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Defence science and innovation

An affordable strategic advantage

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Australia's neighbours in the Asia–Pacific are building high-quality science, technology, engineering and mathematics research capacities and infrastructure. As a consequence, Australia's technological advantage in the defence domain is eroding.

To recover that advantage, our policy should be to make the most of the knowledge, capability and capacity in Australia's civilian science and innovation sector.

This special report analyses current and prospective Australian science, industry and defence science and innovation policy.

Taking into account the recently published report of the First Principles Review of Defence, the forthcoming 2015 Defence White Paper and the 2014 Industry Innovation and Competitiveness Agenda, this report considers:

- whether Australia is getting the biggest bang for its defence research dollar
- if not, what policy options might be available to provide better value for money
- how Australia's defence research and development compares against a number of international comparators
- how defence research and development might fit within the Industry Innovation and Competitiveness Agenda.

Executive summary

History shows that an innovative community can give a nation a competitive edge in times of conflict. But Australia's defence R&D community has recently been shaped more by legacy, short-term demands and budget pressures than by strategic purpose.

Three dynamics suggest that our defence science policy should be updated.

First, technological progress based on sustained investments in science, technology, engineering and mathematics education will play a greater role in regional and global security this century than it did in the previous one. As a leading scientific and technological nation with a relatively small population, Australia should capitalise on defence science as a cost-effective hedge against an uncertain security future—not least because defence science plays an important role in our alliance with the US and strategic partnerships across the 'Five Eyes' community.

Second, as a result of changes arising from the 2003 Kinnaird Defence Procurement Review, the Defence Science and Technology Organisation (DSTO)—the centrepiece of Australia's defence science ecosystem—now has a greater role in the provision of advice, such as capability and risk assessments, for the ADF and Defence as a whole. While this has fulfilled customer requirements, it raises two questions for the Australian Government:

- Could such advice be provided more effectively by the private sector, or by academia?

- Has the allocation of DSTO resources to the 'valued adviser' role been at the expense of Australia's defence R&D efforts?

In recent years, DSTO has undertaken multiple reorganisations in attempts to match its revised role with diminishing resources. Those changes have emphasised the provision of advice rather than new research efforts, so it was unsurprising that the First Principles Review couldn't discern a clear articulation of the value of DSTO's contribution to Defence outcomes.

Third, global R&D expenditure has doubled since 2000, led by private companies, universities and research institutions rather than by national defence organisations, as it was in the 20th century. Research is booming in the Asia–Pacific region, and China is projected to surpass the US in total R&D expenditure by 2020. While our regional neighbours invest proportionally more of their defence budgets in defence science, Australia's defence R&D funding has been more or less constant in real terms since 1975, and has thus fallen as a proportion of the defence budget.

Australian science and innovation spending (specifically, defence R&D spending) hasn't kept pace with real spending growth in other sectors. Government spending on general public services, health and housing has grown at more than twice the rate of spending on defence science.

As witnessed in Ukraine, the Middle East and elsewhere, a diverse range of state and non-state actors are gaining access to, developing and using sophisticated technological capabilities. The ADF needs to be prepared and equipped for a wider range of contingencies. An effective response requires greater agility, adaptability and cooperation on the part of Australia's entire science and innovation community. Such change requires significant reform because science and innovation are a medium- to long-term venture that provides greatest returns when undertaken on a sustained, planned basis over several years.

In the private sector, science and innovation are increasingly undertaken collaboratively between nations and across research institutions and companies. That model can be adapted to ensure that Australia's defence R&D effort remains effective:

- Treat defence R&D the same way we treat materiel acquisition—with an eye to harnessing competition and obtaining value for money.
- Focus DSTO's mission on areas that are not contested by private or public organisations or on areas in which DSTO can offer and demonstrate a better value for money or national interest proposition.
- Establish an Australian Defence Innovation Projects Centre to mobilise the 95% of Australia's research community and resources that are outside the Defence organisation. Such an initiative, separate from DSTO, would build on the success of the Defence Materials Technology Centre as part of efforts to build critical mass across academia, industry and the government research community to produce a viable defence innovation network.
- Separate the executive and scientific functions of the Chief Defence Scientist. The role of chief executive of a $400m+ p.a. government agency conflicts with the obligations of the role of independent scientific adviser to the Secretary of the Department of Defence, the Chief of the Defence Force and the National Security Committee of Cabinet. Separating those functions will improve the integrity of strategic management, the independence of scientific advice in a contestable force development process, governance and decision-making transparency.
- Introduce personnel management and security clearance structures in the wider research community to enable scientists and researchers to move as seamlessly as possible between academia and private and public laboratories, both in Australia and within the Five Eyes community.
- Develop more flexible staffing structures that can readily adapt to the emergence of disruptive technologies, and update recruitment, retention and career practices. Structures that limit external collaboration and workforce flexibility, and imbalances in gender and age, limit research productivity.

The best option to ensure that the ADF keeps its technological edge is to make the most of the full spectrum of Australia's R&D people and assets, from basic and applied research to small and medium-sized industries and advanced industries.

Introduction

A question for the Australian Government and the ADF is whether today's defence research ecosystem is fit for purpose. For defence research to be effective, investment must be commensurate with objectives that contribute directly to Australia's future strategic defence needs.

Rapid growth in the Asia–Pacific region is transforming major economies and reshaping geopolitics. Much of that growth has been enabled by new technology. In terms of people and funding, the total global investment in science and technology has never been higher.

Driven by competition, the nature of science, research and innovation has changed significantly over the past 15 years. However, for reasons explored below, the defence science ecosystem, which is largely driven by the public sector, has been slow to adapt.

The usual reaction of organisations responding to budget and staff cuts is to protect existing programs and activities. This creates conditions that discourage risk and inhibit innovation and is exacerbated by government signals that no new policy or program initiatives will be considered without offsetting savings. At a time when Australia faces significant strategic and disruptive technological challenges, this is not a strategic response for sustaining the ADF's technological edge.

In the 20th century, national defence budgets were prime drivers of technological development. Today, especially with the federal budget in deficit and significant fiscal constraints on public sector research in organisations such as the Defence Science and Technology Organisation (DSTO) and CSIRO, technology development is increasingly driven by the private sector in response to customer demands. New mechanisms need to be found to mobilise and harness the best and the brightest involved in public sector research, industry and academia to collaborate and network to solve the scientific and technological challenges emerging in the 21st century.

The First Principles Review of Defence also reached that conclusion:

- Recommendation 2.19: The Defence Science and Technology Organisation strengthen partnerships with academic and research institutions to leverage knowledge and create pathways with academia and industry.
- Recommendation 2.21: Defence, in partnership with academia and industry, review its research priorities, their alignment with future force requirements and capacity to leverage allied partners to promote innovation.

Science today is an increasingly collaborative and globally competitive endeavour. Scientists and engineers now work across institutions, nations, agencies, universities and companies in multidisciplinary teams to solve shared problems. This trend is driven by value-for-money efficiencies as resources, ideas and risks are shared and measured by the level of research and commercial success.

Science and innovation that will have a bearing on our national defence develop globally and are thus broadly accessible to individuals, organisations and nation-states. However, Australia's defence needs are unique, bound as they are by geography, competing interests and existing strengths. This creates a unique demand for onshore defence science capacity.

This report reviews Australian and international defence science efforts, noting research topics and priorities to illuminate the consideration of policy. It considers whether our current arrangements are fit for purpose and explores policy options to improve value for taxpayers' money.

> In the 2014 review of US Department of Defense strategy and priorities, the Chairman of the US Joint Chiefs of Staff, General Martin Dempsey, wrote: 'My greatest concern is that we will not innovate quickly enough or deeply enough to be prepared for the future, for the world we will face two decades from now.'
>
> — US Department of Defense, *Quadrennial Defense Review 2014*, Washington DC, online.

Australia's defence science footprint

Since ASPI last reported on Australia's defence R&D in 2010,[1] the defence R&D budget has come under pressure. Total expenditure on defence R&D has fallen steadily since 2011, and the government R&D share of the overall defence budget has dropped from 2% in 2008–09 to a forecast 1.1% in 2017–18 (Table 1). Between 2012–13 and 2017–18, DSTO is budgeted to reduce expenditure by around $169 million.

This significant downward adjustment hasn't been accompanied by policy announcements to explain the rationale behind it.

In a more complex security environment and with growing challenges posed by disruptive technologies, the drop in R&D expenditure undermines the technological edge that the ADF needs to prevail on the battlefield.

