CSIRO SUBMISSION

NATIONAL INNOVATION SYSTEM REVIEW

CSIRO

30 April 2008

Table of Contents

Preface - Two questions[1]

1. What is CSIRO's core and distinctive role?

CSIRO is a creative powerhouse that helps offer Australia better solutions to current and emerging issues affecting society, industry and the environment.

Our core and distinctive role in the National Innovation System is the conduct of strategic and applied research that delivers economic, environmental and social benefits for Australia.

Our world class scientists seek to focus on the big issues facing the nation – such as water, clean energy, climate change and obesity. And on major opportunities – for example in minerals, manufacturing, new food technologies or ocean science.

We tackle the big problems and deliver new and practical solutions by forming large, transdisciplinary teams with diverse skills and expertise, who work in close partnership with others in the global innovation system as well as with those who benefit from our research.

The globally unique breadth and depth of our scientific capability – from the atom to the universe - enables us to help drive beneficial change in Australian industry, the environment and society.

2. What if we didn't have a CSIRO?

Size matters.

In CSIRO Australia has a globally competitive capacity to assemble scientific teams at a scale and of diversity that is relevant to the magnitude and complexity of our challenges, and opportunities.

Our teams and their partners consistently deliver the knowledge and innovative solutions required to help address the major challenges facing the nation and our neighbours.

In a 'joined up' world, where science and innovation are key, Australia's current and future competitive advantage would be fundamentally compromised if CSIRO did not exist.

"CSIRO disappearing is like pulling the plug on the nation's brainpower. It might save some dollars, but will leave Australia in the dark."

If we didn't have a CSIRO we would need to create one.

Box 1. Why a CSIRO? A case study: the Murray-Darling Basin Sustainable Yields Assessment

KEY WORDS: national challenges; mission focus; long-term implications; scale and complexity; rapid response; multidisciplinary teams; experienced career investigators; strong partnerships; leading science; practical solutions; delivery of outcomes.

In response to an emerging water crisis in the Murray-Darling Basin, a Water Summit was called by the Prime Minister and the Premiers of the Basin states on 6 November 2006 to discuss options and contingencies. The resulting communiqué called upon CSIRO to report over the next year on the future availability of water resources in the Basin, taking into account climate change, future development, and groundwater-surface water interactions. No previous assessment of Australian water resources had ever been attempted at this scale or this level of scientific or political complexity.

(cont)

[1] Posed by Professor Mary O'Kane, NIS Review Panel member, to the CSIRO Business Forum (Werribee, 2nd April 2008)

Without little advanced warning, within four weeks CSIRO, through its Water for a Healthy Country Flagship, put in place multi-jurisdictional governance and contractual arrangements, negotiated access to data and models from four states, and established a multidisciplinary team of more than eighty scientists drawn not only from right across CSIRO but also the best available capability from universities, state departments and private industry to deliver the largest, most comprehensive study of the projected surface and groundwater resources of a basin this size in the world. The overall project method was documented, externally reviewed and accepted by the Australian Government within two months, and the first regional report was released a month later. In total, 18 regional reports and a whole-of-Basin report document the best assessment that current science and data allow. Fifty additional technical reports provide detailed documentation of every aspect of the project. Significant scientific and technical advances were required and achieved.

To deliver this outcome, the project distilled the latest global climate projections and translated these into future inflows to surface and groundwater systems across the Basin. CSIRO linked some 40 river models and a dozen groundwater models into a single Basin-wide hydrological model, allowing the flows and fate of water to be forecast from one end of the Basin to the other for the first time. These results were then compared to the historical entitlement security of irrigators, towns and the environment under dozens of water sharing plans.

These results provide crucial underpinning for the revised sustainable diversion limit to be developed by the new Murray-Darling Basin Authority, in part because of their comprehensive detail and in part because of the confidence that CSIRO has generated in the results with the high level of governance, review and team capability they applied to the challenge.

CSIRO's unique and differentiated position in the National Innovation System is highlighted by this project: anticipation and alignment with national priorities through the Flagship program; the alacrity to quickly draw together large, multidisciplinary internal and external teams to deliver on a major challenge; and the governance and administrative ability to underpin mission-oriented research in a form that ensures quality and relevance and timeous delivery.

"The Flagships are delivering powerful scientific solutions to national problems."

"Flagships offer the most promising mechanisms yet to drive large-scale activity addressing Australia's National Research Priorities in a collaborative, cooperative and intensively managed manner."

"The (Flagship) model facilitates high quality research but, perhaps more importantly, defines a route from R&D through to national impact."

Review of the National Research Flagships, 2006
(Chair: Dr Robin Batterham)

Executive Summary

Australia's innovation system has evolved over the past century in response to many different drivers and policy initiatives. Our innovation system has now become complex – overly so – and fragmented – significantly so – at a time when there is need for cohesion, coherence and urgency. Equally, it has become internally competitive at a time when there is need for collaboration and connectivity and more coordinated multidisciplinary approaches.

The NIS Review is timely because at present we observe, *inter alia*, that our capacity for R&D is deteriorating, due in part to highly leveraged public funding initiatives and marginal costing models. R&D providers are being diverted from their core purposes; and previously diverse but complementary roles are now converging with increased competition for less funding. At the same time, industries world wide are once again becoming more dependent on universities and public sector research as they shed their own R&D facilities and capability, recognising that 'open innovation' provides greater flexibility, diversity and generally better return on their investment.

In a more interdependent, global environment, the nature of national challenges and opportunities is changing, and becoming far more complex to deliver. Increasingly, this demands much larger research scale, more participants with complementary skills often geographically separated, and a considerably higher degree of leadership and management. Smaller scale, incremental research, whilst important in continuing to build Australia's knowledge base and future talent requirements, is less likely to have outcomes and impact in areas such climate change, energy, security, water, food security and chronic disease prevention, in the necessary timescales. These issues require higher level, systems thinking and more integrated research approaches.

The effectiveness of Australia's NIS, the policy frameworks surrounding the purpose(s) and roles of its constituent players, and the funding and governance arrangements that drive its behaviours, are all in urgent need of review and subsequent overhaul. The goal should be to establish a sustainable system that will contribute to both the prosperity and quality of life of all Australian citizens, and to the international reputation and competitiveness of Australia in its pursuit of global influence and impact.

CSIRO therefore strongly supports the NIS review and makes the following comments and recommendations in the seven areas covered in this submission.

1. National needs, innovation goals

Australia's NIS needs a 10 year strategic plan with a roadmap: where we are headed, why and how? What are our goals? And what practical actions are required to meet these, and how (and by whom)? By what measures do we monitor our progress, and performance?

2. A supportive policy framework

The lack of cohesive whole-of-government policy and principles for the investment of public funds is inhibiting innovation and creating uncertainty among many parts of the NIS.

Adoption by government of the Productivity Commission's rationale for public support of science and innovation could help clarify the roles and responsibilities of each player in the NIS.

There is a need for more effective policy coordination across the NIS.

An independent 'National Innovation Council' could further develop the NIS Plan and monitor its effective implementation.

Such a Council would provide governance/oversight of the innovation system and would be able to conduct studies and make direct recommendations to Government on 'whole of system' issues that cross portfolio and government boundaries.

3. Role clarity in the NIS

A healthy NIS that delivers on the national goals needs to have different players each with clear and distinctive roles.

Role clarity will ensure that a broad range of national needs is met, without unnecessary duplication or inefficient use of resources – particularly important in a small NIS in a very competitive world.

In the R&D part of the NIS, CSIRO (and other PFRAs) and universities have different roles that complement each other.

The CSIRO 'Role House' model has enabled CSIRO to develop management structures and processes that support the roles it has defined and ensure the Organisation operates in accordance with them.

The 'Role House' may provide a model for supporting role definition for other players, and for the NIS itself, and is potentially scalable to define the NIS itself.

4. Greater sustainability, less complexity

CSIRO supports streamlining the NIS to make the system more productive.

There is a need for a much smaller set of governance and performance measures for funding programs and players within the NIS, reflecting the particular roles and responsibilities of each component of the system.

The multiplicity of funding bodies, each with its own administrative and reporting requirements, increases transaction costs, makes coordination difficult and results in inefficiencies for users.

Major problems requiring a large-scale response can be difficult to put together under competitive funding programs offering small amounts of funding for short-term research. Appropriation funding is necessary for research scale and continuity and building capacity in core areas of national capability.

The NIS needs to move towards fewer, but larger scale funding mechanisms, taking into account the full cost of research; and with streamlined governance and reporting mechanisms.

The leverage requirements set by many competitive funding schemes add to complexity, are unsustainable and lead to unintended consequences that threaten the fabric of the innovation system. They can result in the inappropriate use of appropriation funding by some stakeholders and distortion of roles.

Benchmark data for other innovation systems, notably that of the US, indicate that investment in CSIRO's capital building infrastructure (buildings and equipment) is falling short.

CSIRO's capital infrastructure is deteriorating as the costs of replacement and support (depreciation, repairs and maintenance) exceed current appropriation indexation levels.

Sharing through the development of research 'hubs' will create a more efficient (and collaborative) NIS but will not resolve the rising support costs associated with current infrastructure.

Research 'hubs' involving universities, CSIRO other PFRAs and industry, supported by HEEF would provide more cost effective sharing and use of capital infrastructure as well as assist path to impact.

National Facilities and Collections present particularly difficult problems: they require transparent funding, separate from that of the host organisation and sufficient to cover both capital and operating costs.

5. Improving path to impact

A major priority for the Australian NIS should be to introduce mechanisms that ensure more active management of research to achieve impact.

More explicit assessment of potential impact is needed across all three areas of impact (economic, social and environmental) is required prior to investment, and subsequently at the evaluation stage, as well as the contribution of each to national wellbeing.

Greater emphasis is needed on systematic, ex-post evaluation to:

- allocate resources for evaluation in agency budgets; and
- inculcate the practice of following up the use of project outputs and impact. This may require inclusion in agency contracts for provisions requiring customers to provide data).

More detailed attention needs to be paid to the rationale for investment in particular projects/industries. This should build on a detailed consideration of the issues discussed in the Productivity Commission's 2007 report.

There is a need to develop a better understanding across all sectors of the role that IP plays in achieving impact from research.

Greater emphasis needs to be placed on the development of research personnel who are comfortable working across boundaries. The latent desire to make a difference beyond expanding the frontiers of knowledge also needs to be coupled with the ability to work across institutional and other boundaries. CSIRO is actively working to develop the boundary crossing capabilities of its researchers including the creation of a new cadre of 'collabronauts'.

6. Collaboration

An effective NIS depends on effective and efficient collaboration and other interactions among the different players to share ideas, people and infrastructure.

At present, collaboration among organisations comes at a considerable cost – mostly associated with increased transactions from the interplay of different and often incompatible administrative, management, funding and governance arrangements, and from a 'clash of cultures'.

Global linkages need to be supported and funded if we are to access world-class technology, knowledge, people and capital.

The CRC program has been an important mechanism for enhancing national collaboration. The program may have reached its 'use by date' and needs to evolve to a new form or be replaced. Separate programs for collaboration need to be developed for 'public good' and 'industry benefit' collaborations, each with streamlined administrative arrangements.

A properly-managed IP system is critical for stimulating efficient NIS collaborations.

CSIRO's National Research Flagships program has provided valuable insights on how to deliver collaborative research on national scale issues and could be extended across the NIS.

7. Building appropriate national skills and capability

CSIRO and top universities can leverage their reputations to attract and retain the brightest and best in the global talent 'war'.

The NIS needs to increase its supply of skilled people who fuse traditional R&D skills with an increased focus on delivery and impact.

Different players in the NIS provide training to build knowledge and experience and/or skills development relevant to different parts of the innovation pathway.

CSIRO has particular advantages in providing training that is oriented towards industry.

Removing barriers to mobility between sectors is essential to improve the effectiveness of the NIS and attract the best people.

Cultural barriers can impede collaboration but education and mobility can help remove or diminish them.

Recommendations

National needs, innovation goals

- Develop a 10 year NIS Strategic Plan. (Section 1, p. 3).

- Develop the key outputs of the NIS Review as an advanced framework for this plan. (Section 1, p. 3).

A supportive policy framework

- Develop a consistent set of principles for public investment in the NIS, based upon the Productivity Commission's rationale for support of science and innovation; these principles should apply to all Government funding of innovation programs. (Section 2.1, p. 5).

- Form an independent 'National Innovation Council' tasked with conducting studies and making recommendations to government on whole-of-system issues across portfolio and governmental boundaries. (Section 2.3, p. 7).

Role clarity in the NIS

- Individual players should define and clarify their roles within the NIS and develop the management and other processes necessary to support those roles. (Section 3.3, p. 13).

- The CSIRO 'Role House' may provide a scalable model to enable a whole of system view of the NIS. (Section 3.3, p. 13).

Greater sustainability, less complexity

- Streamline the NIS by significantly reducing the number of funding programs aligned with major priority areas. (Section 4.1, p. 15).

- Introduce more consistent and simple administrative, governance and requirements across all government funding schemes building on and using the administrative and governance arrangements of existing organisations. (Section 4.1, p. 15).

- Develop performance measures for programs that are consistent with the agreed roles, responsibilities and policy objectives of that component of the NIS. (Section 4.1, p. 15).

- Move to funding programs that support the full cost of research, including overheads and capital infrastructure. (Section 4.2, p. 17).

- Ensure R&D providers have 'open book' accounting to support and justify the cost of their research. (Section 4.2, p. 17).

- Refine the RDC framework to enable different funding models for ‘near to market’ versus strategic, cross-sectoral issues. (Section 4.2, p. 17).

- Index underlying government funding for research infrastructure to maintain its real value. (Section 4.4.1, p. 19).

- Recognise both the capital and the operating costs associated with its use in funding for new research infrastructure. (Section 4.4.1, p. 19).

- High priority weighting for investment in the HEEF prioritisation process should be given to co-located ‘science hubs’ to provide the opportunity for the sharing of scarce research infrastructure between Universities and PFRAs. (Section 4.4.1, p 19).

- Recognise the importance of National Facilities and Collections and ensure that they are funded on an ongoing and sustainable basis via separate and identified budgets. (Section 4.4.2, p. 21).

- Seek to evolve a consistent framework for the management of National Facilities and Collections around entities of sufficient size and scale to maximise cross-boundary collaboration and stakeholder engagement. (Section 4.4.2, p. 21).

- Recognise that the management of National Facilities and Collections needs to be coupled with an indigenous world-class research and development capability. (Section 4.4.2, p. 21).

- Acknowledge the need for, and develop, a strategy that supports the globalisation of research infrastructure. (Section 4.4.2, p. 21).

- Continue the use of block funding to enable publicly funded research organisations to maintain their core responsibilities (such as mission-directed strategic research for CSIRO). (Section 4.5, p. 23).

- Contestable funding programs should only be used where clear benefits can be identified and then only when players ‘compete’ on a level playing field. (Section 4.5, p. 23).

Improving path to impact

- Strengthen the requirement on publicly funded research programs to explicitly articulate the nature of the impact they are seeking to achieve (the end) and how they propose to achieve it (the path to impact) before making investments in research. (Section 5, p. 27).

- Require explicit performance assessment against appropriate metrics in major public sector R&D investment decisions. (Section 5, p. 27).

Collaboration

- Focus international program funds to increase scale of activities in individual high priority projects for Australia. (Section 6.1, p. 30).

- Increase funding for international researcher mobility while removing non-financial barriers. (Section 6.1, p. 30).

- Include relevant international engagement as a performance criterion for publicly funded research. (Section 6.1, p. 30).

- Expand CSIRO's Australian Growth Partnership Program with SMEs to include a wider variety of players in the NIS. (Section 6.2, p. 31).

- Simplify IP arrangements among government agencies as a priority. (Section 6.3, p. 31).

- The CRC program should change significantly or be replaced allowing for adequate transition arrangements for existing CRCs. (Section 6.4, p. 32).

- Future changes should allow separate development of public good versus commercially oriented CRCs, each with streamlined administrative arrangements. (Section 6.4, p. 32).

- Individual CRCs should not be funded indefinitely through the CRC program. (Section 6.4, p. 32).

- Develop new streamlined collaboration programs that are flexible and allow different players to interact at appropriate times in simplified governance arrangements. (Section 6.5, p. 34).

Building appropriate national skills and capability

- Introduce more undergraduate and postgraduate training (including continuing education) in innovation, e.g. run jointly between science/engineering faculties and business schools. (Section 7.2, p. 38).

- Provide a wider range of graduate and post-graduate training options which link academic learning with the practical experience of the workplace where outcome oriented research is undertaken and innovation is taken up (industry and PFRAs). (Section 7.2, p. 38).

- Expand PhD programs to encourage multidisciplinary research, or time in industry and in jointly supervised programs with PFRAs. (Section 7.2, p. 38).

- Extend the Government's recently announced Enterprise Connect to support the placement of industry people into universities and publicly funded research agencies. (Section 7.2, p. 38).

Introduction

CSIRO recognises that innovation, though relatively simple to define[2], is the result of a complex set of interactions, influenced by many factors both within, and external to, the traditional research and development pathway. As Australia's largest and most diverse, public sector science research agency, CSIRO has confined its submission to observations based on its practical experiences as a research and development (R&D) provider in, and across, the National Innovation System (NIS). Where appropriate, case studies and examples will be used in support of our observations and recommendations.

CSIRO applauds diversity in the NIS as a fundamental contributor to creativity. A variety of approaches is needed to develop scientific capability and capacity, build scientific understanding and create a technically literate workforce as fundamental precursors to delivering impact for Australia from innovation.

Operating for more than 80 years, CSIRO has witnessed significant change in the last decade[3], not only in the nature, scale and urgency of the challenges and opportunities that Australia faces but also in the way that government, industry, research providers and other participants in the innovation system have responded. As with most systems which evolve over extended timescales, redundancy has accumulated in the NIS as operational, funding, and structural responses have been implemented to adapt to changing needs, situations, policy and governance requirements.

Australia's innovation system has now become complex – overly so – and fragmented – significantly so – at a time when there is need for cohesion, coherence and urgency. Equally, it has become internally competitive at a time when there is need for collaboration and connectivity and more coordinated multidisciplinary approaches.

As an important but small player in the global economy, Australia should consider changes to its innovation system within this context. Any overhaul should be directed at better role clarity for its participants, as well as improved connectivity at both national and international levels. National policy and governance frameworks are needed to manage an appropriate balance between the benefits of diversity and the disadvantages of fragmentation. Of extreme importance is the need to streamline and accelerate the current often tortuous, complex, and generally inefficient *path to impact* where ideas can be rapidly translated into successful outcomes.

Given these issues, CSIRO considers the National Innovation System Review to be extremely important and urgent. We ask the Panel to consider the accrued benefits of:

1. National agreement on the challenges and opportunities for Australia where research and innovation can provide solutions; clarity on the innovation goals; and a 10 year 'road map' for getting there with appropriate success metrics.
2. A consistent overarching policy framework to alleviate inefficiencies across the system and facilitate greater synergy and collaboration.

[2] For a 'simple' definition of innovation we like, courtesy of Imperial College's John Bessant (Melbourne Innovation Summit December 2007), "*Ideas successfully applied.*"
[3] See Appendix 1 for a short summary 'About CSIRO' and Appendix 2 for a short overview of the Flagships Program and some outcomes being delivered.

3. Role clarity as the basis for an efficient and responsive NIS.
4. A simplified and sustainable NIS.
5. The opportunities from a streamlined, clear and better understood approach to ‘path to impact’.
6. The need for improved collaboration and connectivity between research and technical providers and all other NIS participants, both within and external to Australia.
7. Mechanisms for providing appropriate skills across a modern NIS;

We would be happy to respond to the Panel more fully, either orally or in writing, around any areas of our submission where further elaboration is required, or on any other matters on which the Panel would like to seek further information or CSIRO’s views.

1. National needs, innovation goals

Key Points

- Australia's NIS needs a 10 year strategic plan with a roadmap: where we are headed, why and how? What are our goals? And what practical actions are required to meet these, and how (and by whom)? By what measures do we monitor our progress, and performance?

CSIRO believes that innovation is fundamental to Australia's continued economic, social and environmental wellbeing. If we are to create a more effective National Innovation System to underpin this wellbeing, Australians need to have clear goals built on a shared understanding of our emerging opportunities and our unmet national needs. These goals then shape our innovation priorities, and the strategies that guide all participants in the NIS to help achieve them. The recent 2020 Summit has begun the process to identify national goals.

We trust that the NIS Review itself will go a long way to formulating this Plan or, at the very least, its key elements. The Plan should take the form of a roadmap identifying what practical actions Australia will take over the next 10 years or so to meet its agreed innovation priorities. It will include a set of targets and performance measures to monitor progress and identify any problems encountered along the way.

Innovation priorities should identify areas in which Australia needs rapid adoption pathways, from R&D via innovation through to impact. Developing an appropriate 'vision of the future' should be an important component of the planning/Plan. An illustration of this approach can be found in the recent PMSEIC Report[4] on innovation in the service industries (Appendix 3).

