Defence Science and Technology's research goals, workforce and infrastructure plans for the next decade

A paper based on a presentation which was to have been made to the Institute on 30 June 2020 by

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Herein, Australia's Chief Defence Scientist outlines the Defence Science and Technology Group's strategic plan for the decade ahead, covering its eight research goals (or 'STaR Shots'), STEM (science, technology, engineering and mathematics) workforce needs, and infrastructure provisions. The STaR Shots will prepare the Australian Defence Force for the 'fourth industrial revolution'; workforce development will be dependent on enhanced STEM education and training in the community; and the infrastructure plan will focus on establishing Defence S&T precincts with industry and academia.

Key words: Australia; defence science and technology; fourth industrial revolution; STEM education and training; Defence S&T precincts.

I am delighted to share with you our vision for defence science and technology in Australia over the next decade.

Australia's Defence Science and Technology Group

Australia's Defence Science and Technology Group (DST), was founded nearly 113 years ago, a century during which it has made a vital contribution to the nation's defence.

Today, DST has a delivery budget of around $580 million a year and a workforce of around 2100 staff, predominantly scientists, engineers, information technology (IT) specialists and technicians.

With the exception of the Northern Territory, we have a presence in every state and territory in Australia. Internationally, we have representatives based in embassies and consulates around the world, including in Washington DC, London, Seoul, Singapore and Tokyo.

As the principal scientific advisor to Defence, there are not many parts of this enormous military machine that DST has not touched or influenced in some way. It has been said that if a soldier wears it, eats it, uses it or thinks it, DST has done the science behind it. We have a long and proud history of providing innovative and sustainable scientific solutions to Defence; solutions which are world-leading and often world-changing.

Importantly, many of our innovations have applications beyond Defence. Take the Black Box flight recorder, for instance. This was developed by Dr David Warren, a Defence scientist at our laboratories in Melbourne in the 1950s, and is now used on every commercial aircraft around the world. Then there is JORN, the Jindalee Operational Radar Network, which provides 24-hour military surveillance of the northern and western approaches to Australia, but also is used in weather forecasting and detecting illegal entry, smuggling and unlicensed fishing.

Recently, one of our senior scientists, Dr Neil Gordon, was recognised for his ground-breaking work developing the Particle Filter algorithm, arguably the most important surveillance algorithm of the past 50 years. The Particle Filter is now used almost everywhere, from predicting weather, to epidemiology, to the extraction of missile threats from satellite data.

As an organisation, we have made – and continue to make – an important contribution to the security and prosperity of the country. Our role has always been to ensure a regionally superior Australian Defence Force (ADF) with the highest levels of military capability and technological sophistication. Today, this role is more important than ever. With our country facing an increasingly challenging and contested security environment, we at DST are positioning ourselves to deliver a strategic advantage across the full spectrum of Defence capabilities. Our success will depend on having a focused science, technology and research programme but also, and perhaps more importantly, on our ability to effectively leverage and shape the national science and technology (S&T) enterprise.

Defence Science and Technology Strategic Research Goals

In May this year we launched our Defence Science and Technology strategy, called *More, together*, which will provide our strategic direction over the next decade. Our strategy is headlined by the introduction of a new concept, a set of ambitious Science, Technology and Research Shots, or 'STaR Shots'. The STaR Shots are a set of ambitious research goals, defined with and agreed to by our Defence stakeholders. They are challenging, inspirational and aspirational – they are scientific endeavours that the whole nation can get behind.

We are borrowing unapologetically from the 'moonshot' concept, but we do not want to limit ourselves to the moon, we seek to go beyond. These STaR Shots will focus research on Defence's strategic objectives and set the foundation for future leap-ahead capabilities. Having

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clearly-defined transition pathways, they will be directed at tangible, future-focused, defence capabilities.

As you can imagine, selecting the correct STaR Shots is absolutely critical and, after extensive consultation and rigorous analysis, I am confident that the eight STaR Shots we have identified are the right ones.

The set of STaR Shots that we have arrived at support the over-arching objective of the ADF: to prevail in contested environments. And, importantly, they support capability needs across each of the warfighting domains. So let me provide you with a brief summary of each of the STaR Shots.

STaR Shot 1: remote undersea surveillance

The detection and localisation of submarines is a significant challenge for any nation, but particularly for Australia where we have a very large maritime domain and a limited set of crewed assets.

To address this challenge, we have a STaR Shot focused on remote undersea surveillance. This STaR Shot is aimed at enhancing our undersea surveillance capabilities by augmenting crewed assets through the use of autonomous, deployable, sensor systems. What will this mean for our Navy? It will mean the ability to create a 200-nautical-mile safe haven around Australian naval bases.

STaR Shot 2: CBRN-contaminated environments

Another of our STaR Shots concerns operating in environments contaminated by chemical, biological, radiological and/or nuclear hazards. Our ADF needs the ability to safely and successfully prosecute its missions in such environments.

This STaR Shot will explore the development of critical capabilities in threat detection, identification, mapping and prediction, and, importantly, will develop innovative and novel tools to assist with situational awareness and decision-making.