The DSTO element of the R&D budget broadly reflects this trend. In 2011–12, DSTO's budget amounted to $598.8 million. In 2017–18, it is forecast to be $384.4 million. Australian defence science and technology investment, as a proportion of defence spending, is less than that of the Netherlands, Canada, Sweden and Singapore. With respect to population growth, per person expenditure has more than halved since 1977[2]. When viewed in constant dollar terms since 1975, this suggests that DSTO's budget is returning to a 'peacetime' state: it declined after the end of our commitment to Afghanistan, just as it did after the Vietnam War, the Gulf War and the Iraq War (Figure 1).

Australia and the ADF have gained strategic, tactical and budget advantages from DSTO's R&D efforts through projects such as the Jindalee Operational Radar Network, the Nulka active missile decoy, the Laser Airborne Depth Sounder system and aircraft structural testing. However, with the change in DSTO's priorities and budget and staffing cuts, it's unlikely that such gains will continue. The long-term R&D that led to such innovative technologies is no longer a core function of the organisation. Unlike countries such as the US and Singapore, we don't entrust defence research to our university sector.

Of equal concern is the drop off in Australian commercial defence R&D. The latest statistics (for 2011–12) suggest that this component of the defence R&D ecosystem fell by around 20% in the previous two years. The 2008 global financial crisis and the shift in Defence acquisition policy to military-off-the-shelf and civilian-off-the-shelf platform solutions may account for some of that decline.

University defence research funding through the Australian Research Council (ARC) is also at risk. Following the establishment of the Safeguarding Australia national research priority in 2002, from 2004 to 2014 the ARC funded some 480 projects directly relevant to the defence and national security portfolios worth around $120 million (Figure 2). One project developed an improved method for detecting improvised explosive devices (see box).

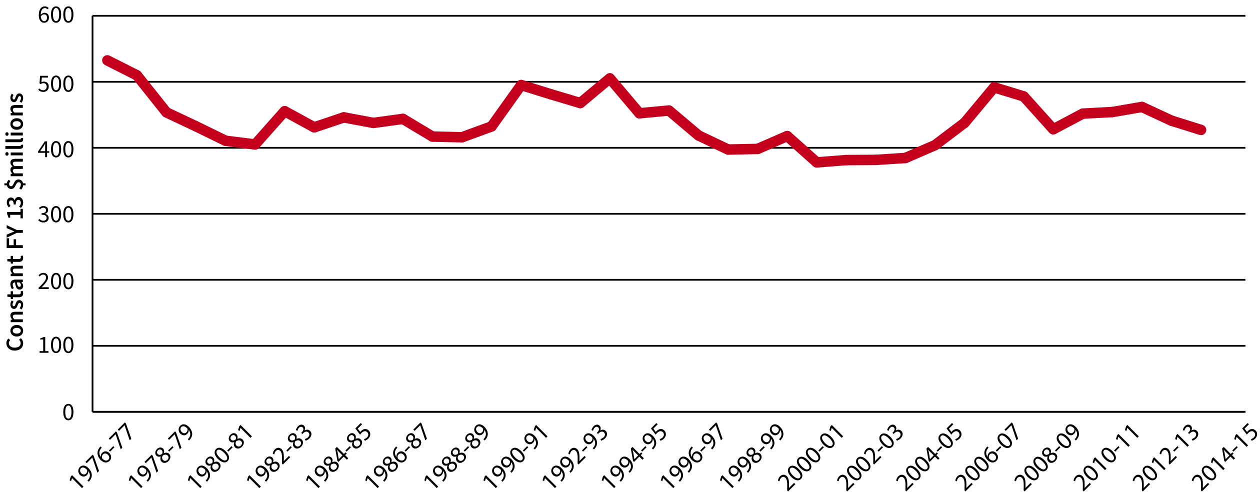
Table 1: Defence and defence R&D expenditure, selected years 2000–01 to 2017–18

	Defence budget ($m)	Total defence R&D ($m)	Govt defence R&D ($m)	Govt defence R&D (% defence budget)	Business defence R&D ($m)	Business share of defence R&D (%)
2000–01	14,453	401.1	238.6	1.6	158.1	39.4
2004–05	20,569	616.6	309.3	1.5	278.0	45.1
2008–09	24,081	800.9	486.0	2.0	259.4	32.4
2011–12	26,320	795.9	598.8	2.3	197.1	24.8
2012–13	26,940	n/a	553.8	2.1	n/a	n/a
2013–14	27,110		421.2	1.5		
2014–15	29,302		416.5	1.4		
2015-16	31,863		431.6	1.4		
2016-17	31,021		405.1	1.3		
2017–18	33,558		384.4	1.1		

n/a = data not available

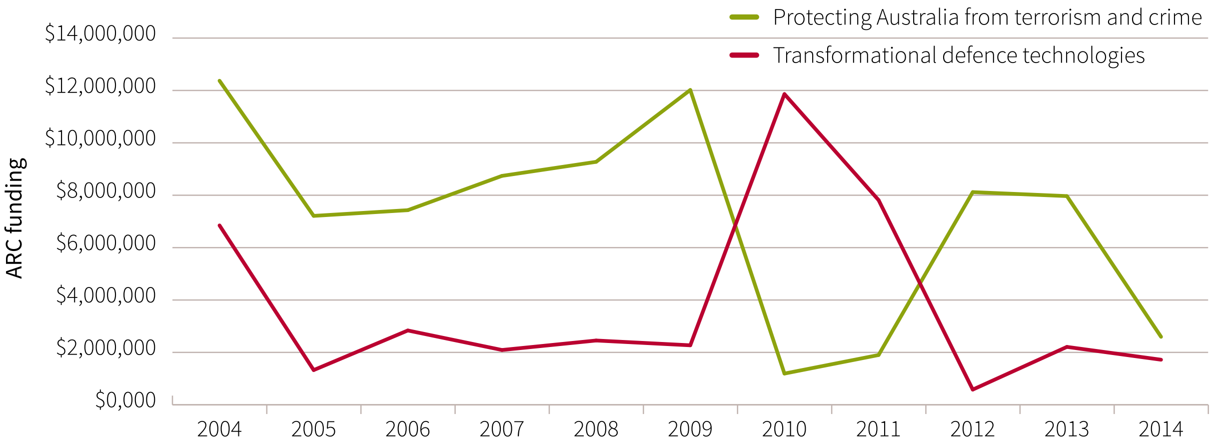
Sources: Australian Bureau of Statistics, cat. nos. 8109.0, 8104.0 (various), Defence Portfolio Budget statements—various.

Figure 1: Funding of DSTO, 1976–2014 (constant 2013 $ million)



Sources: Australian Bureau of Statistics, cat. no. 8109.0; Defence Portfolio Budget Statements; Reserve Bank.

Figure 2: Australian Research Council funding, Safeguarding Australia national research priority, 2004–2014



Source: ARC annual reports.

The national research priorities were discontinued in 2013, and a new set of science and research priorities is now under development.[3]

The loss of the Safeguarding Australia research priority (for which the ARC provided funding across the research sector) discourages rather than enables collaborative defence research.

The lack of a formal transfer or introduction mechanism for research outputs is also disappointing. Such a mechanism would allow research conducted under the auspices of the ARC to be demonstrated to prospective customers in the defence or national security domains and advanced from the laboratory bench to production and distribution supply chains.

Contrast the case study in the box on the next page with recent similar research conducted in Britain by Amethyst Research, which was funded under a call for proposals by the UK's Defence Science and Technology Laboratory's (Dstl's) Centre for Defence Enterprise to develop an infrared explosives and chemicals detector. Following the completion of that research, Dstl continued its involvement and introduced Amethyst to Selex ES, which has a credible supply chain for the manufacture and distribution of the detector.

Case study: Improved detection of explosives

Research into explosives identification has traditionally focused on detecting the metal in explosive devices. However, the ADF's experience in Afghanistan, Iraq and elsewhere has shown that improvised explosive devices don't necessarily contain metal, and many are placed in man-made environments that can contain multiple metal objects. The emphasis for explosives detection has therefore shifted towards detecting the explosive, rather than the metal.

With the assistance of ARC funding through a Super Science Fellowship, Dr Georgios Tsiminis and a team of researchers at the Institute for Photonics and Advanced Sensing at the University of Adelaide have developed a family of sensors that can detect minute quantities of explosives such as trinitrotoluene (TNT) and peroxide-based explosives. The explosives can be identified and quantified by using the interaction of the explosives' molecules with light guided through specialised glass fibres.