Australia has invested in the development of a set of national research priorities. A higher level set of national innovation priorities would complement these and should be consistent with any adopted outcomes of the 2020 Summit. To be effective, a process of identifying opportunity and need would be a whole-of-government response. Further, because innovation is a continuous need, the task is never complete. The requirement for continuous inquiry and consultation needs some form of institutional framework; one way of achieving this might be the establishment of a National Innovation Council, considered in the next section.

Recommendations

Develop a 10 year NIS Strategic Plan.

Develop the key outputs of the NIS Review as an advanced framework for this plan.

[4] Science and Technology-Led Innovation in Services for Australian Industries. April 2008

2. A supportive policy framework

Key Points

- The lack of cohesive whole-of-government policy and principles for the investment of public funds is inhibiting innovation and creating uncertainty among many parts of the NIS.
- Adoption by government of the Productivity Commission's rationale for public support of science and innovation could help clarify the roles and responsibilities of each player in the NIS.
- There is a need for more effective policy coordination across the NIS.
- An independent 'National Innovation Council' could further develop the NIS Plan and monitor its effective implementation.
- Such a Council would provide governance/oversight of the innovation system and would be able to conduct studies and make direct recommendations to Government on 'whole of system' issues that cross portfolio and government boundaries.

2.1 Overarching principles for public investment in the NIS

The lack of a coherent, whole-of-government approach to the investment of public funds in the NIS underlies our complex and fragmented NIS. In response to new issues, funding initiatives tend to create new structures, which often lead to internal competition rather than collaboration and connectivity. CSIRO considers that national policy and governance frameworks are required to bring about an appropriate balance between diversity and fragmentation.

Conflicting policy signals on the role of the public sector in general, or of particular agencies, can create uncertainty. For example, a recent Productivity Commission study[5], together with independent assessments of CSIRO research by ACIL Tasman[6], state that CSIRO's role is not to subsidise industry. Yet the leverage requirements of some programs, particularly those associated with the Rural Development Corporations (RDCs) and the Cooperative Research Centres (CRCs)) can result in CSIRO using its appropriation funding to perform near-market research which, in effect, subsidises particular industries, or even firms, while providing few public good outputs (see Section 4.2).

The solution to these mixed signals could come from an explicit set of principles that address the role and purpose of different forms of public sector funding; these principles would provide guidelines for co-investment decisions when public sector organisations work with the business sector. Based on the principles put forward by the Productivity Commission, such guidelines could clarify the arrangements for such co-investment and make them less costly and more transparent.

[5] Productivity Commission 2007 study of Public Support for Science and Innovation: http://www.pc.gov.au/study/science/docs/finalreport
[6] ACIL Tasman report : http://www.csiro.au/files/files/pa78.pdf

CSIRO's business processes are consistent with the stance recommended by the Productivity Commission. Our principles for the use of appropriation funding are as follows:

- Meet Government's needs for information;
- Undertake strategic research addressing national needs;
- Maintain preparedness to address national needs;
- Co-investment or full funding where addressing market failure;
- Co-investment or full funding with industry in early discovery or strategic research; and
- Avoid use of appropriation for near-market R&D for successful industries.

In view of these considerations, CSIRO believes that there would be substantial benefit in Government being explicit about – for example as part of the before mentioned NIS Strategic Plan – the overarching principles for public investment in the NIS. An agreed set of national policy principles for investment and evaluation would provide additional impetus to the development of a cohesive NIS. CSIRO believes that such a framework would allow individual agencies to develop and refine their specific innovation objectives in the light of Australia's wider goals and innovation needs, recognising their complementary roles within the NIS. Furthermore, the policy framework would guide agencies implementing their own governance and management arrangements, consistent with their roles.

The principles for public investment should contribute towards a framework that is readily available to all players in the NIS, allowing each to target its effort effectively; they would also provide a consistent basis for Government to evaluate Program proposals, as well as allowing assessment of progress towards the goals of the NIS.

Recommendation

Develop a consistent set of principles for public investment in the NIS, based upon the Productivity Commission's rationale for support of science and innovation; these principles should apply to all Government funding of innovation programs.

2.2 Regulation

Overall, CSIRO's experience is that the non-regulatory barriers discussed in other parts of this submission (e.g. multiple governance arrangements, cultural differences, barriers to mobility etc) present a greater impediment to technological innovation than does regulation.

Regulation is one of the ways in which policy can make itself felt – and through which inconsistencies in policy can appear. There is no doubt that removing unnecessary regulation can free up the system and increase its flexibility by reducing the administrative burden that innovators can face. However, the role of regulation in innovation is more complicated than this statement implies and there can be conflicting views as to whether any particular regulation is necessary. Nevertheless, a worthwhile objective is to remove any inconsistency that exists between different governments and between different levels of government, as complexity will always increase the cost of innovation.

The reality is that regulation can inhibit innovation, stimulate innovation or be necessary for an innovation to occur, depending on the particular circumstances and the nature of the regulation.

Regulation can directly inhibit innovation if it prevents the use of new inventions. For example, uptake of genetically modified crops has differed among States due to individual regulatory decisions which have impeded the uptake of these technologies. This resulted in decreased investment in research that could have produced technical advances and new opportunities for innovation in this area.

In other circumstances, regulation can stimulate innovation. For example, the setting of stringent environmental standards for cars can lead to the technological developments necessary to meet them. The impact of this kind of regulation can be very different, depending on whether the regulations stipulate the mechanism for achieving a particular outcome or simply set the standards that should be met and leave it to individual organisations to determine how they might best comply. The latter approach will tend to promote innovation and lead to a diverse range of options for achieving the intended outcome, while the former will tend to stifle innovation by removing any incentive for creative thinking.

An example of regulation being necessary for an innovation to occur is the introduction of an emissions trading scheme, which will require a package of regulation that addresses a wide range of issues. Similarly, appropriate legislative frameworks addressing issues such as liability may be necessary to implement geosequestration or other carbon mitigation technologies.

2.3 A 'National Innovation Council'

We suggest forming a 'National Innovation Council' that has a clear mandate to conduct studies and to make direct recommendations to government on 'whole of system' issues that cross portfolio and government boundaries. It would:

- Consist of independent members (science, government and business) supported by an expert secretariat.
- Draw in further experts from across the NIS, as necessary.
- Hold open and extensive stakeholder consultation.
- Initiate reviews as well as respond to references from Government.
- Report to the executive arm of Government (and preferably to the Prime Minister), which should then table its reports in parliament or otherwise make them public.
- Require Government to respond formally to recommendations in the report within three months of receiving it.

Recommendation

Form an independent 'National Innovation Council' tasked with conducting studies and making recommendations to government on whole-of-system issues across portfolio and governmental boundaries.

3. Role clarity in the NIS

Key Points

- A healthy NIS that delivers on the national goals needs to have different players each with clear and distinctive roles.
- Role clarity will ensure that a broad range of national needs is met, without unnecessary duplication or inefficient use of resources – particularly important in a small NIS in a very competitive world.
- In the R&D part of the NIS, CSIRO (and other PFRAs) and universities have different roles that complement each other.
- The CSIRO 'Role House' model has enabled CSIRO to develop management structures and processes that support the roles it has defined and ensure the Organisation operates in accordance with them.
- The 'Role House' may provide a model for supporting role definition for other players, and for the NIS itself, and is potentially scalable to define the NIS itself.

3.1 Role convergence

Clarity of roles among the different players in the NIS is essential to minimise unnecessary competition between them, drive more creative and collaborative behaviours and focus funding mechanisms on the delivery of the national innovation priorities (Section 1). Some role overlap can be beneficial for maximising the passing of information and solutions across hopefully porous boundaries but it is only so under circumstances where the participants are not contesting each other's roles around activities and leadership.

Over the last 20 or so years there have been some major changes in the structure and composition of Australia's research system, reflecting its increased scale and complexity and greater diversity of players. A significantly increased proportion of the national research effort is now taking place in industry, while a large increase in the number of universities means that the higher education sector performs a greater proportion of the national research effort than the Commonwealth sector[7]. One consequence of these changes is that formerly distinct roles in the NIS have become less clear and, in addition, competition for funding in a more constrained fiscal environment has tended to lead to converging roles rather than the development of complementary specialisations and greater differentiation.

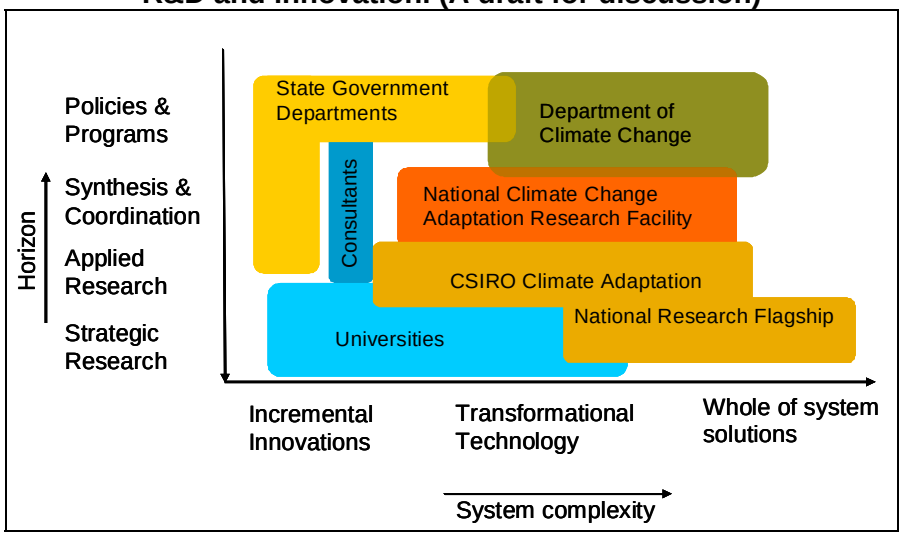
As an example, Figure 1 has been drawn to clarify the developments that have occurred over the last year in the area of climate adaptation. In delivering impact for Australia in this highly important area, it is essential that not only are the relationships between the various

[7] In 1978-79, publicly funded commonwealth research agencies (of which CSIRO is by far the largest) employed 26 per cent of the total human resources devoted to research in Australia and accounted for 30.5 per cent of Australia's gross expenditure on research and development (GERD). The higher education sector employed 39 per cent and accounted for 30.9 per cent of GERD; the business sector employed 19.8 per cent and accounted for 23.3 per cent of GERD. By 2004-05, the employment figures for publicly funded research agencies had fallen to 7.8 per cent, while the figure for higher education had risen to 47.5 per cent and for business to 34.9 per cent. The proportion of GERD performed in the various sectors had changed to 9.9 per cent for the commonwealth, 27 per cent for the higher education sector and 53.5 per cent for the business sector.

participants well understood but that each participant is contributing a role which adds value and in which they have strengths. The diagram begs three questions which are elaborated on in Section 4 of this submission:

i. Is the system too complex and introducing new layers of governance which could otherwise operate through existing structures?
ii. Is each participant in the system operating around their strengths?
iii. Do all the players understand (and accept) their respective roles in this system as well as those of each other?

Figure 1. Roles and interfaces of NIS participants in Climate Adaptation R&D and innovation. (A draft for discussion)



Dialogue around such maps might be a useful way of helping NIS players clarify their particular roles and crossovers.

3.2 Re-establishing role clarity

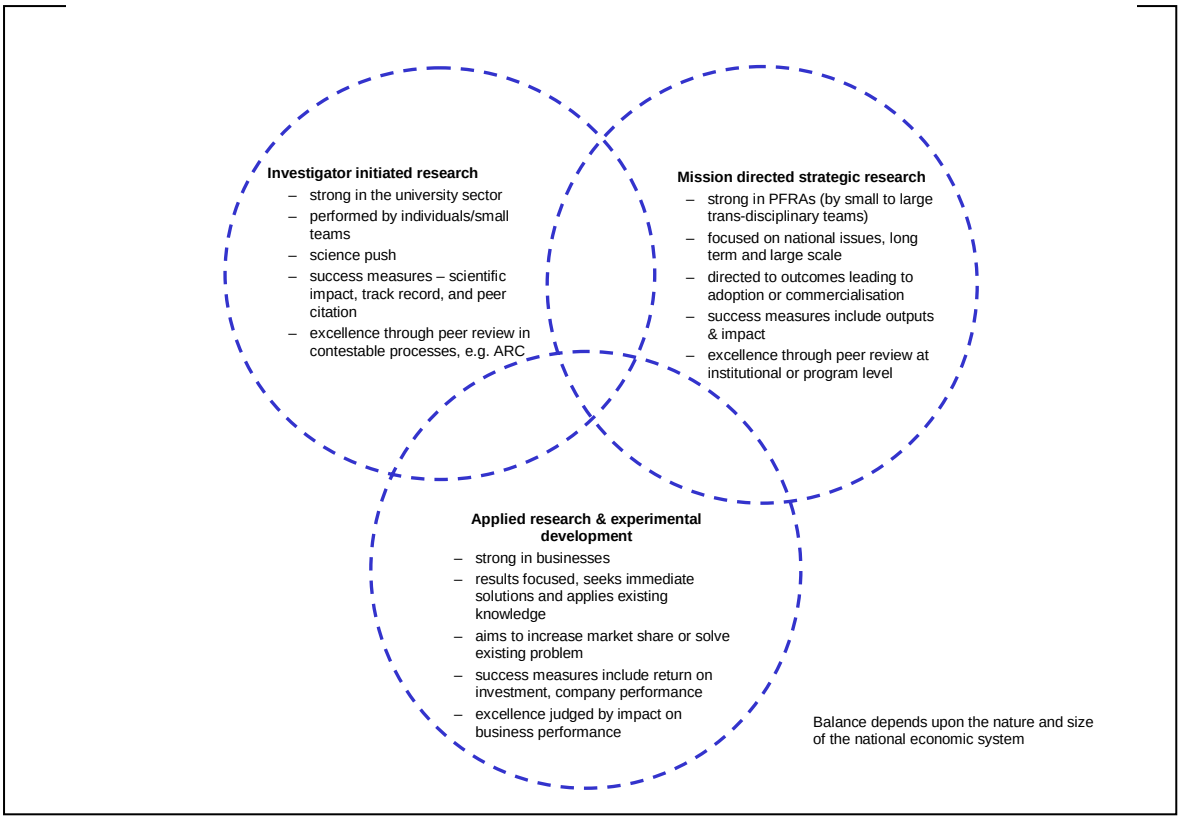
Re-establishing clear and distinctive roles for the different players while maintaining the benefits of diversity is important, particularly if they are defined in response to the different drivers that emerge from national needs and innovation priorities (Section 1). The Australian NIS is small compared with that of many other nations. Our ongoing challenge, therefore, is to foster diversity ('let a thousand flowers bloom') without it leading to fragmentation and lack of scale. Clear and differentiated roles across the NIS would therefore help:

- Spread risk over a more diverse portfolio of activity and approaches across the system;
- Build critical mass because different players can specialise and develop the management expertise needed to support the specialised activity. Moreover, large scale activities create a visible 'brand', attract the best people and provide worthwhile experience and career paths;
- Identify and reduce unnecessary duplication within the system and reduce the level of unproductive conflict resulting from it;
- Identify gaps and possible solutions;

- Design funding mechanisms that reinforce rather than undermine roles;
- Design support mechanisms and performance metrics to ensure maximum productivity for investment.

Figure 2 below seeks to illustrate the three broad areas of R&D activity and how CSIRO, universities and business may be seen to contribute to the nation's activities.

Figure 2. Role differentiation in the NIS



Once roles are clarified, the National Innovation Council proposed in Section 2 could then address a range of questions such as:

- Do we have an appropriate balance between diversity and focus?
- How does the current mix of roles and institutional arrangements manage the likely risk/return to the system?
- What is the NIS evolving towards?
- Is the current balance between investigator-driven versus mission-driven research appropriate? What should be our target?
- Do we have all the links in the chain, or are all the links of the required strength to achieve seamless transfer of science to adoption and impact?
- Have we optimised/aligned the funding models and the governance frameworks with the roles?
- Do we have the most appropriate and relevant performance metrics in place to monitor performance against each of the roles?

The Role House model discussed in the next sub-section may well assist in visualising the outcomes of this analysis.

3.3 CSIRO and the NIS

The Commonwealth Scientific and Industrial Research Organisation (CSIRO), was initiated in 1926 (as CSIR) between two world wars in response to national challenges (e.g., pests, weeds and diseases) affecting our agricultural exports. It was a time when advances in science were highly aligned to economic opportunities and social needs and, as became apparent during the course of the 1940s and 50s, it was also a time when powerful and beneficial science-based solutions touched on the every day lives of ordinary Australians. By today's standards, Australia's innovation system was simple. The contribution of science to the nation's future prosperity was clear and the purpose and roles of R&D community well defined. Policy frameworks were both unambiguous and supportive around purpose and roles, and funding was secure and in its ascendency.

Subsequently, the economies and affluence of industrially-developed nations grew in the more stable, global environment. The imperatives of the post-war Australia changed and, in response, so did the structure and composition of Australia's research and innovation system. CSIRO expanded to include more of the physical sciences and manufacturing; industry significantly increased the proportion of R&D that it did 'in-house'; and the number and size of universities grew to dramatically improve educational standards throughout Australia and, with them, so too did the proportion of national research effort from the higher education sector.

CSIRO's functions in the NIS are laid down clearly under the Science and Industry Research Act of 1949. These are to conduct and apply the results of research for the furtherance of Australia's national and international objectives and, specifically, the economic competitiveness of the Australian industry. Over the 80 years of its existence, CSIRO has built a breadth and depth of capability that is unparalleled not only in Australia but in most other countries. It is uniquely national in both its remit and geographic spread and out of need, has now developed the leadership and management skills required to coordinate large multidisciplinary programs of the type required to deliver to national challenges and opportunities of today.

CSIRO is also an experienced and seasoned manager of National Research Facilities (such as the Australian Animal Health Laboratory (AAHL), the Australia Telescope National Facility (ATNF) and the Oceanographic Research Facility, *Southern Surveyor*) and many National Collections, both biological and non-biological (Section 4.2.2). As the national research agency, we see managing and making available such facilities, fundamental to our purpose in the NIS. National Facilities and Collections not only provide internationally competitive infrastructure to Australia's researchers on a shared basis but also enhance Australia's standing at an international level. They add to the reputation of Australia as evidenced by the recent level of political activity around the Square Kilometre Array, and in the past through the work of AAHL as a global reference laboratory in exotic animal diseases such as Avian Influenza.

It is stated in the Preface (two questions) that if CSIRO did not exist, Australia would have to invent it, as appears to be the case in New Zealand. The New Zealand Government in 1992 disbanded their national research agency, DSIR, in favour of a corporatised Crown Research Institute model. They have recently established Science New Zealand, an approach to reconnect and harness the power of NZ's 4,400 public sector scientists currently perceived to be operating in silos in the Crown Research Institutes. While the need for a large, diverse and

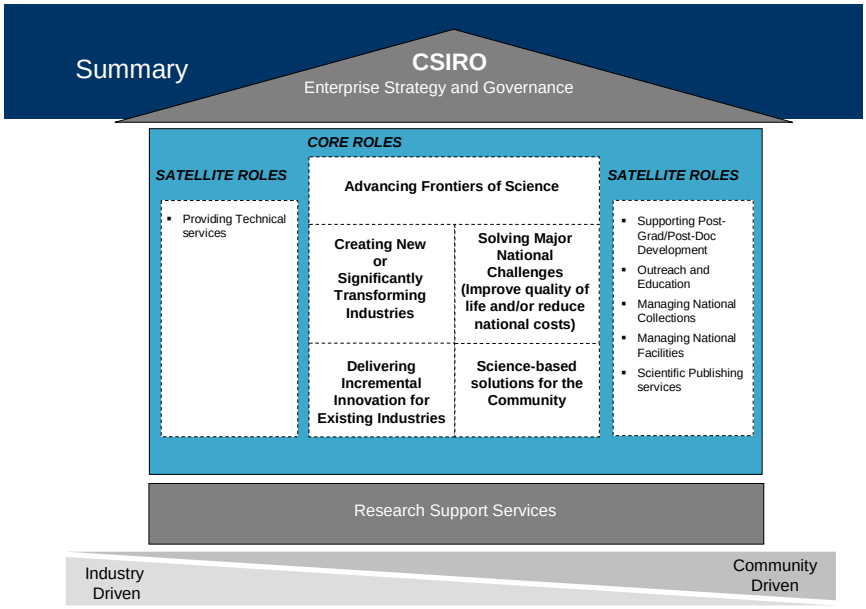
integrated national research agency might not have been a natural conclusion at the end of the last century, CSIRO recognised some years ago that the challenges facing Australia in the first decade of the 21st century and beyond, are also global in significance, and that size does matter. Solving these big problems and, equally importantly, creating opportunities along the way, requires a systems approach to providing solutions, collaboration between non-traditional science partners and scientific leadership at a level of complexity not previously experienced in scientific research.

Over the past 6 years, CSIRO has clarified and defined its roles in the innovation system and, in returning to its origins underlined in its Act, we have developed structures to deliver an outcome and impact focused research portfolio together with governance processes to drive investment and measure progress. CSIRO's governance processes for the use of public money were commended by the Productivity Commission (see Appendix 4); CSIRO's vehicle for research scale and outcome delivery was commended by Australia's previous Chief Scientist, Robin Batterham, Chair of the independent, international Flagship review panel.

