Australian Government

Department of Education, Science and Training

SUBMISSION TO THE PRODUCTIVITY COMMISSION STUDY ON PUBLIC SUPPORT FOR SCIENCE AND INNOVATION

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PRODUCTIVITY COMMISSION STUDY ON SCIENCE AND INNOVATION

PART 1: KEY ISSUES

With an injection of almost $11 billion in new funding through the 2001 and 2004 *Backing Australia's Ability* (BAA) and 2003 *Backing Australia's Future* (BAF) initiatives, the Australian Government positioned Australia to meet the challenges of the next decade. These reform packages represent a strengthened resolve to increase the impact of research, education and training on our prosperity and wellbeing as a nation.

By sharpening the focus on quality, diversity, commercialisation and linkages, further reforms will have a profound effect on the way the portfolio approaches its functions. This submission looks at both current strengths and emerging gaps.

The Department of Education, Science and Training (DEST) and its portfolio agencies play a central role in the national innovation system. Many of the Department's diverse research and education functions are essential to the effective functioning of that system. These include providing direct support to public research agencies including universities, administering block and competitive research grants schemes and programmes, promoting commercialisation of publicly funded research and knowledge transfer, ensuring the provision of quality education and training and the supply of human capital, promoting community engagement in science, and promoting strategic global partnerships.

The Productivity Commission's study is timely as it provides an opportunity to review the impact of recent reforms and a consideration of options beyond BAA. It has been over a decade since the last nation-wide assessment of our research and development (R&D) performance and the global context in which Australia is operating is changing rapidly.

The Productivity Commission is tasked with reviewing three aspects of science and innovation. They are: impact (including economic, social and environmental), impediments and policy formulation/programme design. This submission addresses the terms of reference by providing an analysis of:

- The link between skills, innovation and productivity
- The economic impact of R&D
- Current programme initiatives and emerging challenges.

The discussion is structured around the five broad areas of the portfolio's activities, namely quality research, quality education and training, globally engaged science, connected industry and communities, and world-class infrastructure.

Research

Government support for science and innovation in 2006–07 will total $5.97 billion, much of which will go to supporting the conduct of research in universities and the Publicly Funded Research Agencies (CSIRO, Australian Institute of Marine Science and Australian Nuclear Science and Technology Organisation).

While estimating the economic returns from public sector research is a complex task, DEST has commissioned economic modelling which has produced indicative findings that are very positive for both the returns to BAA and the totality of the Australian Government's support for science and innovation. For example, it is estimated that the BAA initiatives will have a sustained net impact on Australia's GDP growth of 0.12 per cent per annum.

BAA acknowledged that the significant public outlay on science and innovation should be based on an understanding of the outcomes from the research that is supported and the impact it has, but did not look at reforms to research.

A Research Quality Framework (RQF) is the next step in that reform process. An RQF would for the first time give us a robust and defensible approach to measuring the quality and impact of research carried out across the universities and Publicly Funded Research Agencies. By recognising and rewarding research excellence it will help institutions identify their strengths and will enhance diversity in the system. By rewarding impact, research will be promoted that makes a demonstrable change to the way we live. Through applying rigorous and internationally-recognised methodology it will lift the international standing of Australian research.

Development of the RQF will benefit from knowledge of current world's best practice. The challenge is to build a methodology that is appropriate to the Australian context and responsive to community expectations. Part of that will be the identification and collection of reliable, meaningful data that will stand up to scrutiny and produce real improvements in quality. A further challenge is to find an approach that can be applied across the breadth of publicly funded research.

Education and training

Development of human capital is a fundamental element in the national innovation system and an important driver of economic growth. A skilled workforce is innovative, has a greater capacity to accept and work with innovation, is a necessary input to research and development and provides greater opportunities for business innovation.

Australia has a quality education and training system. However, in a competitive global environment, we cannot stand still. Global and domestic forces are presenting challenges to Australian education and training with implications for both our domestic supply and our capacity to successfully export education. The downward trend in engagement in science, engineering and technology study at all levels of schooling and higher education is diminishing the pool of applicants for science, education and technology (SET) positions in industry and the scientific research sector. This is occurring at the same time that global demand for people in the SET professions and trades is increasing, particularly in sectors such as resources, defence and infrastructure. A combination of economic growth, international migration and an ageing workforce are contributing to demand-side pressure.

BAA and BAF provided significant new funding for student places in higher education, particularly in the priority areas of science, mathematics and information and communications technology (ICT). Despite this, there has been negligible growth in commencements by domestic students in natural and physical sciences between 2001 and 2004 and a slight decline in engineering and related technologies. There was a slight increase in completions in that time, but this was mainly driven by overseas students.

There is also evidence of a serious mismatch between the proportion of the working age population that holds vocational training and education qualifications (29.9 per cent) and projected demand for those qualifications (62.3 per cent). The gap will be most significant in occupations requiring higher level qualifications, that is the associate professionals, rather than the trades. The challenge for the vocational training and education sector will be to attract suitable candidates into those levels of training by providing pathways from entry level through to more advanced levels, and multiple entry points throughout working life.

An important element of the Government's response to the emerging skills shortages is to change the attitudes of students and their parents to study and careers in science professions and trades, by raising the public profile and status of science and scientists. Assessments of science awareness programmes supported by the portfolio show they are having a positive impact and could be expanded to a wider audience. A modern innovative society also requires a high level of science literacy and awareness to ensure its citizens are able to recognise the value of science, adapt to the changes wrought by scientific and technological change and engage in informed and constructive debates on science-related issues.

Quality of teaching has a direct bearing on our ability to engage students in the study of SET subjects and our ability to supply broader capabilities for an innovative society. The Review of Teaching and Teacher Education called for a re-energising of the sciences and technology and a prioritising of innovation in our schools. It recommended a range of initiatives to support the professional development of teachers, encourage exemplary practice and encourage the uptake of science, technology and mathematics teacher training.

The challenge for Australian education is to embed initiatives in schools nationally. By the end of 2006, we will have a better understanding of the challenges we face in school science education, when the Australian School Science Education Framework goes to the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA) for endorsement. The Framework's purpose will be to map school science education initiatives throughout Australia, identify gaps in provision and recommend national action to address priority needs.

The higher education sector is being challenged to play to its strengths: to seek innovative ways to restructure university course offerings to better align with their mission and build on their specialities. A more diverse sector should have a greater capacity to find creative solutions to challenges like the shortfall in science and engineering enrolments.

Links between higher education and research and innovation contribute to a stronger human capital base: a strong research base is supported by a strong higher education sector and vice versa.

Industry and community engagement

The Australian Government has long recognised the need for publicly funded science and research to connect to industry. In DEST the Cooperative Research Centre (CRC) Programme is a central plank underpinning that policy with an explicit focus on economic impact and commercial returns. The programme has a history of success confirmed recently through the Allen Consulting Group report[1]. CRCs leverage up to four times their core funding from universities, industry, State Governments and PFRAs. The number of business participants continues to increase and now stands at 1,177 compared to 988 in 2000–01. In the last five years the proportion of industry and university contributions has almost doubled.

Nevertheless, there is a need to look at new models and to address such issues as applicability of the programme to public good/national impact objectives and optimal duration of grant periods given the programme's specific policy objective which has been refined over successive rounds.

Engagement with industry and the community is part of the core business of universities and PFRAs. BAA recognises the role of research commercialisation and transfer of knowledge from public sector research to industry and the community in maximising the impact of science and innovation. Government policy in this area is evolving from a focus on the commercialisation of intellectual property to recognition of the breadth and diversity of relationships between researchers, industry and the community. Supporting these relationships and encouraging institutions to build on their own strengths and unique situations, will help to create more diversity, responsiveness and relevance.

[1] The Allen Consulting Group, *The Economic Impact of Cooperative Research Centres in Australia,* CRC Association, Melbourne, 2005.

Global engagement

Countries around the world are placing increasing emphasis on investment in science and innovation to stimulate economic growth. These countries recognise this effort must be supported by international collaboration if researchers are to have access to the latest and best knowledge and facilities. Given our size and remoteness, the Australian science community arguably has a greater need for international engagement. Australia's capacity to produce world-class science would be seriously undermined if it ignored the approximately 97 per cent of research that occurs beyond our shores.

In addition to helping assure the quality and international competitiveness of the Australian science system, international collaboration has the potential to make a positive impact on our domestic economic and social wellbeing. These potential benefits include increasing Australia's share of the global investment in R&D, stimulating the growth of domestic industries, supporting access to lucrative export markets, developing relationships with regional partners and meeting global challenges (for example on climate change) in a manner that best support Australia's interest.

DEST's experience in managing funding programmes to support international engagement suggests these funding programmes are highly valued by the Australian science community However, a typical success rate of 10 per cent for applications indicates that a substantial number of world-class proposals do not receive support. In addition to addressing this unmet demand, DEST has identified opportunities for a renewal of Australia's international science strategy to better focus who we collaborate with and in what areas, provide increased flexibility in responding to emerging priorities, and increase engagement with key partners (for example the US, the EU and China) and participation in large international science projects. Some of these issues will be examined in the coming months by a working group of the Prime Minister's Science, Engineering and Innovation Council.

Infrastructure

World-class infrastructure is critical to world-class higher education and R&D. The increasing cost of infrastructure is an issue for the education and training sectors. This is particularly the case for universities, where the rapid expansion of the 1970s and 80s has left a legacy of ageing infrastructure. An estimated deferred maintenance backlog of $1.2 billion presents a serious challenge for that sector.

Maintaining the competitiveness of Australian science and innovation requires ongoing investment in major leading edge research infrastructure. The increasing cost and complexity of scientific equipment makes it difficult for individual research institutions to develop and access leading edge facilities and instruments. Research is also increasingly multi-disciplinary, networked and collaborative.

Under the National Collaborative Research Infrastructure Strategy (NCRIS), the Government is funding the development of national research facilities in high priority areas. They will be built and operated jointly by universities, PFRAs, State and Territory governments and the private sector as appropriate and made accessible to researchers wherever they may be based. The NCRIS Committee is expected to provide advice to the Government by the end of 2006 on specific investment proposals in nine priority areas (with several others to follow in 2007).

The NCRIS model is having a significant impact by facilitating greater collaboration and coordination across sectors. However, it does not cover areas of need outside the identified priority areas. Furthermore, it will not address the establishment of landmark infrastructures, which continue to be considered by the Government on a case-by-case basis.

e-Research is becoming increasingly important to Australian research. It covers research activities characterised by advanced ICT capabilities and new methodologies that require access to large and diverse data holdings, high speed networks, distributed and high performance computing facilities and remote instruments. The Australian Government has a role in ensuring not only appropriate infrastructure, but also effective coordination and governance mechanisms.

PART 2: CONTEXT AND ECONOMIC ANALYSIS

1. GOVERNMENT SUPPORT FOR SCIENCE AND INNOVATION

The prevailing Australian Government policy statement on research and research training for higher education is *Knowledge and Innovation* (K&I), published in December 1999 after an extensive public consultation process. Through K&I the Government confirmed its commitment to sustaining national capability in basic research, strengthening the linkages between the different parts of the national innovation system, improving the management of research within higher education institutions and assuring the quality and effectiveness of the research training.

K&I created a strengthened Australian Research Council and national competitive grants system, and created the basis of the current performance-based research block grants. Importantly, K&I adopted the following principles for the funding of higher education research and research training, which are still in force:

- Excellence
- Institutional autonomy and responsiveness
- Student choice
- Linkage and collaboration
- Transparency, contestability and accountability.

