth and change, and others which are far more linear."

Digital technology is seeing exponential growth, says Dr McGinty, because

"individuals or small numbers of people with good ideas are able to test it, field it, improve it, iterate and keep fielding, keep developing and improving. So what you're seeing is that digital technology is now touching so many elements of society – 3D printing, or human biotechnologies. That's why we're seeing the transformation that we are".

THE ROLE OF INDUSTRY AND ACADEMIA

So, what is the role of industry and academia in helping DST grapple with technology foresighting and game-changing technologies? "They are essential, full stop," declares Dr McGinty. "We need to have the breadth of non-traditional thinking. We don't want to get caught in [traditional] defence stove-piped thinking." To look and think outside the box, DST is engaging ever more closely with Australia's broader eco-system: the defence industry, more general industry sectors, and academia.

"We're not looking just for the next big thing. We want to be looking longer-term, and that's where people haven't yet developed a product or a solution that they're trying to market. So we do find that industry and academia are quite open and contributing to the EDTAS that we host *vis a vis* longer-term game-changing exploration activities."

So how does a game changer get into service? How does it transition from what is often quite basic research into an operational capability? Defence needs the commercialisation mechanisms and the flexibility of process – and the patience, for it may take a long time – to be able to achieve that. McGinty agrees.

"The thing for me is making sure that we have Defence holistically on board with what the innovations are," he says; that means exposing Defence to the idea early and keeping it abreast of developments, and therefore excited about its potential. "It's important to make sure that we're considering, when the technology matures, that we do have a path for acquisition."

DST has close relationships with both industry and academia, and helps industry adopt and commercialise new IP, he says, but there is still an internal hurdle sometimes: "Making sure the department's ready to buy the capability; and I often see that as the bigger hurdle." So, either through the ADF's force design cycle or the single services' futures exploration activities such as the RAAF's Plan Jericho, it is essential to have a mechanism "where they are exposed to the development and considering how it might

Image Courtesy of the Australian Government Department of Defence

be used, and then consider ways to adopt the technology".

And new technology is not always directed towards a major project: "The 'satellite on the move' work that was done through the former CTD program was part of one such project – it provided a new capability for Defence that has proved to be quite important but was only a small part of a much larger project."

Getting the best out of a new technology usually involves innovating in one's tactics, processes and procedures in order to exploit new capabilities. That means change. The advent of 5G communications is an example, says Dr McGinty.

"We have fifth generation personal communications just around the corner. Before long all of us will be talking on 5G phones and that will be quite transformational for society because what you get with the internet of things (IoT) will be mind-blowing. I actually think we don't fully understand and appreciate the transformational effect this will have on us as a society. What does that mean for Defence? This is a question we need to explore because Defence wireless communications are comparatively low bandwidth, which means that a potential non-state actor, for example, can have a higher communication capability, situational awareness, command and control, and better bandwidth than Defence, although we have far more robust and secure systems."

The communications world is going through a step-change, says Dr McGinty. All technologies get to tipping points where they will have a transformational effect. "And I think we're at another one of those tipping points in communications. That's one that I flag as being just around the corner. As a Defence Department we really need to tackle it."

AUSTRALIA'S GAME-CHANGING TECHNOLOGIES

Australia's genuinely game-changing technologies are highly prized. Dr McGinty cites the HIFiRE (Hypersonic International Flight Research Experimentation) research program by DST, the US Air Force Research Laboratory, Boeing and the University of Queensland as a contemporary example. "Hypersonics is the classic example from DST," he says. "That has taken leadership and commitment, and that's the other element: not just the concept and the vision, but also strong leadership to realise it."

It is a constantly evolving world, acknowledges Dr McGinty. He cites Graphene, the single-atom-layer mate-

RMIT UNIVERSITY

Ships That Repair Themselves- Best Line Of Defence

Professor Mouritz and the new multifunctional material radial braiding machine

Preserving defence fleets is critical work, but protecting personnel is even more important. Fires on ships at sea or while docked can threaten lives, not to mention millions of dollars in infrastructure.

Researchers are working towards ways to prevent blazes like the one that destroyed HMAS *Bundaberg*, a $54 million Navy patrol boat, in 2014. The massive fire has propelled the research now underway by RMIT University's Professor Adrian Mouritz.