The sensors were developed over a three-year period and were completed and demonstrated in 2014. There are no plans to proceed any further.

Given the size of Australian Government defence procurements over the coming years, and the national security outlook, the new Commonwealth research priorities currently under consideration, in whatever combination, need to explicitly acknowledge and support defence and security-related research.

The Defence organisation uses several programs to encourage businesses and universities to invest in R&D, most notably the Capability Technology Demonstrator (CTD) Program and the CTD Extension Program. Funding for the competitive CTD Program, which has operated since 1997, has been through the Capability Development Group. The program has been administered by DSTO. Funding levels have varied over the years, depending on budget constraints and the number of worthwhile proposals.

CTD proposals are evaluated against a number of criteria, including the proposed technology's potential to contribute to defence capability development, its potential to transition into service and its level of innovation. Since 1997, some $250 million has been invested in 104 projects. In 2013, 94 had been completed, 86 had been demonstrated and 12 were in use with the ADF. In 2014, around $13 million was committed to fund seven projects.

Partly to economise, Defence has recently established the Defence Innovation Realisation Fund. The fund is to act as a clearing-house for various innovation programs supported by Defence, such as the Rapid Prototyping, Development and Evaluation Program, the CTD Program, the Defence Materials Technology Centre, Diggerworks and the Priority Industry Capability Innovation Program.

The Defence Innovation Realisation Fund is funded from the Defence Capability Plan and administered by DSTO on behalf of the Capability Development Group. With the disbanding of the group following the First Principles Review, funding will presumably be through the Capability Acquisition and Sustainment Group.

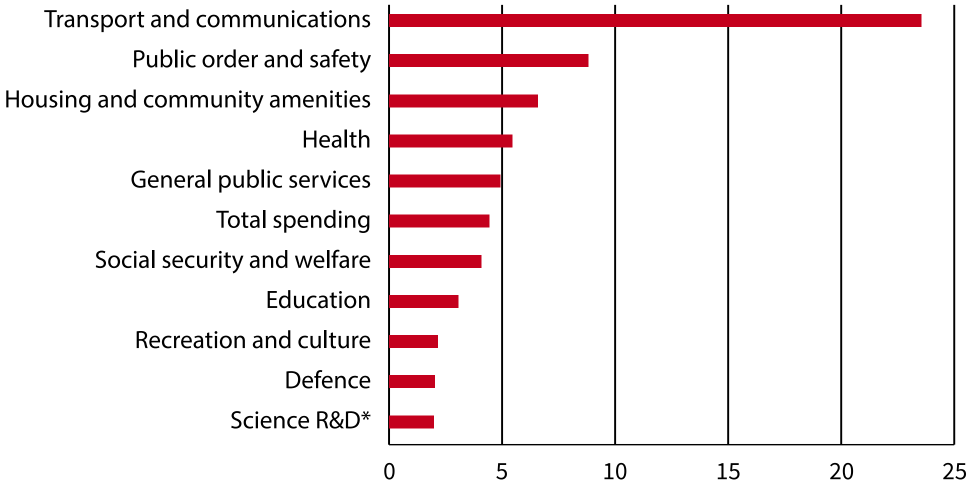
As rolling reviews and assessments have reported, the success of these programs is dependent on the level of funding available. R&D expenditure in Australia as a whole has failed to keep pace with real spending growth in other sectors, and the defence R&D subsector has stagnated (Figure 3).

Indeed, government investment in R&D as a proportion of government spending has fallen to a 30-year low (Figure 4). This places Australia near the bottom of the OECD ladder for R&D expenditure as a share of GDP.

While Australia's R&D expenditure has been much less than the OECD average, our R&D provides a high-quality return on investment.[4] Australia's share of the top 1% of the world's publications in natural science and engineering compares well with that of Western Europe, the US and Canada, and compares even more favourably on a per capita basis.

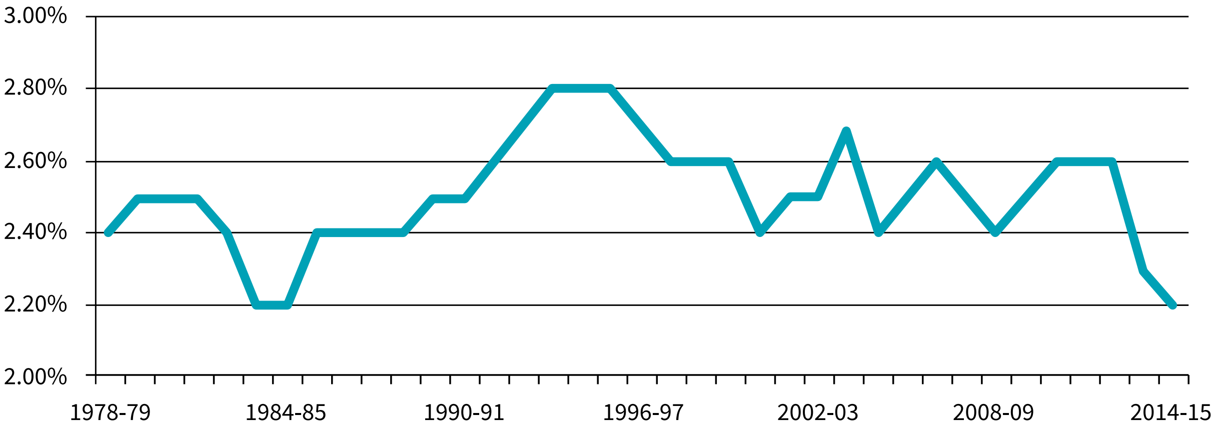
The approximately $300 billion gross expenditure on all science-related R&D in all sectors of the Australian economy since 2000 has not only delivered results, but has also produced world-class capacity. As the real and relative expenditure figures above make clear, growth, excellence, infrastructure and capacity have developed outside Defence. Given our economic and strategic circumstances, this is a major national capacity that should be leveraged for the benefit of the ADF. In many fields, we have global best practice problem-solving resources, specialist science and engineering infrastructure, highly trained talent, high-tech skills and world-class knowledge.

Figure 3: Real annual growth in budget expenditure since 1995–96 to 2014–15 (%)*



*R&D spending has failed to keep pace with spending growth in other areas. Includes spending from multiple portfolios.
Source: Fairfax Media data: Budget papers, Parliamentary Library.

Figure 4: Investment in R&D, 1978–79 to 2014–15 (% of defence budget)



Source: Fairfax Media data: Parliamentary Library, Budget papers.

However, our spending on defence science has diminished in recent years, and the strategic focus of that work has become blurred. Defence in the 21st century will increasingly depend upon technological advantage, so policymakers need to consider whether current arrangements are fit for purpose in the context of global trends in both general and defence R&D.

Fit for purpose: Australian defence R&D

The Defence R&D ecosystem is in many respects a legacy platform. The centrepiece of the system, DSTO, traces its modern antecedents back to 1974, when the Australian Defence Scientific Service, in-house R&D units of the Army, Navy and Air Force and the Science Branch of the Department of Defence were amalgamated.

In the context of the upcoming Defence White Paper, we need to consider whether the way DSTO is currently configured will give the ADF optimal support in the varied deployments and conflict scenarios expected in the future.

In 1979, DSTO had a staff of 4,900, of whom around 1,100 were professional scientists or engineers. Estimated expenditure of $100.7 million in 1979–80 covered salaries, other administrative and operating expenses, machinery, plant, stores and works, the services of 12 defence science establishments and laboratories, and the Woomera range. In 2015 dollars, that's about $410.7 million.

The funding in 1979–80 provided $10.5 million for basic research, $46.2 million for applied research and $30.8 million for experimental development. DSTO's mission then was described as:

> To provide scientific and technical advice on defence policy matters; to provide scientific and technical support to the Defence Force in its task of maintaining effective forces in being and for the development of the Force; to assist in the selection, acquisition and integration of defence materiel (weapons, sensors, platforms, systems); to maintain a technology base to support the Defence Force, the development of defence and defence industry; and to conceive and develop equipment suited to the defence needs of Australia.[5]

At present, DSTO consists of around 2,400 staff at eight sites across Australia and has an estimated expenditure of $431 million. The funds cover salaries and other administrative and operating expenses (expenditure associated with DSTO's facilities is managed separately within the Defence portfolio). The bulk of expenditure comes in the form of block funding through the Department of Defence.