One role for CSIRO that has remained unspoken, but we proffer it here, is that - given our size and 'reach' as Australia's premier national research agency - we can provide the 'central brain', where appropriate and necessary, for the nation's innovation system through thought leadership and well orchestrated responses to national challenges and opportunities. We do this through the current Flagships program and, potentially, through national extensions to it. CSIRO's recent activities in the Murray-Darling Basin illustrate this well (Preface).

CSIRO would, however, like to see clarity in the NIS with other players defining their own roles as well as establishing a mutual understanding of each others' roles. As an example, CSIRO has defined its place in the innovation system around a set of core and satellite roles (the CSIRO 'Role House', figured below and detailed in Appendix 5). It is appropriate for roles to overlap; however while other players will have their own unique mix of roles, the smooth and porous operation of the NIS is highly dependent on clarity of understanding not only between the R&D providers but also by those who wish to fund or engage in other ways with them. We suggest that building on this model, therefore, could be an effective way for establishing this clarity as well as being scalable to assess more broadly in the NIS itself.

Figure 3. CSIRO Role House



Universities also play a vital role in delivering to national challenges, and CSIRO's experiences in the major 'cluster' partnerships with more than 20 of our universities as a key part of our Flagships Program, has been stimulating and successful. In terms of their core focus, universities are necessarily, and rightly, driven by the need to build the skills base and human capital that sustains the nation's prosperity and well-being (see Fig. 2). They also foster the important investigator-led teams of excellent researchers to help build the nation's knowledge. It is legitimate (and important) that these teams are tightly focused around key individuals.

Recommendations

Individual players should define and clarify their roles within the NIS and develop the management and other processes necessary to support those roles.

The CSIRO 'Role House' may provide a scalable model to enable a whole of system view of the NIS.

4. Greater sustainability, less complexity

Key Points

- CSIRO supports streamlining the NIS to make the system more productive.
- There is a need for a much smaller set of governance and performance measures for funding programs and players within the NIS, reflecting the particular roles and responsibilities of each component of the system.
- The multiplicity of funding bodies, each with its own administrative and reporting requirements, increases transaction costs, makes coordination difficult and results in inefficiencies for users.
- Major problems requiring a large-scale response can be difficult to put together under competitive funding programs offering small amounts of funding for short-term research. Appropriation funding is necessary for research scale and continuity and building capacity in core areas of national capability.
- The NIS needs to move towards fewer, but larger scale funding mechanisms, taking into account the full cost of research; and with streamlined governance and reporting mechanisms.
- The leverage requirements set by many competitive funding schemes add to complexity, are unsustainable and lead to unintended consequences that threaten the fabric of the innovation system. They can result in the inappropriate use of appropriation funding by some stakeholders and distortion of roles.
- Benchmark data for other innovation systems, notably that of the US, indicate that investment in CSIRO's capital building infrastructure (buildings and equipment) is falling short.
- CSIRO's capital infrastructure is deteriorating as the costs of replacement and support (depreciation, repairs and maintenance) exceed current appropriation indexation levels.
- Sharing through the development of research 'hubs' will create a more efficient (and collaborative) NIS but will not resolve the rising support costs associated with current infrastructure.
- Research 'hubs' involving universities, CSIRO other PFRAs and industry, supported by HEEF would provide more cost effective sharing and use of capital infrastructure as well as assist path to impact.
- National Facilities and Collections present particularly difficult problems: they require transparent funding, separate from that of the host organisation and sufficient to cover both capital and operating costs.

The Australian NIS is very complex for a small nation. The Australian Government's 2007-08 Science and Innovation Budget Tables identify over 80 major Commonwealth R&D granting programs across eight Government Departments. Although such complexity is not unique to Australia's innovation system, we propose that simplifying the NIS will significantly increase direct investment into science through streamlining the administrative and governance burden that results from the many structural arrangements currently in place. This overhaul would follow from a coherent set of national innovation priorities (Section 1) underpinned by a consistent and unambiguous policy framework (Section 2) which addresses:

- how and where public funding supports Australia's innovation needs;
- the means of sustaining long-term, the national innovation system's capability and infrastructure.

4.1 Organising arrangements

A complex NIS has arisen from the tendency to add new initiatives, entities and governance arrangements in response to new challenges and opportunities, without necessarily removing those which have become less effective, moribund, or simply redundant. This has been especially so in programs introduced to enhance collaborations; over the past two decades we have seen the development of the Cooperative Research Centres (CRC) program, the Australian Research Council's (ARC) Centres of Excellence, the ARC Linkage Grants, the Commonwealth Environment Research Fund (CERF), the CSIRO Flagship Collaboration Fund, National Collaborative Research Infrastructure Scheme (NCRIS) and more, all with different, often incompatible governance arrangements. While each of these programs has individual merit, when taken as a whole they tend to add complexity and cost without any obvious benefit to the system overall or the outcomes expected from it.

In addition to the confusion that can be created in the system by these various arrangements, the resulting overheads and collateral transaction costs are also unnecessarily high. As a further example, the NIS Panel is referred to the recent NCRIS program in which detailed governance arrangements were required not only for the nine core programs of the initiative but often for each sub-program activity[8].

As the number of funding bodies and initiatives grow, each brings with it different application and reporting protocols dependent on different contract management and evaluation[9]. This is on top of inconsistent program objectives. Typically, a single project undertaken by CSIRO in agricultural research can be part of a CRC and be partly funded by an RDC. This can mean reporting at multiple levels to satisfy the individual governance needs of the three stakeholders. Yet, all these fund sources are mostly about investing public money. Streamlining of programs and unifying their administrative and governance requirements would significantly increase productivity from existing investments, and result in more of the funding supporting the direct costs of science.

CSIRO believes that the solution to this challenge lies in developing standard sets of governance arrangements and performance measures to reflect agreed principles for public-sector funding of innovation, according to the role of each type of program within the NIS.

Recommendations

Streamline the NIS by significantly reducing the number of funding programs aligned with major priority areas.

Introduce more consistent and simple administrative, governance and requirements across all government funding schemes building on and using the administrative and governance arrangements of existing organisations.

Develop performance measures for programs that are consistent with the agreed roles, responsibilities and policy objectives of that component of the NIS.

[8] Appendix 6

[9] These are also difficult for SMEs and lead to the frequent use of consultants who, if they take a return on the support awarded, can reduce the direct impact of the government's investment.

4.2 Funding arrangements – Full cost versus the leverage game

The Australian NIS would be greatly simplified if funding bodies invested in the full cost of the research they are supporting. Without this reform, it is not possible to identify the cross-subsidies that distort investments in the NIS. In particular, when research funding organisations do not contribute to the cost of the infrastructure on which they depend, it is inevitable that such infrastructure will deteriorate, fail to maintain currency by global standards or become unavailable (Section 4.4.1).

At present, competitive funding programs in Australia operate as a system of highly leveraged funds that draw on block allocations to science agencies and universities to match program funding. It is not uncommon for research funders or agencies to leverage their funds two or three times (and occasionally higher) with the result that there is really very little new money to sustain the system. It is concerning that this has become the dominant mode of investment because it is producing serious distortions in the strategic roles of R&D providers and undermining their sustainability. This model of research funding results in marginal costing by the research providers and the subsidisation of research through other means; and it distorts the core purpose and roles of research organisations as they jettison their strategic research strategies in favour of shorter-term, near market research.

CSIRO's experience with the Rural Development Corporations program scheme illustrates these points (see Box 2 below).

Fully costed research requires 'open book' accounting on the part of R&D providers to ensure that the costs charged, particularly the indirect costs, are transparent to scrutiny and properly accounted. It is vital that research is conducted efficiently using capability, infrastructure and research approaches which are suited to the task and appropriately governed.

Box 2: The Rural Development Corporation (RDCs) Program

The RDCs are now the major external funding source for CSIRO's agricultural sciences ($47.8m in 07/08). While there are differences between the RDCs, most have a strong focus on shorter-term horizons (1-3 years) around particular agricultural commodities and are less inclined to support longer-term or cross-sectoral work.

CSIRO's appropriation-funded agricultural work should focus on strategic research. While CSIRO can support the industry by performing near to market work, this should receive full industry funding, consistent with the principles articulated in the Productivity Commission study on public support for science and innovation. However, the RDCs use a co-investment/collaborative research model that requires research performing agencies to cover a considerable share of the costs of the research the RDCs are purchasing. Thus, the rural producers are supplementing funding they have received from government by further leveraging public funds from research providers.

An alternative approach would be to separate the producer levy from the matching Commonwealth funding and to use these separate elements for different purposes – the producer levy for the incremental work with the Commonwealth levy for the (fully funded, no leverage!) longer term, higher risk more strategic work aimed at addressing the national challenges faced by agriculture as a whole rather than individual industries. This would simplify the system through role clarity, even though it may require a body to administer what is currently the Commonwealth matching funding, although this could be achieved through an existing program.

Fully costed research should not be confused with the cessation of co-investment approaches; these can, and should continue where there is alignment of collaboration objectives. However it is important to have transparency of the relative contribution of the different parties to ensure that co-investment involving government appropriations takes place only in accordance with generally agreed policy principles for the expenditure of such appropriation (Section 2) and in accordance with the defined roles of the co-investing organisations.

Recommendations

Move to funding programs that fully support the full cost of research, including overheads and capital infrastructure.

Ensure R&D providers have 'open book' accounting to support and justify the cost of their research.

Refine the RDC framework to enable different funding models for 'near to market' versus strategic, cross-sectoral issues.

4.3 Research scale and flexibility

The plethora of individual funding schemes for R&D dilutes funding, with many funding initiatives being sub-scale with short time horizons. As a result, research providers spend time and resources trying to build the funding base necessary to undertake larger scale R&D projects to address major national challenges and opportunities. This increases the transaction costs of research and there is an urgent need to increase the scale of individual programs. We suggest fewer, larger, longer-term grants or investments are needed if we are to address many of the challenges (and opportunities) facing Australia. For example, climate change will drive the need for new modes of water management and energy production and, along with other issues such as obesity, will require investments in the billion dollar range if we are to achieve the innovation necessary to seriously address them. This expenditure will need to come from the private as well as public sectors, especially as the solutions move to the (still high risk) development and application stages. Small scale programs cannot develop practical solutions in the time we have available and will not generate the private sector confidence necessary to develop robust and long-term partnerships based on the sharing of risk and expertise.

Scale also requires continuity and funding certainty. CSIRO has been able to achieve this through the use of the appropriation funding which underpins our capacity to respond to national challenges at scale (see Box 1). A move to further increase the contestability of these funds, as has been suggested in the past, would undermine our very capacity to deliver on our purpose to the Australian community.[10] Interaction with 'sister' organisations overseas confirms the considerable downsides associated with an increasing dependence on small, contestable grants of limited duration. Incorporating CSIRO's block funding within an ARC-based, investigator driven process would also be seriously detrimental to CSIRO carrying out

[10] Appropriation funding is contestable at Cabinet level through our quadrennial funding processes; and CSIRO's internal science investment processes are highly contestable, remaining so through the course of each project, based on our performance management framework (see Appendix 7)

its core roles which depend on enterprise level science planning and management to achieve scale and impact.

4.4 Infrastructure

4.4.1. General

A broad range of physical infrastructure is necessary for sustained innovation, with all players in the system needing buildings to house both people and the necessary research equipment. CSIRO's continued experience is that government appropriation is insufficient to maintain its sites in a state which supports internationally competitive science.

CSIRO's underlying government funding for capital equipment is not indexed and is falling in value in real terms. This creates pressure to ration capital investments. Historically, CSIRO has invested the bulk of its capital into land and buildings which has led to a decline in the scientific equipment and IT equipment base. More recently, we have sought to redress the balance through re-distribution of capital allocations across asset classes and a more active process of capital bid prioritisation.

Capital equipment benchmarking against comparable capabilities in the US indicates that CSIRO is now investing at similar and sustainable levels, although the shortfall from previous years has not been replaced.

Benchmarking investment in scientific buildings suggests CSIRO is falling behind. US data indicates a doubling of investment over the past decade in some areas of science capability while CSIRO's comparable spend has reduced by approximately two thirds.

CSIRO is facing steadily increasing capital related costs over the next decade. These are largely property related and include depreciation (real estate base value continues to rise on revaluation) and repairs and maintenance. All other things remaining equal, there will be a need to almost double spending from $124m in 2007/08 to over $230m in 2016/17.

At the same time CSIRO expects to see increasing R&D capital intensity with, for example, demands for capital investment in IT equipment increasing rapidly due to changes in the nature and capability of the science we are now undertaking (e.g. climate modelling, radio astronomy, materials science). In total CSIRO faces a capital/operating cost shortfall over the next decade for the current range of capabilities of at least $420m (comprised of $250m of capital and $170m in operating costs), i.e., around $45m p.a.

Without an injection of additional capital and related operating funding, either through increased appropriation or a greater acceptance of fully-costed research (or a mixture of both) CSIRO is faced with reducing its R&D portfolio or alternatively its geographic spread. Not to do so would be to accept that the organisation will fall behind on investment to the detriment of both research competitiveness and/or the delivery of beneficial research outcomes for Australia.

CSIRO's strategic objective in developing science/innovation hubs through co-location as a means of promoting the sharing and more effective use of infrastructure will continue and could be enhanced if HEEF funding were to give priority to such hubs from the perspective

of university infrastructure. Initiatives of this kind would also encourage accelerated path to impact opportunities (see Section 5) and promote greater collaboration across the NIS (see Section 6). This approach however, would not relieve the rising support costs associated with current infrastructure.

Recommendations

Index underlying government funding for research infrastructure to maintain its real value.

Recognise both the capital and the operating costs associated with its use in funding for new research infrastructure.

High priority weighting for investment in the HEEF prioritisation process should be given to co-located 'science hubs' to provide the opportunity for the sharing of scarce research infrastructure between Universities and PFRAs.

Governments also have a role in providing or supporting general use infrastructure, especially that which forms part of the national research system, e.g. high-speed, low-cost, broadband, etc.

Governments can also play a role in creating an environment which promotes commercial investment in the physical infrastructure which businesses need in order to innovate. Features of the taxation system, such as depreciation allowances, and decisions to treat pilot plants as part of the R&D process, can all play major roles in changing the propensity of business to invest in technological innovation.

4.4.2 National Facilities and Collections

Innovation cannot take place without access to the necessary infrastructure, and Australian research cannot be globally competitive without access to globally competitive research 'tools'. In the context of increasing cost and scale of the front-rank research infrastructure that underpins the NIS, the role of our National – and indeed international – Facilities (including National Collections and data repositories) will assume greater importance.

Some of the infrastructure required by the Australian innovation system is large, expensive to set up and costly to maintain at the forefront of competitive science. Research facilities such as the ANSTO reactor, the Australian Animal Health Laboratory, the Synchrotron, the Australian Telescope National Facility and the Oceanographic Research Vessel, need to be shared and require national management. Without such facilities Australia cannot remain internationally competitive in its research or its ability to attract talent, nor can it expect a seat at the table of international initiatives where the nation can both contribute to and gain from such R&D collaborations.

Increasingly, there will be scientific facilities that no single institution and, in some cases, country can afford to construct and operate on behalf of the research community. As such the management and operation of National Facilities and Collections needs to be recognised as a specialised but integral part of the NIS. Previously Australia's approach to National Facilities and Collections has been fragmented across the NIS.

World's best practice in the management of National Facilities includes sustainable funding, robust governance arrangements, with broad stakeholder engagement and transparent arrangements for access. It also needs to include an ongoing world-class Australian research capability and technology development program to maintain the international impact and competitiveness of each National Facility. By providing world-class infrastructure and by fostering collaboration across the NIS, National Facilities will also act as global talent magnets for people and act as a focus for industry engagement in the NIS.

Only a few entities with the NIS can provide the breadth and size to deliver National Facilities. CSIRO is one such entity, and CSIRO values its existing role within the NIS as the provider of three of Australia's world-class National Facilities, the Australia Telescope National Facility, Australian Animal Health Laboratory and the Oceanographic Research Vessel. Furthermore, CSIRO's cross-boundary and collaborative approach to research, Government partnerships, broad industry engagement, and extensive business support mechanisms together result in a very strong alignment with the requirements for the delivery of National Facilities, and constitute a significant point of differentiation for CSIRO within the NIS.

CSIRO therefore values its role as a host and manager of National Facilities, acknowledging that a significant in-house research capability with excellent national/international linkages is essential to keep the infrastructure at the cutting-edge. Nevertheless, CSIRO's experience highlights the need for separate and identified appropriations which cover both the full capital and operating costs and the ongoing development and maintenance investment required to keep such facilities at the international cutting edge. Not to do so, or to expect such facilities to be self sustaining in an innovation system where funds are already highly leveraged (section 4.2), leads to role distortion in the innovation system, with host organisations more often than not having to subsidise the facilities. Alternatively, organisations hosting major facilities or collections may take decisions relating to their own strategic direction, priorities or capital refurbishment needs that are not in line with the needs of other potential users of the national facilities that they host.

In addition, CSIRO also manages – as National Collections – a number of major biological collections including the Australian National Herbarium[11], the Australian National Insect Collection, the Australian Wildlife Collection and the National Fish Collection. These represent significant holdings of Australia's biodiversity in these areas and underpin Australia's efforts in a wide range of activities such as biosecurity and trade related matters; conservation and biodiscovery; natural resource management; human and livestock health. CSIRO has developed these collections over its 80 year history, originally as an offshoot of its environmental or agricultural research. They are an invaluable national resource and complement holdings by State Museums with whom CSIRO maintains active collaboration. While the collections continue to provide a platform for much of our biological work, they are a national asset, accessible to others in the NIS. The resource issues for collections are the same as described above for national facilities. Sustaining the basic infrastructure has been challenging as it draws on, and competes for, our core appropriation funds. External sources of funding are rarely prepared to pay for this infrastructure, even when it is critical to the project outcomes. A national approach to funding this valuable resource is urgently needed.

[11] in partnership with the Australian National Botanic Gardens.

Recommendations

Recognise the importance of National Facilities and Collections and ensure that they are funded on an ongoing and sustainable basis via separate and identified budgets.

Seek to evolve a consistent framework for the management of National Facilities and Collections around entities of sufficient size and scale to maximise cross-boundary collaboration and stakeholder engagement.

Recognise that the management of National Facilities and Collections needs to be coupled with an indigenous world-class research and development capability.

Acknowledge the need for, and develop, a strategy that supports the globalisation of research infrastructure.

4.5 Contestability and block funding

Public sector research organisations such as CSIRO receive funding through a variety of mechanisms: direct budget appropriation; grants and contracts from government; contract and fee for service work from the private sector; fees from the sale of products; revenue from existing intellectual property; and revenue from management activities such as asset sales. These mechanisms are not interchangeable because each has particular characteristics, can produce different outcomes and serves different purposes.

Some funding (e.g. grants and contracts) is described as contestable, because it is subject to open competition (usually at the project level), while some, such as the budget appropriation, are described as non-contestable. Arguments are sometimes put forward that increasing contestability is a means of increasing the excellence of the funded research. However, all these funding sources are competitive, but in different ways. Budget appropriation, for example is contestable at Cabinet level and is often subject to allocation processes internal to an organisation that involve both competition and a level of ongoing monitoring that is absent from many competitive schemes.

Budget appropriation provides for the degree of certainty and stability that is necessary to maintain a long-term capability. Appropriation funding is the best way to provide a base for the development of major research projects requiring long-term planning and the assembly of large teams of experts from several disciplines and across different organisations. Appropriation funding also facilitates sustained research into areas of science for which there is as yet no identified user because government, the general community and business have yet to recognise its potential.

There is no doubt that, in many cases, contestability can lead to superior outcomes but it is important to understand that contestability is a means to an end, not an end in itself. A balanced innovation system will use the funding mechanisms best adapted to the purpose of each program and this will involve the use of block or appropriation funding to support the

core roles of publicly funded organisations supplemented by contestable funding to achieve particular ends.

For this reason CSIRO supports the notion of contestability in appropriate circumstances but urges the NIS Review Panel to consider where the concept enhances the innovation system and where other approaches may by more aligned with larger scale collaborative research over long timeframes. Contestability would have greater impact on research quality and innovation if directed at providers who share similar roles and similar drivers – i.e. based on a 'level playing field'.

As an example, the ARC Discovery Program is primarily directed at supporting curiosity-driven, investigator-led research aimed at increasing scientific knowledge. It is appropriate to have contestability among universities for funding under this scheme as it is directed at one of their core roles (Section 3). Although CSIRO also undertakes frontier research we do this for different reasons, primarily to develop capability platforms for the delivery of research outcomes. This makes it inappropriate for CSIRO to be eligible for this research funding mechanism. Consistent with this rationale, funding programs directed towards addressing major national challenges requiring scale, national coverage and longer time horizons require a different set of rules from the ARC Discovery program. Contestability in this case should be between the players who undertake this type of research as a core role. For contestable programs to be fully effective it is also critical that funding schemes recognise and provide the full cost of research.