Funded by the Australian Department of Defence and the US Navy, Mouritz is exploring futuristic ways ships can repair themselves in the event of a fire or missile attack.

Partnering with CSIRO, Mouritz is investigating a polymer that can be squirted onto cracked or damaged fibre composite surfaces and repaired in 10 minutes.

"At the moment, if you damage a composite, whether it's an aircraft, a naval ship, a wind turbine blade, or anything, you need to take it out of service, so you can't use it.

"You've got to cut out, or grind out the damaged area and then put new material in, and that's a pretty slow and expensive way to do it.

"Our method allows you to do repairs immediately when the damage forms and it can heal itself in the same way that your body does."

This work ties in with Mouritz's research on the effects of fire on ships made from fibre composites and also aluminium. While both materials are lightweight and more economical, they are sensitive to high temperatures. This has prompted Mouritz's research, in collaboration with Defence, into managing the fire risks of fibre composites.

"The work we've been doing with Defence is to develop models the Navy can use to predict, if there is a fire on a ship, how long that fire can burn before it becomes a major hazard to the structural safety of the vessel.

"It also allows them to get a better understanding of the fire protection measures needed to put on board a ship which is made out of either aluminium or composite materials."

Experimental tests have led the team to create predictors used to save lives in ships as well as planes and buildings. "We took that information and then developed models, which allow people to predict how these two groups of materials will weaken, and when they'll fail in the event of fire.

"That sort of work has never been done before. These models that we've developed can be used not only for naval ships; they can be used if there's a fire on an aircraft, or in a building."

Mouritz and his team, who are collaborating with local and international organisations, have also investigated how composite fibres react to explosions.

The team's insights continue to inform the next generation of composite materials.

"Before long all of us will be talking on 5G phones and that will be quite transformational for society. What does that mean for Defence? This is a question we need to explore because Defence communications networks are relatively low bandwidth, which means that a potential non-state actor, for example, can have a higher communication capability, situational awareness, command and control, and better bandwidth than Defence."

rial, as an example of a serendipitous breakthrough in science which has so many revolutionary applications, both electronic and structural, for the civil and military communities. "It's very hard to predict all those connections to a particular outcome. The unknown and unexpected will always happen."

Looking back, Nulka and JORN were also game changers, but a very long time ago, in technology terms. More recently, the single photon avalanche diode array is a technology that has developed from being just an idea and has proven to have many applications, says Dr McGinty. "It's an example where somebody has shown the conviction, the leadership and the drive to realise this. Another piece might be the work by [Australian start-up] Silentium with passive radar. Once again, that is fundamental: passive radar is an area that has changed and will continue to change the way the forces operate – and ultimately that's what this game-changing technology's about: a fundamental change in the way we operate, for the better."

DST tries to explore and map these potential changes through its EDTAS symposia. There have been four to date, on Trusted Autonomous Systems (TAS), which pre-dated the establishment of the CRC for TAS in early 2018; on Information, Knowledge & Digital Disruption; on Advanced Materials and Manufacturing; and on Human Biotechnologies. Each of these are linked explicitly to one or more of the technology investment priorities of the NGTF and represents a coherent approach right across DST's S&T portfolio to the needs of its stakeholders.

But as Dr McGinty has pointed out, innovation is not always linear and predictable and the unknown and unexpected lie in wait to change our plans for us. That is called the future, and that is why one of DST's vital roles is trying to 'future proof' the world its stakeholders inhabit.

YOU TO THE POWER OF *us* CAN LIGHT THE WAY TO A SECURE FUTURE

Macquarie University is the home of human-powered innovation. Home to laser technology that could be the first line of defence against emerging threats. Home to researchers who are exploring the extremes endured by defence personnel – then applying that knowledge to next-gen military technology. And home to quantum systems research that is using gravity to find objects hidden in plain sight.

RESEARCH AT THE CUTTING EDGE

Macquarie hosts one of Australia's largest and most-respected photonics research groups. Together, the group is undertaking fundamental and applied research across all frontiers of optical science.

"This includes more than 25 years of research in advanced laser sources for defensive counter measures and other laser applications that range from defence to medical and advanced manufacturing," explains Professor Rich Mildren from the MQ Photonics Research Centre.

One recent focus has been on the development of high-powered directed energy lasers to defend against new threats from low cost drones and missile technologies.

