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CSIRO Submission 15/548

Inquiry into Australia's Future in Research and Innovation

Joint Select Committee on Trade and Investment Growth

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Executive Summary

CSIRO welcomes the opportunity to provide a submission to the inquiry into Australia's Future in Research and Innovation. Whilst acknowledging the breadth of the inquiry, CSIRO has concentrated its submission on challenges facing the Australian Innovation System, the role CSIRO is undertaking to help address some of these challenges and exemplar research, commercialisation and innovation programs from overseas.

CSIRO would like to highlight the facilitation of research connections and national investment in research translation, including through commercialisation as two key areas which have a large potential for enabling the research sector to better assist Australia overcome its geographic, economic, and labour challenges.

Research translation can be improved through mechanisms connecting people and facilities and that develop commercial skills. Particularly important are those mechanisms that build connections and trust between research and industry sectors. Regardless of the mechanisms it is important that cultural differences between industry and research are bridged; for example through training, facilitation and by sharing resources. As well as facilitating connections it is important to invest in human capital and provide mechanisms for that capital to flow between sectors as mobility between research sectors in Australis is low.

Countries that excel in supporting innovation have strong co-investment between government and industry. Their governments also fund significant programs that connect, research, industry and government to deliver market-ready solutions. If Australia wishes to increase access to current and future international markets it is vital that we develop a competitive advantage. Excluding the natural competitive advantage that Australia maintains in certain components of the resources and agricultural sectors, and noting current shortfalls in the Australian Innovation System, a competitive advantage can best be provided through targeted R&D and investment in commercialisation.

Introduction

To maintain and grow living standards in a modern globally connected world requires Australia to develop a competitive advantage that will overcome geographic, economic and labour barriers such as large distances to market and high labour costs. Innovation, defined broadly as the process of translating an idea or invention into a good or service that creates value, and for which a customer will pay, is Australia's best road to developing that competitive advantage.

With over 60 per cent of Australia's productivity growth due to innovation[iii], to remain globally competitive it is crucial that Australia's innovation system is able to efficiently translate research and development (R&D) outputs into innovative new products and services. This ability to efficiently translate R&D is even more important when considered in the context of the Intergenerational report[iii], that highlights that with changing population structures, including an ageing workforce, lower participation rates are expected over the next 40 years. Innovation carries an opportunity for productivity gains, despite lower rates of participation.

A number of measures highlight that the linkages between research and the market are not as strong as they could be. One example is the Global Innovation Index where Australia has a cumulative ranking of 17 out of 141 countries. This score is a result of a ranking of 24 on Innovation Output and 10 for Innovation Input. This results in a ranking of 72 for Innovation Efficiency. The efficiency ratio ranking reflects Australia weakness in commercialising and exporting the innovations Australia creates into new market-ready products and services.[iv] Australia's ranking in the Global Innovation Index compare poorly with ranking of 12th in the world for nominal Gross Domestic Product. In comparison the countries topping the GII rankings perform strongly in the following areas:

- Have created well-linked innovation ecosystems where investments in human capital, combined with strong innovation infrastructures, contribute to high levels of creativity;
- In particular, the top 25 countries in the GII consistently score well in most indicators and have strengths in areas such as information and communication technologies and business sophistication, which includes knowledge workers, innovation linkages, and knowledge absorption; they also create high levels of measurable outputs including creative goods and services."[v]

This paper will discuss approaches which may be implemented to ensure innovation drives Australia's competitive advantage across a range of industry sectors.

Knowledge flows drive innovative activity

The flow of knowledge is critical for innovation and productive commercialisation activities. This knowledge flow relies to a significant degree on the ability of the industry to absorb or generate new ideas. New commercialisation opportunities from research and innovation can either be obtained through employing highly qualified research staff or through working closely with knowledge providers such as research organisations like CSIRO[vi]. Australia's research workforce is average in size for an advanced economy[vii] with four scientists and engineers per thousand people. But unlike almost all other advanced economies, only 30 per cent of Australia's R&D workforce is employed in industry, which is very low by OECD standards, and compares particularly poorly with innovation powerhouses US and Japan who have almost 80 per cent of their R&D workforce in industry[viii]. This low percentage not only limits the ability of Australian industry to undertake its own commercialisation activities but also limits business-to-business commercialisation and business-to-research organisation commercialisation[ix]. The relatively low numbers of industry R&D personnel compared to other advanced economies is compounded by the low number of staff transitioning between research organisations and industry.

To overcome these challenges requires effort to increase mobility between research and industry and to better train research and industry workforce in commercialisation. Some of the issues driving low transition rates between sectors include limited recognition of work in other sectors, difficulties in transferring

employee benefits (notably superannuation), and that the performance of many research staff is assessed by their academic publications, which generally do not continue if the academic takes on an industry role. The later can also affect university to PFRA mobility due to differing emphasis on publications versus applied outcomes. Mobility schemes that allow researchers to transition in the short or long term without detrimental effects on their career would increase knowledge and skill flows across the system. To some extent these issues can be overcome through programs like the Australian Government's Researchers in Business and through developing operating models that bring institutes together (points that are expanded on through this document).

The following issues that were raised in the CSIRO submission to the Senate Economics Reference Committee Inquiry into Australia's Innovation System[x] remain relevant despite several positive policies outlines in the National Innovation and Science Agenda[xi]. To better support collaboration between the public sector research, universities and industry, and between firms, the following measures should be further supported:

1. Support more 'connector' mechanisms (networks) to facilitate and catalyse the forming of valuable human networks, culture and connections, particularly around science precincts and priority industry sectors (in particular, knowledge-intensive competitive industries in areas of global growth);
2. Promote transparency of system wide capabilities and needs; and
3. Promote standardisation and streamlining of commercial access arrangements by publicly funded research agencies.

Active management and feedback loops increase research impact

As well as supporting the translation of research it is important to support research that is likely to result in transformative change. Just like any form of investment a portfolio management approach provides a mechanism for managing risk by constantly adjusting the investment profile to reflect the changing internal and external opportunities and challenges.

Active research portfolio management helps ensure the relevance of research by allowing for research to adapt to market, regulatory and other changes. It encourages the fast fail of projects through modifying or even cancelling projects that are unlikely to deliver on their intended impacts. Active research portfolio management contrasts strongly with the processes applied to the vast majority of investigator-led research. Where research is conducted without active provisions to monitor progress towards impact outcomes, lack of evidence makes it difficult to understand the effectiveness of individual grants and the programs as a whole. It also makes it difficult to inform future research investment decision making and communication with policy makers and industry funders on the benefits of research.