In 2001 the Australian Government launched the five year $3 billion *Backing Australia's Ability* (BAA) initiative, designed to promote science and innovation. Building on that programme, in 2004 the Government injected a further $5.3 billion under *Backing Australia's Ability – Building our Future through Science and Innovation*. Together with existing funding arrangements, these initiatives represent a $52 billion investment in science and innovation over the ten years to 2011. The combined BAA packages cover four elements:

- Strengthening Australia's ability to undertake research and generate ideas
- Accelerating the commercialisation of ideas
- Developing and retaining skills
- Fostering collaboration.

In 2003 *Our Universities: Backing Australia's Future* (BAF) presented a 'blueprint' for reform of the higher education sector to make it more competitive. It was an integrated package, with an additional $2.6 billion in funding from 2004–08, and introduced reforms to address the diversity, sustainability, quality and equity of universities in areas as diverse as teaching, workplace productivity, governance, student financing, research, cross sectoral collaboration and quality.

The Department of Education, Science and Training (DEST) and the science agencies within the portfolio together make a significant contribution to supporting science and innovation. This submission covers the policies and programmes for which DEST is responsible. The portfolio agencies will each make their own submission to the Productivity Commission.

The DEST submission is made in the context of a worldwide re-evaluation of the role of public support for science and innovation. With the rise of the global 'knowledge economy', the developed (and, crucially, many developing) nations of the world are revisiting the question of how government supports science and innovation.

There is nothing new about this question, but it is being asked with increasing urgency in Australia and internationally. The importance of science and innovation is growing, as it is through the successful application of new ideas that many of the economic, environmental and social challenges of the future are to be met. This is part of a long term trend in economic development that is only going to accelerate in the coming century. Public sector support for science and innovation is therefore about building the human, institutional and physical foundations on which new markets, effective social policy, better health outcomes and sustainable environmental management can be built. Practically every nation in the world recognises this, and every nation is responding according to its own specific circumstances, means and aspirations.

The strategic importance of science and innovation to Australia is borne out by the fact that it features as one of the nine strategic priorities identified by the Australian Government.[2] In fact, together with education (another strategic priority), science and innovation interlinks with and underpins all of the areas of strategic focus for the nation. That is why the Education, Science and Training portfolio – including DEST – is central to the future of the nation.

Reinforcing this strategic aspect of public support for science and innovation, there are fundamental economic reasons for government intervention. The need for public support for science and innovation is not just at the margins of improving the operation of existing markets – through helping research and development in current industries, for example. The need is far deeper and much longer term, reaching to issues of human capital development and generating the fundamental knowledge that underpins sustained economic development and social well-being. In launching the second BAA package in 2004, the Prime Minister acknowledged these challenges and said that 'the Government recognises the calculated risk-taking and long planning horizons necessary to reap the benefits of science and innovation'.[3]

2. THE ROLE OF THE PORTFOLIO IN THE NATIONAL SYSTEM

In relation to those policies and programmes for which DEST has responsibility, there are four areas of focus for science and innovation support. Figure 1 is a representation of those areas and how they support national prosperity and wellbeing, understanding that there are other drivers in the economy that also contribute to this goal to a greater and lesser extent. The elements are:

- Quality research – research that is both intrinsically excellent and has real impact, whether in the form of practical application, or the further development of human understanding
- Quality education and training – education that prepares Australians for the future of work, building our national human capital base to help ensure future prosperity and respond to the emerging demands of the global, demographic, social, environmental and economic challenges we are facing
- Globally engaged science – science that puts Australia on the world stage, and leverages opportunities for the nation in international research and development, from basic to applied fields
- Connected industry and communities – connectedness with the national systems of education, research and creative innovation, maximising the opportunities for economic development and global competitiveness.

These are all underpinned by a system of world-class infrastructure, sustained by long term investment.

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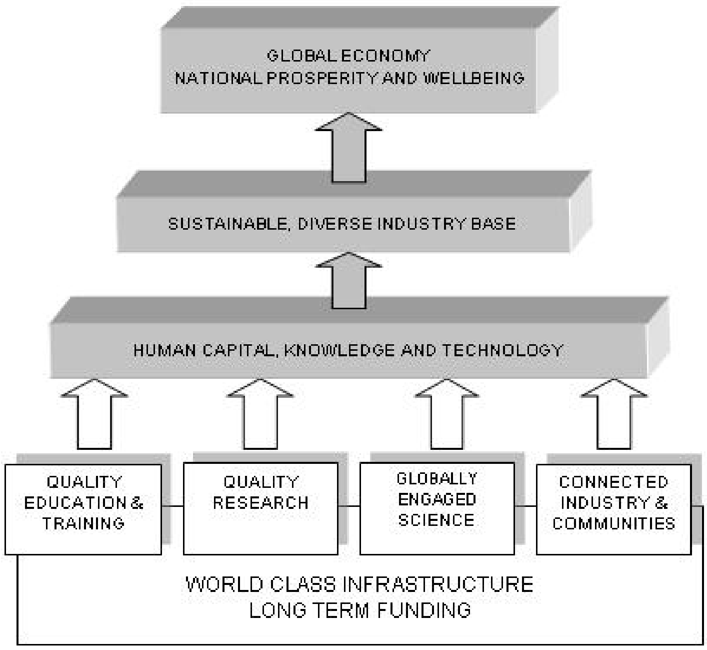
[2] J Howard, 'Strategic leadership for Australia: policy directions in a complex world', speech delivered to a meeting of Committee for Economic Development, Sydney, 20 November, 2002.
[3] Department of Education, Science and Training, *Backing Australia's ability: building our future through science and innovation,* DEST, Canberra, 2004.

Flowing from this diverse but integrated system of public support are the three central elements of an innovative, modern nation: human capital, knowledge, and technology. Having the breadth and flexibility to supply and sustain these allows Australia to establish and maintain a diverse industry base that can respond effectively to the challenges and opportunities of the global economy.

Much of what we do is directed towards preparedness in a context of rapid change and uncertainty. Our role is to provide national leadership to ensure preparation of a skilled and innovative population both now and for the future. National capability must include the flexibility to respond effectively to change, including creating and capturing opportunities.

Science creates many important impacts beyond the purely economic, including social, environmental, and cultural. These can have an indirect economic outcome, but are also valid objectives for Government support in their own right.

Figure 1: Role of Department of Education, Science and Training in the national innovation system



3. SKILLS, PUBLIC SECTOR RESEARCH AND ECONOMIC OUTCOMES

(I) AUSTRALIA'S INDUSTRY BASE

Australia is enjoying its longest sustained period of economic growth. Public commentators have warned against too great a reliance on the current resources boom for our continued good fortune as a nation.

As ANU economist Ross Garnaut wrote in 2004: 'We need to make policy adjustments now to stop the dangerous imbalance in the economy. Without Chinese growth, we may have had a crisis before now. But the China boom of early 2004 is about as good as it gets. We will be a lucky country if the terms of trade hold at those high levels.'[4] Professor Garnaut cites worrying trends such as record growth in private domestic consumption and the current account deficit, and the collapse in manufacturing and agricultural exports.

In his report on the economy in May 2006 Reserve Bank Governor Ian Macfarlane reported that skill shortages were having an economic impact. Around the same time ANU economist and Reserve Bank Board member Warwick McKibbin also highlighted skills as an important economic issue and called for a strategic re-investment in education to expand 'productive capacity to keep the long boom running and prevent a downturn.'[5]

Given DEST's role, there are two specific areas where the Department is critical to the nation's economic performance: skills, and public sector research. The following two sections address each in relation to their impact on economic outcomes, especially productivity.

(II) SKILLS, INNOVATION AND PRODUCTIVITY

Provided that skills are generally current, appropriate and flexibly adaptable to the needs of business, they are connected with innovation in a number of ways, including:

- A more skilled workforce is, other things being equal, itself a more innovative workforce.
- A more skilled workforce has, other things being equal, a greater capacity to accept and work with innovation.
- A skilled workforce is a necessary input to effective research and development towards innovation.
- The practice of higher levels of skill in a flexible work environment provides opportunities for business innovation.

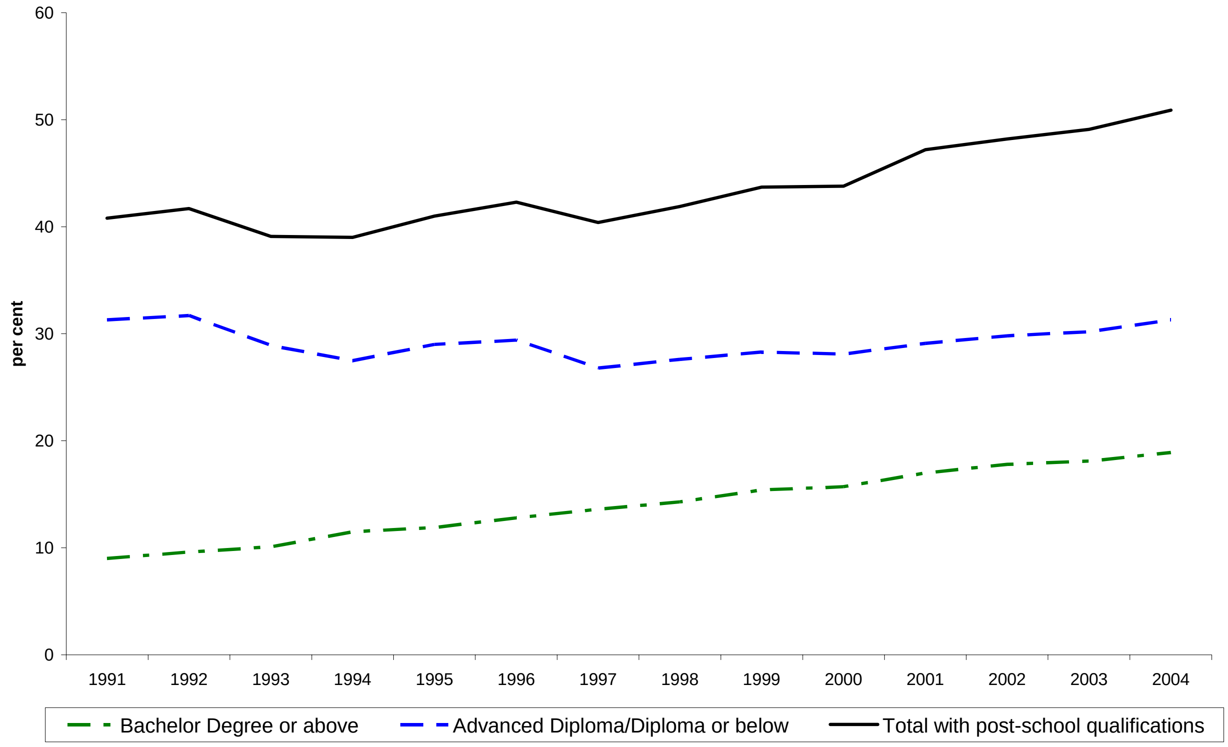
For these reasons, changes in the skills mix in the workforce are themselves indirect measures both of change in the capacity of the economy for innovation and of workforce oriented innovation in the economy. In consequence, changes in labour productivity due to changes in the skills mix are indirect results in part of innovation.

[4] R Garnaut, 'Has Australia lost its appetite for economic reform?', *Online Opinion,* 10 August 2004, viewed 25 August 2006, <http://www.onlineopinion.com.au/view.asp?article=2436>.
[5] P Hartcher, 'Don't blow it, warns RBA man', *Sydney Morning Herald,* 9 May 2006.

Skills and productivity links

In Australia, changes in the skills mix can be, but are not always, positively associated with growth in labour productivity. At an aggregate level, changes in the highest educational attainment of the working age population are correlated with changes in skills. Attainment of the working age population to a higher education level increased steadily through the 1990s and beyond, but attainment to a skilled vocational level actually decreased until about 1998, after which it rose steadily (Figure 2).