"Lasers are seen as a key solution for defending against such targets due to advantages in cost-per-shot and magazine depth."

Work done by the MQ Photonics team has broad application, with the potential to be used in advanced manufacturing and to add new capabilities to space science.

"Mid-infrared lasers are a clear example of an important dual-use technology that addresses defence challenges in optical countermeasures, while also tremendously important for remote sensing and in medicine for surgery," adds Mildren, who was the winner of the 2017 Eureka Prize for Outstanding Science in Safeguarding Australia.

"The mid-infrared wavelength is good for distracting heat-seeking missiles. It also interacts with water vapour in tissue, so when you apply a focused beam to skin, it is strongly absorbed, resulting in a nice clean cut."

NOWHERE TO HIDE

Macquarie's Research Centre in Quantum Science and Technology is looking at ways that levitated quantum systems can be used as an ultra-sensitive, passive radar system.

The research, which could transform Australia's defence capability, involves the generation of large quantum superpositions.

These have the potential to provide a radar system that maps out its surroundings dependent on mass density in real time. Both dense and hollow objects will be visible thanks to their gravitational fingerprints; nothing can hide or deflect its gravitational fingerprint, making detection virtually guaranteed.

PERFORMANCE MATTERS

How can understanding elite athletes help train people to better withstand the demands of roles requiring sustained high performance, mental toughness and resilience?

The multidisciplinary team of researchers at the Centre for Elite Performance, Expertise and Training is investigating the cognitive, emotional, motor and social processes by which individuals acquire, maintain and adjust to elite levels.

The team is using this knowledge to improve workforce resilience-related issues such as risk governance and culture, improve reporting of occupational injury and disease, and better understand ethical decision making.

Notably, researchers are also working to understand the extreme physical and mental conditions under which defence personnel perform, and applying that knowledge to next generation military technologies such as future submarines.

By working together, we could transform lives, change conversations and develop world-changing ideas. For more information about partnering with us contact:

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mq.edu.au

MACQUARIE University

COGNITIVE PERFORMANCE

As the complexity of technical systems and operating environments in the defence sector continues to soar, so too does the requirement to enhance individual cognitive performance and sustain psychological fitness. By **Julian Kerr.**

Human performance is a critical effect multiplier for those systems and under any mission profile," says Dr Eugene Aidman, Principal Scientist, Applied Cognition, and head of a DST team researching cognitive ergonomics – the discipline that deals with human mental processes like perception, attention, reasoning and decision-making.

"Building cognitive strengths is what we're on about and we have the luxury of that growing demand that arises from our end-users and their commitment to add whatever we can offer in that space into their doctrine, into their training programs, into their operational support procedures, and into their technologies," Aidman comments.

He points out that Army has acknowledged that its future fighting ability is limited not by technological superiority, but by the warfighters' cognitive capacity. Consequently, Army training is now aimed at enabling the soldier to 'outthink, outperform and outlast' an adversary.

"Army is the largest training organisation in the country and they're pretty good at what they do. However, most of what they're doing is based on the rather outdated model of one size fits all and they are themselves now calling for what they term tailored training," notes Aidman.

"We translate it into data-driven training…. the idea is to have meaningful assessments front-loaded before the start of the training pipeline for each individual soldier. They can then be grouped up into various sub-types of the training programs that are more likely to benefit them, to accelerate their learning curve and make them a better operator."

Aidman states that a number of seminal research studies point conclusively to self-discipline rather than IQ being the best determinant of on-the-job performance; the good news from such studies being that self-control can be improved, and produce significant benefits.

In a highly regarded New Zealand research program (the Dunedin Study) involving more than 1,000 people from very young age and a massive assessment protocol stretching over more than three decades, those who lifted their self-control scores at age 21 compared to their own score at age five also lifted all their life outcomes at age 32.

"We don't know yet what caused that improvement, but imagine what custom-designed training could do if it nudged up self-control levels across a wider population such as Defence; this is why this New Zealand study is now the talk of the town with policy-makers," says Aidman. "Generating this improvement deliberately rather than just hoping for it to happen could produce massive positive outcomes on a large scale. The evidence is quite overwhelming."

COGNITIVE FITNESS FRAMEWORK

Far-reaching cognitive research findings by the DST team partnered with national and international collaborators have now been translated into an interim Cognitive Fitness Framework to help guide research in pilot Human Performance Centres (HPCs) established by Army in Townsville and Perth.