In CSIRO research is actively managed within sector-aligned impact-focussed business units. The business units, which accounted for 87 per cent of CSIRO's total investment in the 2014/15 Budget, have goals developed around national challenges that are shaped iteratively with input from external experts from industry, government and scientific institutions through advisory committees and review panels. These active and participatory engagements provide significant value in terms of informing, challenging and refining CSIRO's research goals and pathways to maximise the likelihood of the uptake and adoption of research, including through commercialisation. It is CSIRO's experience that active research portfolio management (with a long-term outlook) is essential to ensure that investment of public resources in research achieves its maximum environmental, economic or social impact. Regardless of whether a CSIRO activity services the public and/or private sector, national benefit in the context of national challenges and opportunities is the threshold criteria.

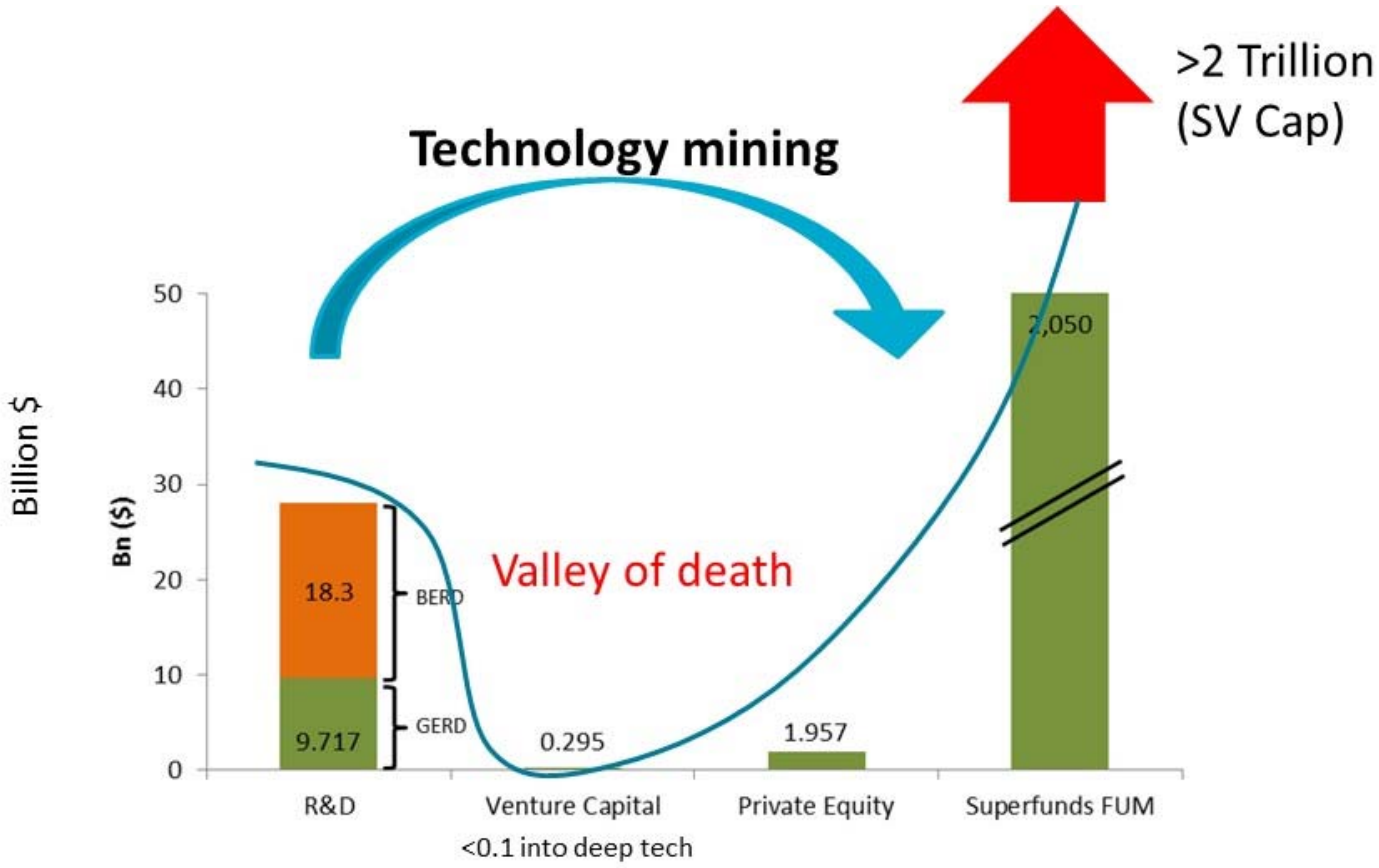
For CSIRO, taking a portfolio approach also allows for more efficient investment in infrastructure creating national, rather than institutional, resources. Large scale infrastructure, including supercomputers such as the Pawsey Centre and the ICT capability of Data 61, the biosecurity function served by AAHL, or facilities such as the Australian Synchrotron, are best managed on behalf of the nation thus avoiding duplication while

facilitating research connections. A portfolio approach to investment also allows for infrastructure at scale to be developed with the double benefit of increasing CSIRO's innovation potential whilst creating world class facilities that attract international research and investment.

Investing in translation is critical

The translation of research and development into exportable commercial activities faces significant challenges. Although not unique to Australia, this challenge is exacerbated by low levels of available investment capital.

Figure 1: Valley of Death – Australia's Investment Landscape for innovation



Source: CSIRO Strategy 2020, Larry Marshall presentation

Labelled the 'Valley of Death'[xii]business wishing to develop R&D into commercial activities face a period of significant cost. The Valley of Death is identified as a phase of commercialisation before 'success as a business' where there is little to no income and a large outgoing cash flow. Often this phase is after a period where there has already been significant investment in R&D and resources may be depleted. In Australia this is exacerbated by a lack of Venture Capital and Private Equity funding. In Australia there is approximately $30 billion expended on R&D and over $2 trillion in capital investment for established businesses. In contrast there is only $0.3b in Venture Capital funds available and $1.96b in private equity.[xiii] This results in a shortfall in investment in the translation of R&D into commercial activities. It is worth noting that if even 0.1 per cent of capital invested in established business was available for Venture Capital and Private Equity it would provide an approximate tenfold increase in the amount of money available in these areas.