The use of contestable mechanisms becomes especially problematic when there are no obvious competitors. This can occur when there is a sole supplier because there is only one facility e.g. research reactor, or where there are no competitors because the intent of the process is to build up a capability that does not currently exist. In these circumstances approaches other than contestability may be more useful – and certainly less costly. The NCRIS approach demonstrated one such way of operating in a more cooperative manner to achieve an outcome in the national interest, notwithstanding some of the unnecessary complexity as already mentioned (see Appendix 6).

Experience with the tender process for the operator/manager of the Victorian Synchrotron highlights some of the problems (and very high transaction costs possible) with contestable approaches and the need to develop other, more cost-effective mechanisms that still ensure value for money and appropriate probity.

There is also an important time dimension to contestability. In the case of many government programs the competition occurs 'before the event' and there is no ongoing assessment, although the grantee may have to prepare a report at the end of the grant period – several years later. In the case of CSIRO, the CSIRO Science Investment Process (SIP) allocates funding for projects which are then subject to regular assessment around science and impact performance criteria (see Appendix 8). This can lead to reduced, or increased, funding or even the complete cessation of funding, depending on the progress made; with a consequent reallocation of funding to the most competitive projects.

Recommendations

Continue the use of block funding to enable publicly funded research organisations to maintain their core responsibilities (such as mission-directed strategic research for CSIRO).

Contestable funding programs should only be used where clear benefits can be identified and then only when players 'compete' on a level playing field.

5. Improving path to impact

Key Points

- A major priority for the Australian NIS should be to introduce mechanisms that ensure more active management of research to achieve impact.
- More explicit assessment of potential impact is needed across all three areas of impact (economic, social and environmental) is required prior to investment, and subsequently at the evaluation stage, as well as the contribution of each to national wellbeing.
- Greater emphasis is needed on systematic, ex-post evaluation to:
  - allocate resources for evaluation in agency budgets; and
  - inculcate the practice of following up the use of project outputs and impact. (Thich may require inclusion in agency contracts for provisions requiring customers to provide data).
- More detailed attention needs to be paid to the rationale for investment in particular projects/industries. This should build on a detailed consideration of the issues discussed in the Productivity Commission's 2007 report, as addressed earlier in this submission.
- There is a need to develop a better understanding across all sectors of the role that IP plays in achieving impact from research.
- Greater emphasis needs to be placed on the development of research personnel who are comfortable with crossing boundaries. The latent desire to make a difference beyond expanding the frontiers of knowledge also needs to be coupled with the ability to work across institutional and other boundaries. CSIRO is actively working to develop the boundary crossing capabilities of its researchers including the creation of a new cadre of 'collabronauts'[12].

5.1 CSIRO and Path to Impact

A major priority for the Australian NIS should be to focus on the more active management of research and innovation to achieve impact[13]. The world is changing rapidly and global problems are becoming more acute; product life cycles are speeding up; international competition is increasing. Delay creates the risk that research outputs may become outmoded or irrelevant because others succeed earlier or that the problem has become worse.

We use 'impact' to mean a beneficial effect on one or more of the economic, social and environmental well being of Australia or "national wellbeing" consistent with the framework developed by Treasury:

- The level of opportunity and freedom that people enjoy;
- The level of consumption possibilities;
- The distribution of those consumption possibilities;
- The level of risk that people are required to bear; and
- The level of complexity that people are required to deal with.

[12] See Appendix 9 for definition of 'collabronauts'.
[13] See Appendix 10 for the Productivity Commission's definition of 'impact'.

Research can use a variety of pathways to deliver impact on national wellbeing, and some of these are illustrated in Box 3. This focus on impact is a key element of CSIRO's distinctiveness over its more than 80 year history.

In our experience, research aimed at delivering economic, environmental or social benefits will use different paths to impact. CSIRO develops collaborative partnerships with potential end-users and experts in technology transfer to ensure the rapid take up of outputs from its research. This is particularly important given that (especially in the case of innovation for economic benefit) the structure of our economy and the small size of many of our firms mean that Australia's adoptive capacity is low. Action is necessary to address the demand side of innovation as well as the supply side if Australia is to have a secure future.

Box 3. Some research impact pathways

Publishing books, conference or peer-reviewed papers

Issuing press releases, podcasts, vodcasts and publishing on the web

Speaking at conferences, to users or to community groups

Exchanging personnel on secondment

Transferring personnel with the technology (e.g., spinoffs)

Contract service provision

Contract R&D problem solving, delivering reports to clients

Collaborative R&D engagement

Seeking IP rights

Licensing of technology

Creation of spin-out companies

Working with government to inform policy development

CSIRO believes that there are two essential principles that all aspects of the government's support for innovation must have if they are to maximise wellbeing: they must begin with a clearly articulated end in mind (section 1); and subsequent activity (in the case of CSIRO, primarily research and development effort) must be managed and/or monitored towards that end. As discussed elsewhere in this submission, CSIRO has put these principles into practice through its own planning, management and evaluation processes and its governance structures[14]. It is CSIRO's view that there are significant opportunities to improve the performance of the NIS if these principles were applied more generally across the publicly funded R&D elements of the innovation system.

Appendix 11 lists some of the direct impacts that can result from the effective management of research. While the aim should be to manage research to achieve planned outcomes, the nature of research is such that:

- not all individual investments will 'pay off' (hence a portfolio view is important and given the small size of many Australian firms, the public sector plays a role in facilitating a portfolio approach);

[14] See Appendix 8, The Science Investment Process

- some investments will pay off in unexpected ways and we should seek to capture these where appropriate, so research management processes should be flexible enough to respond to serendipitous opportunities that might arise; and
- some will have negative impacts (expected and unexpected) as well as positive.

5.2 How can the impact of R&D be measured?

If the operations of the innovation system are to provide the best possible return to Australia, it will be important to measure the impacts arising from public investment in research so that it becomes possible to reallocate funds to the most effective part of the system. However, measuring impact is difficult, not least because different individuals or groups may regard the same impact as positive or negative. This complicates the process of deciding whether a particular research project is an 'appropriate' project for CSIRO to pursue.

Two examples: (1) research may provide benefits to a single firm at the expense of others in the industry, (2) the economy of one state may grow but the national economy may be reduced. This reinforces the recommendation earlier in this submission regarding the need to adopt a uniform set of investment principles across the public sector's involvement in the NIS.

CSIRO has, over a number of years studied how it can best measure the impact of its research and the government's return on its investment in CSIRO. Appendix 12 presents some of its more recent conclusions.

Because of the need to allocate public support where it will have most effect, CSIRO believes that there would be value in the NIS review establishing an overarching evaluation framework for assessing the impact of the 'portfolio' of public sector support for innovation. This would seek to bring together under a single evaluation umbrella the different assessments of "impact" associated with the range of public sector programs supporting the NIS. Adopting a common framework for assessing and evaluating impact in this way would provide an ongoing mechanism by which comparisons could be more readily made between different aspects of government's support for innovation.

Impact has a critical dependence on two factors covered elsewhere in this Submission: appropriate management of IP (section 6.3) and a supply of industry-ready people (section 7.2). Both of these factors illustrate that the smooth and rapid transfer of knowledge through to impact is highly dependent on people and their interaction.

5.3 People – rate limiting for impact

People play a fundamental role in creating impact from research. The technology transfer/diffusion imperative is a people game and (like many of the football codes) somewhat of a contact sport, i.e. appropriately skilled and motivated people working closely with those seeking/needing their outputs. A review of best practice experience in CSIRO, by way of a review of the research programs undertaken, and impact delivered, by CSIRO medal winners over the past 20 years, highlights the importance of the people dimension in the process of generating impact (see Appendix 13).

A desire to have impact beyond expanding the frontiers of knowledge needs coupling with the ability to work comfortably across institutional and other boundaries. Through the impact

orientation of its research CSIRO plays an active role in trying to develop the boundary crossing capabilities of its researchers. This also extends to the role we have in developing early career scientists through our role in post graduate and post doctoral training programs which, experience tells us, makes them more 'industry ready'. In more recent times the emergence of a new cadre of "collabronauts" (see Appendix 9) is increasingly facilitating more rapid technology take up of research and other innovative ideas for commercial and community benefit.

Specific training initiatives to nurture and develop the skills and behaviours promoting rapid and effective 'path to impact' are considered in Section 7.

Recommendations

Strengthen the requirement on publicly funded research programs to explicitly articulate the nature of the impact they are seeking to achieve (the end) and how they propose to achieve it (the path to impact) before making investments in research.

Require explicit performance assessment against appropriate metrics in major public sector R&D investment decisions.

6. Collaboration

Key Points

- An effective NIS depends on effective and efficient collaboration and other interactions among the different players to share ideas, people and infrastructure.
- At present, collaboration among organisations comes at a considerable cost – mostly associated with increased transactions from the interplay of different and often incompatible administrative, management, funding and governance arrangements, and from a 'clash of cultures'.
- Global linkages need to be supported and funded if we are to access world-class technology, knowledge, people and capital.
- The CRC program has been an important mechanism for enhancing national collaboration. The program may have reached its 'use by date' and needs to evolve to a new form or be replaced.
- Separate programs for collaboration need to be developed for 'public good' and 'industry benefit' collaborations, each with streamlined administrative arrangements.
- A properly-managed IP system is critical for stimulating efficient NIS collaborations.
- CSIRO's National Research Flagships program has provided valuable insights on how to deliver collaborative research on national scale issues and could be extended across the NIS.

CSIRO remains firmly of the belief that collaboration is important and can be enhanced to deliver more benefits to Australia[15]. In our submission to the Government's 2004 Review of Closer Collaboration between Universities and the Major Publicly Funded Research Agencies we drew specific conclusions and made a number of recommendations (see Appendix 14) around enhancing collaboration which we believe still have currency. In this current submission we build on these perspectives.

Collaboration has many advantages, such as:

- Building scale and critical mass and generating synergies through interactions among players with different skills, expertise and facilities;
- Optimising the use of large infrastructure;
- Creating opportunities for technology transfer and commercialisation on the path to impact.

As we streamline our rather fragmented NIS, we also need to ensure that collaboration among the players is supported in an efficient and effective way. At present, collaboration among organisations comes at a considerable cost – mostly associated with increased transactions from the interplay of different and often incompatible administrative, management, funding and governance arrangements, and from a 'clash of cultures'.

CSIRO's experience[14] indicates that success in collaborations is driven by

[15] See CSIRO's submission to the Government's 2004 Review of Closer Collaboration between Universities and the Major Publicly Funded Research Agencies at http://www.dest.gov.au/sectors/research_sector/policies_issues_reviews/reviews/previous_reviews/research_collaboration_review/

- a shared vision with a focus on the added value of the collaboration
- a fair sharing of the added value including, where appropriate, an agreed strategy for the ownership and management of any IP resulting from the partnership
- a strategic fit between partners that respect each other's culture
- organisational alignment involving senior executive commitment to the collaboration, processes to build and maintain trust between key staff, mutually accepted governance arrangements and effective communication within the collaboration and to its partners.

6.1 International Collaboration

CSIRO believes that Australia must become a more active and strategic player in the global innovation system. In the competitive global economy, advances in science, technology and innovation increasingly occur at a global rather than a national scale. This transition is being accelerated through shifts from in-house R&D to 'open innovation markets' (where firms source much of their innovation from others), the rise of globally networked operations, the spread of cyber-infrastructure and the development of big science projects in response to emerging global challenges such as climate change and health pandemics.

CSIRO believes that engagement in the global innovation system requires three key activities for Australians:

- **Talent –** Attract and retain world-class researchers to Australia and ensure Australian scientists have opportunities to develop their own skills in an international context
- **Impact –** Promote internationally significant activities aligned with national needs and policy, and undertake joint projects with the key international partners.
- **Networks –** Engage in bilateral and multilateral networks to ensure Australia can access relevant knowledge produced all over the world, along with researchers, organisations and infrastructure.

These activities will enable us to sustain a world-class workforce; participate in internationally significant activities aligned with national needs and policy; access global knowledge and infrastructure and generate markets for our innovative products and services.

Given its relative size, Australia cannot "compete" or seek to match funds with much larger and wealthier nations. What is required instead is an approach which allows Australian researchers to engage more strategically within existing funding. A number of specific suggestions as to how this might be achieved are set out below:

- Current government funding for international scientific engagement is targeted to a number of priority areas and countries, but is still distributed widely across the Australian system in relatively small amounts. Government should only target priority areas and countries where it is prepared to invest significantly on a global scale, spending larger amounts of money on fewer priorities.

- International engagement and impact should be made a clear part of the performance criteria for measuring Publicly Funded Research.

- Benefit would be gained from making an explicit link between science and innovation policy and foreign policy (and other areas of policy, such as climate change), with science recognised as an important part of Australia's public diplomacy and international representation efforts.

- Given the significant distances between Australia and the majority of the world's centres of research excellence, the Australian Government should invest proportionally more in researcher mobility than other countries. This should cover the full range of opportunities for international mobility, from short-term visits to longer-term secondments or sabbaticals and should pay particular attention to addressing traditional barriers associated with gender and family responsibilities to ensure that Australia is able to attract and retain world-leading research staff.
- Greater coordination across the Australian Government of its many programs that support international partnership to ensure maximum impact from a wide range of existing mechanisms for international engagement.

Recommendations

Focus international program funds to increase scale of activities in individual high priority projects for Australia.

Increase funding for international researcher mobility while removing non-financial barriers.

Include relevant international engagement as a performance criterion for publicly funded research.

6.2 Business Collaboration

The level of take-up of outputs from the research sector by commercial NIS entities in Australia needs to be improved, and substantially so, particularly within the Small-Medium Enterprise (SME) sector. For example a recent Australian Bureau of Statistics study has shown that, of the 25% of innovating businesses engaged in collaboration, only 2% were engaged in collaboration with higher education facilities, and only 3% with government organisations. Mechanisms are required for improving technology transfer. These include simplifying IP arrangements and providing appropriate incentives for all parties to reduce transactional costs as well as closely examining the mechanisms and benefits of open innovation to spur the rapid transfer of technology from the public to private sectors of the NIS.

The CSIRO has recently launched Australian Growth Partnerships (AGP), a $16m program supported by funds from the Commonwealth Government for a SME collaboration program. High potential, technology-receptive companies can access CSIRO research capabilities and intellectual property. The intent of the AGP program is to assist SMEs overcome their current technical challenges, thus providing them with an opportunity to significantly accelerate their growth in high impact industries. CSIRO seeks to support SMEs that are aligned with our Flagships program. In return for providing the funding, CSIRO seeks a return on its investment in a variety of ways (royalties, equity, milestone payments or convertible notes) that are negotiated with the AGP partner.

Recommendation

Expand CSIRO's Australian Growth Partnership Program with SMEs to include a wider variety of players in the NIS.

6.3 IP and Collaboration

Intellectual property (IP) rights are a critical currency of collaboration – they can facilitate knowledge transfer from creation to impact, encourage investment in technologies to bring them to market and provide some protection against being locked out of the research agency's core areas.

Innovation can be facilitated by seeking appropriate IP rights and by the efficient management of those rights in collaborations. This includes the smooth negotiation of contractual terms between collaborating parties.

However, in our experience, organisations playing different roles in the Australian NIS have a different understanding of IP rights, manage them in different ways and take different approaches to negotiating collaborative arrangements involving the development of IP or the use of background IP. Sometimes this can be a result of misunderstanding of the role of IP in supporting impact. The costs involved in overcoming these differences can be significant.

There is opportunity for IP management to be streamlined and based on common expectations and understandings particularly among players within the government sector or among those receiving government funding. CSIRO has experienced quite protracted and expensive commercial discussions over IP rights with various government departments and agencies. Negotiations are often taken out of the context of the research and its likely impact pathways. This should be avoided. Providing clarity about the roles and responsibilities of different players in the NIS with respect to commercialisation activities might also help ease this impediment, especially if this involves making a clearer distinction between IP ownership, benefit sharing and IP management responsibilities.

Recommendation

Simplify IP arrangements among government agencies as a priority.

6.4 Cooperative Research Centres Program (CRCs)

The *Cooperative Research Centres* (CRCs) *Program* has been a key in promoting collaboration in the NIS. The program has produced fundamental change in the way that Australian institutions, including industry, interact. This maturity is evidenced by the recent positive experiences in initiating and implementing the National Collaborative Research Infrastructure Scheme in a relatively short period of time (see Appendix 6).

CSIRO has been a strong supporter of the CRC program and has participated in 122 of the 167 CRCs. Our experiences of CRCs are highlighted in Appendix 15. While we have helped create significant value for Australia through our participation, a number of recent events indicate the need for change (also see Section 3). Interest in initiating new CRCs, or in extending existing CRCs into a third round, is flagging both within CSIRO, and also with our research partners. This is driven by a number of factors:

- Our participation in other research vehicles, both within and outside CSIRO, over the past decade has given us a wealth of experience that reveals more attractive models in both commercial and public good areas (such as research consortia, JVs, Flagships).
- Our research priorities have shifted our investments towards large-scale projects addressing significant national challenges through the National Research Flagships program. These require us to direct and realign major research effort towards a big goal with a strong focus on impact. Our collaborations are becoming much more top-down, purposeful ones (for example through the Flagship Collaboration Fund) rather than the bottom-up, self assembling that characterises most CRC bids.
- Participation in new CRCs is becoming increasingly unattractive because of issues of complexity (see Section 3 and above): fragmentation of effort in multiple CRCs competing in the same domain (e.g. biosecurity); leverage issues; complicated IP rights management negotiation; lack of robust termination conditions; diversity of governance models; excessive governance arrangements and reporting requirements relative to scale of operation.

As a consequence, we believe that the CRC program should not continue in its current form. The program has most certainly enhanced research collaboration in Australia and, in particular, made valuable contributions to young researcher training and development. However, having done this job, it contributes to the fragmented and over-governed NIS. If the program is continued we make a number of observations:

- Third-round funding should be the exception, rather than the norm, because long-term CRCs move from being a collaboration among partners to being an institutional arrangement in the NIS system that can compete rather than collaborate with the partners.
- A distinction should be made between CRCs with commercially driven-outcomes and those driven by public-good outcomes because of inherent differences in the arrangements concerning governance, IP, delivery of outcomes and associated measures of success for both classes of CRC, consistent with the principles of simplicity articulated in Section 4.

Recommendations

The CRC program should change significantly or be replaced allowing for adequate transition arrangements for existing CRCs.

Future changes should allow separate development of public good versus commercially oriented CRCs, each with streamlined administrative arrangements.

Individual CRCs should not be funded indefinitely through the CRC program.

6.5 Next Generation Collaborative Research Programs

We propose that new collaborative program(s) could be developed that have the characteristics that we have outlined for our evolving innovation system:

- Simplicity of structure and governance that in the first instance seek to encourage and support existing players in the innovation system to work together more effectively, rather than a preference for creation of new entities
- Scale of funding that is built on the full cost of research and delivery
- Goals that build on, and reinforce, the role(s) of the participants
- Transparency of decision making that emphasises the national interest to deliver outcomes utilising resources efficiently and effectively, rather than being based on willingness to co-invest by different government jurisdictions
- Streamlined IP provisions.

We suggest three possible models below.

1. *An extension of the CSIRO National Research Flagships Program*. The CSIRO Flagships, established in 2003, were conceived with the explicit aim of addressing large, long term goals associated with national challenges (see Appendix 2). As such they are unique in the National Innovation System (NIS). The distinctive features that enable Flagships to work this way are scale (average $50M per annum for each), duration (10-15 year goals), cross-disciplinary teams, effective partnerships and a strong focus on adoption of research outputs.

   Flagships are ensuring that the best and brightest researchers are working on critical national challenges in water, climate, clean energy and health, and on opportunities in niche manufacturing, light metals and mining.

   The 2006 independent Review chaired by the then Government's Chief Scientist, Robin Batterham concluded that "*Flagships offer the most promising mechanism yet to drive large scale activity addressing National Research Priorities in a collaborative, cooperative and intensively managed manner*", and "*The (Flagship) model facilitates high quality research but, perhaps more importantly, defines a route from R&D through to national impact*." The Review panel concluded that the model was consistent with their vision for a "*more effective NIS through the funding of goals rather than silos*".

   Collaboration is critical for Flagship delivery and over 400 partners have been involved with Flagships to date. The Flagship Collaboration Fund was set up to promote partnerships with universities and other publicly funded research agencies. It supports three year collaborative research "clusters", shorter (one year) research projects, visiting Fellowships and postgraduate scholarships.

   Clusters are sharply focused on solving scientific challenges that contribute to achieving the audacious goals of Flagships. They are better able to focus on scientific goals because essential activities such as business development, path to impact, commercialisation and communications are managed by the parent Flagship through CSIRO.

Twenty one Australian universities (and several other research organisations) are participating in ten clusters working in areas as diverse as hydrogen generation and storage, the identification of bioactive ingredients in food, causative factors for Alzheimer's disease, and the improved environmental management of iconic areas such as the Murray River mouth and Ningaloo Reef. The Fund has also so far supported 109 jointly supervised PhD students, 36 research projects and 22 visiting Fellowships.

The Flagships model can be extended in format to other participants in the innovation system and need not involve CSIRO. A few participants would be funded to form a collaborative effort to lead and deliver on a given area of national priority. Additional funding could be oversighted by this collaboration or provided by other innovation programs to enable other players in the innovation system to be drawn into the innovation pathway as needed.