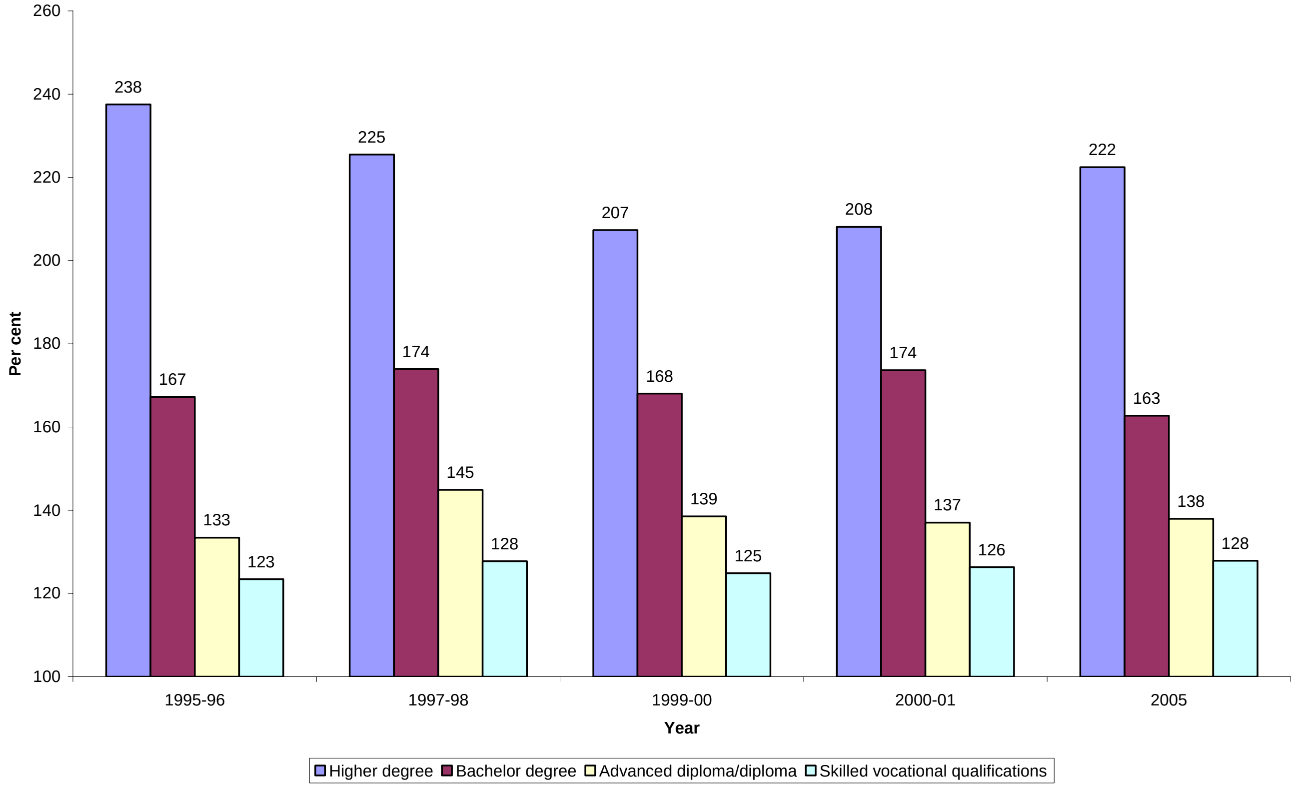
Figure 2: Percentage of population aged 15 to 64 with post-school attainment



Source: *Education and Work Australia*, ABS Catalogue 6227.0 various issues

At the same time, the relative wages of workers (a prima facie proxy for relative productivity) with higher levels of attainment decreased slightly before stabilising from about 1998 (Figure 3).

Figure 3: Earnings by highest educational attainment relative to those with no post-school qualifications



Source: ABS Surveys of Income and Housing (various)

We are using a simple example in Figure 4 and Figure 5 which is based on OECD methodology[6] as reported in various OECD publications[7]. It shows that the combination of these factors leads to a negligible impact of change in the skills mix on labour productivity growth during the 1990s. However a significant impact is demonstrated from the late 1990s. If, as suggested above, change in skills is correlated with at least one dimension of innovation, then an expected result would be a probable low correlation of innovation to economic returns during the 1990s, but an increasing return since.

Figure 4: Notional productivity returns to education on a change in skills mix

	Working age population share	Relative productivity	Workforce participation rate	Relative productive output
	a	b	c	=a*b*c
Degree or better	19.0%	170%	90%	29.07
VET qualification	31.0%	130%	90%	36.27
No post-school	50.0%	100%	70%	35.00
Total	100.0%			100.34
Change in skills mix				
Degree or better	+0.5%			
VET qualification	+0.5%	→	→	+0.65%
No post-school	-1.0%			
After change in skills mix				
0.005	19.5%	170%	90%	29.84
0.005	31.5%	130%	90%	36.86
	49.0%	100%	70%	34.30
				100.99
Increase in production				0.65%

Figure 5: Estimated change in production on previous year due to change in skills mix

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
0.74	-0.97	0.55	1.12	1	-0.59	1.02	1.31	0.16	1.61	1.02	0.44	1.19

Calculated from skills mix rates in Figure 2 and column b and rates in Figure 4.

There are broad considerations of change in the Australian economy during the 1980s and 1990s, which tend to support a stronger relationship between innovation and economic returns after mid-90s as compared with the period before the mid-90s:

- Many skill sets of a technical or management orientation became redundant (with a lagging unemployability effect still in evidence), both because of the uptake of ICT and because of the development of the service and knowledge economies. In these circumstances, skills related innovation would be low, as would be the incentive of firms to invest in innovation.

[6] P Schreyer, *Measuring productivity: measurement of aggregate and industry-level productivity growth: OECD manual,* OECD, Paris, 2001.
[7] S Scarpetta, *The sources of economic growth in OECD countries,* OECD, Paris, 2003; and Organisation for Economic Co-operation and Development, *Education at a glance: OECD indicators 2005,* OECD, Paris, 2005.

- There was a strong emphasis on the increase of labour flexibility through the reduction of restrictive practices and flexible market-determined pay structures. In these circumstances, returns to the uptake by firms of regulatory reform (rather than innovation) would initially be high, but with diminishing returns expected later.
- Firms could achieve improved performance by adoption of international best practice and technologies, that is, of pre-existing innovation elsewhere, not investment in innovation.

In the present circumstances of strong economic growth, skills growth and productivity, not enough has been made of the implications of the increased general skills attainment of the Australian working population. This is partly due to the apparent weak connection of skills growth and productivity in the 1990s noted above and discussed by the Productivity Commission[8] and Parham[9].

The skills transition to higher levels of attainment evident from the late 1990s will, even without further changes in educational participation policies, continue for another twenty or thirty years as older, less skilled workers exit the workforce. This will lead to an increasingly high proportion of the workforce with the general advanced reasoning, communication and adaptability skills associated with higher education, as well as high levels of professional technical skill coupled with disciplinary understanding. Similarly, at the trade skill level, an increasing proportion of the population will demonstrate the versatility associated with an advanced knowledge of practice in their field. These changes will have a positive impact on productivity.

While these circumstances are not a guarantee of increased returns to innovation, they provide a highly fertile ground for it and would tend to stimulate it, other things being equal.

Skills and innovation links: examples from literature

Links between workforce skills and innovation activity (and ability) of the economy are not new ideas in economics. Both theoretical and empirical research tends to point to skilling of the workforce both as a cause as well as an effect of R&D and innovation. From first developments in the analysis of human capital in the 1960s to more recent efforts devoted to understanding changes in productivity and growth, the literature points to the unambiguous necessity of training and skilled workforce in engaging in R&D. More recent work from Griffith, Redding and van Reenen[10] also points to two sides of R&D: not only is more skilled workforce essential for native innovation activity but it also is able to secure more rapid transfer of technology since firms/economies already engaged in R&D find it easier to close the gap to the technological frontier.

[8] Productivity Commission, *Microeconomic reform and Australian productivity: exploring the links,* Commission Research Paper, Productivity Commission, Canberra, 1999.
[9] D Parham, 'Microeconomic reforms and the revival in Australia's growth in productivity and living standards', paper presented to the 31st Annual Conference of Economists, Adelaide, 1 October 2002.
[10] R Griffith, S Redding and J van Reenen, *Mapping the two faces of R&D: productivity growth in a panel of OECD industries*, DP no. 2457, Centre for Economic Policy Research, London, 2000.

At firm level, econometric studies analysing the provision of workplace training generally find unambiguous positive association between a firm's engagement in innovation and the skills of the labour force. For example, Baldwin and Johnson[11] found strong support for the proposition that human development is complementary to as well as complemented by the innovation and technological change. In particular, they show that training incidence is closely linked to the importance of research and development in firms' priorities. Kapuscinski[12] similarly has found a uniformly positive and statistically very strong association between firms' development of new products and technology and the provision of development of skills in the labour force (through provision of employer training to apprentices and trainees). Rogers[13] has also found similar positive links between innovation activity (including investment in new equipment) and the presence of more general training schemes as well as the reverse link between higher levels of workplace training and innovation-related change.

Given that capital also can be viewed as past R&D embodied in machines, it is not surprising that similar results are also found for the links between skills of the workforce and the state of capital. Bartel and Lichtenberg,[14] for example, report that relative demand for educated (skilled) workers declines as the capital stock in the firm ages. Not surprisingly, this effect is magnified in R&D intensive industries. Such results imply that policies which affect the take-up of new technology (either through own R&D or through acquisition of new R&D embodied in new technology) is likely to significantly alter the skills/educational levels of the workforce (through the effects on labour demand). Similarly, encouragement of human capital development has the potential to accelerate the adoption and diffusion of new technologies.

(III) THE ECONOMIC IMPACT OF PUBLICLY FUNDED RESEARCH

Why governments fund research

The economic and policy arguments for public spending on science, innovation and research are well-known. If investment in science and innovation were left solely to the private sector, there would be a serious risk of under- and misdirected investment, mainly due to the following factors:

- Markets by themselves cannot deliver on public-good objectives, such as national security, environmental considerations, and intergenerational equity
- Not all the benefits of the investment can be captured by the investor (for example, medical research resulting in better health care management may deliver substantial economic benefits to whole communities rather than individual companies)
- There are often high levels of risk and uncertainty
- Long time-lags between the initial investment phase and a return on investment.

When considering the rationale for government intervention, these characteristics of the Australian situation need to be taken into account:

[11] J Baldwin and J Johnson, *Human capital development and innovation: the case of training in small and medium sized-firms*, WP no. 74, Statistics Canada, Ottawa, 1995.
[12] C Kapuscinski, *Entry level training in Australia in the nineties: an analysis of factors influencing the provision of employer training to apprentices and trainees*, REB report 6/2000, DETYA, Canberra, 2000.
[13] M Rogers, *Innovation in Australian workplaces: an empirical analysis using AWIRS 1990 and 1995,* Melbourne Institute Working Paper 3/99, Melbourne Institute of Applied Economic and Social Research, Parkville, 1999.
[14] AP Bartel and FR Lichtenberg, 'The comparative advantage of educated workers in implementing new technology', *Review of Economics and Statistics*, 59(1), 1987.

- Australian industry is highly innovative,[15] and, even though Australian industry is not R&D-intensive by international standards (largely because of the structure of the economy), it is nevertheless the single largest provider of R&D in Australia, ahead of higher education, government and the not-for-profit sectors
- There are high levels of diversity in the way innovation occurs in Australia, with significant variations in investment patterns, research and development pathways and knowledge transfer modes, depending on the specific technologies, industries and disciplines involved
- Innovators and researchers are increasingly adopting collaborative strategies to combine different forms of knowledge and to share risks (and therefore returns), and seeking to diversify their activities rather than vertically integrating up the production chain (resulting in more 'open innovation' systems and approaches)
- However, there can be impediments to collaboration between researchers and industry, arising from their very different economic circumstances and motivators, with most researchers operating within public institutions and universities, and most businesses and investors operating within markets, often global in scale
- A relatively low (although growing) number of researchers work in industry,[16] resulting in fewer industry 'receptors' who can identify relevant research outputs and who understand research culture

An overview of Australian Government expenditure on science and innovation is at Appendix 1.