STaR Shot 3: quantum-assured position, navigation and timing

Position, navigation and timing (PNT) systems are vital for military operations to maintain constant situational awareness. Today's PNT systems are reliant on global navigation satellite systems, in particular the 'Global Positioning System' (GPS). Access to these systems, however, can all too easily be constrained, either by adversarial jamming, poor environmental conditions, or even the nature of the terrain – thereby undermining the reliability of critical PNT systems.

As the name suggests, the 'quantum-assured PNT' STaR Shot will explore quantum technologies to ensure the ADF has trusted PNT systems to support battlespace networks and ensure mission success.

STaR Shot 4: resilient multi-mission space capability

Our existing space capability is becoming highly vulnerable in what is becoming an increasingly contested domain. The 'resilient multi-mission space capability' STaR Shot will provide resilient global communications, PNT data, and geo-intelligence directly to ADF users in real time.

This critical capability will be enabled by a smart satellite constellation, an 'intelligence cloud' of next-generation space systems that are resilient and responsive to mission requirements. It is important to note that we will be leveraging *Australian* technologies, but our solution will be 'coalition-ready', suitable for global operations in contested battlespaces.

STaR Shot 5: disruptive weapon effects

The rapid development of advanced missiles and high-speed systems is challenging current missile defence capabilities due to their speed, range and manoeuvrability. For the ADF to carry out its missions in contested environments, we need to develop effective countermeasures against these types of advanced high-speed systems.

The 'disruptive weapon effects' STaR Shot is aimed at doing just that. It will develop, mature and demonstrate technologies to specifically counter adversary anti-access, area denial capabilities and enable joint freedom of manoeuvre. It will explore how to increase the speed and range of weapons, how to use teaming and co-ordinated effects to overwhelm enemy combat systems, and how best to employ defensive capabilities, such as directed-energy weapons, for surviving within the contested environment.

As with all our STaR Shots, this STaR Shot will draw on the best of Australia's innovation sector; universities, small-to-medium enterprises and industry primes. It will leverage Australian research strengths in hypersonics, tactical booster design, transformative energetics, collaborative weapons teaming, advanced sensors, and directed energy technologies.

We expect this STaR Shot to deliver new, innovative and novel weapon technologies. It could also see the growth of an Australian weapons industry base. This is an example of a STaR Shot that has, in effect, already commenced through the established work on high-speed weapons.

STaR Shot 6: information warfare

As we are all increasingly aware, the information environment is the new theatre of war. Our military systems are reliant on it; our infrastructure is reliant on it; our economies are reliant on it. Control the information environment and you control the contest.

The information warfare STaR Shot is focused on developing autonomous 'information warriors' to fight the 'information war' through blended awareness and effects across the human, information and physical realms.

STaR Shot 7: agile command and control

The nature of war is changing, and the conflicts of the future will be very different to those that the ADF has contested in the past decade or two. Operating domains recently considered 'global commons' are now contested and freedom of operations cannot be assured. Our ADF needs to be technically and tactically prepared for high-end conflicts against technologically-advanced adversaries. Military success will require the ability to simultaneously generate effects with and across every operational domain, a concept termed 'joint all-domain operations'. This is the new reality of modern warfare.

Joint all-domain command and control is fundamental to success across the continuum of conflict, turning individual capabilities into a synchronized, coherent force. The 'agile command and control' STaR Shot will leverage enabling technologies such as artificial intelligence, machine learning, autonomy, and human-machine interactions; and combine those technologies with emerging command and control, and situation understanding concepts. The end result will be a continuously evolving, end-to-end, joint, all-domain, command-and-control capability that will be reconfigurable and deployable.

This new capability will enable commanders to make rapid decisions based on actionable information and enhanced situation understanding of complex battle-spaces.

STaR Shot 8: battle-ready platforms

This STaR Shot may not be quite as sexy as our 'space STaR Shot', or our 'quantum-assured PNT STaR Shot', but it is no less important.

Maintenance of ADF platforms is a significant cost for Defence. Traditional maintenance approaches have been based on predetermined life cycles which often do not take into account the loadings placed on the platform nor the environment that the platform has been operating in. This has led to the reduced availability of platforms due to premature breakages or through maintenance on equipment that could actually have operated for longer before it is maintained.

With the advent of industry 4.0[2] and the emergence of digital twins, advanced data analytics, artificial intelligence, and advanced platform management systems, there is the opportunity to revolutionise the maintenance of our platforms and significantly improve fleet affordability. This STaR Shot will develop technologies that lower maintenance costs and improve the availability of platforms for operational service.

Defence Science and Technology STEM Workforce

The foregoing summary of the strategic plan gives you a broad understanding of each of the STaR Shots and what they will achieve. But the STaR Shots will come to nothing without a smart and innovative workforce behind them – specifically a 'STEM' workforce: graduates with skills in science, technology, engineering and mathematics.

This is a topic that is particularly close to my heart. Along with the STaR Shots, developing a highly-skilled, innovative, collaborative and inclusive workforce is a critical part of our strategy. You probably do not need me to tell you that STEM is where the careers of the future are. If you have a child of an influenceable age (*I have three*), then I would encourage you to open their eyes to the possibilities of a STEM career. Seventy-five per cent of the fastest-growing occupations in the world today require people with STEM skills.