This cooperation has been advanced largely through the Human Performance Research Network (HPRnet), which is aimed at harnessing the research capabilities of leading Australian Universities to explore the methods of enhancing the performance and well-being of Australia's military personnel. Funded by Army in 2016 for four years, the network is led by DST with input from seven partner universities.

Never before has Army actively engaged on a large scale with both DST and Australian universities as the sponsor of a research network.

Fresh backing for HPRnet is anticipated from the Next Gen Tech Fund to not only continue but expand the cross-disciplinary expertise being delivered through the network, including the addition of RAAF and RAN question sets and the ability of the academic partners, with industry collaborators, to bid for specific work themselves.

Included in the Cognitive Fitness Framework is the concept of the Cognitive Gym. Analogous to a physical gym, this involves foundational training in self-awareness, attentional skills, task switching,

impulse control, and the basics of teamwork in the co-action space.

Although still under development, aspects of the Cognitive Gym are already being trialled in the HPCs and Aidman is confident of the concept addressing the Gold Standard training paradigm of "isolate, overload and over-recover" – the sequence well-known to sports scientists.

Advanced training within the Cognitive Gym concept involves controlled response, energy management, the basics of situational awareness with detection, sense-making and anticipation skills, moving on to further teamwork development and adaptability, and to the decision-making space.

"This is going to end up being the critical skillset for the soldier of the future and within that decision-making space we're also beginning to work on their decision biases and their confidence calibration," explains Aidman. "We know confidence is a big factor that impacts decision quality. It is driven by our metacognitive capacity to watch and adjust our own cognitive performance. Overconfidence, for example, could be disastrous - it is known to undermine both individual and collective decision-making."

MISSION-READINESS TRAINING

The next step is mission-readiness training. Here the objective is to improve operators' tolerance to pain, stress, sleep loss, monotony, frustration, uncertainty and tactical surprise; their resistance to distraction, deception and manipulation; and their resilience.

With resilience, the long-standing challenge of how it can be measured has been met by sophisticated neuroscience-driven measures.

"We can measure the body's response to a sudden loud thump – by not just observing behaviour but by measuring the more subtle physiological responses," says Aidman. "We measure autonomous nervous system responses such as heart rate, respiratory response or even skin conductance which reflects the minute changes in sweat production."

Repeated presentation of that loud thump at random intervals usually results in ignored gradual reduction in response, known ass habituation,

although international research had shown that habituation does not occur in some patient groups, including those diagnosed with posttraumatic stress disorder (PTSD).

"Now, however, we have a measure that can give us robust evidence as to whether or not any of our training interventions aimed at improving resilience are actually effective or not."

While human performance is a critical effect multiplier for technical systems it can also turn missions' strengths into vulnerabilities in an instant, Aidman warns. "Diagnosing and treating conditions like PTSD is not our territory. But our work is contributing to the prevention side of the equation. In the Defence context the whole of government approach to mental health seems to be running relatively thin on prevention and attention is turning onto building strengths, and building cognitive strengths is what our work is about."

OPERATIONAL AUGMENTATION

Mission-readiness training caps off the cognitive training cycle. It is then complemented operational augmentation typically delivered by operational support systems. This encompasses cognitive state monitoring, adaptive mission aids and operator state-aware autonomy, the latter an area where autonomous systems can sense when an operator is tired or distracted and intervene appropriately.

Elements of the Cognitive Gym are already being used within existing Army training systems but, as Aidman points out, DST's research is not aimed at replacing what Army is doing but at improving its training protocols.

"We're relying heavily on Observer Trainers (OTs) with our research; basically they're the first consumers of the research data that we're generating.

"We acknowledge that Army training has a very busy schedule and trying to offer a new course, call it what you will, will be met with 'how on earth are we going to fit it in?' We're focusing on the specifics of professional skills and the possibility of encroaching on the protocols being trialled at the HPCs with no more than an extra 30 minutes a day to be gradually introduced into the culture of army training.

"We contribute to Army's own vision of cognitive training; we respect that and acknowledge that they will continue trying different things as they often do and we get invited to assist in the evaluation of those trials.

"But at some stage we're anticipating that the two lines of effort will actually converge."