Relative to many other OECD countries, Australia spends a significant proportion of GDP on public sector research and development (0.76 per cent).[17] Between them, government ($2.48 billion) and higher education ($3.43 billion) performed R&D costing $5.91 billion in 2002–03, which was around 46 per cent of the gross domestic expenditure on R&D (GERD) for that year.[18] Given this level of investment, what is the economic impact of public sector research? This is a central question for the Productivity Commission study, but answering it is by no means a straightforward matter. This is because of factors of context, data and analytic constraints.

Broader innovation system

Public sector research takes place in the context of the wider innovation system (see Figure 6 for an adaptation of one recent depiction of the system). The Australian innovation system:

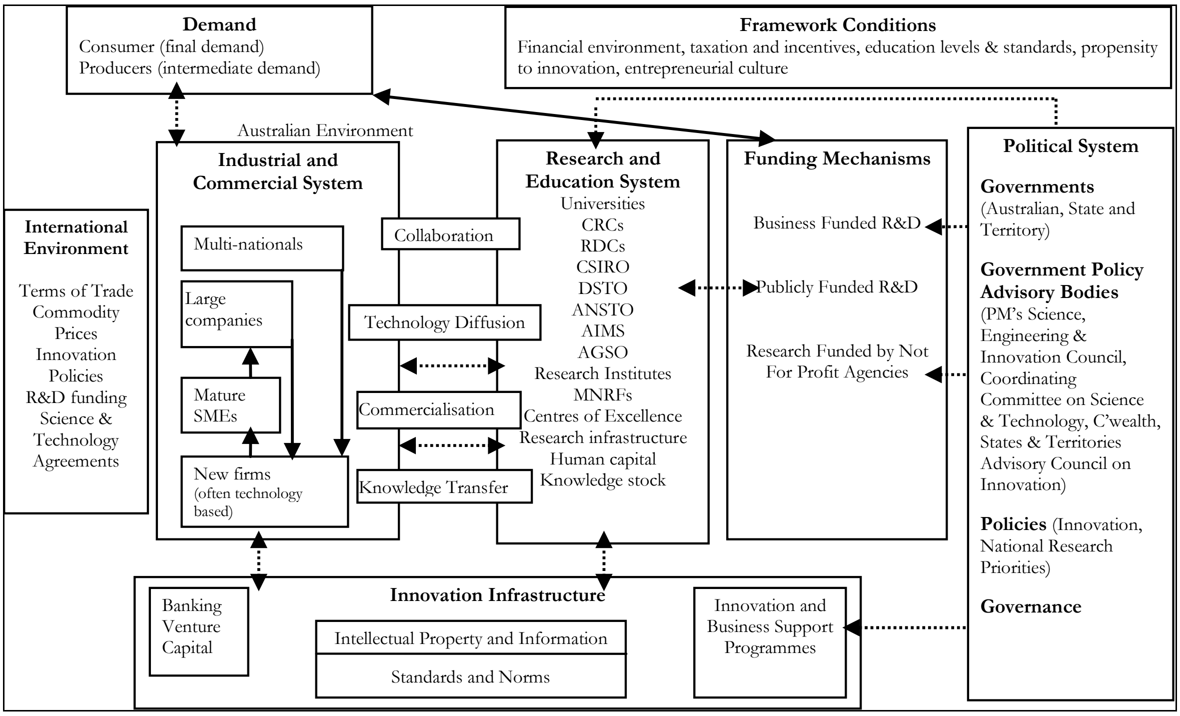
- Is highly integrated (that is, it includes elements that are interdependent)
- Is permeable (that is, it intersects with other economic and social systems and structures)
- Is whole-of-economy, drawing on public and private sources of funding, with outputs being generated by both sectors
- Is internationalised, with cross-border flows of funding, intellectual property (IP) and people increasing as Australia's economy and research system become more integrated with the rest of the world
- Encompasses much more than the R&D activity traditionally captured in most financial and statistical data

[15] Australian Bureau of Statistics, *Innovation in Australian business, 2003,* ABS, Canberra, 2005.
[16] Department of Education, Science and Training, *Australian science and technology at a glance,* DEST, Canberra, 2005, pp. 50–55.
[17] Organisation for Economic Co-operation and Development, Main Science and Technology Indicators database, 2006/1.
[18] Department of Education, Science and Training, *Australian science and innovation system: a statistical snapshot,* DEST, Canberra, 2005.

- Operates over the long term, with investment and activity often not resulting in tangible benefits for many years
- Is integral to generating positive outcomes in the economy, society and the environment.

This means that any model (econometric or otherwise) of the system should take into account many interconnected factors, including business conditions, industrial structure, international trends, education standards, skills supply or changing national priorities. It also means that it is not possible to separately consider public sector research and its impacts and fully control for external variables in the wider innovation system.

Figure 6: Australia's innovation system



Source: Based on Department of Industry, Tourism and Resources, Submission to the House of Representatives Standing Committee on Science and Innovation Inquiry into Pathways to Technological Innovation, May 2005.

Framework conditions

Macroeconomic conditions affect innovation – including public sector R&D – in three ways:

- By promoting the conditions for demand for new ideas, inventions and innovation
- By providing the resources (especially tax revenues) to support public sector R&D
- By encouraging the flow of knowledge and innovation between the public and private sectors and among firms, in the form of skilled graduates and employees, as well as innovative products and services
- By affecting relative costs and benefits/risks of all investment (including investment in R&D) – in other words it affects the supply of new ideas, inventions and innovation.

The economic and policy framework within which public sector research occurs is therefore crucial to its impact. R&D – including government and higher education R&D – is an important contributor to innovation output and thus to multifactor productivity growth. The relationship is not one way, however; the best environment to enhance R&D outcomes is one where productivity growth is high.

OECD research[19] suggests that the right macroeconomic environment for fostering high productivity growth includes stable, low inflation and other conditions which favour investment, including labour and product markets that are flexible, lightly regulated and open to foreign trade and investment, efficient capital markets and ease of market entry for new firms. These factors tend to encourage rapid uptake of new technology and to promote innovation more generally. It is also clear that effective technology and knowledge transfer contributes to positive economic conditions, especially in highly developed, open economies such as Australia's. When coupled with a well-educated population and workforce, capable of absorbing and applying new technologies and ideas, and incentives to increase business R&D, (such as tax concessions and patent rights), the full economic advantages of government and higher education R&D expenditure can be realised.

There is a similar interplay between research and broader social and environmental circumstances. Public sector research and its effective dissemination and application contribute to social harmony, educational outcomes, an effective health and welfare system, and a vital and sustainable environment. Similarly, social and environmental factors influence the performance and long-term viability of public sector research, not least because these are important factors in the supply and retention of high quality researchers.

Basic research and its contribution to the innovation system

One of the defining characteristics of public sector research is that it tends to focus considerable resources on basic, fundamental or 'blue sky' research, especially when compared to the private sector.

In 2002–03, around 24.9 per cent of GERD was invested in basic research. This proportion has remained more or less constant since at least 1988–89. Basic research in 2002–03 constituted around 0.42 per cent of GDP (compared to 0.33 per cent in 1988–89). Over half of this was carried out in the higher education sector, while around one-seventh was carried out in the private sector. Although private sector basic research has double from 0.03 per cent of GDP in 1988–89 to 0.06 per cent in 2002–03, it remains much less significant than public sector – especially higher education – basic research.[20] In 2004, 51.6 per cent of higher education R&D was in basic research.[21] The comparable figure for business R&D was 6.7 per cent.[22] This pattern is to be expected, as basic research is much less likely to result in short-term benefits, or in benefits that can be captured and exploited commercially. Nevertheless, it is crucial to the overall performance and sustainability of the innovation system.

On international comparisons, Australia's level of basic research as a proportion of GDP (0.42 per cent) ranked fifth out of the 21 OECD countries who reported a figure for 2002. It is notable, however, that there is considerable variation between countries. Countries that ranked higher than Australia included the US (0.49 per cent) and Israel (0.90). At the lower end of the scale were Canada (0.22) and China (0.07).[23] Clearly, the proportion of basic to applied research will tend to be driven by the characteristics and needs of the country in question.

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[19] S Scarpetta, *The sources of economic growth in OECD countries,* OECD, Paris, 2003.
[20] Department of Education, Science and Training, *Australian science and innovation system: a statistical snapshot,* DEST, Canberra, 2005.
[21] Australian Bureau of Statistics, *Research and Experimental Development, Higher Education, 2004,* ABS cat. no. 8444.0, ABS, Canberra, 2006, p. 10.
[22] Australian Bureau of Statistics, *Research and Experimental Development, Business, 2002–03,* ABS cat. no. 8104.0, ABS, Canberra, 2004, p. 10.
[23] Department of Education, Science and Training, *Australian science and innovation system: a statistical snapshot,* DEST, Canberra, 2005.

As a small, open economy with a well educated population and a strong resource base, Australia has the capacity and the need to contribute to the global basic research effort. In doing so, Australia reaps the benefits of international flows of knowledge and innovation, allowing the nation to better leverage the contribution we make to the world's knowledge stocks (2.93 per cent of world scientific publications[24]) and gain early and effective access to the rest of the world's science and innovation production. As pointed out by the OECD, although 'free-riding' – profiting from global research without contributing to its production – may seem attractive to a small economy, in fact 'countries need their own R&D to understand and absorb knowledge developed abroad, to become part of innovation networks, and to develop their own skills'.[25] While measuring this benefit of research – especially public sector basic research – in economic terms is difficult; that does not make it any less real.[26]

Business R&D and industry-research linkages

A crucial factor in understanding the economic impact of public sector research is its relationship with business R&D. While it is well recognised that Australian business expenditure on R&D (BERD) as a proportion of GDP is relatively low by OECD standards (although growing at a faster rate than many comparable economies), it is less frequently observed that business, nevertheless, does more R&D than all other sectors combined. In 2002–03, business accounted for 51.2 per cent of Australia's gross domestic expenditure on R&D, compared with 26.7 per cent for higher education, 19.3 per cent for government, and 2.8 per cent for the private non-profit sector.[27]

Clearly, given the importance of the private sector to innovation, the extent and quality of linkages between public sector research and industry are of considerable importance in understanding the economic impact of public sector research.

According to ANU economist Steve Dowrick,[28] the rate at which small firms innovate is dependent on their proximity to university researchers in the relevant fields, and a country's ability to absorb foreign technology is enhanced by investment in education and by investment in its own R&D. Given the interconnectedness and interdependency of public and private research, the scale and nature of business R&D are important determinants of the performance and impact of public sector research. Not only does the public sector train most private sector researchers, it also directly or indirectly provides much of the 'raw material' on which private sector research (and, by extension, innovation) is based, including basic and leading-edge research, concept testing, and validation. Universities and public research institutions are generally responsible for the science on which regulatory, industry and international standards are based.

The evidence base for industry-research interactions is still developing, through initiatives such as the Australian Bureau of Statistics' R&D and innovation surveys and DEST's National Survey of Research Commercialisation.

[24] Department of Education, Science and Training, *Australian science and technology at a glance,* DEST, Canberra, 2005, p. 75.
[25] Organisation for Economic Co-operation and Development, *The new economy: beyond the hype: the OECD growth project*, OECD, Paris, 2001, p. 47.
[26] D Stokes, *Pasteur's quadrant: basic science and technological innovation*, Brookings Institution Press, Washington DC, 1997.
[27] Department of Education, Science and Training, *Australian science and technology at a glance,* DEST, Canberra, 2005, p. 18.
[28] S Dowrick, 'A Review of the Evidence on Science, R&D and Productivity', paper prepared for the Department of Education, Science and Training, 11 August 2003.