2. *Research Consortia/Joint Ventures* – CSIRO's experiences with research consortia and specialist joint ventures provide another model for collaboration with industry. We have formed consortia with a wide variety of players across the innovation chain, such as the Boeing Corporation (advanced materials & ICT in aerospace), with Bayer (biotechnology), with Cotton Seed Distributers (cotton plant breeding) and with the Grains Research and Development Corporation (crop biofactories) and joint ventures with the Bureau of Meteorology (climate modelling), and New Zealand's Forests Research (forests and forest products), and the Victorian Government (food science). (See Appendix 16 for an example in Western Australia, specifically the Australian Resources Research Centre, ARRC). Compared with CRCs, it is possible to keep the governance arrangements uncomplicated and projects can be evaluated by the participants and funding shifted as priorities change.

3. *Specialisation* – Another emerging model for collaboration is that being developed by the Primary Industries agencies (State Departments of Agriculture and CSIRO) whereby individual agencies move to more specialisation of research effort, with collaborative processes in place for all players to capture the benefit of R&D on behalf of the nation. This is already evident in beef (QLD), cotton (NSW), wine (SA) and dairy (VIC) related research. National plans are underway for pre-competitive grain breeding.

Recommendation

Develop new streamlined collaboration programs that are flexible and allow different players to interact at appropriate times in simplified governance arrangements.

7. Building appropriate national skills and capability

Key Points

- CSIRO and top universities can leverage their reputations to attract and retain the brightest and best in the global talent 'war'.
- The NIS needs to increase its supply of skilled people who fuse traditional R&D skills with an increased focus on delivery and impact.
- Different players in the NIS provide training to build knowledge and experience and/or skills development relevant to different parts of the innovation pathway.
- CSIRO has particular advantages in providing training that is oriented towards industry.
- Removing barriers to mobility between sectors is essential to improve the effectiveness of the NIS and attract the best people.
- Cultural barriers can impede collaboration but education and mobility can help remove or diminish them.

"One critical success factor will be our ability to become a global talent hub. In a globalised knowledge economy, talent will be the key to economic success. Talent will provide the intellectual and innovation capacity to sustain the technological edge and competitive advantage of a country. Indeed, investments and economic growth will follow talent. This will be the economic paradigm of the 21st Century." [Tony Tan – Deputy Prime Minister of Singapore].

Innovation requires highly educated people having a wide range of skills and experience. People generate, develop and test ideas for change; and the implementation of these ideas will generally require different people with other complementary skills. People also play a fundamental role in creating impact from research. Australia needs a strong and internationally competitive education system (from pre-school to post-doctoral) that produces the talent that provides the life blood of innovation. Government plays a central role in maintaining and developing this system.

7.1 The Talent War

At present, Australia is working at near capacity and recruitment across key parts of the NIS is problematic. CSIRO is finding it difficult to recruit a range of skilled researchers, including in areas of national challenge, such as:

- Mathematics and statistics – these skills are fundamental to research across all sectors and have been in particularly short supply for many years.
- Mining and exploration – at present we are competing with the booming minerals industry (and corresponding remuneration premiums) for engineers and other experts in the mining industry.
- Hydrologists – we are expanding our hydrological expertise in response to water issues as a result of shifts in rainfall patterns, yet such skills are in short supply.
- Post-Harvest specialists – we have progressively downsized our activities in the post-harvest grains area after not being able to recruit into this area for over a decade, despite its importance for grain exports and food security.

Skill shortages are not just limited to trained researchers. It is equally important for CSIRO to have access to skilled technical support staff; to top quality managers, to marketers and communicators, to human resource experts and people with financial or business development and commercialisation skills. These skills can also be in short supply.

If we are to compete internationally for talent, Australia must provide an attractive working environment with conditions that match those found anywhere else in the world. This is not just a matter of salaries and work environment but covers issues such as certainty and, in scientific fields, the availability of leading edge infrastructure and ready access to overseas groups and facilities. The Australian Research Council (ARC) and CSIRO have both developed programs to make Australia attractive to researchers. The Federation Fellow Scheme (ARC) recognises research excellence in investigator-led research for top international talent. The CSIRO Office of Chief Executive Science Leader Scheme is more targeted at excellent researchers in mission-oriented research.

Young people can be discouraged from entering science because of a perceived lack of clear career paths and an associated lack of security, with many positions dependent on relatively short-term, competitive grants. This problem is made worse because of a commonly held view that the major career path for scientists is to continue doing research. In fact the knowledge, skills and approaches developed even through specialised postdoctoral work can have application in many fields other than science and there is a need to encourage mobility between different sectors. Nevertheless, there is a problem for early career scientists and NIS as a whole needs to address this if it is to retain the skills it needs. CSIRO has developed a series of fellowships in its 'Talent Ladder Initiative' that support its researchers from early career onwards (Appendix 17).

Sustaining CSIRO and other key research institutions as world class is important if Australia is to remain an attractive employer for scientists. CSIRO's block appropriation funding enables us to develop our capabilities while delivering on mission-directed research. It gives us a capacity to create a working environment that gives some security of employment to scientists. Flexible remuneration packages increase our capacity to attract and retain staff in areas of short supply. Funding for researchers should encourage researcher mobility, including short-term visits and longer-term secondments to overseas locations to 'connect with the best of the 98%' in helping develop research outcomes of importance to Australia. Barriers associated with gender and family responsibilities need to be removed to ensure that Australia is able to attract and retain world-leading research staff.

7.2 Training across the Innovation System

All players in the NIS are involved in training, either formal or on-the-job. Universities have a key role in developing talented, well-educated people who are curious and innovative. CSIRO and Universities both participate in the training of post-graduate students and post-doctoral fellows. In the case of CSIRO, we can train people with a particular mindset: to be mission-oriented; or to be industry-focused or solutions-based. We can train people to be part of a team, and to be part of, and ultimately, to lead, large integrated projects. More broadly, we develop business-oriented people with expertise in the management of IP and its exploitation for national benefit. Our funding (and indeed that of universities and other publicly funded organisations) needs to recognise this vital role performed on behalf of the nation.

In addition, in CSIRO we have found that our collaboration activities and personal interactions with university partners are significantly enhanced through the over 700 postgraduate students our staff currently supervise, co-supervise and/or sponsor, including the more than 130 supervised in collaboration with CRCs.

Many of the most pressing issues and opportunities in innovation require people comfortable in crossing boundaries, for example to bring a business perspective to scientific issues or a scientific understanding to the analysis of start-up business plans. CSIRO and universities can increase their training role to meet this need in a variety of other ways:

(1) *Exchanges with the business sector*. CSIRO benefits enormously in its legal and commercialisation areas from the movement of skilled people from the business sector into the organisation, and vice versa. It may be useful to explore ways to expand this, so it could occur as a secondment or exchange for a defined period around particular projects, particularly in the science areas. Such exchanges would develop people having broad experience and a deep understanding of the issues faced by different players across the innovation system. It also – and more importantly - facilitates the transfer of tacit knowledge: "technology travels on two legs."

The system must work together to create incentives, remove barriers and disadvantages.

(2) *Company Board Representation*. Competent scientists sitting on company boards are a necessary complement to industry experts providing advice to research agencies. Innovation builds on the cross fertilisation of ideas, not just through different scientific disciplines or between the physical and social scientists, but between business and science, or government and research. An effective innovation system encourages and facilitates the movement of people between sectors, across boundaries and into different disciplines; and provides the support necessary to allow people to perform when they do make such changes.

(3) *Innovations in Graduate, Post-Graduate and Post-Doctoral Training.* There is opportunity to integrate much more industry-based experience as part of post-graduate or post-doctoral work. For more than 30 years, the UK for example has linked graduate and post-graduate academic training to the broader experience provided in the workplace (industry, government and PFRAs). The so-called 'sandwich' degree courses are highly popular, providing both the opportunity for young talent to test the diversity of the potential 'marketplace' while they are training, and to experience the reality of the working environment. Similarly the Cooperative Award in Science and Engineering (CASE) PhD Studentship Scheme, links university and industry investments focusing high quality (precompetitive) research on the particular strategic need of a company. Once again the Scheme provides post-graduates with the opportunity to train to high academic standards while experiencing the demands of outcome orientated research and the team dynamics of the commercial workplace.

Post-doctoral fellowships, in particular, could be offered as joint appointments in business and CSIRO, in the same way that CSIRO and universities can, and do, share appointments. Such appointments may be particularly valuable to SMEs and start-ups who cannot otherwise afford to invest in R&D. It is noteworthy that Singapore is now planning joint science/business initiatives, as part of teaching of innovation, down to primary school level.

(4) *Joint Appointments.* The previous section, on enhancing collaboration, and our earlier submission to the 2004 Collaboration Review (summarised in Appendix 14), has highlighted the potential benefits from joint appointments in bringing together different, yet complementary players in our national innovation system. In so doing the learning and development of individuals concerned enhances their ability to contribute at increasingly high levels in the NIS.

Training and diverse experience can help to overcome cultural divides. Cross boundary issues become especially prominent in translating ideas into outcomes. Innovation inevitably requires the bringing together of different players with different skills sets, and experience. This was one of the drivers for the creation of the CRC Program. Some of the highs and lows of this program were a result of cultural divides being conquered or reinforced.

A cultural barrier internal to science is that the training and work ethic of science (as reflected also in selection criteria and the operations of recruitment panels) still tends to promote a degree of individualism, despite the increasing proportion of projects that are collaborative, producing papers involving multiple authors. The training of scientists should place greater emphasis on the importance of team work, the significance of the contributions made by non-scientists to the overall innovation process and to developing a stronger understanding of the innovation process – including of the risks, costs and constraints that can operate in different parts of the system and the value added at different stages. CSIRO's Flagships Program has been especially effective in fostering a team approach to problem solving.

Recommendations

Introduce more undergraduate and postgraduate training (including continuing education) in innovation, e.g. run jointly between science/engineering faculties and business schools.

Provide a wider range of graduate and post-graduate training options which link academic learning with the practical experience of the workplace where outcome oriented research is undertaken and innovation is taken up (e.g., industry and PFRAs).

Expand PhD programs to encourage multidisciplinary research, or time in industry and in jointly supervised programs with PFRAs.

Extend the Government's recently announced Enterprise Connect to support the placement of industry people into universities and publicly funded research agencies.

9. Appendices

Appendix 1 – About CSIRO

Our history

The Council for Scientific and Industrial Research (CSIR) was established in 1926 with its primary research devoted towards agriculture. In the late 1930s this was extended to include industrial research.

In 1949, the CSIR was reconstituted as CSIRO, and gradually expanded its activities so that its research was related to almost every field of primary, secondary and tertiary industry.

Today, CSIRO is a trusted source for creative ideas and practical technologies to deliver impact for the nation. It seeks to be a valuable partner with strong international relationships.

Our purpose

By igniting the creative spirit of our people, we deliver great science and innovative solutions for industry, society and the environment.

CSIRO is a research enterprise dedicated to delivering benefit to industry and the community through world-class science.

What we do

CSIRO carries out scientific research in areas including energy, the environment, information technology, health, mining, manufacturing, agriculture, and natural resources. We seek to make a difference and generate impact by focusing on the nation's big challenges and opportunities. Our research delivers:

- integrated solutions to help meet major national challenges
- technologies to transform or create new markets for Australian industry
- innovative technologies to improve the competitiveness of existing industries
- advice, information and research to meet specific community needs
- knowledge-based services to governments and businesses.

How we deliver

We strive to deliver value to our clients at all stages of research, development and commercialisation. We conduct our research through Divisions, National Research Flagships, Joint Ventures and other entities. Some facts:

- CSIRO currently leads six National Research Flagships that bring focus and scale to research addressing some of Australia's most important and complex challenges and opportunities, and has launched a further three Flagships in 2007–08
- CSIRO transfers know-how through secondments, industry workshops, seminars and specialist publications and last year produced nearly 5000 scientific publications, over 13 000 client reports and around 260 media releases
- CSIRO is the largest single participant in the Cooperative Research Centre (CRC) Program (participating in 36 of the 57 centres, during 2006–07)
- CSIRO typically has over 3000 active research contracts each year serving small, medium and large businesses in Australia and overseas, as well as public sector agencies, national and state governments, and other research organisations

- CSIRO hosts three major National Research Facilities (the Australian Animal Health Laboratory, the Australia Telescope, the Marine National Facility – Research Vessel *Southern Surveyor*) and over 30 other research facilities such as the Riverside Life Sciences Centre in Sydney and the Australian Resources Research Centre in Perth
- CSIRO manages 11 national reference collections including: the Australian National Fish Collection, the Australian National Insect Collection, the Australian National Herbarium, the Australian National Wildlife Collection, the National Tree Seed Collection and the Scientific Marine Data Collection
- CSIRO offers more than 50 specialised technical and analytical services. These include analyses for air pollutants and satellite imaging of natural resources through to fire testing of materials and diagnosis of exotic animal diseases
- 88 per cent of CSIRO's total expenditure is directed towards the priority goals associated with Australia's National Research Priorities
- CSIRO Publishing produces multimedia products for CSIRO and partners such as The Learning Federation, and publishes about 50 new books each year and over 20 peer reviewed journals, in partnership with the Australian Academy of Science and other scientific societies, for international markets.
- worldwide, CSIRO is involved in over 700 current or recently completed research activities, working with leading scientific organisations and firms in the United States, Japan and Europe, and with developing countries, especially in Asia
- CSIRO is Australia's leading patent filing enterprise, holding over 3900 granted or pending patents
- more than 150 spin-off companies are based on CSIRO generated intellectual property and expertise.

Education and outreach

- in collaboration with university colleagues, our staff supervise, co-supervise and/or sponsor over 700 postgraduate research students, including more than 130 supervised in collaboration with CRCs
- through this sponsorship and supervision of MSc and PhD students, our extensive postdoctoral programs, our distinguished Visiting Scientists program, the CEO's Science Leader scheme and other initiatives we are continuing to build and foster a world-class team of scientists and helping to develop the science leadership Australia needs to meet future challenges
- stories involving CSIRO science are reported in around 12 000 news or feature items every year in print, radio and television and there are approximately 30 000 articles relating to CSIRO on Australian and International web pages each year
- CSIRO media releases posted on Eurekalert (an online, global news service operated by the American Association for the Advancement of Science) are viewed by about 60 000 subscribers each year
- the number of CSIROpod podcast listeners continues to grow rapidly, with now over 400 000 downloads of CSIROpod a year
- CSIRO's nine Science Education Centres engage over 350 000 students, parents and teachers each year, including school visits in metropolitan and regional areas with the 'Lab on Legs' program

- CSIRO's Double Helix Science Club has over 25 000 members, with its two magazines *The Helix* and *Scientriffic* and hundreds of club events. Our weekly e-newsletter, 'Science by Email' has 26 000 subscribers, one third being teachers
- CSIRO jointly produces SCOPE, a science TV program, with a viewing audience of over 400 000 each week
- the Discovery Centre in Canberra is CSIRO's showcase, featuring an interactive exhibition, modern events facilities and an education program that gives children a chance to explore real research issues in a scientific setting complete with working laboratories. The centre had over 60 000 visitors during the past year. CSIRO's radio telescope in Parkes had over 96 000 visitors last year who learnt about the telescope, radio astronomy and CSIRO
- CSIRO Enquiries serves a diverse range of general public, industry, education and internal clients with a one-stop service for information about CSIRO research and activities. The contact centre handles over 35 000 enquiries a year (1300 363 400, enquiries@csiro.au)

Our Journey

CSIRO addresses challenges that matter to Australia.

CSIRO has a special and trusted place in the hearts and minds of the Australian community, with a track record of achievement spanning more than eight decades. Our strengths are our multidisciplinary approach and scale, the quality of our science, our focus on delivery, and our people.

Our approach

We are focused on national – and global – challenges and opportunities, bringing to bear a powerful diversity of disciplines, experience and expertise. We build high-performing expert teams to attack big problems.

Effective partnering is fundamental to our success. CSIRO fosters integration between universities, overseas institutions, investors and industry. Our staff are especially adept at linking with international research to help solve Australian challenges. CSIRO scientists are valued collaborators. Knowledge sharing is what we do.

Discovery and delivery

CSIRO is a powerhouse for needs-driven innovation. The National Research Flagships exemplify this, harnessing wide-ranging talent and partnerships in bringing science of scale to bear on major issues facing the nation – in water, energy, climate change and promoting health, and in creating new industries and new jobs.

We are also building broad-based platforms of leading scientific capability, particularly in transformational biology, computational and simulation sciences, advanced materials, and sensor network technologies. Our frontier science helps lead the way, from understanding the universe and adapting to climate change through to exploring the earth's crust.
Our teams have the systems, facilities and boundary-crossing culture to support their ambitious goals. We are custodians of key national infrastructure. We work hard to be

responsive and easy to deal with. Through an uncompromising focus on impact and relevance we strive to maximise the value of public investment in our research and development. We seek to lead in public sector efficiency.

Our people

CSIRO staff are positive and performance-oriented, valuing diversity. We strive to be fair and transparent. Our people believe in what they do and are passionate about it. They feel proud to work for CSIRO. Our staff and our many visitors are enriched through passion and commitment – and through learning and development opportunities. Time spent in CSIRO creates new avenues for our employees.

Australia looks to CSIRO for leadership in science and innovation. Ultimately our people are responsible for helping to embed the importance of scientific endeavour into the fabric of Australian society. We are proud when young scientists and engineers choose to work with CSIRO.

Appendix 2 – CSIRO's National Research Flagships

Established in 2003 the National Research Flagships assemble multidisciplinary teams from across the National Innovation System to address Australia's major challenges and opportunities.

CSIRO's unique position as the premier national research organisation has enabled it to create the Flagships for the benefit of the nation.

More than ever before in our history, Australia faces challenges in critical areas such as water, climate, clean energy, and health. Effective solutions to these complex issues call for innovative partnerships that harness national expertise on an ambitious scale.

The National Research Flagships

The Flagships program is one of the largest scientific research programs ever undertaken in Australia – with the total investment to 2010–11 expected to be more than $1.5 billion.

In establishing the Flagships, we have moved beyond the traditional models of how science delivers benefit. Flagships recognise that complex, large-scale challenges require sophisticated cross-boundary responses that can only be delivered by bringing together the best and the brightest from across the Australian R&D system.

Flagships are focused on outcomes. They are committed to delivering research solutions that target clearly defined goals. Their objectives have been framed based on Australia's national research priorities and a comprehensive understanding of industry directions, community expectations and end-user needs. What distinguishes Flagships from other research initiatives is their larger scale (averaging $50m per annum), longer timeframes, cross-disciplinary teams, effective partnerships and a strong focus on adoption of research outputs aligned with significant national challenges and opportunities. These are critical to achieving maximum impact for the benefit of Australia.

Nine Flagships now operating

As the original six National Research Flagships in energy, water, health, light metals, oceans and food accelerate their delivery of outcomes, in 2007/08 CSIRO has created three new Flagships to respond to major challenges and opportunities in climate adaptation, minerals and niche manufacturing.

Attachment A lists the challenges, opportunities and goals which the Flagships address. Attachment B provides some examples of outcomes being developed.

The new Flagships are developing goals and research agendas that will help position Australia as a world-leader in adapting to problems related to climate change, that will enable revolutionary new approaches to mineral exploration and extraction, and will facilitate the establishment and growth of new niche industries in the rapidly growing field of nanotechnology.

A partnership approach

Effective partnerships are integral to the success of the Flagships program.

No research organisation can tackle these critical national challenges and opportunities alone. Collaboration ensures that Australia exploits the full breadth and depth of its research expertise to address our most urgent research priorities. Partnerships also provide the pathways for Flagship research to be taken up and applied by industries and communities to deliver economic, environmental and social benefits for the nation.

Flagship collaboration is a reality. Already, more than 350 partners have been involved in the Flagships initiative, with 400 individual collaborative agreements signed from 2005 to 2007.

Industry alignment

Another central platform of the Flagships initiative is the development of strong, long term relationships with Australian industries that will result in practical, positive outcomes for Australia.

Flagship partners include many of the largest and most innovative companies operating in Australia and internationally. These companies are leaders in areas central to Flagship goals such as mining and metals, agrifoods, health and medicine, energy generation, and infrastructure management. Many are also at the forefront of developing innovative responses to challenges such as water management and climate change.

Our industry partners play a vital role in helping to set directions for Flagship research and ensuring effective paths to adoption. End users and researchers must work together for technologies to be successfully applied and adopted, and the review of the Flagships initiative found this to be the case.

Flagship Collaboration Fund

The Flagship Collaboration Fund provides an innovative mechanism for establishing and nurturing collaborative relationships.

The contestable Flagship Collaboration Fund is an essential element of the Flagships model, designed to enhance and reinforce collaborative partnerships between CSIRO, Australian universities and other publicly-funded research agencies.

Managing for delivery

Flagships are supported by a rigorous governance framework, overseen by a CSIRO enterprise level, Flagship Oversight Committee. Flagships are driven by clearly defined aspirational goals, linked to detailed path to impact roadmaps which specify critical ‘stage-gates’ against which outcome and impact delivery can be measured. Importantly, Flagships are flexible entities incorporating fast-fail mechanisms which enable the selection and prioritisation of the most effective research path and the means for the program, when appropriate, to respond to changes in the external environment (technology, policy and industry). Flagships have terminated and redirected projects in response to these drivers and mechanisms.