A major impediment in the ability to translate R&D into economic, social and environmental impacts is that it is often not market or investment ready when commercialisation is attempted. There are a number of reasons why this is more prevalent in Australia than in other advanced economies. Two of the major reasons are:

- Limited funding is available for the development (the D in R&D) that is required to demonstrate to a potential investor that an innovation has the potential to provide a competitive advantage. Examples of development and analysis that may be required to ensure market readiness include market analysis and proof of concept demonstration, customer trials, prototyping and scale up amongst others.
- Incentives for most of the publically funded research revolve around publications, student supervision, research revenue and other measures that do not necessarily align with those required for R&D translation.

Through supporting the movement of knowledge and people, coordinating the research portfolio, and providing the support and incentives to ensure that R&D is market ready Australia can increase its innovation potential. The next two sections provide examples of overseas initiatives that target these challenges and discuss how CSIRO through its 2020 Strategy is addressing some of the challenges.

Consideration of international models for innovation

Government support of science and innovation has led to many radical and transformative innovations that have fuelled the dynamics of capitalism; from railroads to the internet, modern-day nanotechnology to pharmaceuticals, and GPS to touch screen displays; many innovations trace their most early, risky and capital-intensive investments back to a government. However, despite this formative role that government investment can play, a translation partner is required to deliver social, economic, and environmental benefits. In the case of the development of new products and services, receptive and resourced industry partners are critical to translate the research.

The percentage of GDP dedicated to innovation, research and development is necessarily different depending on national context but it is worth noting that those countries with strong international reputations for innovation, and an associated export market for that innovation, spend a minimum of 3 per cent of GDP on R&D per annum. In comparison Australia spent 2.1 per cent of GDP on R&D in 2013/14[xiv]. The OECD found that a one per cent increase in public R&D expenditure could be expected to generate a long run increase in productivity of 0.28 per cent[xv]. This compares with a productivity increase of 0.11 per cent for a one per cent increase in business R&D expenditure. Noting its significantly positive impact CSIRO recommends an increase in government spending on research and development in the two areas of connecting research with industry and research translation.

International models for government support of innovation, while needing to be applied with care to suit Australia's situation, can offer insight into mechanisms and investment targets and levels that create successful outcomes. Case studies which highlight successful practices of commercialisation of research and support for collaboration in research and development are provided in Appendix A. Of particular note, the Fraunhofer-Gesellschaft institutes from Germany and the Gazelle Growth program previously active in Denmark focus on developing exports.

From the case studies in Appendix A the high level lessons of relevance have been summarised below.

Key lessons

- Support for the critical stages of research and development and the facilitation of linkages between research and industry can help to increase the number and quality of innovations.
    - Government support may alleviate a crucial gap faced in the commercialisation of innovations and can allow the development of necessary supports (e.g. relevant HR practices) for profitable industries.
- Creation of or access to an expert advisory group along with shared resources between research and industry sectors can help to facilitate the successful commercialisation of research.

  - In the case studies this is often through a physical hub where industry, government and research interact in a vibrant setting – relevant expertise being housed in that location – although this can also be a virtual structure. The case study of the High Value Manufacturing Catapult Centre from the UK (see below) provides a specific example of this.

- Shared funding models (i.e. where two or more stakeholders fund a project) are commonly used to fund innovation and commercialisation and there are examples where they have functioned to promote the viability of research partnerships.

  - Some projects that are jointly funded have found the model has increased their impact because of the relationships built through the process.
  - Further, if funders are sharing costs for a project it may increase the length of time that that project can operate.
  - Often joint funding is structured in a competitive tendering process.
  - Shared funding can be flexible and may be structured as research partnerships, conditional block funding agreements, competitive awards based programs or facilitated funding.

CASE STUDY – AUSTRALIAN MANUFACTURING AND MATERIALS PRECINCT

AMMP is home to 40 per cent of Victoria's manufacturing companies, as well as CSIRO, Monash University, the Australian Synchrotron, and the Melbourne Centre for Nanofabrication. The objective of the project is to be a hub for a wider network of industry and research-based organisations to connect, collaborate and focus on translating research outcomes to industry. Three of the initiatives onsite, Lab 22, the Australian Synchrotron and the Melbourne Centre for Nanofabrication, are described below:

Lab 22

Located at Clayton, Victoria, Lab 22 offers Australian companies with a unique opportunity to access and explore new technologies so that they can innovate with less capital investment risk. The metal additive manufacturing site is valued at over $6 million and makes the following technology accessible to industry thus increasing its adoption across Australia:

- Metallic 3D printing (e.g. titanium, aluminium)
- Advanced machining for improved profitability
- Surface engineering for enhanced performance
- Laser assisted additive deposition
- Laser heat treatments

Australian Synchrotron

Officially opened in July 2007, the Australian Synchrotron is one of a few facilities around the world capable of revealing the innermost, sub-microscopic levels of materials that allow researchers to improve the properties and performance of materials. The Synchrotron is adjacent to Monash's Clayton campus and is funded by State and Federal governments, the New Zealand government, CSIRO, and a number of Australian universities and medical research institutes. The Australian Synchrotron is operated by ANSTO, Australia's nuclear science and technology organisation. Although less than nine years old, researchers at the Synchrotron have, among other advances, developed new methods to enhance the resilience of metals, improve the productivity of plants, and solve complex diseases.
www.synchrotron.org.au

Melbourne Centre for Nanofabrication

The Melbourne Centre for Nanofabrication's (MCN) mission is to facilitate the integration of nanotechnology techniques into research activities that support innovation and manufacturing in Australia. MCN is a joint venture facility bringing together the technical expertise of six Victorian universities (Monash University, The University of Melbourne, RMIT, Latrobe, Deakin and Swinburne) and CSIRO to provide open access for industry to state-of-the-art fabrication capabilities in Victoria. The MCN is the national headquarters of the

Australian National Fabrication Facility (ANFF), is operated by Monash University and is adjacent to the Monash University Clayton campus and the Australian Synchrotron.
www.nanomelbourne.com

There are currently several joint initiatives in place to drive the further development of AMMP, including:

1. The New Horizons building that has collocated some of Australia's leading manufacturing and engineering capabilities at Clayton in 2013;
2. The Victorian Centre for Sustainable Chemical Manufacture which was established in partnership with the Plastics and Chemicals Industry Association and the Victorian Environmental Protection Authority; and
3. The Factories of the Future Innovation Centre at Swinburne University that provides open access for industry to advanced prototyping and production capability.