Unlike in 1979, any money raised through external funding (outside of Defence and other Australian Government departments and agencies) is returned to consolidated revenue rather than reinvested. DSTO's current strategy is described by the Chief Defence Scientist as:

> … to build on our strength of being a **valued adviser** to government and to focus our efforts towards future Defence and national security capability by being a **collaborative partner** and an **innovation integrator**.[6]

Within Defence, DSTO has morphed into a 'one-stop shop' for defence science matters. Its priorities and resource focus have subtly shifted over the past few years. Following the 2003 Kinnaird review of defence procurement, more resources were allocated to respond to requests by the ADF and the department on the technological feasibility, maturity and overall technical risk of major defence acquisitions and capabilities.

Additional resources have been allocated in overcoming technology hurdles and system integration challenges and in reducing delays that have beset a number of big-ticket developmental 'military acquisitions', such as the Wedgetail airborne early warning and control aircraft, the Tiger and MH-90 helicopters, airborne refuelling tankers and, most recently, the air warfare destroyer. Those additional resources have been at the expense of a domestic defence R&D program.

Australia's partnership with the US provides unparalleled access to state-of-the-art defence platforms and systems as well as access to other areas of US military, R&D, intelligence and security organisations. As the relationship has grown closer, the ADF's interoperability with US forces has developed, as have the complexities of equipment and software integration. To its credit, DSTO has carved out a significant record of achievement in this area and developed a unique capability for solving difficult problems.

While Australia's defence science ecosystem has evolved, the development of global science and technology has been faster, and in directions difficult to predict. In the 1970s, worst-case scenario threats were limited to land forces coming to Australia by sea and long-range air attack, potentially with nuclear weapons. Global development and progress in international order have reduced such threats but new threats and disruptive technologies have emerged, enabled by economic and technological developments.

A variety of prospective disruptive technology threats are already appearing from the cyber, space and biological spheres. Equally, individuals or loosely arranged organisations are also harnessing emerging and relatively inexpensive technologies in creative ways to disrupt and to do harm.

In 2013, a series of NeXTech war games initiated by the US Department of Defense and led by the Noetic Organisation, an Australian-based company, identified a number of other technology areas with the potential to affect the future strategic environment. They included additive manufacturing, autonomous and semi-autonomous systems, directed energy and human performance modification.[7] Such complexities pose challenges at a number of levels for our defence and security infrastructure, which has been designed to tackle 20th century security challenges.

From the perspective of the ADF, competitive institutional responsiveness is needed to deal with future adversaries. Rapid technological change is a worldwide trend, and the adoption of new technologies can accelerate strategic surprise (consider the role of social media in the 'Arab Spring'). As asymmetrical warfare becomes an operational norm, countering the rapid adoption of emerging low-cost technologies, such as drones and cyber weapons, by non-state actors will be increasingly important to our defence. Importantly, effective countermeasures are by definition not available off the shelf.

If communities, markets and adversaries are able to adapt faster than our defence bureaucracy, then our defence capacity will become less effective. If we're not in the business of creating new ideas and rapidly turning new ideas into new effects, the ADF will become slower to respond and less effective over time.

> In order to continue to maintain our technological advantage and stay on the cutting edge of technology, we must be willing to take risks in our innovation and creative thinking.
>
> —Chuck Hagel, Secretary of Defense, *'Defense Innovation Days' opening keynote (Southeastern New England Defense Industry Alliance)*, 3 September 2014.

Drift

Over the past 15 years, the external drivers of defence R&D have included the ADF's high operational tempo (more than 30 operations, with a focus on the Middle East area of operations) and, more recently, falling government revenue after the mining boom, which has resulted in the series of budget cuts noted above. Internally, DSTO's very high turnover of decision-makers has not helped its cause and has limited the formulation and management of strategic planning for defence science.

Since 2000, there have been five chief defence scientists, 10 assistant defence ministers (with responsibility for defence science) and nine defence ministers.[8] The average joint duration of a Chief Defence Scientist and both levels of minister has been less than a year, and the longest duration less than two years. In response to operational needs, particularly combat operations and budgetary pressures, successive leaders have directed fewer resources (relative and actual) to longer term strategic research.

An acquisition/capability approach to defence science management would ensure greater strategic consideration and medium- to long-term control. This would allow stability, which would provide capacity to plan and time to undertake high-impact research. It would also ensure that the strategic objectives are pursued. This would require formal medium- to long-term input by the ADF on research directions and assessments.

The current model provides few incentives for innovation to meet Australia's unique defence needs, according to our geography and strategic interests. It also encourages the maintenance of the status quo, rather than promoting innovative approaches and risk-taking in research. Under the current framework, in the absence of a customer requirement, the likelihood of DSTO developing a promising blue-sky technology is remote.

Indeed, given modern R&D practices, the extent of collaborative engagement defines the likelihood of deploying major innovations. The lack of such progress in the past few years has reduced collective confidence in our capacity for defence innovation.

The metamorphosis of DSTO, Australia's premier defence research establishment, into a technology management advisory body has probably been less a consequence of deliberate strategic policy and more a response to short-term political, financial and acquisition expediencies. It was unsurprising that the First Principles Review team was unable to discern a clear articulation of the value of DSTO's contribution to Defence outcomes.

While DSTO provides highly qualified expertise to the ADF, its infrastructure and human resources remain mostly geared for pre-2000 science and technology. This suggests that the talents of its scientists, technicians and engineers, along with its specialised facilities, equipment and resources, may be underutilised. Within the defence portfolio, significant scope exists to update R&D structures and introduce more flexible working arrangements that enable the broader science and innovation community to be more actively engaged.

Applying a defence acquisition/capability funding approach, either partly or wholly, would also allow the ADF to have more of a say on research directions and the measurement of deliverables.

DSTO's change of its main role to 'valued adviser'[9] suggests that it brings to defence and national security expertise that is not and will not be readily available from the private sector or academia. It also suggests that strategic defence and national security research is no longer a worthwhile government undertaking. These assumptions should be questioned.

The ability of any organisation to remain fit for purpose lies in part in its ability to adapt. Because risk aversion is a characteristic cultural trait of advisory bodies, DSTO's change of focus is a concern for defence technology innovation and for DSTO as an organisation.

The role of defence science as a key element of the art of warfare has been subsumed in the quest for savings and by risk assessment and risk mitigation activities. Given the power and availability of modern high-tech weaponry (particularly in the hands of non-state actors), our defence science investment should be considered in the same manner as materiel acquisitions.

Covering the waterfront

The *Defence issues paper 2014* noted that 'Australia has long had a highly capable DSTO that works to enhance ADF equipment and personal performance.'[10] Key questions for the 2015 Defence White Paper to address are to ask: How Defence should best use science and technology capabilities in coming years? How can innovation be promoted more effectively? How should Defence draw on the private sector and Australia's university and research sectors to help sustain and improve critical military capabilities?

There's no doubt that DSTO has proven itself in certain disciplines, such as radar, weapons systems and system integration, and that it includes a cadre with unique world-leading skills and expertise, but whether the current model of covering the entire defence R&D waterfront makes sense is another matter.

The 2015 Defence White Paper will produce a medium to longer term plan informed by R&D needs, threats and opportunities, including some accommodation for the unknown in future technological developments. Government expenditure on both civilian and defence R&D will be constrained for the foreseeable future, so we should make sure that our defence research ecosystem functions efficiently, as well as effectively.

This approach has been adopted in the UK, Japan and Canada. Together with the US, these countries recognise that it's no longer practical to have defence research institutions that cover the entire waterfront.[11] Rather, their governments have decided (and in some cases mandated) that government funding be redirected to universities and industry to solve defence and national security problems.

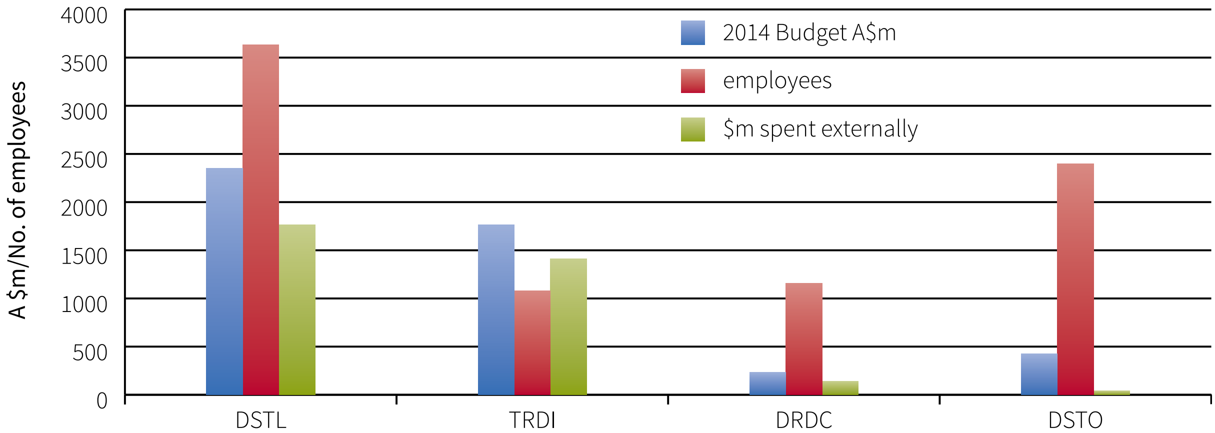
A range of relationships and agreements support DSTO activities with firms and universities. Yet, despite the arrangements, DSTO directs only 5%–10% of its budget to industry and academia. If Defence funding administered by DSTO is included (such as the CTD Program), the proportion increases to 20%–30% (Figure 5).