SOME FEEDBACK ON THE FLAGSHIPS

Major Challenges

"Without CSIRO's intervention through the Flagships, Australia would not be tackling these major issues in such a systematic way". Professor Tony Burgess, Director, Melbourne Branch, Ludwig Institute for Cancer Research.

"Innovation is the key to Australia competing in a global marketplace. The Light Metals Flagship brings together a breadth and depth of research expertise that could not be assembled by a single research organisation or company. The Flagship has the facilities and vision to commit to the big issues that affect the nation's future". Ron Knapp – Executive Director, Australian Aluminium Council

Strong Linkages

"The Flagship is the best multidisciplinary group in the world working on colorectal cancer. By clearly identifying the specific problems in health, and then constructing the solutions in a multidisciplinary and collaborative manner, it is establishing a unique place in the world". Professor Graeme Young – Head of Gastrointestinal Services, Flinders Medical Centre

"The Wealth from Oceans Flagship provides us with unprecedented access to large-scale multidisciplinary and expert scientific capacity. It is game changing in terms of its focus on practical outcomes – that is why Navy is a partner". Commander Andrew McCrindell, Director, Oceanography and Meteorology, RAN

Benefit/Cost – practical solutions

"The equation is simple: less water used per hectare allows irrigators to expand production and consider options to return water to the environment… the Water Flagship work has shown ways to save in excess of 250GL of water. This is nearly half of the water being sought through the Living Murray Initiative…(This is) a great example of the benefits of existing and ongoing investment in the Water Flagship program." Doug Miell – Chief Executive, NSW Irrigators' Council.

An Acil-Tasman study (2006) study on two of the Flagships, evaluating return on investment of public money concluded that:

"The values created from just two of the five themes in the Preventative Health Flagship are conservatively estimated to be over $370m (2006-07 prices) - against the Flagship's overall expenditure to date of $70m

"The present value of impact generated as a result of research in three of the Water for a Healthy Country Flagship's six Themes is about $900m. This may be contrasted with planned Flagship expenditure over the next four years of $175m and expenditure to date of $56m."

Jos Mensink – (then) Head of Water Strategy, WA Government stated that:
"In WA the Water Flagship has already pointed the way to save the WA taxpayers millions every year. The Flagship work on the Gnangarra Mound (a major underground aquifer) has revealed how Perth can recover an additional 20GL of water annually. When each new GL costs the taxpayer about $10 million, that is already a massive return on investment in Flagship science."

Flagships and the NIS

The independent international Review (2006) stated that the Flagships have **"***defined a new key role in the NIS which articulates a route from R&D through to national impact and which engages the national end-users"*. In the Review Team's view, the Flagship concept was *"applicable on a grander scale in the NIS"* and consistent with their vision for a *"more effective NIS through the funding of goals rather than silos"*

A final word

"*The Flagships are delivering powerful scientific solutions to national problems…(and) offer the most promising mechanisms yet to drive large-scale activity addressing Australia's National Research Priorities in a collaborative, cooperative and intensively managed manner*"

Review of the National Research Flagships, 2006
(Chair: Dr Robin Batterham)

"Flagships are indeed Australian science aiming high – the toughest challenges, the strongest teams, the most audacious goals. They are about delivering the best future we can envision, in a practical, efficient and sustainable way."

2003
Dr Geoff Garrett, CSIRO Chief Executive

Attachment A

Challenge/Opportunity	Flagship	Aspirational Goal
Water security	Water for a healthy Country	To achieve a tenfold increase in the economic, social and environmental benefits from water by 2025.
Low carbon emission energy and alternative fuels	Energy Transformed	To halve greenhouse gas emissions and double the efficiency of the nation's new energy generation, supply and end use, and to position Australia for a future hydrogen economy.
Novel food production opportunities for Australia	Food Futures	To transform the international competitiveness of, and add $3 billion annually to, the Australian agrifood sector by the application of frontier technologies to high-potential industries.
Prevention of major Chronic Diseases	Preventative Health	To improve the health and wellbeing of Australians and save $2 billion in annual direct health costs by 2020 through the prevention and early detection of disease.
Sustainable opportunities from our Oceans	Wealth from our Oceans	To position Australia by 2020 as an international benchmark in the delivery of economic, social and environmental wealth based on leadership in understanding ocean systems and processes.
Building a competitive Australian light metals industry	Light metals	To lead a global revolution in light metals, doubling export income and generating significant new industries for Australia by the 2020s while reducing environmental impact.
Challenges and opportunities from Climate Change	Climate Adaptation	To equip Australia with practical and effective adaptation options to climate change and variability and in doing so create $3 billion per annum in net benefits by 2030.
Securing sustainable minerals industry	Minerals Down Under	To assist the Australian minerals industry to exploit new resources with an in-situ value of $1 trillion by the year 2030, and more than double the size of the associated services and technology sector to $10 billion per year by 2015.
Initiating and growth internationally competitive niche manufacturing in Australia	Niche Manufacturing	To support the development of niche manufacturing businesses based on nanotechnology worth in excess of $3 billion per year by 2020.

Attachment B

Examples of economic, social and environmental value from Flagships

OUTCOME	BENEFITS	IMPACT
WATER MANAGEMENT		
First ever mapping of the water resources (inputs and outputs) of the entire Murray Darling Basin.	Allows informed policy on industrial and domestic water usage to align objectives for sustained water security in Australia.	Water security for Australia whilst managing economic, social and environmental needs of the Nation.
Perth's water security	Annual water savings of 20GL.	Values at over $200m annually.
CLIMATE & ENERGY		
Novel technology to enhance natural gas using solar energy ('SolarGas')	Alternative source of conventional energy.	26% increase in energy output, and use.
Lightweight, high output 'Ultra Battery'	Cheaper, lighter, more efficient hybrid cars	50% reduction in emissions with greater hybrid uptake
Intelligent Energy Grid for distributed energy in trials in Newcastle.	Allows use of renewable & intermittent energy sources on the grid	Will contribute up to 30% greenhouse gas emission reduction target.
Post combustion C02 capture technology being trialled in 3 Australian coal fired power plants and one in China (Beijing)	Reduction of CO2 emission for Australia's major domestic and exported energy resource	80-85% emission reduction from each plant. Major contributor to Australia's Kyoto commitments.
AUSTRALIA'S INDUSTRIES		
CSIRO's Cathode Cell Technology being trialled prior to commercial adoption	Lower energy costs (15-30%)	Increased competitiveness of Australia's aluminium industry
Prawn Aquaculture: Improved genetic stock and novel high nutrient algal source.	Lower production costs, higher quality product and sustainable feed production.	$20m to date increasing to $150 m+ by 2013. Prawn feedstock from sustainable non-fish sources (algae) valued at $300m.
Improved magnesium alloy production through CSIRO's 'T-Mag' technology – first plant commissioned.	Competitive SME's in mag-alloy products e.g. engine block currently in trial with GM/Holden.	Forecasted $150m dollars in new business/exports.
Improved extraction efficiency in Aus. bauxite in trial.	More economic and competitive industry.	Australian bauxite production from existing known stocks doubled to $20b through improved efficiency of extraction.
Lower cost titanium production process to halve the current cost (titanium is a potential $1B+ industry for Australia). Pilot plant agreed under private funding.	Titanium production (uniquely Aust. raw material), competitive with other light metals.	Development of new light metal production and manufacturing industry in Australia valued at $1 billion / year.
HEALTH (DISEASE PREVENT'N)		
Colo-rectal cancer biomarker.	Early prediction of colorectal cancer.	Human wellbeing, lives saved, higher national productivity from healthy aging workforce, lower health costs.
UNDERSTANDING OUR OCEANS		
Successful predictive modelling of ocean flows, currents and cycles.	Impact on weather and environment prediction, naval and coast guard effectiveness, fishing industry	Prediction of optimum fish stocks through current and temperature predictions; naval and coast guard requirements for current projects.

Appendix 3 – On Vision, an example (Australia's Services Future)[16]

It is 2028, and Australia has spent the last twenty years focussed on building a strong and vibrant services economy.

Services and Economic Growth

Knowing that the demand from emerging economies such as China and India for Australia's raw materials will eventually weaken, and competition from commodity industries will increase, Australia has embraced the service economy.

Australia has leveraged its highly educated population, innovative institutions, open economy and links with Asia to become a regional services powerhouse. This wasn't easy, as it meant that the country had to come to grips with its changing reliance on primary and secondary industries. However, Australia tapped into the core strengths of its economy to build service offerings around traditional businesses as well as develop new services in niche areas where we have competitive advantage.

Australia's finance and insurance sectors, equal in size to those in Singapore and Hong Kong, created strong links with research and development institutions to ensure that they took full advantage of eCommerce, trusted information networks and advanced data mining of information about their customers. Australian finance is world-renowned for taking a systems approach to investment, while giving advanced personalised service to clients. Australia is regarded as the world leading manager of superannuation and pension funds.

The Australian manufacturing industry has teamed with researchers and the Australian ICT industry to invent new ways of combining services and products together. Many manufacturing companies now identify themselves as services companies, outsourcing the low-value commodity businesses to focus on service delivery. Similarly, our mining industry has continued to focus on selling mining services overseas, using innovative business models to ensure that it captures value from mining operations around the world. Australian mining companies now provide turn-key operations for mining companies in emerging markets where mining and resources experience and skills are scarce.

Australia has also used its experience in agricultural production and addressing environmental issues of global significance (such as the impacts of climate change) to become a world leader in environmental services. Through a concerted R&D program strongly linked with industry, Australia is now the regional centre for all greenhouse and environmental futures trading. It delivers water management technologies and services all around the globe, and is the centre for environmental monitoring and prediction. Australian financial institutions have a global reputation for the most innovative offerings in carbon, water and biodiversity markets.

Acknowledging that it only produced 2% of the world's intellectual property, and that gaining access to the other 98% was critical to wellbeing, Australia has embraced open source platform development. Many Australian platforms have become standard across the

[16] Extract from PMSEIC's *Science and Technology-Led Innovation in Services for Australian Industries* Report April 2008 (pp 37-38).

world, which gives Australia a unique edge as key developer and custodian in the delivery of commercial services on top of these platforms.

Services and the community

The community has also benefited greatly through the increased efficiency as a result of this focus on the services economy.

The delivery of on-line government services has dramatically increased the efficiency of the delivery of these services. Government services are now tailored to a citizen's specific needs, and accessed through central information portals. Interactions between government departments have also increased dramatically, thanks to technology platforms which allow common service delivery.

Health services in particular have been revolutionised though national health technology platforms, allowing customised strategies on prevention to be developed and ensuring efficient service delivery. Citizens now have more and improved access to information about their own health care, stored in private, secure and distributed locations. Australia invested heavily not only into new e-health technologies, but also into the health delivery system as a whole, and Australian health services are some of the most efficient in the world. This is reflected in reduced waiting lists, lower health insurance costs and better utilisation of Australia's existing hospital infrastructure.

The Australian government also provided strong incentives for business to embrace eCommerce, through innovative procurement strategies. As the largest procurer in Australia, preference was given to providers who could integrate their services with national technology platforms. These became a critical piece of national infrastructure and were eventually adopted by business to dramatically reduce their operating and transaction costs.

Increasing efficiency in production through services has also resulted in massive resource efficiency. Traditionally, economic growth was coupled with increased waste and emissions – during the 90s and noughties, emissions of carbon dioxide were closely correlated to changes in economic activity. In embracing the services economy, it was recognised that services provide key opportunities to decouple economic growth from resource utilisation, improving the natural environment and reducing the inefficiencies of large waste streams.

Challenges

This focus on the services economy did not come without its challenges, however.

With so much information available about individuals, privacy has become a real concern. This is being managed however, and a new industry around privacy has emerged, exporting privacy services overseas.

An employee in the services economy also requires a range of different skills to one working in mining, manufacture or agriculture. A national services skills program was successful at building the skills of these workers for this new economy at all levels from school to tertiary education. Degrees and vocational training in Services Science, Management and Engineering are now highly sought after, and Masters in Services Administration are now more popular than MBAs.

At the same time Australia was growing its services economy, other OECD countries (from the United States to Scandinavia), were also investing significantly in this domain. However, by focussing on its traditional strengths, on growing niche opportunities where it had competitive advantage, and by ensuring that its services sector was closely coupled to its research and development institutions, Australia was able to raise its standing in the global services market maintain its edge.

In Conclusion

In 2028 the world will have experienced a dramatic shift. Capital, knowledge and labour will flow easily across any physical barrier and the services economy will have an even greater impact on our economy and wellbeing. Australia must choose if it wants to be an active participant and leader in the development of this economy. Of critical importance is how Australia aligns its National System of Innovation to best connect services and innovation together.

Appendix 4 – Extract from the 2007 Productivity Commission study into Public Support for Science and Innovation[17]

Key points

- The principle objective of public sector research agencies is to perform socially beneficial strategic and applied scientific research that would not, or could not, be conducted by other research providers and, wherever appropriate, widely diffuse the results from that research.
- Australia devotes a relatively high proportion of its total science and innovation budget to public sector research agencies compared with other countries. It also has a multiplicity of such agencies, although CSIRO and the DSTO dominate the research funding allocated to these bodies.
- Recent changes to CSIRO's research investment processes have improved its research focus and provide a framework for ensuring that the organisation does not perform research that the private sector would otherwise undertake. Given the scale of CSIRO activity and the dominance of small and medium sized firms in Australia's industrial structure, it is also unlikely that CSIRO crowds-out private sector research effort.
- Block appropriation funding for CSIRO needs to be sufficient to enable the organisation to make appropriate strategic investment decisions and to maintain its research capability in a range of areas. The share of CSIRO's revenue from that source has declined considerably over the last few years. The real level of block funding should not be reduced.
- Aspects of CSIRO's approach to priority setting and performance management may have wider applicability to other parts of Australia's innovation system (for example, other Federal and State public sector research agencies and the CRC program). The aim of adopting such an approach would be to reduce the risk of unnecessary duplication of research effort and increase accountability across that system.
- The effectiveness of research conducted by the DSTO depends critically on the procurement practices and research directions set in *consultation with* its principal customer, the Australian Defence Organisation. An option to improve the effectiveness of defence-related research is to raise the share of research funding distributed by the users of DSTO research. This would allow users, if they wish, to allocate funds to external providers.

[17] page 463.

Appendix 5 – CSIRO's Roles in the NIS

Overview

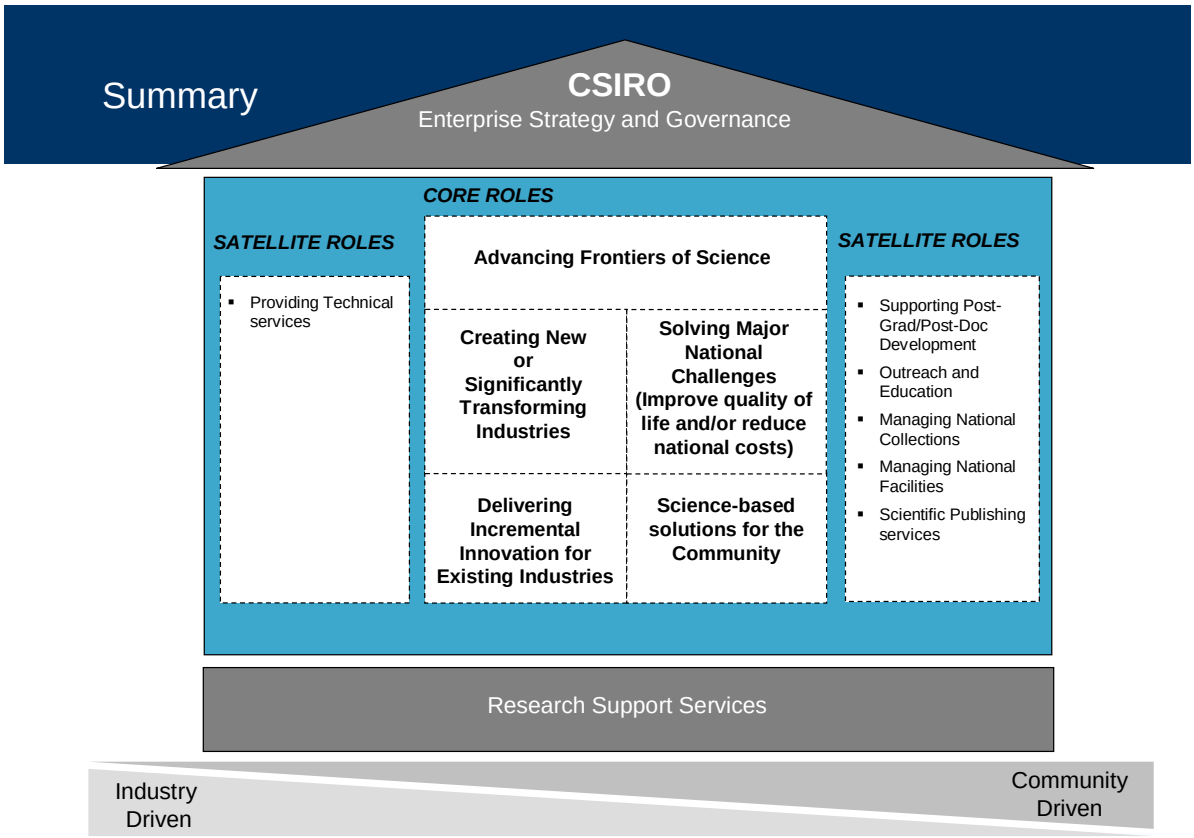
We have just a handful of 'core' roles. Advancing the Frontiers of Science, e.g. gene silencing, the discovery of double pulsars or the world's fastest wireless connection, is obviously central in our business. But so too are helping create new industries, e.g. through new titanium technologies, or helping them evolve, e.g. new techniques for aquaculture, as well as helping deliver incremental innovation for existing industries, e.g. new polymers for bone repair or artificial heart valves, or metallurgical processing improvements.

Improved quality of life through helping solve major national challenges is key for us. Our work in clean energy, obesity, predicting and adapting to climate change, and dealing with our water-challenged society are cases in point. We are also active in developing science-based solutions for the community at large, whether it be the biological control of aquatic weeds, helping rebuild communities after tsunami devastation or helping eradicate the yellow crazy ant in the NT.

We also have some important 'satellite' roles. Our education and outreach initiative is one such role: our nine national science education centres engage with nearly 400,000 scholars, their parents and teachers each year. In collaboration with university colleagues we co-supervise/sponsor over 700 postgraduate research students. 'CSIRO Publishing' also provides an important service as does 'CSIRO Enquiries' (phone 1300 363 400!). We manage major national facilities, e.g. the Animal Health Laboratories in Geelong, the Oceanographic Research Vessel, the *Southern Surveyor*, and the Australia Telescope National Facility; for NASA we also oversight the Canberra Deep Space Tracking Station.

CSIRO's roles can be represented via a model of a house. Each 'room' (or role) in the house describes the nature of the outcomes of our research efforts. The 'house' illustrates CSIRO's core roles at the centre of the diagram, surrounded by satellite roles. The enabling functions are represented as the 'roof' and the 'floor' of the house, highlighting the support they provide to the other roles. The house also illustrates CSIRO's continuum between industry driven activities (the left side of the house) and community driven activities (right side of the house) for the various roles. The industry driven/community driven continuum is a spectrum.

While all of CSIRO's activities deliver public good benefits for Australia, some activities are more driven by industry needs and others are more driven by community needs. The dashed lines within the house represent the integration and interdependence between the roles. Within the core roles, time horizons correlate with the height of the house. In other words, 'Advancing Frontiers of Science' has a long term horizon while 'Delivering Incremental Innovation for Existing Industries' has a much nearer time horizon.



It is important to note that the roles in the role house do not distinguish between the type (or by any implication the quality) of the science that is delivered to achieve the outcome, and nor should they. The role house is about research OUTCOMES only.

Any simplistic representation has its limitations. People are at CSIRO's core; yet the house model does not adequately emphasise the importance of the roles that our scientists and other staff play in delivering impact to Australia. Nor does it highlight the importance of collaboration with external parties. CSIRO's collaboration with other players within the National Innovation System (NIS) is critical to leverage the benefits of a 'Team Australia' approach. The house diagram might also give the (false) impression of a static and unchanging CSIRO. In addition, the house does not represent the proportional size of each of the roles within CSIRO. Nonetheless, the house diagram is arguably a useful and simple tool that reflects the roles of CSIRO.

Role Description

'Core' roles are immutable – they define the essence of the organisation and abandoning the role is inconceivable. CSIRO is first and foremost an enterprise that delivers impact for Australia through its science. Thus CSIRO's core roles are all around science – whether through applying and integrating existing technologies to solve problems, coming up with clever new innovative science-based approaches or through creating new paradigms in the understanding of leading edge science areas. The five core roles central to CSIRO's purpose that are areas in which CSIRO is or has the potential to be distinctive and have very high

value for Australia. For example, one of these, ‘Solving Major National Challenges’ is illustrated by the National Research Flagships.