Case Study – High Value Manufacturing Catapult Centres (UK)

The objective of the centres is to support the UK's high value manufacturing capabilities as it is seen that this offers the best opportunities for economic growth in manufacturing.

The value of the project is estimated as follows; an initial £107 million core Catapult public investment has led to £290 million research & development investment resulting in £1.6bn of additional value for the UK economy - i.e. every £1 of core public funding for the HVM Catapult has generated net benefits worth £15. Furthermore, it is estimated that the HVM Catapult could generate an additional £6.1bn in the next five years.

Companies interact with the HVM Catapult centres through collaborative R&D activity, access to facilities and equipment, working with HVM Catapult centre staff, co-location of staff, and joint bidding and delivery of commercial and publicly funded contracts.

The HVM Catapult centres offerings are tailored to the specific requirements of the target sector(s) and commercial market, as well as the needs of the individual business. Key strengths highlighted by businesses who work with HVM are product testing facilities, development of demonstrators, helping to establish commercial relationships, access to networks, as well as increasing the capacity to innovate and translate research into products or processes.

The HVM Catapult centres are also often used by businesses as a venue for meetings, marketing and networking events. In particular, projects supported by the HVM Catapult centres clearly highlight that collaborations between the HVM Catapult centres and businesses directly contribute to enhancing national manufacturing competencies. Examples of key benefits to date include: novel manufacturing processes; adapting existing business models to accommodate diversification or larger scale manufacture; application of existing processes and techniques across sector such as aero-structure sheet forming techniques to healthcare use; and, increasing the intelligent management of energy and resources.

The HVM centre concentrates resources in broadly equal amounts from these three areas:

1. Business - through funded R&D contracts;
2. Collaborative applied R&D projects, funded jointly by the public and private sectors, won competitively; and
3. Core public funding for long - term investment in innovation infrastructure, expertise and skills development.

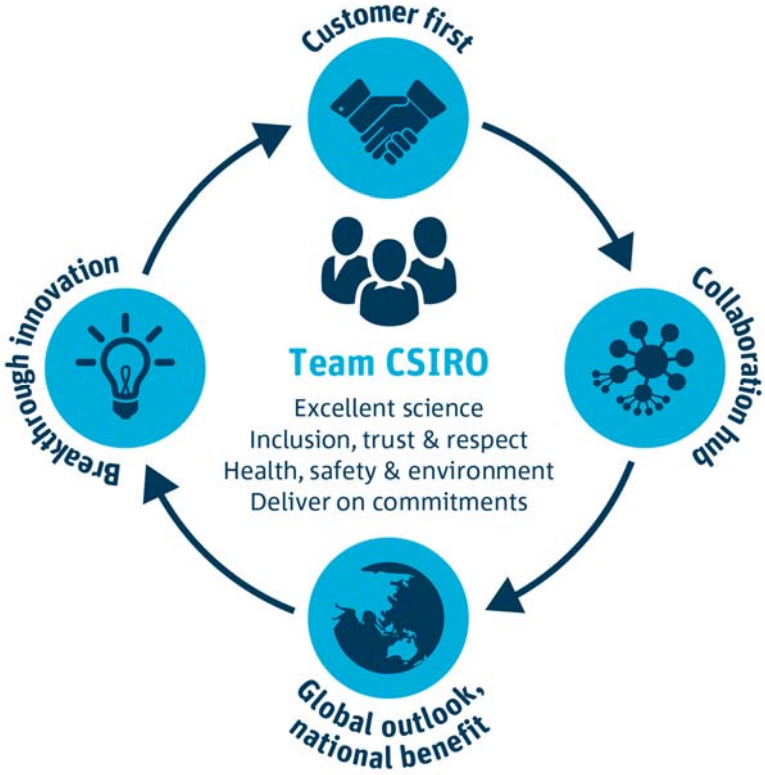
Businesses were specifically asked about the strengths of the HVM Catapult 'offer'. Most frequently cited was the unique nature of the HVM Catapult support - "there is nowhere else we are aware of, which could have that kind of impact on an organisation". The responsive and flexible nature of HVM Catapult support was also highlighted as a key strength, as was the calibre of the staff within the HVM Catapult.

CSIRO's vision to be Australia's Innovation Catalyst

CSIRO as the nation's science agency has a role to play in catalysing connections between research and industry and fostering innovation through the system. In developing its 2020 Strategy CSIRO undertook analysis to determine how to better use its core capability – people, infrastructure and locations – and networks to help ameliorate shortfalls in the Australian Innovation System. The CSIRO 2020 Strategy is structured around four externally focussed Strategic Actions and four internally focussed Strategic Actions as outlined in Figure 2.

CSIRO VISION: Australia's innovation catalyst, boosting Australia's innovation performance
CSIRO MISSION: Create value for customers through innovation that delivers positive impact for Australia

Externally focussed Strategic Actions



Customer First: To create deeper innovation relationships with our customers and prioritise the highest value investments.

Global outlook, national benefit: To deliver connectivity to the global science, technology and innovation frontier as well as access new markets for Australian innovation.

Collaboration Hub: To integrate the best solutions for our customers, increase our flexibility and enhance Australia's innovation performance.

Breakthrough Innovation: To increase our capacity to help reinvent existing industries and create new industries for Australia and deliver public good.

Figure 2: Overview of the CSIRO 2020 Strategy

National Connector

Although not its only role, CSIRO has an important role in connecting research, industry and government across the national and global innovation systems. CSIRO was charged in the Prime Minister's Innovation Statement with 'not only driving growth in Australia, but is also ensuring that more Australians are imbued with its culture of imagination, of research, of invention.' In the Statement CSIRO was allocated Commonwealth funds that, together with receipts from the WiFi inventions and private sector support, will form an innovation fund to aid start-ups. CSIRO has also been funded to expand its accelerator program, aimed at aiding its scientists in getting their research market ready, to all universities and PFRAs in Australia. These Government initiatives reinforce the role outlined in the CSIRO Strategy to strengthen CSIRO's role connecting research and industry sectors and to manage programs on behalf of the nation that facilitate connections across the system.