In contrast, the UK's Defence Science and Technology Laboratory (Dstl), which has around 3,600 employees and a budget of £617 million for defence-related activity and £661 million for non-defence (national security) related activity, outsources more than 75% of its research budget. Similarly, Canada's military research laboratory (Defence Research and Development Canada) consists of 1,160 employees and spends more than 60% of its C$270 million research budget externally. Japan's Technical Research and Development Institute (TRDI), with 1,082 employees, allocates about 80% of its budget to industry and academia.

In the US, the Naval Research Laboratory contracts out around 54% of its budget to external providers, while the scientific research arm of the US Air Force contracts around 70%. The US Defense Advanced Research Projects Agency (DARPA), which operates with around 240 employees, commits its entire research funding allocation of US$2.8 billion to industry, universities and other research bodies.

To provide impetus to agencies to outsource as much of their budgets as possible, the US Government introduced the *Federal Technology Transfer Act* in 1986 to encourage the commercial use of technology developed in federal laboratories. The Act allows government inventors and the laboratories where they work to share royalties generated by commercial licensing of their inventions. It also encourages the establishment of cooperative research and development agreements between, for example, national research laboratories and non-federal entities, such as state and local governments, universities and business corporations.

Figure 5: Defence R&D expenditure, employees and A$m spent externally, UK, Japan, Canada and Australia, 2013–14



Dstl = Defence Science and Technology Laboratory (UK); TRDI = Technical Research and Development Institute (Japan); DRDC = Defence Research and Development Canada; DSTO = Defence Science and Technology Organisation (Australia).

Sources: Dstl, TRDI, DRDC & DSTO budget statements.

Case study: Precision inertial sensing—an example of DSTO making a difference.

In 2011, the Australian National University (ANU) Quantum Sensor and Atom Laser Group teamed with DSTO to embark on the construction of a cold atom precision inertial sensor, a gravimeter, that would be the prototype for future field-deployable sensors for defence and national security. The project was funded through DSTO at a little more than $1 million over one year.

The task of improving the sensitivity of existing ANU sensors by five orders of magnitude was a substantial one for a small team. However, the decision to go ahead was made after careful consideration of the advanced nature of the cold atom sources, optical sources and precision coupling of light and matter, which the ANU team had developed over the previous decade.

The project was completed a few weeks ahead of deadline and on budget. The gravimeter was comparable in sensitivity to the very few existing precision cold atom devices around the globe and catapulted Australia to the forefront of this research field. Since then, the group has received a further $400,000 in funding from DSTO to continue to develop the device.

Stable funding would enable the team at ANU to engineer this device into a field-deployable unit that could substantially enhance the ADF's capability in a variety of critical scenarios.

Security concerns are often cited as a reason why independent advice or services can't be obtained externally by Defence or DSTO. In a submission to the Productivity Commission in 2006, Professor Donald Sinnott queried the extent to which national security might be compromised by moving away from in-house provision:

> Without detailed inside knowledge, which security considerations would normally preclude, it is difficult for an 'outsider' to challenge such agency judgments. But circumstantial evidence points to the fact that the 'security/confidentiality' flag is all too readily used to ensure research is kept in-house. For example, in other countries defence research, some of it heavily classified, is carried out in many universities to a far greater extent than in Australia. In the US, as the draft research report notes, the Defence Advanced Projects Agency (DARPA) spends its entire massive research budget externally.[12]

The Industry Innovation and Competitiveness Agenda

In 2014, the government released an action plan for a stronger Australia—the Industry Innovation and Competitiveness Agenda. The plan included initiatives to strengthen Australia's competitiveness by:

- reducing the burden of regulation and taxation
- increasing student engagement in science, technology, engineering and mathematics (STEM)

- attracting highly skilled migrants to address short-term skill gaps
- establishing 'growth centres' covering five promising industries:
  - food and agribusiness
  - mining equipment, technology and services
  - oil, gas and energy services
  - medical technologies and pharmaceuticals
  - advanced manufacturing.

The government also signalled that it would work with industry and researchers on a plan to focus its $9 billion per year investment in research to achieve a better commercial return. It said that particular attention should be paid to:

- working with the research sector and industry to identify and implement policy and program changes to ensure that the research effort addresses national priorities and supports the translation of research into commercial outcomes
- sharpening incentives for collaboration between researchers and industry, ensuring that research training adequately prepares researchers, and supporting the provision and maintenance of world-class research infrastructure.

The agenda made no mention of defence innovation as a potential growth driver for the economy. It's hoped that this omission will be corrected in the upcoming Defence Industry Policy Statement.

In addition to the work on Australia's national research priorities, led by Australia's Chief Scientist, Professor Ian Chubb, the Chief Scientist is also looking for initiatives to lift Australia's STEM profile. In September 2014, the Office of the Chief Scientist published *Science, technology, engineering and mathematics: Australia's future*,[13] which was based on a 2013 position paper titled *Science, technology, engineering and mathematics in the national interest: a strategic approach*.[14] *STEM: Australia's future* calls for a whole-of-government approach to investment in STEM.

The second meeting of the Commonwealth Science Council, held in April 2015,[15] agreed on a further work program, including the government response to the *STEM: Australia's future* report and the adoption of science and research priorities. The meeting communiqué stated that the strategic science and research priorities would be announced shortly.

Pertinent to defence science and industry is the point, made in *STEM: Australia's future*, that 'Collaboration also lifts the capacity of Australian SMEs to break into global value chains, at the high-value end where we can compete.'[16] A key recommendation for government is to adopt an international strategy for science, research and education that provides for collaborative activities, excellence-driven institutional and individual collaborations, and business partnerships.

Current defence procurement plans suggest that Australia will spend some $50 billion offshore during the next decade.[17] Significant procurements likely to be foreshadowed in the 2015 Defence White Paper include replacements for our frigates, land combat vehicle systems and submarines.

Unlike other nations, Australia steers clear of using its national government's purchasing power to drive innovation. However, the OECD considers that, as a large-scale purchaser of goods and services, the public sector is in a strong position to promote innovation by being an informed and demanding buyer.[18]

Part of the problem is a lack of effective mechanisms to foster innovation through promoting greater collaboration between suppliers and the government as a customer.

In 2013–14, funding to take research from discovery to defence acquisition amounted to $15 million (not including co-investment from the research sector or industry). With the exception of the Defence Materials Technology Centre (government, $7 million; industry, $4−6 million; research sector, $8 million), current programs focus relatively modest resources on industry development.

While improvements have been made over the past several years to engage the rest of Australia's R&D ecosystem, those improvements have occurred off a very low base. In terms of real and relative investment, the level of engagement remains inadequate. Given Australia's fiscal position, the country can't afford the luxury of operating a defence R&D model largely independent from the rest of the Australian research community.

We need to develop programs and initiatives that seamlessly integrate the two and provide incentives for Australian civilian researchers to become involved in solving and addressing defence and national security problems and challenges. Other countries are productively using a variety of mechanisms to leverage their civilian R&D base to address defence challenges. In Australia, this legacy separation is hindering defence science productivity.

Two programs operating in the US have a proven record of success in harnessing civilian researchers and R&D for the benefit of defence:

- Small Business Innovation Research Program

  The US Congress created the Small Business Innovation Research (SBIR) Program in 1982 to help small businesses participate more actively in federal R&D. All federal government departments and agencies with an extramural R&D budget exceeding $100 million are required to participate in the program. SBIR is the largest source of early-stage technology financing in the US. Total federal SBIR funding in financial year 2013–14 amounted to $2.5 billion. The US Department of Defense accounts for nearly half of the total program. The program funds early-stage R&D in small technology companies and is designed to stimulate technological innovation, increase private sector commercialisation of federal R&D, increase small business participation in federally funded R&D, and foster participation by minority and disadvantaged firms in technology innovation.