Table 1: Industry-research linkages

Linkage Factor	Data	Data Source
Collaboration	Of the 34.8 per cent of Australian businesses that were identified as innovating: • 27 per cent engaged in some form of collaboration • 6.5 per cent collaborated with the public sector (including universities) • 2.7 per cent collaborated with universities	ABS *Innovation in Australian Business, 2003*
Sources of ideas	Of the 34.8 per cent of Australian businesses that were identified as innovating: • 18.8 per cent reported the public sector as a source of ideas or information • 42.5 per cent reported web sites and journals (which often have public sector researchers as contributors) as sources of ideas	ABS *Innovation in Australian Business, 2003*
Funding	$243 million in Industry-funded R&D in the higher education sector. This was: • an increase of $69 million (39.7 per cent) at current prices, from $174 million in 2002 • about 5.7 per cent of total higher education expenditure on R&D [HERD], compared with 5.1 per cent in 2002. Total HERD increased by $853m (24.9 per cent) from 2002. *Income from other than deptl appropriations:* / *From Government:* CSIRO: $347.6 million / $593.9 million ANSTO: $42.6 million / $129.7 million	ABS *Research and Experimental Development, Higher Education, 2004* Education, Science and Training Portfolio Budget Statements 2006–07.
Research Contracts and Consultancies	Between 1996 and 2004 universities' income from consultancy and contract research doubled in nominal terms from $322.3 million to $645.8 million. As a proportion of total university income, this is an increase of 20 per cent (from 4 per cent to 4.8 per cent).	DEST, *Selected Higher Education Finance Statistics*, 1996; DEST, *Finance*, 2004
IP sales	The 45 universities and publicly funded research agencies and institutions which participated in the National Survey of Research Commercialisation for 2000, 2001 and 2002 reported: • $223.6 million in licence income (total for the three years) • $108.8 million in equity holdings in start-up companies in (2002) The 124 respondents to the Survey for 2002 reported (totals for all respondents): • $78.4 million in licence income • $123.2 million in equity holdings	DEST 2004, *National Survey of Research Commercialisation 2001 and 2002*

The available evidence suggests that the level and performance of business interactions with public sector research is uneven, but improving. As shown in Table 1:

- Rates of collaboration between innovating businesses and the public sector – including universities – seem low (although there are no comparable international or time series data available to determine the relative significance of these figures)[29]
- What the optimal level would be is difficult to estimate, but it would clearly be determined by the size and character of Australian industry (that is, the 'absorptive capacity' factors) and the quality and performance of Australian research institutions and universities (that is, the 'technology supply' factors)

[29] For example, several submissions to the recent House of Representatives Inquiry into Pathways to Technological Innovation highlight issues around business-university and business-PFRA interactions.

- Similarly, innovating businesses do not seem to source their ideas from the public sector or universities at a high rate, but it is reasonable to infer that they do obtain information and ideas indirectly from these sources, through web sites and journals, and through recruiting research-trained graduates
- Business seems increasingly willing to buy research services from universities, contributing an increasing proportion of funding for higher education R&D, and buying more contract-based research
- The market value of public sector IP is reasonable, without being high.[30]

In addition to these factors indicating the market value of public sector research, the propensity to make capital investments in research and research outputs is an important consideration. Australia's venture capital industry is relatively small and still developing, which is one of the reasons the Australian Government established the Pre-Seed Fund. There are, however, several recent examples of venture capital funds being established in the higher education sector with private sector funds participating:

- Uniseed: over $60 million under management; Universities of Queensland, Melbourne and New South Wales and Westscheme
- Murdoch Westscheme Enterprise Fund (MWEP): $10 million; Murdoch University and Westscheme
- Australian National University, Motor Trades Association of Australia Super venture capital partnership: MTAA Super invested $20 million in the Partnership; the ACT Government is providing a repayable grant of $10 million.

These are relatively small funds, but the trends are encouraging.

Modelling the economic impact of public sector research[31]

As a tool for assessing the impact of R&D (let alone innovation), econometric modelling is still 'a work in progress'. A recent Productivity Commission Staff Working Paper by Shanks and Zheng on *Econometric Modelling of R&D and Australia's Productivity* (April 2006) found that even in the methodologically more straightforward area of business R&D '… at least for the time being, empirical estimates of the effects of R&D on Australian productivity are unreliable' (p. xix).[32] Given this, it is important that any economic modelling of public sector research be approached with caution. Although a powerful analytical tool, such modelling is limited by data availability, the extent and nature of underlying assumptions, and the difficulty in controlling for extraneous factors that can significantly affect the actual impact of research – both positively and negatively. The results of such modelling are generally indicative rather than definitive.

[30] For an estimate of the potential level of IP income to Australian universities if they were to meet world's best performance, see The Allen Consulting Group, *Building effective systems for the commercialisation of university research,* Business Council of Australia, Melbourne, *2004*.
[31] This section is based in part on as yet unpublished work carried out for DEST by Econtech.
[32] It is important to note that this research used time series data. As Dowrick points out, however, 'studies of cross-country evidence are perhaps the most appropriate for evaluating the national benefits and costs of R&D' (S Dowrick, 'A Review of the evidence on science, R&D and productivity', paper prepared for the Department of Education, Science and Training, 11 August 2003, p. 1).

Despite the inevitable caveats, economic modelling generally shows findings of a significant and positive rate of return to publicly funded R&D investments. Martin et al (1996) present a comprehensive survey of early literature on this field.[33] The authors show that most of the studies in their review reach the same conclusion: that there is a positive and relatively high rate of return to R&D investments at the public level. Their literature survey also shows that there is great variation in the estimated rates of return by sector and by study. In spite of this variation, several studies place the economy-wide social rate of return on overall publicly funded research on the order of 25 to 40 per cent a year.[34]

Additional studies included in a different literature survey (Office of Technology Assessment[35]) also report very high internal rates of return on public sector agricultural research. The rate of return varies from 21 to 100 per cent, with the majority of estimates in the 33 to 66 per cent range.

A summary of selected econometric studies on rate of return to publicly funded R&D is shown in Appendix 2. The rate of return to public R&D varies from 28 to 67 per cent, depending on the subject of the study and the methodology.

The literature on publicly funded R&D also includes studies that investigate the impact of R&D on productivity. For instance, Guellec and Van Pottelsberghe[36] investigated the impact of various types of R&D (business R&D, foreign R&D and public R&D) on multifactor productivity growth using a panel of 16 OECD countries. There are three main results from this study. Firstly, the authors found that the long-term elasticity of government and university performed research on productivity is 0.17. This means that a 1 per cent increase in public R&D results in a 0.17 per cent increase in productivity growth. Secondly, Guellec and Van Pottelsberghe found that the long-term elasticity of multifactor productivity with respect to business R&D is 0.13. This means that an increase of 1 per cent in business R&D generates a 0.13 per cent in productivity growth.

This elasticity effect is larger in countries which are intensive in business R&D, and in countries where the share of defence-related government funding is lower. Finally, the authors found that the long-term elasticity of foreign R&D on productivity is 0.46. This means that a 1 per cent increase in foreign R&D generates 0.46 per cent in productivity growth. A key implication of this study is that any nation that wishes to maximise the productivity returns to R&D needs to be well-integrated with the international research and innovation system, and willing and able to contribute its share of the global R&D effort in order to reap the benefits.

An important example relating to spill-over benefits is that of medical research. There is evidence that Australian investment in health and medical research produces high returns, including through spill-over benefits. Public funding of medical R&D generates returns by a variety of routes. Direct savings arise from reductions in health care costs, while indirect savings arise from increased workforce productivity.

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[33] B Martin, A Salter, D Hicks, K Pavitt, J Senker, M Sharp and N Von Tunzelmann, *The relationship between publicly funded basic research and economic performance*, Science Policy Research Unit, University of Sussex, 1996.

[34] For example: E Mansfield, J Rapoport, A Romeo, S Wagner, and G Beardsley, 'Social and Private Rates of Return from Industrial Innovations', *Quarterly Journal of Economics*, vol. 77, 1997, pp. 221–40; I Nadiri, *Innovations and technological spillovers*, NBER Working Papers 4423, National Bureau of Economic Research, Cambridge, Mass., 1993; President's Council of Economic Advisors, *Supporting research and development to promote economic growth: the Federal Government's role*, White paper, Washington DC, 1995.

[35] Office of Technology Assessment, *Technology, public policy, and the changing structure of American agriculture,* (OTA-F-285), US Government Printing Office, Washington DC, 1986.

[36] D Guellec, and B Van Pottelsberghe, *R&D and productivity growth: panel data analysis of 16 OECD countries*, OECD Working Papers, vol. 3, OECD, Paris, 2001.

Other gains are due to improved quality of life, which has an estimated financial value in addition to the obvious benefits to society. As reported in the report of the Investment Review of Health and Medical Research (*Sustaining the Virtuous Cycle for a Healthy Competitive Australia*),[37] Access Economics found very large ($5,000 billion) consumer benefits since 1960, as a result of gains in longevity and gains in quality of life. The findings of a US metastudy estimated annual savings of US$70 billion due to medical research, while the US National Institutes of Health estimates that the rate of return on publicly funded research is at least 25 to 40 per cent per cent a year.

As mentioned later in this submission, a study was recently conducted to measure the delivered benefits of the CRCs. The findings of that work include the conclusion that GDP is cumulatively (in 2005 dollars) $1,142 million higher; real consumption is cumulatively $763 million higher; real investment is cumulatively $417 million higher; and Commonwealth taxation revenue is cumulatively $66 million higher. These results indicate that, counting only those measurable benefits that the authors were able to quantify, at the very minimum a solid return of 60 cents additional GDP is being generated for every dollar allocated by the Government to the CRC Programme.

Aside from the specific results, the CRC study shows that the economic impact of publicly funded research:

- Is frequently the result of long-term investments (the average time from investment to impact in the case of the CRCs was nine years)
- Is specific to the circumstances and performance of particular programmes and initiatives (the economic impact can vary significantly, even within a single programme such as the CRCs)
- Needs to be measured on the basis of sound empirical evidence, where possible, including specific case studies[38]
- Can have significant spill-over benefits, even when a relatively conservative methodology is employed.[39]

DEST-commissioned modelling

DEST has commissioned the economic consulting firm Econtech to carry out some modelling of the economic impacts of public sector R&D. The work is still underway, and the results are preliminary. Once the work is complete (by the end of August 2006), DEST plans to make the full report available to the PC for review.

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[37] Investment Review of Health and Medical Research, *Sustaining the virtuous cycle for a healthy, competitive Australia: final report,* Department of Health and Ageing, Canberra, 2004.

[38] DEST notes that there are many sources of such case studies, including the National Survey of Research Commercialisation, which includes selected 'success stories' and details of spin-out companies formed by universities and publicly funded research agencies and institutions. Reports for 2000, 2001 and 2002 are available at http://www.dest.gov.au/sectors/research_sector/policies_issues_reviews/key_issues/commercialisation/. The Survey report for 2003 and 2004 will be available late in 2006. Other submissions to the Productivity Commission study will also include various case studies, and many were included in submissions to the recent House of Representatives Science and Innovation Standing Committee's Inquiry into Pathways to Technological Innovation.