Overcoming Australia's geographic challenges

Global connections for national benefit is a Strategic Action in CSIRO's new strategy. CSIRO is well connected to national and international research agencies as well as industry. It has helped numerous Australian companies achieve international success and will look to strengthen that capability over the coming years growing on strong physical presence in the US, Indonesia and Chile with a greater footprint in key international markets such as the US and China. In growing its international presence, CSIRO would like to highlight the value that the Government can deliver through Austrade and the Department of Foreign Affairs and Trade. This includes through facilitating the presence of Australian R&D in international supply chains and highlighting the skills of Australian researchers to potential customers.

CASE STUDY – CSIRO CHILE

CSIRO established an office in Chile in 2013, initially through funding from the Chilean Government for an international centre of excellence in mining. The CSIRO Chile research foundation promotes collaboration between Chile and Australia in delivering world-class applied research in mining, mineral processing and is expanding to environmental and water management. The Centre engages both the community (e.g. through a recent report on attitudes to mining), and industry through key partners including Codelco, BHP Billiton, Anglo American Chile, Antofagasta Minerals and Glencore Xstrata.

The USA remains Australia's largest commercial and research partner. CSIRO is engaged in a number of collaborations across different fields of research with a number of leading US research institutions, such as the University of California, the Lawrence Berkeley National Laboratory, California Institute of Technology, MIT, and Harvard University. CSIRO also has a number of strategic partnerships with institutions in the USA, such as NASA, NOAA, Boeing, GE, Bayer and DuPont. As well as providing a conduit to global connections, CSIRO helps small Australian firms to achieve the competitive advantage needed to access international markets.

CASE STUDY – THE TEXTOR STORY

CSIRO and Textor Technologies, a Victorian family-owned company, partnered to develop a novel and highly absorbent textile to create competitive advantage in the market place. CSIRO's partnership with Textor resulted in improved manufacturing processes and efficiency, in turn increasing annual gross turnover and profitability. Textor now manufactures 100 million square metres of moisture-trapping fabric each year, making them a key supplier to the global market. There has also been increased investment in Textor's manufacturing plant and equipment to support expansion into international export markets, including the Asia-Pacific, Russia and the United States. The new material is being incorporated into the millions of nappies produced in Sydney, the USA, and Russia by global company Kimberly-Clark. The growing export activity contributes to the improved sustainability of the Australian manufacturing sector.

CSIRO would like to highlight another important initiative for overcoming geographic challenges that was outlined in the National Innovation and Science Agenda, that of increased support for digital research capability. Digital technology will disrupt every Australian industry and each part of our business must reinvent itself to help Australia respond to this global challenge. However, by its virtual nature the digital realm provides Australia an opportunity to compete with organisations overseas without the additional cost of transportation. In addition, an increase in digital R&D capability can help the services sector compete internationally.

Overcoming Australia's economic challenges

Through the Breakthrough Innovation Strategic Action, CSIRO will create pathways to improve uptake of R&D and to build deeper connections between the research and industry sectors.

CSIRO has been participating in a Lean Launch Pad program with UTS for a number of years and the program brings scientists and industry together to work through their market strategies. As well as teaching researchers and industry leaders to think about their products from an evidence based design and customer

perspective, going through the program together helps to build trust across sectors. As a result of the success of this program and in support of CSIRO's mission to create value for customers, Lean Launch Pad has been made available across CSIRO's 5000 staff through an online interactive portal.

In 2015 the CSIRO Acceleration program was launched which provides a competitive process for scientists to develop their ideas to be market ready, with coaching from leading entrepreneurs. With government backing through the Innovation Statement this program will be opened so that all public universities and PFRAs can submit proposals. It will provide another mechanism to bring innovators together and facilitate the process of moving ideas into innovative goods and services.

CSIRO's SME Engagement Centre has a national team that is connecting local companies with the research sector and helping establish partnerships that will increase Australia's global competitiveness. Working with Australian SME's is a key element in delivering on CSIRO's role. Since 2008, the SME Engagement Centre has been helping small to medium enterprises to grow and gain a competitive advantage through accessing cutting edge research and technology. Supported by the Department of Industry's Research Connections program, the SME Engagement Centre facilitates researcher placements to help SMEs overcome technical challenges and implement new innovative solutions. These placements generally involve committing a researcher to work within a company for a period of time.

CASE STUDY – AW BELL

AW Bell is a Victorian-based, family-owned and operated manufacturing business that has been supplying metal parts in Australia for over 50 years. In 2010, AW Bell was presented with an opportunity to enter a new export market within the aerospace sector. In order for AW Bell to address technical requirements, they needed to improve their casting process. In collaboration with CSIRO they were able to develop a new technique for metal processing, and as a result of this project, AW Bell have become the preferred supplier to a major international company within the aerospace industry.

In 2015, CSIRO as a whole worked with approximately 3000 customers including 500 major Australian companies and more than 1200 Australian SMEs developing and delivering innovation to existing industries and through testing and evaluation.

Overcoming Australia's labour challenges

CSIRO, like other R&D organisations has both direct and indirect effects on addressing Australia's labour challenges through providing innovative solutions to industry and government and developing the innovative workforce of the future.

Innovation plays a critical role in allowing Australian firms to compete in high value products, whilst maintaining a high standard of living and providing ongoing development of staff. Although it is important to note that regular ongoing innovation is required to maintain a competitive edge over low cost countries. An example of where CSIRO is playing a role in developing new industries which leads to new jobs, is outlined below in the case study of the carbon fibre industry in Geelong.

CASE STUDY – CARBON FIBRE IN GEELONG

The carbon fibre hub began as an Education Investment Fund (EIF) funded program under the $103m Australian Future Fibres Research and Innovation Centre at Deakin. Now the hub consists of Deakin's $34m Carbon Nexus Facility, CSIRO's research capability and industry partners based on site such as Carbon Revolution and Quickstep attracting investment to the area and creating local jobs. CSIRO, with Deakin, is working to improve fibre quality and lower the cost of production to strengthen the competiveness of the industry. CSIRO and Deakin have co-invested in new equipment, due to be installed in early 2016, which will help complete the production line for carbon fibre at the site and bring more improvements to fibre quality. This is one of only a handful of carbon fibre centres worldwide.