- Defense Advanced Research Projects Agency

  DARPA was created to fill a gap between the work of the military service R&D organisations (the equivalent of DSTO) and fundamental research in which new science, new ideas and radical new concepts emerge. Through the management and direction of basic and applied R&D projects, DARPA advances research and technology where risk and pay-off are high to very high. The agency seeks to mine fundamental discoveries, accelerate their development and lower their risk until they prove their promise and can be adopted by the services.

DARPA operates with low overheads, directing 90% of its funding to a mix of university-based researchers, start-up firms, established firms and industry consortiums. There's no dividing line between basic research and applied research, since the two are deeply intertwined. The goal is to produce usable technological advances. DARPA's mandate extends to helping firms get products to the stage of commercial viability.

In support of DARPA's 2015 open call for new technology, DARPA Technology Transfer Office Director Dr Brad Tousley said, 'We're looking for ideas that show significant promise to enable revolutionary new mission capabilities, significant increases in mission effectiveness and dramatically reduced system costs.'[19] Part of DARPA's task is to use its oversight role to link ideas, resources and people in constructive ways across different R&D sites.[20] Projects are typically 3–5 years in duration and have a strong focus on end goals. Ambitious public 'grand challenges' harness the talents of world-class experts drawn from industry and academia to work in temporary teams on projects of relatively short duration.

Google has adopted the DARPA model,[21] and similar organisational structures have been established to support the US intelligence community (IARPA), the Energy Department (ARPA-E[22]) and Homeland Security (HSARPA[23]). Other countries have also adopted and adapted the DARPA model to suit their particular circumstances.

Outsourcing defence science

In December 2014, the Australian Government released a ministerial paper titled *Smaller government—towards a sustainable future*, which sets out a new governance policy.[24] The policy seeks to ensure that government decisions to establish new bodies, or to review existing ones, accord with the most efficient governance arrangements for the delivery of government goods and services.

A three-stage 'gateway' process tests whether:

- the Commonwealth has the constitutional power to undertake an activity
- there's an advantage in delivery through a government provider, as opposed to a non-government provider
- the activity can be consolidated into an existing body or warrants a new autonomous structure.

Reviews of the departments of Education and Health have been completed and the 2015 Budget signalled that a further eight departments and agencies would be reviewed in 2015–2016 to determine whether the current functions are aligned with the Government's policy priorities and whether they're working as efficiently as possible.

The idea of outsourcing DSTO was noted by the 2014 National Commission of Audit,[25] whose recommendations formed part of the terms of reference of the First Principles Review of Defence.[26]

The National Commission of Audit recommended that 'DSTO should be assessed for its outsourcing potential',[27] noting that DSTO 'was not tested as part of Defence's earlier outsourcing efforts'. The question of outsourcing DSTO has been looked at in past reports, including *Future directions for the management of Australia's defence* in 1997[28] and *DSTO's External Engagement and Contribution to Australia's Wealth* in 2004[29] Neither report recommended outsourcing.

The National Commission of Audit suggested that the Department of Defence 'should compare a fully costed in-house bid to that offered by industry to provide confidence that the chosen option represents best value for money' because the 'default position should remain that, apart from combat and combat-related functions, all Defence activities are contestable'.

The First Principles Review was completed in April 2015. The findings will inform the development of the 2015 Defence White Paper.[30] Insofar as outsourcing DSTO was concerned, the Review sensibly recommended that:

> Whilst wholesale outsourcing [of DSTO] would not be wise, there is more opportunity to outsource elements to the broader scientific community, particularly in industry and academia. **We recommend that strong partnerships be established with key academic and research institutions to leverage the knowledge of scientists and create pathways into and out of academia and industry.**[31]

The 2009 and 2013 Defence White Papers paid attention to Australia's defence science and technology effort. Each included a chapter outlining Australia's defence science interests and needs. While both chapters guided important initiatives to strengthen defence science, including engagement with academia, their main weakness was that the focus was DSTO-centric. Given the recommendation of the First Principles Review, it's hoped that the 2015 White Paper will pay more attention to the instruments that might be used to establish strong and transparent partnerships with academia and industry.

In all areas of research, the efficient and effective use of an institution's resources necessitates timely access to national and international science infrastructure, data, talent and services. While obvious security considerations exist, making the best use of the vast majority of Australia's research infrastructure, which is outside DSTO, to build our strategic defence is the key.

One way to achieve this would be to scale up academic and defence industry engagement by building on the original concept behind the successful Defence Materials Technology Centre. For example, an Australian Defence Innovation Projects Centre (ADIPC) could co-fund joint academic, public and private sector projects that tackle emerging disruptive technologies of concern and interest to the ADF.

Such an initiative, which would have attributes of the DARPA model, would reinvigorate the Australian defence R&D agenda and provide a focal point for commercialisation efforts. This initiative should be equipped with the capacity to attract the best and the brightest involved in public sector research, industry and academia to meet 21st century defence scientific and technological challenges. One goal of the ADIPC would be to mobilise the 95% of Australia's research community and resources that are outside Defence for strategic defence needs.

As the Defence Materials Technology Centre has demonstrated, research sector and industry collaborators are willing to commit necessary co-investment and accept associated risks if the program is designed efficiently from the beginning and overheads are kept to a minimum. However, significant returns won't be gained from the $9 billion Australian research system (and those of our allies) if strategic collaborative investment is less than the critical mass required to carefully spread risk and bring about collaborative arrangements that can compete internationally.

Australia's defence research and industry sector doesn't have the function provided in the US by DARPA: Defence-led management and direction of basic and applied R&D projects within industry and academia. In the past, part of DSTO's task was to do such basic and applied research as was regarded as sufficient for ADF and national security needs. The real and relative diminution of defence science budgets over the decades and the booming globalisation of R&D both suggest that it's time to seriously consider revamping the current model and building on a concept that's been able to attract and mobilise private and academic interests and resources.

The DARPA model was acknowledged in the recent Australian Technology Network of Universities report prepared by PricewaterhouseCoopers titled *Innovate and prosper: ensuring Australia's future competitiveness through university–industry collaboration*, which was released by the Minister for Industry and Science on 30 March 2015.[32] The report stated that 'DARPA represents an impressive example of government, industry and university collaboration with relatively small investment from companies and universities in projects with short timescales.'[33]

By contrast, current Australian efforts ($15 million p.a. or 3% of the defence R&D budget, excluding collaborative co-investment) are spread thinly across the maturity spectrum. The programs are small, with unnecessarily high overheads in staff, application and monitoring costs.

Several times that investment in defence–academic–industry collaboration is needed to stimulate and leverage emerging Australian science and technology and problem-solving ability to deliver revolutionary mission capabilities (see box), dramatically reduced system costs, or both.

Submarine tech

Over the next 10–15 years, remotely operated underwater vehicles are likely to have a disruptive impact similar to that of remotely operated aerial vehicles over the past 15 years. Major navies are already operating such platforms to complement their submarine forces and perform tasks that would otherwise put their sailors at risk.[34]

In Australia, the proposed ADIPC could enable collaboration among the Royal Australian Navy, DSTO, CSIRO, the Australian Maritime College, the gas and drilling industry and Australian universities on a long-term R&D program to develop such capability. The Navy's cutting edge would be sharpened by this strategic collaborative research response to this potentially game-changing technology.

Given their mutual interest in underwater drones, the UK, Canada and New Zealand could also collaborate, thereby using their research and industrial capacity for mutual benefit.

Functions of the office of the Chief Defence Scientist

Another element of Australia's legacy platform requires a rethink: the two hats worn by the Chief Defence Scientist (CDS). The CDS is not only the government's principal adviser on defence science matters but also the chief executive officer of DSTO. While the First Principles Review recommendation that DSTO become part of the Capability Acquisition and Sustainment Group[35] was rejected, the scientific advisory and strategic management roles should be distinct.

After the 2003 Kinnaird review of Defence procurement, the government provided the office of the CDS with a remit to provide independent advice. In practice, because DSTO's advice is 'on tap' and the CDS is 'responsible for DSTO's wellbeing', there's an incentive to discharge both responsibilities in a mutually supportive fashion. This is a sensible attitude for a leader of a government agency, particularly in times of budgetary constraint and interdepartmental and intragovernmental competition for funds.