‘Satellite’ or ancillary roles relate to the core science activities that CSIRO performs. CSIRO performs a number of satellite roles important in delivering value to Australia, such as managing National Facilities like the Australian Animal Health Laboratory. The roles are important, and they contribute meaning to what it means to be CSIRO.

Enabling Functions are supporting activities that make it possible for the organisation to perform its core and satellite roles. In CSIRO the two most important enabling functions are: providing ‘Research Support Services’ and ‘Enterprise Strategy and Governance’.

Summary of the ‘House Model’

The ‘house model’ serves as a visual overview of CSIRO’s role mix. By being explicit about the role mix or balance, CSIRO can make its investment decisions in a more transparent and comprehensible manner through its Science Investment Process (SIP).

Appendix 6 – CSIRO's Experiences with NCRIS

The National Collaboration Research Infrastructure Scheme (NCRIS) was an innovation in collaboration research programs. Introduced in 2006, it established a new approach to collaboration, in this case for sharing infrastructure in the NIS. CSIRO is involved in 12 of 16 NCRIS platforms with a total investment of $112m. The lessons learnt about the NCRIS program include:

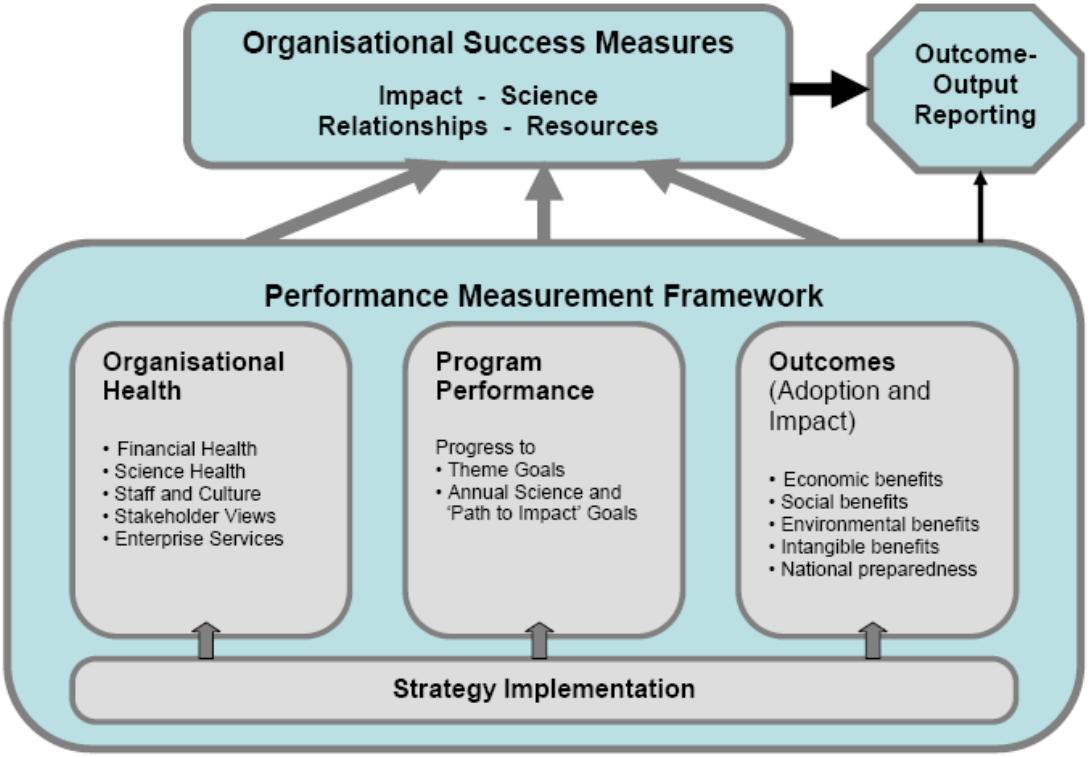
- Active engagement and oversight by the Steering Committee (and of its supporting secretariat), at all stages of the process enabled the program (and the resulting proposals) to be fine-tuned during its implementation. It also meant that preparation of proposals was relatively efficient in time and cost compared with competitive processes.
- Strong leadership of collaborative ventures was critical in successful bids. Short time–frames to develop considered proposals meant that successful projects were biased towards those in which there had been widespread development in the NIS prior to the announcement of the program.
- The collaborative approach of the program enabled a national, coordinated response in key activities by bringing together all relevant parties although at times the equity principle may have been applied too broadly, allowing players in the NIS to join the scheme, regardless of scale or capability.
- Flexibility in the scale and type of activities that could be supported enabled funds to be directed at a variety of hard and soft infrastructure. Provision to fund operating costs of facilities was also appreciated. However, the program has been under-resourced for the breadth of the program given that the large, pent-up demand outstripped resources.
- Reliance on co-investment has led to over-leveraging and/or underinvestment by some participants. Long-term sustainability of the program is uncertain beyond the first five years even though National Facilities require ongoing support and maintenance.
- Considerable effort was put in to develop a limited number of governance arrangements. However, each NCRIS platform has developed its own governance model, including those at the sub-platform level and this has added to the complexity of the system.

Appendix 7 – CSIRO's Program Performance Framework

CSIRO has sought to develop strong, well-integrated processes for planning, measuring, managing and reporting performance. The CSIRO Strategic Plan articulates Organisational vision and aspirations, and describes a broad path to achieving these through a set of strategic initiatives and objectives. The CSIRO Operational Plan provides an overview of strategy implementation activities and the allocation of resources to those activities on an annual basis. In a broad sense the Strategic Plan describes what we hope to achieve and the Operational Plan begins to describe how we set about achieving it. These two enterprise-wide documents are supported by more specific detail in Theme Statements and Divisional, Flagship and Corporate Group plans. These documents describe the 'building blocks' of research themes and capabilities and specify annual performance goals and budgets.

To promote robust business planning, good target setting and strong accountability, CSIRO's research is organised into ***Themes, Streams and Projects*** (as defined in the box below). This classification has been adopted across the organisation to ensure the alignment of individual projects with high level strategic goals and to monitor progress toward these goals through the 'Program Performance' element of CSIRO's broader Performance Measurement Framework.

CSIRO's Performance Management Framework



The level of investment in each Theme is determined through the Science Investment Process (SIP)[18] and progress is then monitored regularly and reported in an Organisational Performance Report three times per year. This includes an assessment of progress toward longer term Theme Goals and actions taken in response to that assessment, as well as progress toward specific Annual Performance Goals (APGs) at the Stream level. APGs

[18] See Appendix 8 on the Science Investment Process

emphasise both scientific milestones and other milestones on the path to impact (e.g. the development of relationships with delivery partners) that are required for successful achievement of stream objectives and theme goals.

This organisation-wide framework was originally developed to support CSIRO's introduction of the National Flagships Program and its transformation from a national research institute to a research enterprise with global reach. Operating since the beginning of the 2003/04 financial year, it has since been implemented across the whole research portfolio and has significantly enhanced CSIRO's capability to:

- proactively manage and evaluate its research portfolio delivery against plan;
- align its 'Bench (scientist) to Board' measurement process;
- provide those outside the organisation with a detailed, accurate view of its research portfolio;
- understand the organisational and national context within which its work is undertaken;
- identify a clear link between Annual Performance Goals and personal performance agreements;
- readily identify work within the organisation that is thematically related – promoting greater exchange and integration between projects;
- provide greater consistency in CSIRO-wide planning and evaluation;
- link Annual Performance Goals with longer term goals; and
- manage milestone delivery.

A Theme refers to a significant area of research that is directed towards a specified outcome with a clear strategic purpose. For example, the goal for the Urban Water Theme in the Water for a Healthy Country Flagship is: *To provide science and technology that enables the delivery of socially acceptable, affordable and environmentally beneficial management solutions for Australia's urban water infrastructure and natural water systems - to address the projected 2030 water deficit of up to 1,000 GL in our cities*. Increasingly, individual Themes draw on capabilities drawn from across the organisation and external partners. The Urban Water Theme amalgamates all of CSIRO's urban water research to bring CSIRO's full weight and diverse skill base to advance research in this priority area.

For each Theme, a 'Theme Statement' is prepared, providing a detailed summary of the Theme's relevance and planned impact, the capabilities and resources applied, and specific Stream-level annual performance goals.

A Stream represents a collection of related projects that address a particular aspect of the Theme Goal. For example, the goal of the Urban Water Theme is pursued through five mutually supporting streams of activity: *Integrated water systems, Demand management, Recycling and diversified supply, Infrastructure technologies, and Urban water environments*. Each Stream has an explicit medium-term Stream Objective supported by annual performance goals

(APGs). APGs include both scientific/technical milestones and other milestones – specifically engagement with delivery partners – that are necessary for the achievement of the stream objectives and the outcomes articulated in the theme goal.

A Project is the core unit of research activity and budgetary control. Individual projects are required to have a project plan in accordance with CSIRO's project management policy.

Appendix 8 – CSIRO's Science Investment Process

A critical component of the implementation of CSIRO's Strategic Plan 2003-2007 has been the introduction of an enterprise-wide Science Investment Process (SIP). The SIP provides a systematic approach to science and support investments across the organisation, ensuring that CSIRO's skills and resources are built and focused on the most important issues for Australia. The SIP is being further refined over the course of the new Strategic Plan 2007-2011, and will be instrumental in enabling CSIRO to deliver against the strategic elements of: Addressing National challenges and opportunities; and Focusing and strengthening our core science capability and delivery.

The principal aims of the Science Investment Process are to:

- Continue to increase the impact and relevance of CSIRO science;
- Maintain an appropriate balance between the roles and responsibilities of CSIRO (as represented in the SIR Act and in the Role House); and
- Ensure the wise investment of our appropriation funding.

In addition, the Science Investment Process seeks to:

- increase linkages across the organisation;
- tap into CSIRO's distinctive strengths in cross-disciplinary initiatives;
- encourage longer-term perspectives in science planning;
- increase transparency and rigour of decision making throughout the organisation;
- increase transparency of purpose to foster greater complementarity with broader national innovation system (NIS);
- promote a trust-based approach through which the right people are making the appropriate decisions; and
- make evolutionary rather then revolutionary changes to CSIRO's portfolio.

The SIP occurs on an annual cycle and has two principal stages: Broad Direction Setting and the Investment Review. Built into the second stage is an iterative cycle to review the likely down-stream impact of the outcomes of the process.

Broad Direction Setting: The CSIRO Executive, taking into consideration internal and external factors such as global science trends, advice from industry, government research priorities, economic data and assessments of comparative research strengths, sets broad directions for research investments for the next financial year and beyond, translating CSIRO's Strategy into medium term investment priorities. The Broad Direction Setting is an annual discussion of CSIRO's strategy and may focus on particular or different topics and issues from year to year. In 2008 the Broad Direction Setting stage will see directions set for 2009-10 and beyond, expressing the directions via outcome domains in line with the new 2007-2011 Strategic Plan.

Investment review: The SIP invests predominantly in aggregations of research projects and programs called outcome 'themes'. CSIRO reviewed its research portfolio of 105 research 'themes' to determine its investment for 2007-08 and beyond. The Themes were assessed

against a set of criteria such as the 'value' of the research and its likely benefit to Australia socially, economically and environmentally (see Table 1 for list of theme criteria). Critical in the theme review is articulation of appropriate pathways for technology adoption and societal impact.

Table 1: Assessment Criteria – Investment Review Stage

	Prioritisation ('Lens 1')	**Judgment/Balance ('Lens 2')**
Relevance	• Significant potential benefit for Australia (Industry/Community) • Aligned with National Research Priorities or stated Government/ industry priority area • Delivery of Science and Technology is key to outcome	• Builds important capability in CSIRO with broad applicability (including Intellectual Asset/Intellectual Property) • Results in valuable additional benefits (e.g. reputation enhancement, Australian global positioning) • Top leadership commitment • Aligned with CSIRO strategy (CSIRO role in National Innovation System)
Impact	• Distinctive (and differentiated) science (Science Quality) • Theme (researcher's) track record of delivery (last five years including delivery of scientific outcomes) • Clear community/industry delivery pathway (including Intellectual Property/Knowledge diffusion pathway)	• Science "hotspot" • Appropriate leadership capacity • Divisional performance and competencies • Staff "achievability" (Recruitment/ refocussing) • Appropriate investment level • Level of technical uncertainty • Level of other risks – political, legal, cultural, reputation

Stakeholder engagement is a key part of the SIP, from official consultation with CSIRO's formal Sector Advisory Councils (SACs), to interactions with clients and government. It should be noted that significant industry/community input occurs in theme recommendation stage. This is manifested through research collaboration and co-investment in areas which are priorities for the partners.

Appendix 9 – 'Collabronauts'[19]

Rosabeth Moss Kanter introduces a space-faring analogy and the concept of "collabronauts", a new corporate player charged with searching for collaborative advantage and alliances.

"(They) are good at making connections, both human and intellectual. They are constantly on the look-out for new ways to benefit from combining forces with partners. They venture into unfamiliar territory, make deals, and return with knowledge that transforms their home world. They bring organisations closer together, introduce people and build relationships among groups that can initially seem like aliens to one another. They manage rumours, mount peace-keeping missions and solve problems. They convince their colleagues to forget old rules and try something new, something that a comes with having partners."[20]

Kanter draws out five lessons from the most effective "collabronauts" she has studied in enterprises like Amazon.com, Sun Microsystems, CISCO and Hewlett Packard. They are:

1. Focus on the future and be open to discovery of new and unimagined opportunities from collaboration.

2. Devote resources and pay attention, as nurturing networks is no idle task or after-thought.

3. Get embedded in the partner's business, both as a supplier and as a customer.

4. Exercise diplomacy, work at seamless connections between partners so that customers get what they want, however the relationships are configured. Collaboration is an adult relationship, as your partners may also be in partnership with your competitors. The rules of engagement must be clear – neither isolation nor outright war.

5. Master internal change, so partnerships are real and vital at all levels in the organisation and internal barriers to collaboration are dismantled.

Just as we have witnessed the paradox of collaboration and competition co-existing, it may be that excellent business performance in today's volatile, online, connected world will be driven by proficiency in community and relationship-building skills.

Rosabeth Moss Kanter, in fact, sums this up in the intriguing idea that tomorrow's successful corporations will not be hierarchical ordered bureaucracies, but will resemble open, inclusive, slightly chaotic communities of purpose, with permeable boundaries, shared knowledge, good grapevines and bonds based on mutual contributions and responsibilities.

[19] text taken from now unavailable website.
[20] Rosabeth Moss Kanter. Evolve! Succeeding in the Digital Culture of Tomorrow. Boston: Harvard Business, 2001, 352 pages

Appendix 10 – Productivity Commission on impact[21]

4.2 What is meant by 'impacts'?

In common usage, 'impacts' is a term that means effects of any kind. However, in this chapter a more narrow meaning is used, consistent with the framework in chapter 7. Impacts (or 'outcomes') are conceptualised as effects that are beneficial to Australians. The impacts could be:

- specific beneficial economic outcomes (such as new products or services, faster adoption of overseas technologies, the formation of rapidly growing high-wage industries, reduced costs, and increased consumer surplus). A summary measure of impacts will be their effect on aggregate productivity, if that is properly measured;
- beneficial social and environmental outcomes, some of which may only partly be visible in markets, such as reduced dry-land salinity or improved public health outcomes; and
- other intangibles (chapter 3), such as national prestige, contributions to the global common knowledge pool, implicit aid to developing countries and the development of capabilities that have future option values, even if they are not immediately useful (for example, a capacity to understand whether or when nuclear energy is a viable option for Australia).

Higher level impact measures have several desirable properties.

First, they should indicate the extent of the benefit, not just whether a particular beneficial objective was achieved. For example, in the case of a research program aimed at developing a vaccine for cervical cancer, it is preferable to know not just whether the project was successful, but whether that success translated to big or small benefits (such as, what is the likely effect of the uptake of the vaccine on reduced cervical cancer rates and the consequent improvement in well-being and reduction in health and other costs).

Second, if possible, measures should be commensurate across projects, so that the aggregate benefits of a suite of projects can be assessed. This is why measures of value expressed in dollars are useful.

Third, measures should take account of the indirect effects of projects or programs. Even a 'failed' project builds up human capital, indicates unprofitable research directions and adds to knowledge that may be useful in the future in many other ways. These indirect effects are just one manifestation of the non-linear nature of the innovation process.

However, it is often not possible to devise impact measures with these desirable traits, or in some instances any impact measures at all. In many cases, outputs are used as proxies for likely impacts. Some examples are high quality human capital, patents, academic papers and their citations (which reveals how widely the underlying knowledge may be diffused and gives an idea of their quality). Research outputs are mainly inputs into broader innovation processes and whether they produce outcomes depends on their character and the context in which they become available. There are many lower quality academic papers and lapsing patents, whose ultimate effects on Australians' well-being are likely to be weak.

[21] Productivity Commission 2007 Report on Public Support for Research

Nevertheless, while the existence of outputs from public support is not sufficient to be assured of a subsequent outcome or impact, an output of some kind is at least necessary for that objective. Accordingly, carefully-interpreted outputs can sometimes be useful as proxy indicators of ultimate outcomes.

Moreover, it may be useful to measure outputs (and sometimes inputs) as well as outcomes because this can better indicate what kinds of policies are effective in generating outcomes/impacts. For example, a study of national multifactor productivity growth might show a high ultimate impact from the conduct of R&D, but it is also useful to know whether any separable effects stem from good quality human capital and problem solving capabilities, the diffusion of codified knowledge or particular areas of research. Gans' analysis (sub. 10, pp. 12ff) of Australia's innovation capacity proceeds along these lines (albeit looking at Australian patents granted by the US Patent and Trademark Office per capita, which is arguably an output measure rather than an outcome measure).

Another important facet of the impacts of public support is their distribution among Australians. This can be particularly pertinent to programs or projects that have low additionality or where the gains mainly come in the form of higher private returns, since these imply large transfers to relatively few shareholders. As noted by Baumol (2002, pp. 143ff), the usual assumption that non-distortionary lump-sum taxes can address this is improbable. However, while distribution is a relevant issue, it can only realistically be assessed on a program by program basis.

Where information is available, this chapter explores the above aspects of impact. In some cases, as in the human capital effects of the science and innovation system, the discussion is elsewhere in this report (chapter 5 and appendix L).

The distinction between economic and social/environmental effects

The terms of reference for this study separately examines economic, social and environmental impacts. In doing so, the chapter implicitly adopts the conventional, though not rigorous, view of economic benefits as those that are apparent in markets (and typically represented in official national accounts measures).

However, in fact, from an economic perspective, people's well-being is not just determined by goods and services that are counted in GDP. Since most people value peace of mind, good health and sustainable environments, these are also relevant to economic well-being, properly defined. They are also, in theory, measurable, since it may be possible to discover the tradeoffs people are willing to make between market-produced goods and others, such as biodiversity and reduced crime. In some cases, social and environmental impacts are, in any case, also standard economic benefits. For example, improved environments can increase productivity (for instance, reduced salinity raises crop yields), as can investments in animal and human health.

Where possible, the Commission draws attention to quantifiable measures of social and environmental benefits — whether in the market system or not. Nevertheless, in many instances, eliciting accurately people's aggregate preferences about such non-market goods is often difficult (and some people consider the preference-based approach to valuing such non-market goods is flawed in any case). Given these difficulties, assessment of the social and environmental impacts of R&D often use qualitative as well as quantitative approaches, and invariably involve more subjectivity (sections 4.5 and 4.6).

Appendix 11 – Impacts from Research

Economic benefits are achieved principally by

- reducing costs of production processes, products or services
- generating additional revenue from new or improved products
- contributing new expertise into the economy through outcomes of basic and applied research

Social benefits principally relate to

- improving the health, safety or wellbeing of individuals or groups of people
- increasing the skills or capability of people in ways which enable them to better participate/cope/earn etc
- people valuing knowledge for its own sake (i.e. intrinsic or non-instrumental value)

Environmental benefits principally relate to changes in environmental parameters such as

- reducing pollution / increasing resilience / maintaining diversity.

There are two other 'overarching' or intermediate ways in which benefits may be transmitted

- by informing policy that subsequently has economic, social or environmental impacts
- by reducing risk in ways that result in economic, social or environmental benefits

Appendix 12 – Measurement of research impact – some recent findings of a CSIRO commissioned study

The consultancy firm ACIL Tasman was engaged by CSIRO in 2007 to assist us it with evaluating the impact of research we had undertaken over the previous triennium and to provide some insight into this difficult question.[22]

1. There is no silver bullet! (no surprise!!)

2. There are many evaluation and measurement tools/methods which can be useful. Each has limitations but is suited to particular circumstances or to analysing particular types of question (another no surprise!). For example:

    a. Benefit-Cost Analyses: BCA is most useful where R&D is at the delivery stage and uncertainty is low. It can yield a lower bound on benefits, to compare to some or all costs of portfolio, but care is needed to avoid upwards bias in these estimates. BCA ignores the marginal research dollar and can result in underestimating of the full value of the discovery and development stage of R&D.

    b. Econometric Analyses: Focus here is on the link between productivity and R&D. This omits non-market social and environmental benefits. Results are frequently inconclusive due to problems with aggregate time series data, relatively small samples, long lag times, and lots of 'noise' in the data.

    c. General Equilibrium Modelling: This has the advantage of 'netting out' interactions between different sectors and economic agents - but relies heavily on deriving/estimating appropriate 'economic shocks' and the development of the 'business as usual' baseline from which estimates are measured.

    d. Indicators: May be useful for communicating to particular stakeholders and for highlighting social and environmental outcomes which are difficult to quantify. They are potentially misleading if not underpinned by a strong rationale, collected on a consistent basis and presented in context.