ENSURING THE STEM PIPELINE

As demand for STEM skills continues to grow, Defence and industry are faced with the task of creating a pipeline of future employees despite the shortage of graduates. By **Julian Kerr.**

As the leader of science and technology (S&T) for Defence and national security, DST requires a skilled and innovative STEM workforce. But as the demand for STEM skills continues to grow exponentially, Defence and industry are challenged with a shortage of graduates choosing careers in STEM fields.

DST's focus therefore is on ensuring that it as an organisation has a pipeline providing sufficient skilled personnel to deliver the outcomes of the 2016 White Paper and its accompanying Integrated Investment Plan both for Defence, and in the national security area.

The importance of this role was recognised in the White Paper with $1.6 billion allocated to DST for initiatives over the 10 years from 2016, including $730 million for the Next Gen Tech Fund.

THE STRATEGY

As explained by Dr Todd Mansell, Chief Science Strategy and Program Division, DST's formal STEM strategy involves five engagement objectives: shaping the national STEM agenda, partnering to develop a cohesive approach to STEM, inspiring students to seek careers in STEM, promoting employment pathways into Defence, and retaining STEM professionals in Defence.

These can be expected to harmonise with the long-term Defence Industry Skilling and STEM Strategy now in development – a major national endeavour referencing the land, sea, air, cyber and space domains to support the development of a skilled workforce and help to meet future capability requirements in the ongoing recapitalisation of the Australian Defence Force.

Each DST objective encompasses a range of actions, many of them centring on a cohesive One-Defence approach to influence and support school curricula, engage directly with universities, develop and share best practice models for leveraging STEM outcomes through hubs and shared infrastructure, and facilitate cross-sector mobility pathways to advance STEM career development.

Other elements include auditing the STEM programs supported in DST and identifying linkages with other programs within Defence, sponsoring high-profile science and technology competitions, and generally raising awareness of the diversity of STEM careers available in Defence through engagement with career advisors and the sponsorship of influential STEM educators.

Importantly, the strategy also proposes implementing a model for forecasting future Defence S&T workforce demand, developing and monitoring the broad range of pathway programs that transition STEM students into Defence and S&T careers, and finding and removing the barriers to enable rapid commencement of employees.

There are no surprises in the Retention strategy: focus groups, a longitudinal study to identify the key attributes of a career in S&T, analysis of exit data provided by departing STEM employees, the creation of tailored career pathways, and benchmarking STEM salary and benefits in the broader community.

TALENT MANAGEMENT

As the Lead Human Resource Business Partner DST, Maree Mahoney plays a vital role in the recruitment, development and retention of the current and future workforce for what is Australia's second-largest publically funded research and development organisation. Part of the

Defence People Group, Mahoney is embedded in DST to work with the Chief Defence Scientist in what she describes as talent management – "having the right people and enough to meet future demands, how you develop 21st century skills, transition them, build leadership skills, and the right organisational culture".

For her, creating a STEM pipeline starts early with making STEM real – "for kids, STEM is just a term but what does it actually mean, what are the types of things you can do with a STEM qualification, what sort of problems can you solve, how does it relate to real-life problems?

"We need to work with STEM teachers and career advisers, we have to provide role models of people that are already doing STEM so the kids can see there are inspiring people out there doing fantastic work using their STEM skills and qualifications."

More broadly, DST needs to develop partnerships across other parts of defence industry and academia to influence the government on STEM requirements, and ensure it and Defence are represented on all the relevant professional bodies and associations that have a national presence.

"Quite a lot of work is going on through other (government) departments including Defence but it's fragmented. We're a large employer of research so we have a responsibility so far as Defence is concerned to help bring it all together," notes Mahoney.

"Defence has established a One Defence STEM Council to drive the Defence STEM strategy and influence the interaction that's needed with other Government bodies, industry and academia on how we all contribute to building a STEM workforce for the future."

As DST needs a range of STEM professionals, , DST is continuing to build the STEM Talent pipeline at several levels from DST scientists participating in a school STEM programs, including Professionals in Schools which is a program managed by CSIRO and aimed at attracting children into science.

"It could be primary schools or high schools, it could be experiments, it could be building a robot in the classroom to help the kids identify with a real live scientist and understand what they do, and hopefully that inspires them," says Mahoney.