However, because scientific and technical knowledge is increasingly found across disciplines, institutions and countries, there's a growing tension between how to acquire best available advice and how to advance one's own agency. Practically, there's some degree of disincentive to go beyond DSTO or Defence to form judgements, solve problems and advance research.

Separating the executive and advisory functions of the CDS office would ensure that distinct responsibilities are assigned for the strategic management of the science and technology organisation and for the scientific leadership of research, development, testing and evaluation (RDT&E) within the Department of Defence and the national security community.

A separate chief executive officer to lead and manage DSTO would enhance governance and decision-making transparency. The CDS would have a clear remit to lead research and to secure and communicate the best possible scientific and technical advice available within Australia, from international academia and from the defence science and technology agencies of our allies.

With a separate role, the CDS could pay greater attention and apply more scientific expertise to the quality and timeliness of technical advice provided to the ADF service chiefs, the Capability Acquisition and Sustainment Group and the Defence Materiel Organisation, and subsequently to procurement assessment gateway reviews for capital acquisition projects. Sitting outside DSTO, the CDS would report to the Secretary of the Defence Department and have advisory obligations to both the Chief of the Defence Force and the National Security Committee of Cabinet. Greater attention and management expertise would be afforded to the CEO of DSTO to manage the strategic interests of a major research organisation.

In the UK, the roles are separated. The UK's Chief Scientific Adviser is responsible for providing strategic management of science and technology issues in the Ministry of Defence, most directly through the ministry's research budget of well over £1 billion. The Chief Scientific Adviser also sits as a full member of the Defence Management Board and the Defence Council, the two most senior management boards within the ministry.

The chief executive of Dstl (the UK's equivalent of DSTO) is responsible for ensuring that the requirements for managing public monies are met and that proper procedures are followed for securing regularity, propriety, value for money and feasibility in the handling of the public funds administered by Dstl.

In the US, the chief executives of the various defence research laboratories and establishments are separated from those in the Pentagon responsible for the strategic management of science and technology issues and the overall distribution of the federal defence science and technology budget.

Personnel limitations

Technological trends also influence the ability of research organisations such as DSTO to recruit and retain high-level talent. DSTO is in a difficult position, as a significant cadre of scientists and researchers recruited during the 1980s and 1990s is reaching retirement age. Australian Public Service and Defence recruitment freezes and staff cuts over several years are hindering DSTO's ability to refresh its pool of researchers, engineers, scientists and technicians. It's a major concern that graduate recruitment rounds have been restricted or cancelled over the past three years.

Adapted recruitment and retention practices are needed to attract and retain high-quality staff and to redress chronic gender and age imbalances. The inefficiencies caused by retirements and the under-representation of women in researcher and scientist ranks should be addressed by ensuring that external collaboration mechanisms enrich potential career paths. Greater collaboration with both industry and academia can also address the STEM education challenge,[36] which is currently a focus of government science policy.

As evidenced by the disruptive technologies on the horizon, Defence and DSTO need to establish a human resource model that encourages mobility among the defence research community. The skilled scientists and researchers currently employed mightn't necessarily be the scientists and researchers needed to address those technologies.

An ability to apply talent, internally and externally via collaboration, to emerging challenges will be a pivotal capacity. To strengthen that capability, we urgently need to implement a security clearance framework for researchers in academia and other government research agencies. It should be modelled on the current contractor security clearance framework, prequalifying researchers to allow them to work on defence and national security research projects.

Successive budget cuts and reforms (driven by continuous reviews) have diminished and fatigued DSTO's human resources. Because certain highly educated specialists are in very high demand in the mining, banking, manufacturing and IT sectors here and overseas, we need to provide stability, career structure and strategic purpose to compete against higher salaries on offer elsewhere.

Consideration also needs to be given to enabling academics and researchers from other government research agencies to transition employment conditions of service and superannuation arrangements so that they're not disadvantaged while working on defence-related R&D projects.

The lack of security clearances and the transfer arrangements for working in a government defence laboratory have previously restricted and delayed research associated with defence activity. Investment is also needed to put in place secure rooms and secure IT capability in university and research institute buildings to allow researchers and scientists ready access to required infrastructure and to aid timeliness.

International trends

Despite the 2008 global financial crisis, annual global investment in science and technology has more than doubled since 2000. Today, it's estimated to be US$1.6 trillion per year,[37] of which the Australian Government funds $9 billion, producing approximately 3% of the world's research and 4% of citations from 0.3% of the global population.

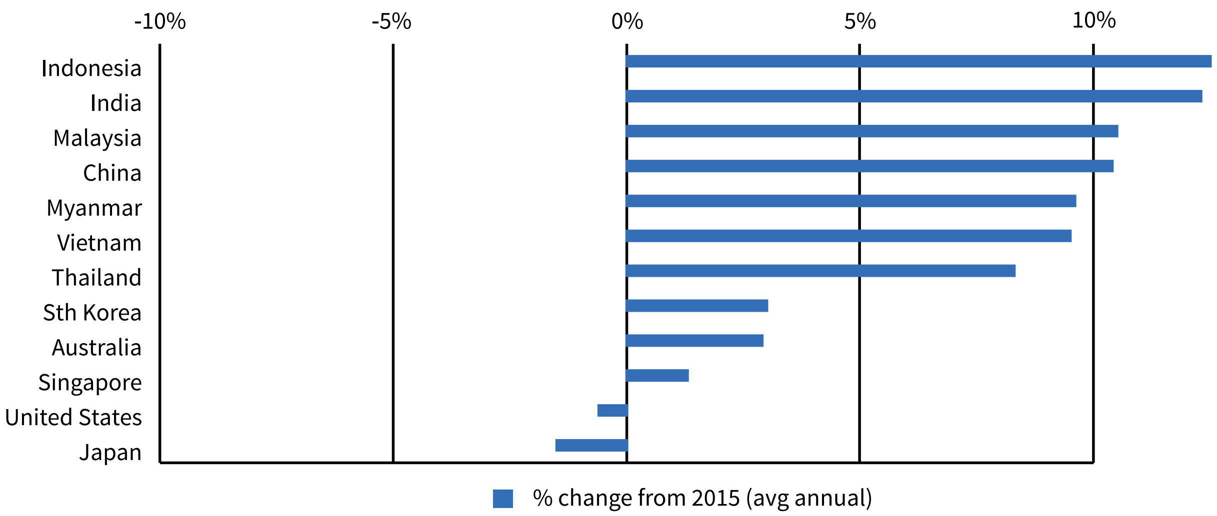
Research is booming in the Asia–Pacific. China is projected to surpass the US in total R&D expenditure by 2020, having recently overtaken the EU. In physics and astronomy, it's now the leading producer of citable documents.[38] Driving this transformation is China's policy to spend 2.5% of GDP on R&D by 2020.[39] Today, its research intensity is on par with the EU28 average (2%). China now has six universities in the top 200 of the Shanghai ranking,[40] compared to just one in 2005.

Australia's regional neighbours are investing proportionally more of their budgets in R&D. This extends to defence RDT&E: IHS Jane's data suggests that, on current budget projections, Australian RDT&E growth will lag behind eight countries in the Asia–Pacific region by 2021 (Figure 6).

The process of science, research and innovation is changing in response to increased investment, cheaper communication and the proliferation of technological endeavours worldwide. These changes influence Australia's overall strategic environment and outlook.

Science today is highly collaborative and globally competitive, and scientists and engineers increasingly work across institutions, nations, agencies, universities and companies in multidisciplinary teams to solve shared problems.[41] The trend is driven by the quest for efficiency, as resources, ideas, talent, data, knowledge and risks are openly pooled.[42] This networked approach affords ready access to tools and resources, which increases responsiveness to discoveries and technological developments and as a result transnational collaborations are increasing rapidly.

Figure 6: Defence RDT&E, projected average annual change from 2015 to 2021, selected countries (%)



Source: Graphic by Inga Ting; data from IHS Jane's (January 2015).

At his ceremonial swearing-In on 6 March 2015, US Secretary of Defense Ash Carter said:

> As technology and globalization revolutionize how the world works, and also as the Pentagon's budget tightens, we have the opportunity to open ourselves up to new ways of operating, recruiting, buying, innovating, and much more. America is home to the world's most dynamic businesses and universities. We have to think outside this five-sided box and be open to their best practices, ideas, and technologies.[43]

Since the global financial crisis, a number of countries in the OECD have repositioned their R&D and innovation policies to capture the benefits of this networked approach and to expedite the process of turning scientific discovery to commercial or national applications.[44] Such initiatives have included Germany's new 'high-tech strategy',[45] the UK's Catapult Centres[46] and the US's Advanced Manufacturing Partnership.