In Australia, there is a growing dependence on the STEM workforce to drive innovation and ensure we remain competitive in a tough global economy. Unless we take action in the coming years, our demand for STEM talent will not be met.

Defence, in particular, recognises that to meet the defence and national security challenges of the future, it is critical that we build a world-leading, STEM-capable workforce. Inspiring students to choose a career in STEM, particularly in Defence and Defence industry, is a high priority.

I have the privilege of co-chairing the Defence STEM Council. The council was established in 2018 and brings together senior executives from across Defence and other government agencies to take a collective approach to progressing Defence's STEM workforce.

In 2019, we launched our strategic vision for our STEM workforce: "Moving towards a high-tech future for Defence". Through this vision, we hope to address some of the key challenges confronting our nation.

A critical issue is the decline in the performance of the Australian school system over the last decade, particularly in core STEM subjects of science and mathematics. We need to increase the ambition and motivation of students in STEM subjects.

There is also a need to make the vocational education and training sector more responsive to our future priorities. We need to ensure that we are accessing the best talent from all parts of a diverse Australian community to build the workforce.

Currently women represent only 16 per cent of Australia's STEM-skilled workforce. Significantly, more indigenous students are now enrolling in STEM courses, representing an 8.34 per cent annual increase: however, indigenous Australians are still under-represented in STEM courses. An inclusive lens on STEM engagement is needed to increase the representation of women and indigenous Australians in STEM, leading to a stronger and more diverse STEM workforce.

As a major employer of STEM skills, you will see Defence taking a leading role in shaping the national STEM agenda and communicating our workforce needs for the future. DST received the Athena Swan Award at the Science in Australia Gender Equity Awards, acknowledging institutional commitment to advancing the careers of women in STEM and medicine in higher education and research. This award demonstrates the priority and value Defence places on gender and talent diversity in STEM disciplines, and our commitment to ensuring that this is what drives us as we continue to grow our impressive STEM workforce.

Defence Science and Technology Infrastructure

I have touched on two key elements of our S&T Strategy for Defence: the STaR Shots and our workforce. The final piece of the puzzle is ensuring that we have outstanding infrastructure to power the innovation for which we are striving.

While state-of-the-art research networks, facilities and equipment are critical, our STaR Shots will usher in a new way of working that will see increased collaboration between government, industry and academia. To accom-

[2]The 'fourth industrial revolution', usually referred to as 'industry 4.0' (i4.0), is the ongoing transformation of traditional manufacturing and industrial practices by combining them with the latest computers, self-reporting smart sensors and similar smart technology.

modate this new way of working, we will be looking to establish Defence precincts at locations around Australia, where we can co-locate with our partners. It is a shift away from current arrangements, where collaborative arrangements are constrained by physical barriers, with our Defence scientists operating behind secure perimeters and firewalls. It is an exciting development and one that will allow us as researchers to truly embrace collaboration and all that it offers. Not surprisingly, there has been a lot of interest from our industry and academic partners in sharing infrastructure and the establishment of Defence precincts.

Conclusion

I am incredibly excited about the future of Defence science in this country. As we travelled around the country towards the end of last year, consulting on the strategy, it was clear to me that the research community is really keen to work with us. They are keen to partner on developing and growing a national STEM workforce. They are keen to work with us to develop innovative technology solutions for Defence.

There has been great interest in the STaR Shots. After many months of devising, consulting and refining our strategy, I am looking forward to putting it into practice. I am confident that it is the right strategy at the right time. It focuses our research efforts on fewer, mission-driven research priorities. Importantly, it provides the framework for transitioning ideas into capability. It will nurture, grow and develop the S&T talent pool, and permanently shape the national S&T enterprise as a key contributor to Defence capability.

History has shown that Defence-driven innovations can, and often do, have much broader applications which benefit society in general. I have no doubt that, with this strategy, we are putting in place the building blocks that will enable the transformational breakthroughs of tomorrow.

The Author: Professor Tanya Monro is a research physicist whose field is photonics, with a focus on sensing, lasers and new classes of optical fibres. She became Australia's Chief Defence Scientist in March 2019 and is also a member of the Board of the Commonwealth Scientific and Industrial Research Organisation.

Previously, she had been Deputy Vice Chancellor (Research and Innovation) at the University of South Australia. From 2005 to 2014, she was inaugural Chair of Photonics at the University of Adelaide, and served as the inaugural Director of the Institute for Photonics and Advanced Sensing, and the inaugural Director for the Australian Research Council Centre of Excellence for Nanoscale Bio-Photonics.

She is a Fellow of the Australian Academy of Science (FAA), the Australian Academy of Technology and Engineering (FTSE), the Optical Society of America (FOSA) and the Australian Institute of Physics (FAIP). Her awards include: the Prime Minister's Malcolm McIntosh Prize for Physical Scientist of the Year (2008); South Australian Scientist of the Year (2010); South Australia's Australian of the Year (2011); and the Eureka Prize for Excellence in Interdisciplinary Scientific Research (2015).
[Photo of Professor Monro: Department of Defence]