R&D organisations play an important role in training students and engaging with the community. Through its 2020 Strategy CSIRO has reinforced its role in developing the innovative and entrepreneurial workforce of the future across the continuum from Primary to Year 12 through to undergraduate, post graduate and professional development. CSIRO jointly supervises PhD students with domestic and international universities, to a total of 621 students in 2015. CSIRO also participates in Work Integrated Learning programs with many universities whereby undergraduate students learn about key industries and working with industry partners. In addition there are CSIRO traineeships, including an Indigenous program that encourages community involvement in science and provide on the job training with retention of the position encouraged at conclusion of the traineeship. To improve participation in STEM disciplines CSIRO also manages a Scientists and Mathematicians in Schools program on behalf of the nation. The program builds flexible partnerships to allow researchers to get involved in classroom education. Since the program began in July 2007, a total of 4848 partnerships have been established in 2453 schools across Australia. Currently, 1838 partnerships are active in 1283 schools as at 31 October 2015. In 2014 BHP Billiton provided $28.8m over 5 years to CSIRO STEM activities targeted to Aboriginal and Torres Strait Islander students.

Commercialisation of research and development

Commercialisation can be described as the process by which ideas are turned into useful products (or services) that are valued by someone else (customers) who are willing to pay for significant volumes of the products (market demand). When there is a good fit between new ideas and actual customer need then technical developments can be transferred from scientists to markets. Commercialisation therefore provides a mechanism for moving new science from research organisations to industry users, providing renewal and efficiency gains for companies.

Whilst a typical technical development pathway might start from the idea stage - undertake basic research testing, move on to small scale prototyping followed by larger scale pilot plant operation before settling on a standardised scaled technology, and is technology-centric - a commercialisation pathway has a stronger focus on the market from inception. The commercialisation readiness pathway might start with the concept of a market need, explore market dynamics, develop a value proposition with customers about the products benefits, build a prototype that represents the product, validate real demand, scalability, resources, partners and cash flows, before settling on a sustainable commercial model that delivers value for both the business and customers.

Case Study: Medical Developments International (MDI)

CSIRO continues to engage with industry and develop partnerships with innovative SME's so that they can access CSIRO's Research and Development capability and expand into the global marketplace. One success story that demonstrates this is CSIRO's engagement with the Australian healthcare company Medical Developments International (MDI), an Australian listed company with unique and innovative products to assist in the management of acute and procedural pain, delivery of asthma medications, resuscitation and oxygen therapies for human and veterinary patients.

In 2012 MDI received investment funding through the CSIRO's Australian Growth Partnership (AGP) program for the next generation production of the drug methoxyflurane – the pain-relieving ingredient used in Penthrox (commonly known as the "Green Whistle") for the purpose of significantly reducing the cost of producing Penthrox and to facilitate large-scale production to support the company's plan to expand sales of Penthrox into the UK and Europe.

The project has now successfully completed the second stage of the CSIRO Penthrox manufacturing project and commenced work on the final phase of the project to deliver significant cost reductions. The company has also made excellent progress in drug registration approval process for Penthrox in Europe and if registration is given, Penthrox will be approved for sale in the UK, France Belgium and Ireland.

Penthrox is manufactured at MDI in South East Melbourne and is currently sold in 11 countries around the world.

Successful commercialisation requires that the technical and commercialisation readiness pathways are both sufficiently well developed to improve the chances of success. It is a truism that failures are more likely to come from a lack of customers than from poor technology development; excellent science does not make up for insufficient customers willing to pay for the product. Customers are less concerned with the technology; they want to fulfil needs and obtain solutions to problems. When the proposed technology solution matches the problem, then commercial success is more likely to follow.

CASE STUDY: ZEBEDEE - HANDHELD LASER SCANNER

Zebedee is a handheld laser scanner that creates 3D maps of difficult environments in the time it takes to walk through them. It doesn't rely on GPS, making it suitable for a range of scientific and commercial applications.

Already Zebedee is being used by the QLD Police as part of routine investigations and it has also been used to map the Leaning Tower of Pisa, the Jenolan and Koonalda caves, the Shrine of Remembrance in Melbourne, the Australian War Memorial, the World Forum in The Hague, Fort Lytton, Peel Island and a WW1 tank.

Zebedee/SLAM has been licensed by CSIRO to 3D Laser Mapping and has formed a new entity, GeoSLAM, to commercialise the technology. GeoSLAM is 50 per cent owned by CSIRO. 3D Laser Mapping has signed an exclusive agreement to distribute what is thought to be the world's first, truly mobile, hand held, rapid laser mapping system.

In that regard, the technology value proposition needs to be able to demonstrate the features of the product that embodies the science, and how those features address needs and provide customer solutions. Providing there is a strong fit between these two fundamentals, then other aspects of the commercial model need to be addressed. These include: how to acquire and grow customers; how will money be made from the business; what are the key assets of the business, including the IP underpinning the technology and whether there is freedom to exploit it given competing products; and, who CSIRO will partner with in the supply chain.

CASE STUDY: POLYMER BANKNOTES

An example of this is the polymer banknote co-developed by CSIRO and the RBA. When high-quality counterfeits of newly-issued $10 banknotes appeared, a serious market issue arose: the need for new ideas to protect the nation's currency. Over a period of time, discussions between CSIRO and the RBA were able to rigorously define the product specifications, including novel features to address known problem areas. After prototype feasibility testing, large scale trials were held and feedback obtained from key stakeholders in the supply chain market (cash handlers, banks, general public, and suppliers). Following the successful market validation of the product, a full roll out ensued. In subsequent years there has been strong commercial success, with product distribution of over 3 billion polymer banknotes and export to over 17 countries worldwide.

The global nature of the modern business world means that products developed locally are often considered for off-shore markets, especially well-researched products that provide novel solutions to long-standing problems.