"We do a range of other outreach activities in specific diversity groups and in the indigenous space, as well as the vocational sector through an apprenticeship program and a range of technical traineeships." We also have a range of programs aimed at the tertiary level from student placements, cadetships, PhD internships to post doc https://www.homeaffairs.gov.au/trav/visa-1/186-#tab-content-1ural employment.

As an example the DST cadetship program established in 2016 as part of the Defence White Paper People Initiatives which is an entry-level employment pathway for high-performing undergraduate students currently studying a relevant STEM degree. The program will soon reach 50 participants.

Illustrating the scope of DST's activities, the relevant disciplines comprise aerospace/aeronautical engineering, and naval architecture; computer sciences, IT, software engineering, telecommunications; electronic/electrical engineering; psychology and social sciences; materials science; mechanical and mechatronic engineering (including robotics); chemical, radiological, biological and food sciences; and mathematics and physics.

Computer science, electronic engineering "and anything around data analytics" are of particular interest to DST, Mahoney says.

An agreement signed with the Australian Mathematical Sciences Institute in 2017 involves 100 internships at PhD level over four years. This program gives PhD students an opportunity to work in DST on a diverse range of problems and with leading researchers.

The Research and Innovation (R&I) stream, part of the Defence Graduate Program was established in 2016 and comprises an eight-month rotation within DST and an external four-month rotation in another part of Defence or a different DST division for honour or masters graduates. It also provides a pathway to graduates who want to further develop their research skills through a DST-supported PhD. At the end of the graduate program the participants will be placed in an ongoing science role within DST.

STEM AND GENDER

Only 17% of women are employed in the science classifications in DST, which is similar to the representation of women in the physical sciences at university. This gender imbalance is being addressed primarily by DST's participation in the SAGE (Science in Australia Gender Equity) program that is designed to improve gender equity and diversity in STEM and medicine disciplines.

Mahoney acknowledges difficulties for schools to balance humanities with the strong focus on STEM. Traditionally there is greater interest in high school and University courses that also incorporate arts and the humanities. "When we're looking for graduates we're looking in particular for people who have enterprise and 21st century skills which are around creative thinking, problem solving, team work, collaboration and communication. These days scientists need to be able to talk to the general public about the impact they have in a way that is easily understood by a person that does not have the technical specialist background.

"So we're looking for people who are not just high achievers in their academic studies, but can bring the other skills as well."

KNOWLEDGE TRANSFER

The Defence White Paper's focus on maintaining the ADF's regional technology superiority, supported by an innovative, sustainable defence industry base that is recognised as an FIC, means transfer of knowledge and the pursuit of collaboration are far more systematic than before. By **Gregor Ferguson.**

Knowledge is like money – it has no value unless it is used properly. For DST this has traditionally meant exploiting the fruits of often-classified research, sometimes transferring it to an industry partner who can commercialise the intellectual property (IP) concerned and transform it into something the ADF can acquire and put into service.

The 2016 Defence White Paper deliberately strengthened this process. Its focus on maintaining the ADF's regional technology superiority, supported by an innovative, sustainable defence industry base that is recognised as a Fundamental Input to Capability (FIC), means transfer of knowledge and the pursuit of collaboration are far more systematic than before. The process of achieving this is helped by new funding and collaborative mechanisms such as the Next Generation Technologies Fund (NGTF), Grand Challenges and Defence CRCs.

'Knowledge transfer' is something that DST has always done, Dr Ian Dagley, the Chief of DST's Science Partnerships and Engagement Division, tells *DST OUTLOOK*. "We build up knowledge and expertise and 'transfer' can just mean us providing advice to other parties, which we do. I think 'technology transfer' can have a slightly different meaning: for me that implies we've developed something internally and we support some other party turning that into a capability.

"Increasingly, we work on projects where we've identified a defence need and we've got the party that's going to turn that research into a capability as part of our team," he adds. "As early as possible in the process, the industry partner is engaged and it makes the transition from being a research activity into a development activity, and then turning it into a capability, more seamless."

EXTERNAL PARTNERS

Knowledge and technology transfer are both increasingly important mechanisms for collaboration with Australia's research and industry sectors, especially where both the strategic environment and technology are changing rapidly. DST does not have the internal resources to do everything asked of it so it needs trusted external partners, Dagley explains: "It's essential that DST collaborates with the wider research community and industry to make sure

that we maximise the capability edge that we deliver to Defence."