[39] Spill-over benefits are also relevant to estimates of the benefits of private sector research. Based on OECD data, estimates of private returns to firms' own investment in R&D are commonly in the range of 20 to 30 per cent. The net private return on R&D investment appears to be broadly comparable with the return on investment in physical capital. Spill-overs of knowledge from the firms that perform the R&D to other firms and industries typically raises the estimated gross rate of return on business investment into the range of 30 to 40 per cent (Dowrick 2003). The spill-over benefits of public sector research may be higher on average, because of the tendency for the results of such research to be non-rival.

The modelling uses Econtech Pty Ltd's MM600+ model, which is a long-term computable general equilibrium model of the Australian economy. It is a highly detailed model, distinguishing 108 industries that produce 672 products. Econtech used the MM600+ model to examine situations - one involving the role of BAA program and the other involving the role of the public R&D activity as a whole. To model these two situations four scenarios are necessary:

- A BAA baseline scenario which reflects a situation where there is no BAA programme which is then compared with
- A BAA scenario (that is, the impact of the investment in both the 2001 and 2004 packages);
- A public R&D baseline scenario which reflects a situation where there is no public R&D which forms the basis for evaluating
- A public R&D scenario (that is, the impact of all public R&D spending, activity and outcomes).

Results to date indicate that compared to the relevant baseline scenario:

- The BAA scenario shows a per annum net increase over the long-term on every factor modelled, that is:
  - real GDP of 0.12 per cent (after accounting for 0.02 per cent costs)
    - on this basis, BAA would show a return on its $8.3 billion ten year outlay of $9.5 billion over the same period
  - exports of 0.18 per cent (compared to an increase in imports of 0.11 per cent)
  - private consumption of 0.07 per cent
  - investment of 0.08 per cent
  - consumer living standards of $289 million (2005 prices)
- The public R&D scenario shows a per annum net increase over the long term for:
  - real GDP of 1.02 per cent
  - exports of 1.49 per cent (compared to an increase in imports of 0.94 per cent)
  - private consumption of 0.70 per cent
  - investment of 0.73 per cent
  - consumer living standards of $2.985 billion (2005 prices).

The Econtech modelling is exploratory, and DEST is considering whether further work is required to validate the results and their sensitivity to changes in parameters. However, the results are likely to be reasonably robust, because:

- On a number of parameters the model is likely to generate a lower bound for returns
- The input assumptions are drawn relatively conservatively from the ranges identified in the literature, with attention to matching to Australia's economic and institutional circumstances.

As this and the other modelling results cited above show, the economic modelling of the impact of research and innovation is still a developing science, but there is consistent evidence that there are significant returns to R&D, including public sector R&D. The precise level and nature of those returns are matters for debate and further analysis. It is clear, however, that maximising the returns to research and innovation requires a comprehensive and sustained policy effort, ensuring funding, support and framework conditions are all oriented towards generating and sustaining the cycle of innovation.

PART 3: DEST SUPPORT FOR SCIENCE AND INNOVATION

1. QUALITY RESEARCH

DEST provides support to research through a diverse range of institutional arrangements. This includes support to higher education through a variety of funding mechanisms, Publicly Funded Research Agencies (PFRAs), private non-profit medical research institutes, Cooperative Research Centres and Centres of Excellence. The portfolio also includes the Australian Research Council.

The portfolio PFRAs are CSIRO, the Australian Nuclear Science and Technology Organisation (ANSTO) and the Australian Institute of Marine Science (AIMS). These agencies are mission-oriented research organisations funded primarily through Government budgetary appropriations. Their roles and responsibilities are broadly defined by their legislation. The appropriation funding they receive from Government is premised on the pursuit of specific objectives and their performance is assessed on the basis of delivery of particular research outcomes. Consistent with this mission-oriented approach, part of the agencies' role is to develop linkages with end users and stakeholders. As a consequence, their appropriation funding is substantially augmented by external earnings.

DEST's submission will only look at those elements administered within the Department.

(I) A DUAL SUPPORT SYSTEM

Australia, like many developed nations, operates a 'dual support system' for the public funding of research and research training in its higher education sector. A dual support system is one in which core public funding for research and research training is allocated independently of funding for specific research projects, programmes, or fellowships. The former is typically distributed through a system of (often performance-based) block grants; the latter through some form of merit-based, peer-determined competitive process.

One advantage of the dual support system is that it offers governments a range of levers to influence the direction and performance of publicly-funded research and research training. Importantly, a dual support system also supports diversity and system robustness, by allowing a focus on national priorities linked to economic and social aspirations, or a focus on research excellence, to be balanced with the ability to support and maintain strategic research capabilities over the long-term, or develop emerging research areas, irrespective of the availability of competitive funding.

The project- or programme-oriented, competitive element of Australia's dual support system is represented by the approximately $1 billion a year administered by the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC). This funding takes the form of research grants and fellowships awarded, mainly to universities, on the basis of advice from expert assessors. While national research priorities have an important role, funding decisions are largely based on the relative scientific merits of the proposed research, the track record of the researcher or research team, or the extent of collaborative linkages with industry and other end-users, depending on the specific scheme.

In comparison, approximately $1.15 billion a year is provided to Higher Education Providers (HEPs) as block grants for research and research training, through a variety of performance-based schemes administered by DEST. HEPs have considerable autonomy in deciding what research projects, teams and students, and what equipment and infrastructure, this funding should support. In this way, the system recognises that these sorts of decisions are often best made by those with the information advantage: the HEP, and its researchers and stakeholder communities.

The major block grants administered by DEST are the Institutional Grants Scheme (IGS), Research Infrastructure Block Grants Scheme (RIBG), Research Training Scheme (RTS), Australian Postgraduate Awards (APAs), and Commercialisation Training Scheme (CTS).

(II) PERFORMANCE-BASED BLOCK GRANTS

The block grants are allocated to HEPs based on formulae comprising a mix of the following performance-based metrics: research publications, research income, higher degree by research (HDR) student load, and HDR student completions. These indicators were chosen for the way they represent (or are 'proxies' for) a range of qualitative factors that government is interested in rewarding and thus encouraging. For example, HDR completions is a measure of the HDR student as an output of the HEP, as well as, at a very broad level, a measure of the quality of the student's major research output (normally the thesis).

The research income and publications indicators serve as proxies for the quality of the research that is undertaken in the HEP, because it is assumed that in order to be published, or in order to attract research income, research has to be of relatively high quality, relevance, or both. Publications and research income are also measures of the quality of the research training environment, insofar as research students benefit from training in a setting where their supervisors and colleagues are engaged in actual research. Independently, the research income measure can also indicate the level of engagement that the HEP has with industry and other collaborating organisations, while the publications indicator represents the important task of knowledge dissemination.

In this way, these indicators appear comprehensive and have the advantage of being reasonably easy to collect. The major disadvantage of these indicators, however, is that while they incorporate some element of quality, they are actually quite coarse. There is no way to measure gradations of quality, or to compare actual quality across HEPs and across disciplines.

For example, the volume of research published by researchers at a particular HEP tells us little about the relative quality of the work (and even the source of the publication is not always a good indicator of this). Similarly, we know how many students completed their research degrees at a particular HEP, but we don't know whether on balance those students had an enjoyable or unenjoyable experience, whether they learnt a broad or limited range of skills, or whether their theses were exceptional or merely passable. Research income can also be problematic when given too much emphasis, as success in obtaining competitive grants can be a virtuous cycle that other researchers, especially those in the early stages of their career, can find difficult to break into. Research income also tends to be discipline-biased in its broad allocation pattern.

The limitations of the indicator-based approach are one of the reasons for the introduction of the RQF, with its potential to provide a more nuanced approach to quality assessment. The RQF Expert Advisory Group recommended that the RQF supplant the IGS, and replace the current publication and research income proxies of the RTS as a measure of the quality of the research training environment.

Notwithstanding the limitations of their method of allocation, the block grants are an essential component of Australia's science and innovation system. They are described in more detail on the following pages.

Support for research and research infrastructure

Institutional Grants Scheme

The IGS provided $296 million in 2006 to eligible HEPs to support research and research training activities. HEPs have broad discretion in the way they spend their IGS funding, and it may be used to support any activity related to research. This allows HEPs to manage their own research activities and their own priorities, assists them to respond flexibly to their research environment in accordance with their own strategies, and enhances support for areas of research strength.

As mentioned, HEPs have considerable autonomy in how they internally allocate their IGS and other block grant funding, and they all use slightly different methods for doing so. However, according to information supplied in Research and Research Training Management Reports, the majority of HEPs follow the broad pattern of reserving a proportion of funds centrally – for internal competitive schemes, scholarships, awards, and infrastructure or other capacity-building projects – and awarding the remainder to the faculties or departments that 'earned' it.

Internal allocation often occurs on the basis of similar metrics to the ones that DEST uses to allocate the block grants, although DEST guidelines state that these indicators are not intended for this purpose. DEST understands that this internal allocation also relies on information not currently available to DEST, that is, research performance to a greater level of disaggregation within the HEP.

A downside to this institutional autonomy, from a public policy point of view, is the lack of available information about the type and quality of research being supported with the block grants – beyond the high level research publication indicator. The RQF is seen as an important tool for addressing this issue, as it will provide important qualitative information about the research being undertaken, as well as provide further incentives for pursuing quality research, while maintaining the important principle of devolved decision-making described here.

The RQF, however, is unlikely to distinguish between the research being undertaken with support from the block grants, and that being undertaken with support from other sources such as the ARC. In many respects it is not useful to consider the block grants and the competitive funding in isolation from each other. Much of the block grant funding is actually being used to underpin the important research being undertaken with support from competitive schemes.

Research Infrastructure Block Grants Scheme

RIBG provided approximately $200 million in 2006 as block grants to eligible HEPs to enhance the development and maintenance of research infrastructure. A HEP's RIBG amount is determined on the basis of its relative success in attracting research income from competitive funding schemes listed on the Australian Competitive Grants Register (ACGR). A scheme like RIBG is necessary because the majority of competitive research grants are marginally costed, that is, they don't cover the indirect costs of undertaking the research, such as large and small equipment, libraries and other infrastructure. These costs have to be covered through HEPs' other funds, including their block grants. RIBG assists HEPs in meeting the infrastructure and overhead costs associated with undertaking the important research funded by the ARC, NHMRC and others. In *Backing Australia's Ability – Building Our Future through Science and Innovation* the Government stated that the amount of RIBG funding provided would continue to be set at 20 cents for each dollar of competitive grants. In addition, the Government stated it is important that the RIBG funding pool maintain this ratio.

DEST is also aware that there are concerns in the higher education sector about the increasing requirement to use funds from other sources, especially the block grants, as 'leverage' for additional research funds. There are reports that through leveraging, universities lose flexibility in how they can use research funds. One of the key purposes of RIBG and IGS is to allow HEPs to build capacity in areas of emerging or strategic strength, rather than in those areas that already have a track record of excellence or support from other sources. There are concerns in the sector that leveraging funds may limit capacity-building in this regard.

Support for research training

Research Training Scheme

Research training is fundamental to ensuring Australia's continued supply of qualified and skilled researchers, independent and original thinkers, wealth creators, opinion shapers, and leaders. In 2004 there were 33,074 (EFTSU) domestic and international students undertaking higher degrees by research (HDR) in Australian HEPs, representing a significant proportion of Australia's research-active workforce. Through the RTS, the government provided $563 million in 2006 to eligible HEPs to support research training for approximately 21,500 (EFTSU) domestic HDR students. The advantage of being an RTS student is that you study in a fully subsidised place, with no HECS liability and no tuition fees to pay. Other, non-RTS HDR students either pay fees, or will be supported by scholarships or by HEPs' own funds (in the fee-paying domestic waived category).