Appendix A: Case studies

UNITED KINGDOM CATAPULT CENTRES[xvi]	
Purpose	To 'transform the UK's capability for innovation' Catapult centres create an environment which supports commercialisation of research by providing access to expert technical capabilities, equipment, and other resources required 'to take innovative ideas from concept to reality.'
Structure	Catapult Centres are a network of physical hubs located across the UK where businesses, scientists and engineers share space in order to encourage radical innovations and streamline the commercialisation process. The program is run as part of Innovate UK funding. Seven Catapult centres have been established guided by five criteria: 1. The existence of potential global markets which could be accessed through the centre that are predicted to be worth billions of pounds per annum. 2. World-leading research capability in the area in the UK. 3. UK business ability to exploit the technology and make use of increased investment to capture a significant share of the value chain and embed the activity in the UK. 4. Potential for the centre to enable the UK to attract and anchor the knowledge- intensive activities of globally mobile companies and secure sustainable wealth creation for the UK. 5. Close alignment with national strategic priorities. Catapult Centres established to date (reflective of national strategic priorities) are: - Cell Therapy - Digital - Future Cities - High Value Manufacturing - Offshore Renewable Energy - Satellite Applications - Transport Systems.
Budget	The program received initial investment of more than £200 m (AUD c. $410 m) in September 2010 and operates a funding model with a ratio of 1:3 government investment to contract sourced funding.
Operations	The High Value Manufacturing (HVM) Catapult centres provides an example of how Catapult operates. Companies interact with the HVM Catapult centres through collaborative R&D activity, access to facilities and equipment, working with HVM Catapult centre staff, co-location of staff, and joint bidding and delivery of commercial and publicly funded contracts. The centres are also often used by businesses as a venue for meetings, marketing and networking events. In particular, projects supported by the HVM highlight that collaborations between the centres and businesses directly contribute to enhancing national manufacturing competencies. The value of the HVM centres is estimated as follows, that an initial £107 million core Catapult public investment has led to £290 million research & development investment resulting in £1.6bn of additional value for the UK economy - i.e. every £1 of core public funding for the HVM Catapult has generated net benefits worth of £15. Furthermore, it is estimated that the HVM Catapult could gene rate an additional £6.1bn in the next five years.

FRAUNHOFER-GESELLSCHAFT INSTITUTES - GERMANY	
Purpose[xvii]	To promote and conduct applied research in an international context to benefit private and public enterprise and is an asset to society as a whole. The broad focus of the institute benefits the local and European economy through its success – it is one of the world's major international research organisations.
Structure	There are 67 Fraunhofer-Gesellschaft institutes and research units across Germany, employing c. 24,000 staff, and numerous international locations. The Fraunhofer institutes are grouped in seven working alliances devoted to specific broad research areas. Their purpose is to coordinate work on related fields of research within the Fraunhofer-Gesellschaft, to pool essential resources in core disciplines, and to present a unified image in the marketplace. These are: 1. Information and Communication Technology 2. Life Sciences 3. Light & Surfaces 4. Microelectronics 5. Production 6. Defence and Security 7. Materials and Components These research institutes form working partnerships with government, industry and with other of the institutes. The different Fraunhofer-Gesellschaft institutes will form permanent alliances or pool expertise in ad hoc interdisciplinary collaborative networks dedicated to specific projects. Through this approach, they have become recognised leaders in the development of system solutions and the implementation of complete innovative systems.
Budget	Fraunhofer-Gesellschaft has a €2 billion annual research budget with €1.7 billion generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding. As a consequence, the Fraunhofer-Gesellschaft operates in a 'dynamic equilibrium' between application-oriented fundamental research and innovative development projects. In 2014 the budget was € 2,060 m (AUD c. $3, 105 m) maintaining the 30:70 split of public block funding to generated funding.
Operations	Programs and outcomes are aimed at promoting the economic development of industrial society, with particular regard for social welfare and environmental compatibility. Funded projects are often limited to two to five years. Support for German industrial companies and their exports has seen Fraunhofer focus on the international character of the supply chain and expanded its international activities on a sustainable basis. It has done this through pursuing excellence in applied research and successfully enabling technology transfer between science and industry. In 2014, revenues generated from projects with international partners includes € 27 million in revenues resulting from contracts between Fraunhofer subsidiaries outside Germany and external third parties and Fraunhofer's international revenues grew by 10 percent.

DANISH NATIONAL ADVANCED TECHNOLOGY FOUNDATION	
Purpose	Moving technical breakthroughs out of the laboratory and into the market.
Structure	The Danish National Advanced Technology Foundation (DNATF) helps bring innovative products to market through a 'mediated funding' scheme which combines project grants with active facilitation and conflict management. At any given time, the organisation is supporting more than 300 different projects in key sectors of the Danish economy: • construction • energy/environmental • biomedical • manufacturing • IT and communications • agriculture
Budget	Each year, DNATF provides over $US100 million in funding for these private-public partnerships.
Operations	As universities and businesses collaborate, they must work through a range of cultural differences. The experience, expertise, and approaches found in a research university are far different from those found in a commercial enterprise. This process also delivers another enduring outcome, the development of human resources able to conduct mediation between research and industry. The success of DNATF's projects depends on effectively bridging this gap through a cadre of project mediation officers, who receive significant training through a joint DNATF/Harvard Business School Executive training program and form a peer group of STEM experts who have sought a career in supporting knowledge transfer into industry. The selection of a firm to participate in the program 'helps it to stay financially viable and significantly decreases the likelihood of bankruptcy by up to 2.7 times (270 per cent) four years after funding application. Selection also increases the average level of employment by 9.8 to 14.2 more employees for chosen firms, respectively two and three years after application. For innovative performance, selection of a firm for participation meant an increase in filed patents by up to 520 per cent, granted patents by up to 430 per cent and peer-reviewed publications 370 per cent, but the effect of selection was mainly felt in quality of the innovations.
Other programs	Two other programs of interest which have operated in the Danish innovation sector are: ***The Danish National Advanced Technology Foundation***[xviii] The Danish National Advanced Technology Foundation offers private firms and universities the funds and the framework for developing new and important technologies. The general objectives of the Danish National Advanced Technology Foundation is to enhance growth and strengthen employment by supporting strategic and advanced technological priorities within the fields of research and innovation. Up to this day the Foundation has invested in 273 advanced technology projects with a total budget exceeding 700 million euros. Half of the finance comes from firms and research institutions themselves. Average support per project is approximately 1.5 million euros with a support range of each project from 0.5 to 12 million euros. ***Gazelle Growth***[xix] The Gazelle Growth programme helped small firms achieving their growth potential on foreign markets – especially the US-market. Due to the size of the home market, especially small gazelle firms from small economies have to look at foreign markets

	sooner than small gazelle firms from big economies, if they want to grow. That can be at a time, where their net – work and knowledge of foreign market can be limited. With the Gazelle Growth programme small gazelle firms was advised and trained, so the entry on a foreign market can go faster and succeed then if they tried themselves. The Danish Gazelle Growth programme was terminated by the end of 2010.