Currently, Australia is ranked in the bottom quartile of OECD countries for business-to-research collaboration. For strategic and economic reasons, we need to adjust to this evolving technological networked revolution.

Conclusions

The adaptation of Australia's defence R&D engine is warranted because our defence science footprint is diminishing at a time when our strategic outlook is becoming much more complex and global technological and defence science trends are rapidly evolving. Fortunately, appropriate adaptation is manageable and would be a cost-effective strategic investment, especially as we can leverage most of our public and private research sectors.

Australia's assets don't include cheap labour, a huge population or vast capital. However, we have an advantage that most countries lack: deep technological problem-solving expertise, born from decades of public investment.

The upstream infrastructure that offers Australia's universities, research institutions and industry opportunities to collaborate with Defence on basic and applied research challenges needs to be rebuilt. Refocusing DSTO on strategic basic and applied research and rebalancing defence science resources to enable effective collaboration and networking (to a level more closely mirroring that adopted overseas) is one approach.

The siloed internalised nature of Australia's defence R&D system is inconsistent with how defence R&D is being conducted by Australia's allies, which engage in a highly collegial and globally networked endeavour. The other major difference is our level of expenditure. Current policy, which can be seen as 'cut back to only essential needs', is short-sighted.

The changing nature of technological progress, especially globalisation and commercialisation, suggests that an internal advisory defence science function is unlikely to meet Australia's future defence technology needs. It certainly won't make the most of our broader research investment, or that of our allies.

The scaling back of Australia's defence R&D efforts over the past decade isn't in the nation's strategic interest. That it seems to have been unintentional or a by-product of other defence policies suggests that it was a mistake by omission. The shift of DSTO's mission from open-ended problem-solving to risk mitigation tasks, to create a technology management consulting organisation, leaves a significant gap in Australia's defence R&D ecosystem—one that's likely to have significant adverse ramifications in the medium to longer term.

The difficulty of research planning and investment, involving guidance based on reactive interests, has fostered a short-term service provision posture. If defence science is to contribute directly to our strategic defence, as it does for our major allies, then the production of transformational and disruptive innovation is required. Because such an effort is significant (involving hundreds of millions of dollars over many years), defence science investment should be considered in the same manner as materiel acquisition; that is, it should be thoroughly scoped, planned and monitored over the long term in the light of well-established strategic objectives.

Better value for money can also be achieved by updating DSTO's mission to focus on areas that are demonstrably uncontestable by either private or public organisations. The establishment of the Australian Defence Innovation Projects Centre, proposed in this report, would provide Defence with the mechanism it needs to unlock the 95% of Australia's research community and resources that is currently not methodically or entrepreneurially tapped.

Separating the executive and advisory functions of the office of the Chief Defence Scientist would ensure that distinct responsibilities are established for strategic organisational management and the provision of scientific leadership and advice.

The recruitment and retention of high-quality staff are core to the efficiency and capacity of the defence R&D ecosystem. Creating flexible working arrangements to greatly improve mobility between government, industry and academic organisations (including the organisations of our allies) could enrich career paths to address current gender and age limitations.

The changing nature of technological evolution, global research practices and defence science policy described in this report should inform current thinking about Australia's strategic defence.

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Acronyms and abbreviations

ADF	Australian Defence Force
ADIPC	Australian Defence Innovation Projects Centre (proposed)
ANU	Australian National University
ARC	Australian Research Council
CDS	Chief Defence Scientist
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTD Program	Capability Technology Demonstrator Program
DARPA	Defense Advanced Research Projects Agency (US)
DRDC	Defence Research and Development Canada
Dstl	Defence Science and Technology Laboratory (UK)
DSTO	Defence Science and Technology Organisation
EU	European Union
GDP	gross domestic product
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
RDT&E	research, development, testing and evaluation
SBIR Program	Small Business Innovation Research Program (US)
STEM	science, technology, engineering and mathematics
TRDI	Technical Research and Development Institute (Japan)

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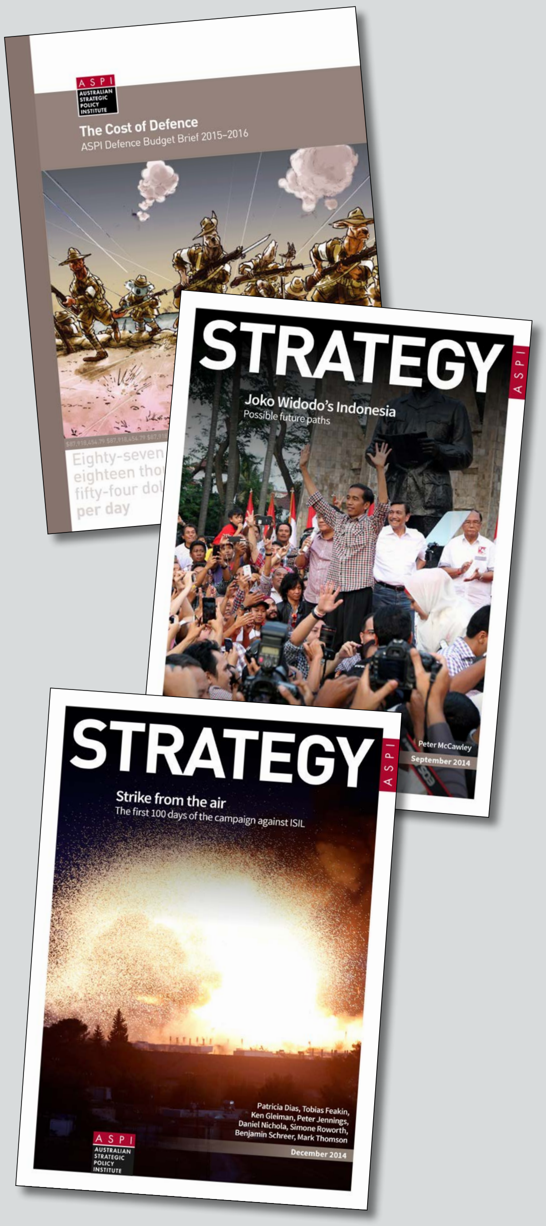

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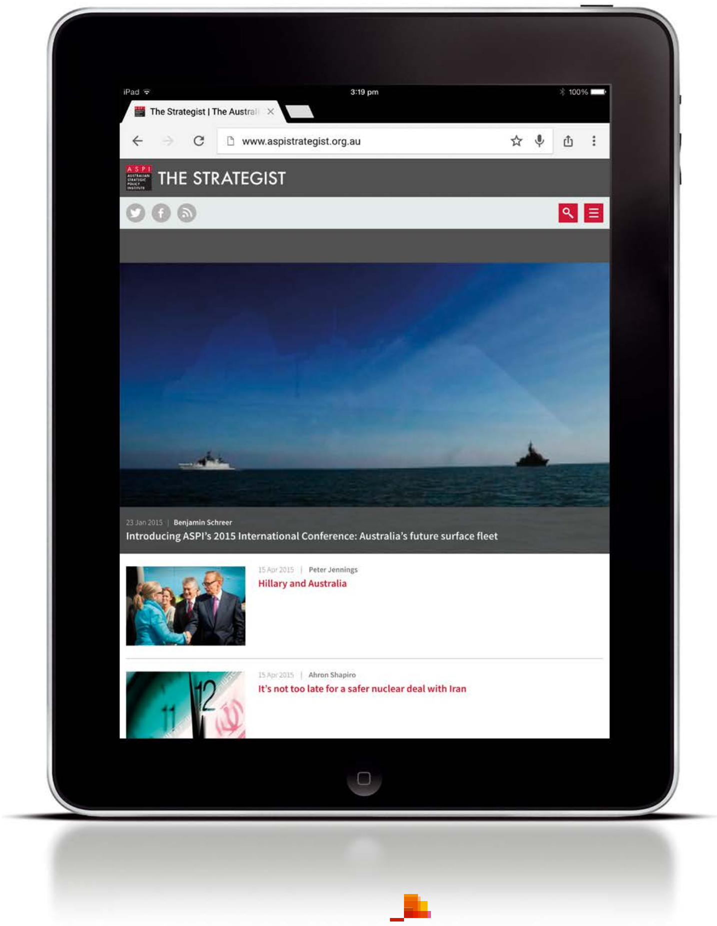

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