While the RTS is driven by a formula that rewards performance, the limitations of the available indicators means that the connection between the policy objectives of the RTS and the actual funding formula intended to give effect to those objectives is not as strong as it could be. This is important, because much more than the stated objectives of a scheme, it is actually what is being measured and rewarded that drives organisational behaviours. Two of the RTS indicators – publications and income – correspond more with measuring research than research training, while the third, the HDR completions indicator, encourages the pursuit of timely degree completions but does not necessarily encourage the pursuit of quality research training provision or quality research training outputs (the thesis or the student). All three indicators emphasise quantity over quality, in contrast to the stated objectives of the RTS, which are predominantly qualitative.

Consequently, there is currently no way of identifying the quality of the outputs of research students, whether through their thesis or other research publications produced during their enrolment, the skills of the students, or the quality of their overall research training experience. Consultation on the development of the RQF has focused attention on the quality of research training. Although the RQF Expert Advisory Group's *Final Advice on the Preferred RQF Model* does not incorporate the assessment of research training outputs per se for logistical reasons, it does recommend that DEST undertake further work in this area as a separate work programme. DEST has since embarked on a longer-term work programme of measuring the quality of research training in parallel with the development of the RQF. In addition, the Minister recently signalled her view that the work of research students should be regarded and considered towards RQF outcomes. Through the consideration of the processes and environments for research training in context statements, the RQF will enable the contribution of HDR students to be valued.

During their training HDR students underpin and contribute significantly to the overall research and knowledge outcomes of HEPs and the nation as a whole; a contribution that continues into their future careers, whether within academia, government or the private sector. It is therefore important that they receive appropriate support and the highest quality training experience possible, and this is why Australia targets a large proportion of its research block funds explicitly at research training provision – some $662 million per year through the RTS, the Australian Postgraduate Awards and the Commercialisation Training Scheme. The special emphasis placed on research training in Australia demonstrates a genuine recognition of the significance of research training to national aspirations, and it is important that government support for research training is maintained and built on. That support also needs to extend beyond research training, as there are widely held views that there is shortfall in funding for the support of early career researchers, including the number of postdoctoral fellowships.

<u>Australian Postgraduate Awards</u>

The APA scheme provided $93 million in 2006 as stipends to high-performing students to support them with their living costs during study. An APA is intended to give an HDR student the financial security and freedom to concentrate on their studies, deliver a quality research product and graduate in a timely fashion. In this way it complements the aims of the RTS. HEPs have responsibility for determining which students should receive an APA, based on the DEST guidelines.

The number of APA stipends (around 4,500 EFTSU) falls far short of the number of RTS places (around 21,500 EFTSU), a ratio of almost 1:5. This means competition for APA stipends is fierce and many quality students are missing out on the support that the scheme offers. Secondly, the APA stipend term is limited, in nearly all cases, to three years for PhDs (with a maximum of three and a half), whereas support for PhD places through the RTS is provided for four years. Because the stipend is insufficient to cover the realistic length of their studies, it forces students to seek employment, and thus study part time, at the most critical juncture of their candidature, the writing up stage of their thesis. This can affect the quality of their research output as well as their motivation to finish their research training.

<u>Commercialisation Training Scheme</u>

The CTS is a new scheme that will allocate $5 million a year from 2007 in order to provide around 250 new postgraduate research scholarships, so that existing HDR students can develop skills in research commercialisation and intellectual property management. The objective of the CTS is to provide high quality research commercialisation training for the next generation of Australian researchers as a means of equipping them with the skills necessary to bring ideas, inventions and innovations to market.

That the need for these types of non-research, or ‘generic’, skills is becoming more recognised in Australia and worldwide is symptomatic of the gradual shift away from the perceived role of the research degree – especially the PhD – as being solely the preparation for an academic career, to that of it being simply the next step in the education staircase, leading to a range of employment options. There is therefore an expectation amongst employers that HDR graduates – given the time they have spent in further education and the possible salary premium they either command or expect – will bring certain useful and transferable skills to the workforce.

In addition, there will certainly be an expectation amongst graduates that their several years of further education and toil should facilitate them gaining appropriately rewarding employment. Problems may arise, however, when there is a mismatch between these two expectations. Meeting expectations of both kinds is the reason for the current focus on generic skills. It is likely that this focus will strengthen over the near future, and will need to be integrated into an improved quality-based approach to research training.

(III) NATIONAL RESEARCH PRIORITIES

Governments exercise influence over a nation's science and innovation system through more than spending programmes. Strategic direction setting is also important. For this reason, in December 2002, the Prime Minister announced Australia's National Research Priorities (NRPs) to focus the Australian Government's research effort in areas that deliver significant social, economic or environmental benefits to Australia. The priorities are broadly based, thematic and multi-disciplinary in scope and draw on many fields of research. The initial priority goals were enhanced in 2003 to strengthen the contributions of social-science and humanities research. Australian Government research agencies and funding bodies are implementing research priorities by directing additional resources to the priority areas in order to achieve greater scale, and by exploring opportunities for collaboration.

The NRPs are intended to be a light-touch approach to priority setting: they do not prescribe for agencies where and how their research resources should be directed and there is no intention that all of their resources will be allocated to priority areas. To help identify emerging priorities, agencies are encouraged to provide an indication through their progress reports of the non-NRP research being undertaken.

(IV) RESEARCH QUALITY FRAMEWORK

In 2004, the Prime Minister announced that Quality and Accessibility Frameworks for Publicly Funded Research would be established under the second BAA package.

The Research Quality Framework (RQF) is being designed to develop a broad assessment mechanism of research quality and impact that will be relevant across the full breadth of research organisations in receipt of public funding.

Research assessment is of growing importance to countries that are seriously engaged in research, in order to measure and improve the quality and global competitiveness of their research. Despite efforts at the level of individual institutions, in Australian universities and Publicly Funded Research Agencies (AIMS, ANSTO, CSIRO) there is currently no system-wide and expert-based way to measure research quality, nor to estimate its benefits to other research and the wider community.

An Expert Advisory Group (EAG) was established to begin development of an RQF model, chaired by Professor Sir Gareth Roberts. A staged approach was adopted where the RQF would, in its first instance, be applied to the university sector.

In March 2006 the Minister for Education, Science and Training received the *Research Quality Framework: Assessing the quality and impact of research in Australia – Final Advice on the Preferred RQF Model* paper from Professor Roberts and released it for consideration by Australia's research sector.

The RQF model was developed after comprehensive consultation with the research sector and the consultation process involved public meetings including a major National Stakeholder Forum in June 2005.

To progress the work of the EAG Minister Bishop announced, in March 2006, the establishment of the RQF Development Advisory Group, to be chaired by Australia's Chief Scientist, Dr Jim Peacock AC.

The 12 member Development Advisory Group will provide advice on the next phase of the RQF process, particularly how the framework model, if adopted, could be most effectively implemented.

The first meeting of the Development Advisory Group took place on 1 June 2006. At this meeting the group agreed to further develop the RQF model and to engage in additional consultation with the higher education sector.

Also at its first meeting, the Development Advisory Group made a strong recommendation to the Minister regarding the timeframe for implementing the RQF and the Minister accepted that advice. As a result the Minister has proposed that the RQF will come into operation in 2008, with the next RQF exercise to be undertaken six years later in 2014.

Under this proposed timeframe, data gathering would take place in 2008, with financial consequences to flow from 2009. 2007 will be a year for universities to refine the processes and finalise the detail of the data gathering.

If implemented, an RQF would give greater transparency to the quality of research arising from public investment, as well as benchmarked data against which the international standing of Australian research can be measured. It would reward the quality and impact of research carried out within universities by providing the basis for distribution of nearly half of the Government's research block funding.

Specifically, the RQF is an outcomes-focused reform initiative aiming to:

- Recognise and reward high quality and high impact research wherever and whenever it occurs, by evaluating the outputs and outcomes of research through a rigorous and internationally-recognised assessment methodology
- Transparently indicate to government and taxpayers the results of the public investment in research
- Ensure that all publicly funded research providers are encouraged to focus on the quality and impact of their research, whether it is curiosity-driven blue-sky research, or mission-oriented applied research
- Raise the overall standing of Australian research at both a national and international level.

(V) PFRA RESEARCH PERFORMANCE ASSESSMENT PROCESS

Under the Triennium Funding Agreements (TFAs) for 2004–07 AIMS, ANSTO and CSIRO are undertaking a continuing process for assessment of research performance consistent with the objectives of the RQF process.

The elements of research performance that are being assessed are:

- The quality of research
- Systems for determining research activities
- The application and/or dissemination of research outputs
- The development of researchers.

The process is overseen by the *Committee To Oversee the Publicly Funded Research Agencies' Performance Assessment Process* which is chaired by the Chief Scientist. The Terms of Reference are to assist the Minister for Education, Science and Training in her assessment of research agency performance assessment by:

1. Considering assessment procedures including terms of reference to ensure that they meet the objectives of the Government's quality and accessibility framework; and
2. Reviewing assessment reports and actions proposed to be taken in response by research agencies.

The agencies' assessments of research performance are at different stages of development. The AIMS assessment process has recently commenced, the CSIRO process is well advanced and ANSTO has recently completed its process.

2. QUALITY EDUCATION AND TRAINING

(I) SET SKILL SHORTAGES

Increasingly Australia is competing in a highly competitive global market and our capacity for innovation and discovery are dependent upon the availability of people with SET skills. Like other OECD countries, Australia is experiencing a decline in the SET share of higher education enrolments, as well as an apparent decline in youth interest in SET study and careers. In addition, national and international demand for SET skills is high, leading to shortages in the SET-based professions and trades.

The recently completed *Science, Engineering and Technology Skills Audit*, examined rates of participation in science subjects, current and projected shortages of personnel in SET professions and trades, school students' perceptions and career aspirations and international demand for Australian SET skills.

The report's findings demonstrate the Australian Government's commitment to research, development and innovation. However, the audit has identified challenges relating to SET skills in terms of increasing community awareness of SET, engaging the interest of pre-school and primary school children, encouraging people to seek out and stay in SET careers, and promoting effective pathways for early- to mid-career SET researchers in Australia.

It found that the proportion of domestic students in SET study across all education and training sectors has remained static or declined in Australia over the past decade. This was particularly apparent for enabling sciences, which include advanced and intermediate mathematics, physics and chemistry.

In contrast, overseas students constituted an increasing proportion of enrolments and completions in Australian SET courses at the undergraduate and postgraduate level at Australian universities, helping to ensure the sustainability of some courses. The result of the downward trend in domestic school enrolments and vocational training and higher education SET commencements/enrolments and completions is a decreasing pool of applicants for SET positions in industry and the scientific research sector.

The audit highlighted a perception among industry and the vocational and technical education and higher education sectors that many students leaving school were ill-prepared for tertiary study and employment in SET fields. There was also a strong perception that Australia lacks sufficient suitably qualified secondary school science teachers, which impacts adversely on student engagement in SET.

There was also a concern about a lack of quality careers advice. Negative community perceptions of careers in SET industries and the research sector were also reported as having had an effect on young people's perceptions of SET careers. The perceived benefit of SET study in schools, and the number of students considering SET careers, is relatively low compared to some other high profile areas (for example, medicine and law).

A common theme was that a lack of community awareness of SET, including a poor understanding of the beneficial role that SET plays in society, and limited knowledge of SET career options, is inhibiting the uptake of SET study. Participants were concerned that the career advice provided by parents, teachers and career counsellors may act to discourage participation in SET study and careers because their knowledge of SET career opportunities is limited.

The audit found that international migration may also impact on the availability of SET skills in Australia. In recognition of the fact that SET skills are in demand, the EU and US and the emerging economies are developing policies aimed at retaining their own SET skills base and attracting overseas SET-qualified staff. Although there was a net inflow of skilled people to Australia between 1998 and 2003, the increasing emphasis and associated expenditure on R&D by OECD countries may result in a net outflow of Australia's SET skills in the future.

Australia's labour market is currently very tight, and this is set to continue due to strong growth in many industries and an historically low rate of unemployment.