VINNOVA – SWEDEN's INNOVATION AGENCY	
Purpose	To promote sustainable growth and societal benefits in Sweden
Structure	Working under the Ministry of Enterprise Vinnova plays three main roles: 1. provider of funding for science and innovation 2. expert authority in science and innovation policy, and 3. national responsibility for providing information and advice regarding the EU's Framework Programme for Research and Technical Development. To achieve its purpose Vinnova funds research and innovation projects which address challenges in four thematic competence areas. The focus is on: • Health and healthcare • Manufacturing and Working life • Transportation and environment • Services and ICT It employs 200 employees in Brussels and Stockholm offices.
Budget	Reporting in 2014 Vinnova invest annually 2,7 billion SEK (c. AUD $440 m) in about 2,400 research projects and requires that projects are co-financed.
Operations	Vinnova projects are all designed under three key principles; *connect*, *catalyse* and *stimulate*. Operations are guided by the following principles: - for increased impacts of research - broad innovation perspective; goods, services, processes, etc. - confidence in the actors to define their own development strategies - develop and test new forms for investments - develop and strengthen beneficial international cooperation Programs operate for a defined period of time, usually from three to ten years, and are designed to address one or more issues that are hindering innovation. Requirements for picking a program are industry-relevance, industry-academy-research institute- public sector partners, co-funding level. The amount of funding usually allocated is c. $0.45 to 15 M AUD per project. In 2014 Vinnova had a core focus on developing the university sector with 44 per cent of total budget spent on research within universities.

SMALL BUSINESS INNOVATION RESEARCH (SBIR) - UNITED STATES[xx]	
Purpose	To support scientific excellence and technological innovation through the investment of Federal research funds in critical national priorities to build a strong national economy.
Structure	SBIR is one of the largest STEM talent concentrations in the world it is designed to address gaps in support for research in order to assist development into viable commercial activities. It is focused on small businesses. Established in 1982, SBIR funds ideas through a competitive awards-based program through funds provided from federal agencies with extramural research and development (R&D) budgets that exceed $100 million. These (11) agencies are required to allocate 2.8 per cent of their R&D budget to these programs.

Budget	Funding for small business awardee organisations is divided into three phases. These are: - Phase I: usually below USD $150 k (AUD c. $200 k) and is to establish merit and performance ahead of Phase II. - Phase II: is based on achieved results, technical and scientific merit and commercial potential and generally do not exceed USD $1M over 2 years. - Phase III: is not funded by SBIR but funding may be negotiated by US Government Agencies who wish to further the commercialisation of a Phase I or II output.
Operations	SBIR has four goals: - Stimulate technological innovation. - Meet Federal research and development needs. - Foster and encourage participation in innovation and entrepreneurship by socially and economically disadvantaged persons. - Increase private-sector commercialization [sic] of innovations derived from Federal research and development funding. Reserving a specific percentage of federal R&D funds for small businesses, SBIR supports the small business and enables it to compete in R&D in a comparative way to larger businesses. SBIR funds the critical start up and development stages of R&D and it encourages the commercialisation of the technology, product, or service through partnerships. Funding enables small businesses to explore their technological potential and provides the incentive for them to profit from its commercialisation.

References

[i] Commonwealth of Australia (2011) Australian Innovation Systems Report 2011
[ii] Barnes P & McClure A (2009) Investments in Intangible Assets and Australia's Productivity Growth, Productivity Commission Staff Working Paper
[iii] 2015 Intergenerational Report. Commonwealth Government of Australia. Released 5 March 2015.
[iv] Cornell University, INSEAD, and WIPO (2015): The Global Innovation Index 2015: Effective Innovation Policies for Development, Fontainebleau, Ithaca, and Geneva.
[v] Global Innovation Index Report 2015 – Executive Summary
[vi] Schmidt (2005) Absorptive Capacity – One Size Fits All? A Firm-level Analysis of Absorptive Capacity for Different Kinds of Knowledge
[vii] The Australian economy is different from many seemingly similar economies. Care needs to be taken translating lessons to Australia. Some of the attributes that differentiate the Australian economy are that it is heavily resource focussed and has a relatively small per cent of high/medium high technology manufacturing.
[viii] OECD (2011), OECD Science, Technology and Industry Scoreboard 2011, OECD Publishing
[ix] Department of Industry (2013) Australia Innovation Systems Report, see Table 2.1 Indicators of Australia's collaboration activity by innovation active businesses, pg 56
[x] CSIRO (2014) CSIRO Submission 14/498 Australia's Innovation System
[xi] Australian Government (2015) National Innovation and Science Agenda http://www.innovation.gov.au/page/agenda
[xii] R&D Cost Curve available at http://www.slideshare.net/endofcap/national-geospatial-technology-development-system, accessed 15 January 2016.
[xiii] CSIRO Strategy 2020 presentation CEO Larry Marshall, 2016.
[xiv] Australian Bureau of Statistics 8104.0 - Research and Experimental Development, Businesses, Australia, 2013-14, http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/8104.0Main%20Features42013-14?opendocument&tabname=Summary&prodno=8104.0&issue=2013-14&num=&view accessed 2 February 2016
[xv] Khan and Luintel (2006) OECD Science, Technology and Industry Working Papers 2006/06: Sources of Knowledge and Productivity – How robust is the relationship?
[xvi] Hauser, Hermann, 'Review of the Catapult Network' available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/368416/bis-14-1085-review-of-the-catapult-network.pdf, accessed 6 January 2016.
[xvii] Fraunhofer-Gesellschaft, 2015, 'Mission Statement' available at http://www.fraunhofer.de/en/about-fraunhofer/profile/mission.html, accessed 5 January 2016.
[xviii] Analysis of the Danish Research and Innovation System, 2014, available at http://ufm.dk/en/publications/2014/files-2014-1/analysis-of-the-danish-research-and-innovation-system_web.pdf, accessed 6 January 2016.
[xix] Ibid.
[xx] Small Business Innovation Research website, 2016, available at https://www.sbir.gov/, accessed 4 January 2016.