Many of the emerging technologies that are important to Defence are dual-use technologies developed often very rapidly in academia, by research providers such as CSIRO and in industry. DST needs to maintain awareness of these technologies and work with the best people in these new eco-systems, nationally and internationally, to help maintain Defence's capability edge.

The explicit focus on ADF capability, the increasing complexity of some technologies and the growing rate of technological change mean that DST is becoming more pragmatic about how it selects its partners, Dagley says. "What we're trying to do is select the very best research partners for developing a particular technology, and selecting the very best company that is ideally placed to exploit that because it's got expertise in the market, the right supply chain, and all the rest of it."

Initiatives such as EDTAS (the Emerging Disruptive Technology Assessment Symposium) and the NGTF have had a profound effect on the way DST undertakes knowledge transfer and collaboration more generally, says Dagley. The NGTF in particular "has provided a much larger source of funding than we've had historically to do long-term, high-impact, game-changing technology development with partners. It's really turbo-charged our collaborations with universities and industry, particularly nationally, because the money has to be spent in Australia".

The bottom line for DST is addressing Defence's need, and this drives its choice of research and industry partners. Getting the best possible research outcome means bringing together the best people to solve the problem, says Dagley. Maximising the chances of a successful commercialisation means finding the right industry partner and involving it at an early stage. And the ADF's own input is vital, not just in defining the problem but maintaining regular contact with the project to ensure it is on track and for ensuring the need still exists and that things have not changed unexpectedly.

SELECTING THE RIGHT PARTNER

To select the right research and industry partners, it is important to understand where the strengths lie for defence science across the nation, says Dagley. Hence DST's investment of cash and manpower in its networks of universities across Australia: the Defence Science Institute (DSI) in Melbourne, Defence Innovation Partnership (DIP) in Adelaide and Defence Innovation Network in Sydney. DST seconds some of its high-performing scientists to each organisation on two-year rotations, working as part of the management team while also being able to reach back into DST for knowledge and expertise.

"DST needs to be seen to be delivering value. The taxpayer needs to be shown that a dollar invested in defence science pays a strong dividend."

"They are providing us with an excellent overview of what the strengths are in those three states. They're also important because, first of all they're establishing a single point of contact for companies, in particular, who are looking to collaborate with universities in a given state, and they can go to the local network which will be able to bring together the best people from the universities in that state for a particular problem that they've got to solve."

This makes it easier for industry to access the research infrastructure and capabilities that exist within Australia, says Dagley, not just within DST. These networks are also enhancing the defence science capabilities of the member universities because they now have access to funding for projects and they are also fostering collaboration with other universities and with industry. The people working on those projects are typically post-doctoral fellows or Ph.D students, so the networks are also growing the STEM pipeline for Defence, adds Dagley.

DST needs to be seen to be delivering value. The taxpayer needs to be shown that a dollar invested in defence science pays a strong dividend. This is not too difficult: to underline the importance of DST's work and the knowledge transfer that it undertakes, economics consultancy ACIL Allen published a report in 2015 that calculated the tangible economic benefits of DST's research since 2003. The conservative figure it arrived at, based on just 10 project case studies, was $5.1 billion. However, it says, "… it may be reasonable to conclude that the extension of the case study approach across all DST projects would yield 4 to 5 times the value ($20 to $25 billion)".

DST's value is measured against the tangible impacts it makes that are critical to Defence, and these increasingly rely on DST's relationships with its external partners, says Dagley. "I think the trajectory is clear. Collaborations are still a work in progress, but we're going to do more. The NGTF spending will ramp up as the program starts to mature so we'll be doing much more partnering with outside parties than we have historically. That's only going to increase."

INTERNATIONAL COLLABORATION

As the rate of technological change increases, nations find they do not possess the capacity to maintain mastery of every domain that is essential to them. By **Gregor Ferguson.**

Australia is part of a more general trend in defence technology, believes Dr Ian Dagley, Chief of DST's Science Partnerships and Engagement Division. As the rate of technological change increases, nations find they do not possess the capacity to maintain mastery of every domain that is essential to them. Allies and like-minded nations are partnering with each other to share resources and tackle common, or at least similar, problems and threats.