3. Most methods do not value the options created by all stages of research or the capability of research institutions, with the risk that important areas of the R&D process are undervalued. Commonly, costs are seriously overestimated because they ignore abandonment and deferral options.

4. The strengths of different methodologies may be exploited, and their weakness redressed within a strong and coherent framework. They suggest that 'real options analysis' provides an overarching framework for impact assessment suitable for R&D.

[22] For more detail refer to the report at:
http://intranet.csiro.au/intranet/opu/ImpactReviews/ImpactReview_ACILTasmanStageOne060621.pps

a Real options analysis is analogous to the analysis of financial options. Reflecting modern investment theory, R&D involves diverting resources from other uses, and directing them at changing the options available – to firms or the wider community. The primary objective is to create a different portfolio of options, with greater option value.

b In relation to R&D, therefore, real options analysis addresses the question: 'Would an informed community have preferred (or placed a higher value on) the set of outcomes and options that were created with CSIRO R&D investment over the set of outcomes and options that would have been realised without CSIRO investment?'

c. A variety of methodologies can then be employed to identify and assess value in this context. They become tools for providing information on aspects of the total option value, building to lower bound estimates of option value. [23]

[23] Significantly, the real options approach has much firmer theoretical and common sense underpinnings than traditional benefit cost analysis and can address important weaknesses of BCA in relation to investments in R&D. Real Options analysis can account more accurately for the counterfactual, identify additional value which is not obvious using traditional BCA, and can provide insights for the design of R&D programs and delivery mechanisms. [ACIL Tasman report]

Appendix 13 – Delivering innovative solutions to industry: Experience from CSIRO Medal winners

In considering the effectiveness of the uptake of research results by industry, a subset of internationally recognised and award winning CSIRO scientists were asked their views of what features of the innovation system assist or impede delivering science and technology based innovation into Australia. Over the last ten years this cohort has a track record of delivering new products and services into diverse Australian industries and beyond, for example:

- ICT; decision support tools and enterprise search engines (Funnelback ™)
- Energy; world-leading wind resource mapping system Windscape™, and the UltraBattery
- Agribusiness; leading plant varieties in cotton, grains and wine grapes; food processing technologies for valuable manufactured products, new functional foods, technologies for extending shelf-life (for example MicroMAX™); textile and fibre technologies (for example SportWool™, OPTIM™); and Predicta-B™ DNA diagnostics for soil pathogens
- Environment; Aqualab, an in situ monitoring system for water-quality, and Landguard™ for the rapid treatment of pesticide residues
- Manufacturing; T-Mag ™ technologies for lightweight motor vehicle parts

Although a wide range of business models were used to develop and transfer research to industry (licence, spin-off, joint venture, co-investment etc) a common set of principles drove the ultimate uptake and use of the technology by industry:

- *Importance of Champions* – fundamental to all these success stories is a dedicated, passionate champion for the R&D within CSIRO (typically the lead project scientist) and an equally passionate recipient in the company. Typically these transactions take 2-5 years and rely heavily on the strength of the people to people relationships that outlive the management churn present in research institutions and companies alike.
- *Team approach essential* – scientific excellence is not sufficient; business, legal, IP and commercialisation skills need to be accessed as the project progresses along the R&D pipeline and each needs to respect the legitimacy of the others in contributing to project goals. In this context, the general shortage of skills and capacity in IP management and valuation in Australia is a current concern. A high degree of focus and commitment is required by all of the team and there is a risk in spreading key personnel too thinly over many projects. Continuous involvement of the champion is critical but it may be necessary to change project leadership and team composition during different stages of the project.
- *Choosing the right company* – identifying who to do business with is much easier if the unmet need addressed by the technology, and the potential impact for the company bottom line, is clearly understood. Alternative routes to the markets need to be evaluated as increasingly R&D is accessed by major companies through their suppliers, not by direct investment. There is a danger in locking in or overly committing to one company too early in the R&D pipeline. This business and market analysis requires serious investment of time and effort and is another skill set in short supply in Australia. Early engagement is key, and if the contribution to the company bottom line is clear from the

outset then the technology will receive senior management support through the "ups and downs" of its development.

We also need to consider continued engagement with the company following technology transfer (e.g. membership of the Board) to maintain momentum and commitment to uptake of the technology.

- *Lowering Technology Risk* – a common trend is the desire by industry to minimise their technology risk by accessing mature technologies. In the case of SME's (with limited R&D budgets) preference is for proven prototypes or even early stage products, and large companies are increasingly willing to outsource and pay a premium for very advanced solutions to significantly "de-risk" their technology investments. As a result additional time and resources need to be invested to move from the traditional "proof-of-concept" technology transfer point to "reduction to practice" if the technology solution is to be attractive to industry. The art is to then recoup these additional up front R&D costs through mechanisms such as downstream benefit sharing.
- *Strategic Co-investment* – as a counter point to the above observations, increasingly some of the RDCs are willing to co-invest in longer term strategic science (e.g. in the development of new plant germplasm), leaving the final stages of development and commercialisation of the new plant variety to the private sector. This willingness to co-invest is based on longstanding and deep personal relationships of the researcher(s) with the industry as well as a track record of delivery (for example, the contribution of CSIRO's long term R&D to success of the cotton, grain and wine industries in Australia). In a similar vein developing close working relationships and delivering science solutions to meet immediate customer needs can often lead to identification of new and challenging basic science opportunities or the rolling release of new technologies, creating a virtuous cycle of discovery and delivery e.g. in the ICT and energy sectors.
- *Managing Career Risk* – typically the passion of the researcher drives the whole process. All started their "research entrepreneur" phase of their careers from a base of science excellence and a strong desire to have impact through the uptake of their research. To achieve this requires a considerable commitment of time and it can be all consuming for several years. This in turn can impact negatively on traditional science career progression based on the "publish or perish" paradigm.

  There was a strongly held view that appropriate and more consistent recognition and reward mechanisms are needed if we are to attract early career scientists to become "research entrepreneurs" and to encourage mobility of researchers between universities, industry and PFRAs. A broadening of post-graduate training to include IP and commercialisation skills would be advantageous.

  Embarking on a "research entrepreneur" role in a start-up company carries additional career risks. Venture capital investors have a strong preference for full commitment to the business (i.e. they discourage secondments or part-time positions) and to encourage risk taking by early career scientists, research institutions need to consider their flexibility in re-employing scientists from start-up companies that either do not succeed or no longer need the particular research capability.

Appendix 14 – Summary and recommendations from CSIRO's submission to the 2004 Government Review of Collaboration

Executive Summary

CSIRO welcomes this review of *Closer Collaboration between Universities and the Major Publicly Funded Research Agencies.* It is timely for Government to consider these issues with the roll out of implementation plans for National Research Priorities and with the consideration of further funding for the research and innovation system after *Backing Australia's Ability*. CSIRO's Strategic Plan for 2003 to 2007 has a specific objective *to focus and intensify collaboration with universities, CRCs and other agencie*s. This objective builds on our key behavioural message to *Partner or Perish* and recognizes that improved collaboration is necessary to deliver other strategic objectives, particularly the National Flagships Program, which is one of CSIRO's major strategies to deliver on the National Research Priorities.

CSIRO believes that collaboration can be enhanced to deliver more benefits to Australia, noting that

- diversity of research providers and funders underpins the resilience and flexibility of the national innovation system
- the Australian system is already by and large quite collaborative—the CRC Program remains unique in the OECD in explicitly bringing together the PFRAs, universities and industry
- collaboration is a means to an end, not an end in itself
- effective collaborations cannot be mandated but are highly relationship dependent building on trust, commitment and shared vision
- the system needs qualitative improvements in collaboration rather than major and potentially disruptive interventions
- Governments and institutions—and most importantly people—need to work together to remove impediments and enhance drivers and incentives

CSIRO's experience indicates that success in collaborations is driven by

- a shared vision with a focus on the added value of the collaboration
- a fair sharing of the added value including, where appropriate, an agreed strategy for the ownership and management of any IP resulting from the partnership
- a strategic fit between the partners that respects each other's culture
- organisational alignment involving senior executive commitment to the collaboration, processes to build and maintain trust between key staff, mutually accepted governance arrangements and effective communication within the collaboration and to its partners

Drawing on international experience CSIRO believes that there are some achievable steps that could be taken to tangibly enhance collaboration within the Australian innovation system. CSIRO would encourage the Review to consider a range of initiatives, including

- introducing a new nationally competitive scheme to support participation by all research players, and particularly universities, in the National Flagships Program aimed at the National Research Priorities
- encouraging mobility across the innovation system by the introduction of specific programs of targeted fellowship schemes and/or joint appointments between the PFRAs and universities
- modifying the CRC Program to build critical mass and reduce overlap

CSIRO agrees that there is scope to enhance cooperation in commercialisation and notes

- multidisciplinary science requires clear IP management and benefit sharing arrangements to allow successful commercialisation
- prevailing contractual negotiations and arrangements are frequently tension-filled and protracted and can be significantly simplified and standardised—CSIRO commits to such an approach and would offer inputs from its own recent programs for contract simplification and business improvement
- the formation and development of regional clusters might be enhanced through facilitated collaboration between the PFRAs, universities and SMEs

CSIRO notes the following about the relationship between excellence and contestability

- agrees that excellence in research is fundamentally important
- notes that peer review of science is a necessary but not sufficient criterion for excellence in mission oriented, strategic research, where outputs and outcomes—with defined paths to end use—are essential; also, that it can be undertaken at many levels from the individual, the project, the program and the institution, and can be (and is) done on block funded research
- is concerned that over-simplistic arguments maybe used to favour some funding models over others

CSIRO recommends that any changes in its funding arrangements take account of CSIRO's Strategic Plan for 2003-2007, and the significant change process which it is driving. This process, ongoing for some two years now, has been strongly endorsed by the CSIRO Board and senior Government stakeholders but is at a vulnerable stage of implementation. CSIRO also notes that its block funding

- maintains a range of functions other than research, including large infrastructure and national collections
- provides resources for research into large scale national problems that require significant capability and large teams
- is increasingly rigorously applied and evaluated, for example through the introduction of a comprehensive program performance framework
- provides a platform for collaborative and/or contestable funding arrangements

In conclusion, CSIRO offers a number of specific recommendations (summarised in the following two pages) to enhance collaboration. In supporting these recommendations, CSIRO commits, subject to the formal approval of its Board where necessary, to

- a proactive program of consolidation of its estate, with over 50%of property capital and infrastructure investment for 2003-2008 invested in collocation on or close to university sites
- tangible (financial) support and behavioural modifications essential to support new programs aimed at enhancing collaboration

***

Key Recommendations

1. All players and stakeholders in the Australian innovation system, including the Government, recognise that the Australian system needs qualitative improvements in collaboration aimed at improving the "softer" behavioural aspects of successful collaboration rather than major and potentially disruptive structural interventions. (Section 3.2, p8)

2. Collaboration should be fostered as a means to
    - achieve national and global scale and impact thereby facilitating participation in large science initiatives, co-investment with international companies and the attraction of personnel
    - address the National Research Priorities particularly where this requires a trans-disciplinary approach via vehicles such as the National Flagships Program, the CRCs or other major Centres of Excellence
    - facilitate exchange of codified and tacit knowledge, and
    - generate economies of scale from better coordination and the development of critical mass and costly infrastructure. (Section 3.3, p9)

3. Given the importance of attitude and behaviour in the success of all collaborative ventures
    - A formal training program is established (building on the experience of previous programs) to allow scientists and support staff entering major collaborations to explore the softer issues of collaboration and enhance team skills. This program should possibly be directly subsidised by DEST to keep cost of attendance at a reasonable level
    - Organisations should give more weight to team skills in promotion and other reward structures. (Section 3.4, p10)

4. Funding schemes and agencies (including DEST) should seek to decrease the extent of leveraging requested in applications and review any associated drivers to ensure that any "anti-collaborative" tendencies are identified and moderated quickly. (Section 3.5, p11)

5. A set of national principles for "frictionless collaboration" be developed and adopted by all research providers. These should
    - recognise trust and commitment as key elements of successful collaborations
    - be based upon agreed governance structures and IP management principles for collaborative relationships, and
    - provide a range of simplified and consistent contracts governing collaborative relationships. (Section 3.5, p11)

6. The recommendations of the recent DEST-commissioned review of the CRC Program should be implemented as soon as practical. (Section 4.2, p13)

7. All new funding schemes should recognise and reward value adding collaborative arrangements and have flexibility in guidelines to enable different kinds of institutions to participate. This goal should be explicitly built into performance indicators. (Section 4.3, p14)

8. Understanding and appreciation of the respective roles and values of PFRAs and universities be enhanced by increasing staff mobility across boundaries and reducing the costs associated with the development of social capital by
    - The introduction of targeted schemes of fellowship and/or joint appointments designed to deliberately enhance mobility between universities and PFRAs, e.g. a visiting fellow scheme by which university-based researchers spend periods of residency in PFRAs. (CSIRO would enthusiastically endorse such a scheme and tangibly support it through specific project and overhead support.) A complementary scheme to help fund PFRA researchers to take up short term fellowships in universities might be another possibility
    - Modification of the new ARC Networks Scheme to allow PFRA researchers to benefit from that funding when in the national interest. Construction and maintenance of networks is not costless and explicit funding to cover these costs encourages collaboration at the research level. The current ARC rules give little incentive to participate by researchers from the PFRAs if, in addition to the research costs, all network costs have to be borne by their home organisation. (Again, CSIRO would tangibly support such an extension through, for example, matching overheads and project support costs.)
    - An expanded post doctoral program that would encourage early career scientists to spend some time in the PFRAs, particularly in strategic research programs or in national facilities and/or collections. (CSIRO would also be keen to support this program through appropriate matching)
    - A PFRA-university collaborative scheme modelled on the ARC linkage scheme with industry. Under such a scheme the ARC/NHMRC would fund the university research partnership with the PFRA partner being funded through its own appropriation funding and linked to one of the PFRA's strategic research programs. (Section 4.3, p14)

9. That whenever opportunities arise for collocation of universities and PFRAs these be actively pursued, as well as investigating the possibility of strengthening links with the local successful industries to develop research platforms that might support cluster formation. (Section 5.3, p17)

10. A new national competitive research grants scheme is developed to allocate new funding to enhance the National Flagships Program aimed at the National Research Priorities. Such a scheme should recognise the distinct metrics of strategic research, the need to have explicit paths to adoption, be of scale and duration to make a difference and build "Team Australia" by encouraging the engagement of all players but particularly university researchers with such Flagships. (Section 6.1, p19)

11. Any changes in funding arrangements should take account of CSIRO's Strategic Plan for 2003-2007, the significant change process, which that is driving, and the risk to delivery and execution by potentially disruptive interventions at this time. (Section 7.2, p24)

Appendix 15 – CSIRO Experience with CRCs

An internal review in CSIRO of its participation in the program, conducted by the Phoenix Group, highlighted that the CRCs that CSIRO had participated in had created value for Australia. Findings from that review and other observations are:

- The objectives of the CRC program and of CSIRO are compatible (harnessing science and technology to benefit Australia);
- The CRCs that we have participated in have been successful overall and created value for Australia;
- The value creation is related to the nature of the CRC with the agri-food and fibre area assessed as producing highest total value followed by Manufacturing/IT, Minerals/Energy and Environment;
- Value creation fell as disputations between CSIRO and other parties were assessed as above 'minor';
- Conflict arose in a number of ways – IP ownership, governance issues, resource allocations and poor leadership;
- The transaction costs of engaging with CRCs are high, we estimate them to be around 30% of the Commonwealth grant;
- Problems do emerge with CRCs that continue for more than a single term as capability development and research infrastructure costs are borne by the research provider. Loss of key staff or funding cuts to parent bodies make continuity of participation over 12 or more years difficult (e.g. Weeds CRC);
- Leverage issues (see Section 4.2) and fragmentation of research effort across a number of CRCs in related areas have pushed CSIRO investment to the limit in many domains (e.g. biosecurity) making it difficult to provide in-kind resources;
- IP benefits of CRCs are often divided by the ratio of inputs from participants generating unrealistic measures of in-kind contributions. The Phoenix Group report found that value creation in CRCs declined with the number of locations in a CRC;
- In our assessment, technology adoption occurred with 23 % CRCs (e.g. Australian Mining and Exploration Technology; Cardiac Technology; Plant Science) although many CRCs did start down the commercialisation/adoption route;
- The leadership skills of the CEO of the CRC were critical to success they need to work predominantly through influence rather than authority;
- Most of the resources available to a CRC are in-kind. Technically, these resources needed to be realigned with the CRC goal to achieve impact. In practice, this realignment was voluntary and more often than not, activity in participant organisations occurred in parallel in a loose collaboration. Such a system may be suitable for many research problems but it would not be possible to redirect and align significant people around an emerging and urgent challenge such as the Murray Darling Basin Sustainable Yields Project (see Box 1);
- It is our observation that CRCs in which we participate can either enhance collaborative relationships among the parties and build a body of knowledge to underpin policy advice, or they can have a strong delivery focus on specific large outcomes, but they rarely do both successfully.

Appendix 16 – ARRC – an example of CSIRO's Joint Venture experience

The Australian Resources Research Centre (ARRC) was established in 2001 as a joint initiative between the Western Australian Government, CSIRO and Curtin University of Technology with the vision of creating a world-class minerals and petroleum R&D Centre in Perth. The State's $35 million investment in the Centre was directed towards construction of a purpose built facility, relocation of CSIRO staff from Sydney and Melbourne and support for collaborative R&D initiatives.

Seven years on and ARRC has gone a long way towards achieving its vision of becoming a world-class R&D Centre, with major research and industry partnerships a feature. Four Cooperative Research Centres have a presence at the Centre, together with three Western Australian R&D Centres of Excellence – clear evidence of the close collaboration that exists between CSIRO, universities and industry. The creation of the Western Australian Energy Research Alliance (WAERA), a joint venture between CSIRO, Curtin University and the University of Western Australia, exemplifies the important role that ARRC now plays in the region in helping harness the capabilities of local, national and international research communities to work with industry to help secure Australia's long-term energy needs. Since its establishment in 2004, the Alliance has formed major partnerships with key industry clients such as Woodside Energy and Chevron, thereby ensuring the uptake of research outcomes.

Reinforcing the Centre's growing reputation, nationally and internationally, was BHP Billiton's decision in 2006 to establish one of only three Global Technology Centres at ARRC. Proximity to the company's iron ore and nickel assets in Western Australia was an important factor in this decision, as was ready access to the world-class minerals R&D capabilities resident at ARRC. Whilst it's still early days, the benefits to CSIRO of being co-located with the world's largest resource company at ARRC are already evident and confidently expected to grow over time. Government agencies too have recognised the benefits of co-location and collaboration at ARRC, with the Federal Government's National Measurement Institute recently relocating its Perth-based operations to the Centre.

Over its relatively short life ARRC has become a resources R&D centre of international standing. Central to its success has been an emphasis on collaboration between CSIRO and the university sector as the basis for successful engagement with the minerals and petroleum industries.

Appendix 17 – CSIRO's talent ladder initiative

The development and maintenance of science excellence is critical for CSIRO and Australia. Over the last few years CSIRO has implemented a number of programs aimed specifically at maintaining high quality research and scientific capability. The outcomes of these programs have been to:

- Build a pipeline of research leaders by attracting and developing high-quality, early and mid career scientists who have the potential to become leading scientists in CSIRO and other parts of the NIS.
- Develop an integrated "career program" to continue to attract the talented individuals to science careers and to develop this talent to build capability for CSIRO and Australia's broader research sector.

Elements of this program include:

- Significantly expanded and specialised PhD and Post-doc programs, providing early career scientists with a mentored and differentiated experience including the development of project management, collaboration, commercialisation and research leadership skills.
- More positions for early career scientists through the Julius Career awards. This High Achievers Program includes an emphasis on professional development of the scientists, through the funding of 3 and 12 months international experience and/or experience in industry .
- The CEO Science Leaders Program which attracts world leading mid-career researchers to Australia, placing them into science leadership positions in CSIRO.
- Fellowships designed to support researchers who have taken career breaks to care for family, to re-establish themselves and re-connect with the research underway in their field and related fields of research.
- Collaboration initiatives including:
    - Flagship Fellows program which supports academics becoming involved in the CSIRO Flagships
    - Fellowships for senior CSIRO researchers for secondments to other institutions and laboratories
    - Distinguishing Visiting Scientists initiatives, attracting world leading scientists to CSIRO to inject skills and capabilities into research groups across the organisation.
- The CSIRO Fellowship program aiming to both recognise and utilise the immense experience of our senior scientists.