When it comes to defence technology, DST is Australia's flag-bearer and its much more open stance towards international collaboration reflects the realities that have driven fundamental policy changes in the past several years. Dagley's job did not even exist less than a decade ago.

"What we're doing is very similar to what our close allies are doing: we're trying to make sure that we select high-impact technologies to develop; we're trying to find the best partners for those, both nationally and internationally," he tells *DST OUTLOOK*.

DST has traditionally collaborated with its Five Eyes partners – Canada, New Zealand, the UK and the US – through the medium of The Technical Cooperation Program (TTCP). But increasingly that collaboration is climbing from relatively general information-sharing at one end of the scale towards more meaningful, deeper collaboration where the five TTCP partners are not just sharing information but actually co-developing technologies with an operational focus.

Furthermore, DST is collaborating with a wider spread of international partners and like-minded nations, says Dagley. DST has bilateral agreements with countries like France as well as Memoranda of Understanding (MoUs) with a number of other countries, under which specific project agreements are now in place. Australia has long posted Defence Science Counsellors to the Australian Embassy in Washington and High Commission in London; these posts are being upgraded, says Dagley, with the latter now accredited specifically to France as well as interacting regularly with NATO and Scandinavia. Some time ago a similar position was created at the Australian Embassy in Japan; this will be complemented in 2019 by newly created Defence Science

Counsellor positions at Australia's High Commission in Singapore and its Embassy in the Republic of Korea.

"So we certainly are reaching out beyond our traditional Five Eyes partners," he says. "And once again we're doing what a lot of like-minded countries do: we're looking really to partner with people who are leaders in various aspects of defence science – not just our traditional allies."

This growing focus on international collaboration is all about making sure the ADF maintains the best possible capability edge, says Dagley. "And so that means we're not just relying on the skills within DST, or indeed the skills that exist within the country, or the skills that we can draw upon from our traditional Five Eyes partners. We recognise that other countries are also leading in different areas of defence technology and we're very keen to partner with them."

The term 'partner' implies a two-way street, and the average Australian would be surprised to learn that Australia brings a lot to these partnerships. "The partnership is driven because there are benefits to both sides. You don't collaborate with someone who doesn't bring something to the table that you haven't got," he says. "And that works both ways."

Australia has developed solutions for problems that its partners have often never had to address; when they do find they have a need, Australia has many of the answers. But Australia's contribution to systems in service globally has also been significant: the US-Australian Nulka active missile decoy is a case in point, as is Australia's contribution to the capability of the US Mk48 CBASS heavyweight torpedo and that of the ASRAAM air-air missile, both of which are in service in Australia as well as their parent countries.

The sheer complexity of emergent technology, ranging from the weapons mentioned above to new technologies such as advanced materials, quantum science and cyber, is exposing capacity constraints among our allies, as well as in Australia, says Dagley. These technologies are driven by expertise largely outside Defence, but DST and its overseas counterparts need to follow leading edge developments and partner with people in key areas if they are going to exploit those technologies for defence applications.

So collaboration with trusted allies and like-minded nations is a deliberate policy: "Each nation is seeing its ability to improve its capability edge as not just confined to its internal skills, or indeed the skills that exist in its own country. For example, the US is seeing the innovation system and industry capability in its allies as part of a broader technology base that it can draw upon."

Is there a universal template for international collaboration? The answer is no, according to Dagley, though an acknowledgement that capability needs to be refreshed and enhanced, and therefore budgeted for, is an important enabler. "Each country has its own approach and there's not one particular way of doing it. But I do think we have the pre-requisite for it to work in Australia, with the current major investment in new capability, and manufacturing that capability here in Australia," says Dagley.

You can trace this change in policy back to the 2016 Defence White Paper and the creation of the Next Generation Technologies Fund (NGTF), says Dagley. "It had a profound effect. The Defence White Paper has been the driving force behind the capability acquisition program that's had a profound effect on Defence as a whole."

DST continues to open up to wider and deeper domestic partnerships, says Dagley, and its international partnerships are on the same trajectory: "It's just going to continue down that path of much closer and much more meaningful collaboration with our international partners," he tells *DST OUTLOOK*.

"The partnership is driven because there are benefits to both sides. You don't collaborate with someone who doesn't bring something to the table that you haven't got. And that works both ways."

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