There has been strong recent growth in demand for SET skills related to growth in the resources sector, defence and infrastructure development and renewal. Employers are experiencing difficulties recruiting people with engineering, earth sciences, chemistry, spatial information sciences, entomology, high-level mathematical and statistical skills. However, this is not only due to problems with the supply of SET skills, but also because a significant proportion of qualified people tend to work in occupations that may not be immediately relevant to their training.

The report found that the rate of participation in SET careers will be influenced by the ageing of the SET workforce; as well as a decline in the number of school leavers from 2010 onwards (as a result of demographic change, the low profile of SET careers, limited community awareness of the benefits of investment in the sector, and concerns about the adequacy of funding with respect to student places and teaching infrastructure for education and training providers).

Labour market projections to 2012, derived by Monash University, demonstrated that demand for SET skills arising from staff turnover, movements and retirement is likely to be even greater than that resulting from economic growth. However, these projections are based on historical data and may not fully reflect emerging labour market needs. Consequently, there is a need to monitor labour market developments in science and engineering occupations.

The report identified challenges in the areas of education, community awareness, skills acquisition and infrastructure, which are helping to direct policy initiatives across the DEST portfolio. These challenges include:

- Improving the capacity of the education and training system to deliver high quality SET courses, including the supply of well qualified science and mathematics teachers
- Ensuring an adequate stock of scientists, engineers and technologists through emigration and immigration
- Improving awareness of opportunities for SET study and careers among students, parents, industry and the community
- Enhancing understanding of SET career opportunities among early to mid-career researchers and work with public and private research sector to provide rewarding career paths for young researchers
- Facilitating more rapid SET skills acquisition by existing workers, apprentices and new entrants to the labour market to meet demand in a responsive way
- Ensuring quality infrastructure is in place to support SET training and research.

In response to these challenges research has been commissioned to gain a greater understanding of specific issues and ways in which Australia's SET capacity can be improved.

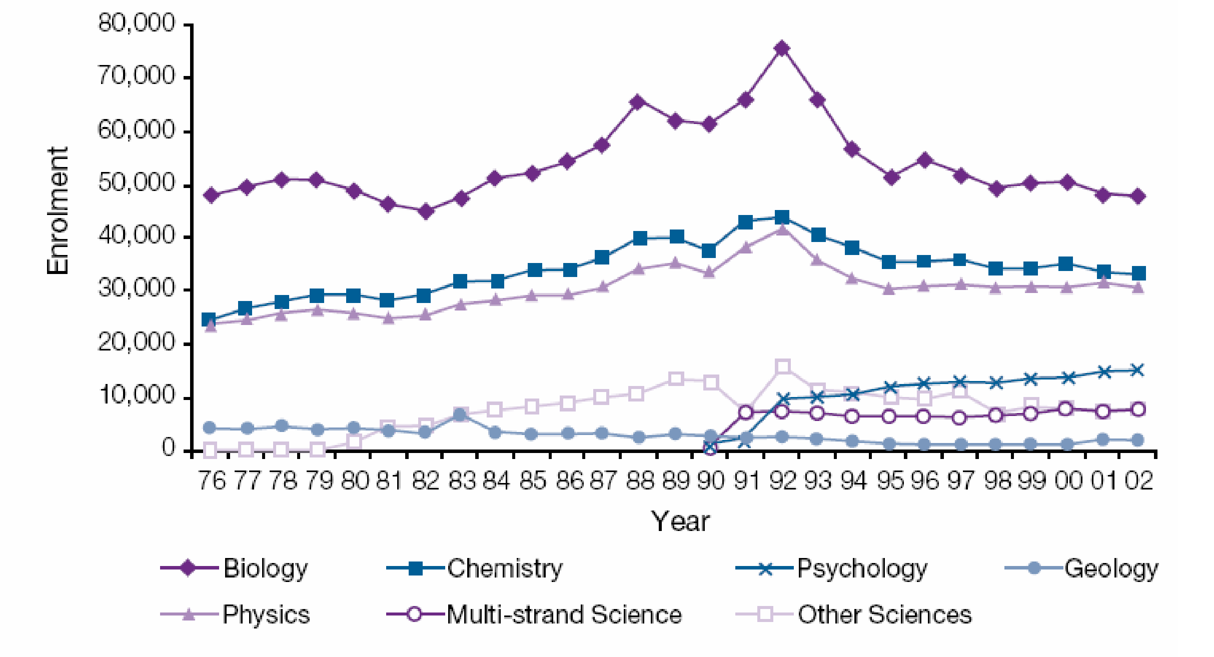
(II) STUDENT DEMAND FOR SET COURSES

As the SET Skills Audit showed, lack of engagement in science, engineering and technology as career choices is evident in the subject choices made by students in university and in the post-compulsory years of schooling, and apparent low levels of engagement in these subjects throughout the high school and primary school years.

Year 12

Falling participation rates in mathematics and physical sciences at Year 12 and tertiary levels are concerning. Following historical highs reached in the late 1980s and early 1990s, there were declines to the mid-1990s in the absolute numbers of students studying physics, chemistry and biology in Year 12 to 2002 (see Figure 7 below).

Figure 7: Enrolments in Year 12 science subjects from 1976 to 2002



Source: Dekkers et al 1991, and DEST Statistical Collection 1991 to 2002, quoted in DEST, *Australia's teachers, Australia's future: advancing innovation, science, technology and mathematics*, 2003

Overall participation in Year 12 science has however remained fairly stable since the mid-1990s, in the range of 143,000 to 148,000 enrolments annually (see Table 2).

Table 2: Year 12 enrolments in science and mathematics 2000-2004

	2000	2001	2002	2003	2004
Science (all)[a]	146,602	143,585	142,923	146,053	147,757
Physical sciences[b]	66,504	65,199	64,271	66,283	67,401
Physics	30,805	31,003	30,542	31,141	30,859
Mathematics[c]	162,488	171,185	173,330	174,042	174,060

[a] Includes: applied science, behavioural science, biological science, biology, earth science, earth and environmental science, general science, geology, human biology, marine studies, mixed biology, multi-strand science, oceanography, psychology, science, senior science, science of natural resources, web of life (subjects differ by jurisdiction).
[b] Includes: chemistry, electronics, physical sciences, physics, physics pilot, physics/electronics.
[c] Includes all streams of Year 12 mathematics

The dramatic growth over the last twenty-five years in the number of students continuing to Year 12 has been achieved in part by secondary schools providing a much wider range of learning experiences to cater for an expanded spectrum of student interests and abilities. A consequence of the greater choice now available to senior secondary students is that many who may previously have opted to study science or mathematics are now choosing subjects, such as business studies, psychology or computing, which they perceive to be more relevant or interesting or to lead to more desirable careers. The challenge is to endow science and mathematics learning with the kind of relevance and stimulus that will appeal to all students in the primary and lower secondary years and encourage more of them to continue to advanced levels in upper secondary.

Higher education

Lack of student demand for these subjects is of major concern in the university sector where, an injection of significant new places under BAA has failed to have the desired impact due to lack of student demand.

BAA provided 2,000 additional targeted places commencing in 2001 with a priority on mathematics, science and information and communications technology, growing to about 5,470 in 2005 as students continued in their courses. Additional funding has been provided over the five years from 2006–07 to continue the extra 5,470 higher education places provided in the first five years of BAA.

As part of the BAF package, 9,100 new places commencing in 2005 were allocated to universities. These places will grow to nearly 25,000 new places by 2008. Of the 9,100 places, 967 were allocated to science courses. These places will grow to 1,692 in 2006 and 2,644 by 2008.

In addition, the Australian Government recently announced the allocation of 4,668 new higher education places.

Despite these new places into the sector, there has been little change in the number of students enrolling in natural and physical sciences courses over the 2001-2005 period, with around 21,000 commencing students each year, and the number of students enrolling in engineering and related technologies courses has declined each year since 2002 by an average 1.5 per cent a year (Table 3).

Table 3: Domestic Commencing Students in 'Natural and Physical Sciences' and 'Engineering and Related Technologies' courses, 2001-2005

	2001	2002	2003	2004	2005 (prelim)	% change 2001-2002	% change 2002-2003	% change 2003-2004	% change 2004-2005 (prelim)
Natural and Physical Sciences	20,999	20,610	20,717	21,355	21,000	-1.9	0.5	3.1	-1.7
Engineering and Related Technologies	14,031	14,171	14,033	13,742	13,590	1.0	-1.0	-2.1	-1.1

Source: Higher Education Student Data Collection, DEST

There was a modest increase in the number of completions in natural and physical sciences or engineering over the 2001 to 2004 period, largely due to growth in overseas students (see Table 4, Table 5 and Table 6, on the following pages).

Enrolments by overseas students in SET courses only account for a small proportion of the total. However, they have the potential to become an important source of skilled labour in the science and engineering fields.

Table 4: Award course completions: domestic students by broad level or course for selected fields of education 2001–2004

Level of Course	Natural and Physical Sciences				Engineering and Related Technologies			
	2001	2002	2003	2004	2001	2002	2003	2004
Higher Doctorate	7	8	9	8	0	3	0	3
Doctorate by Research	884	881	999	963	324	379	422	420
Doctorate by Coursework	0	0	0	1	0	0	0	0
Master's by Research	177	160	164	147	147	147	148	150
Master's by Coursework	157	231	269	329	636	624	663	645
Postgrad. Qual/Prelim.	5	8	2	5	6	5	8	1
Grad.(Post) Dip. - new area	117	150	160	166	91	108	145	116
Grad.(Post) Dip. - ext area	63	79	80	129	111	65	66	45
Graduate Certificate	158	209	197	246	201	156	192	247
Bachelor's Graduate Entry	17	38	31	20	2	2	2	1
Bachelor's Honours	2,315	2,314	2,262	2,192	629	599	568	736
Bachelor's Pass	8,519	8,339	8,499	9,004	5,430	5,120	5,261	5,243
Associate Degree	10	5	1	3	80	75	64	44
Advanced Diploma (AQF)	57	3	23	22	60	55	40	57
Diploma (AQF)	44	30	27	27	27	56	52	23
Other undergraduate award courses	400	103	23	97	112	292	212	444
TOTAL	12,930	12,558	12,746	13,359	7,856	7,686	7,843	8,175

Source: Higher Education Student Data Collection, DEST

Table 5: Award course completions: overseas students by broad level or course for selected fields of education 2001–2004

Level of Course	Natural and Physical Sciences				Engineering and Related Technologies			
	2001	2002	2003	2004	2001	2002	2003	2004
Higher Doctorate	0	0	0	1	0	0	0	0
Doctorate by Research	174	166	183	217	97	99	109	151
Doctorate by Coursework	0	0	1	0	0	0	0	0
Master's by Research	49	46	68	51	60	41	46	73
Master's by Coursework	152	222	262	408	916	1,071	1,716	1,942
Postgraduate. Qual/Prelim.	2	5	4	5	2	0	1	0
Grad.(Post) Dip. - new area	25	39	29	31	15	26	51	45
Grad.(Post) Dip. - ext area	16	21	28	88	42	39	44	37
Graduate Certificate	26	14	28	24	49	85	49	37
Bachelor's Graduate Entry	0	0	0	1	1	0	0	0
Bachelor's Honours	75	117	151	177	149	128	164	181
Bachelor's Pass	608	778	923	1,307	1,508	1,620	1,833	2,039
Associate Degree	1	0	0	0	0	0	1	2
Advanced Diploma (AQF)	67	1	1	0	16	19	11	12
Diploma (AQF)	0	2	1	2	1	17	23	44
Other undergraduate award courses	7	1	11	8	1	5	52	12
TOTAL	1,202	1,412	1,690	2,320	2,857	3,150	4,100	4,575

Source: Higher Education Student Data Collection, DEST

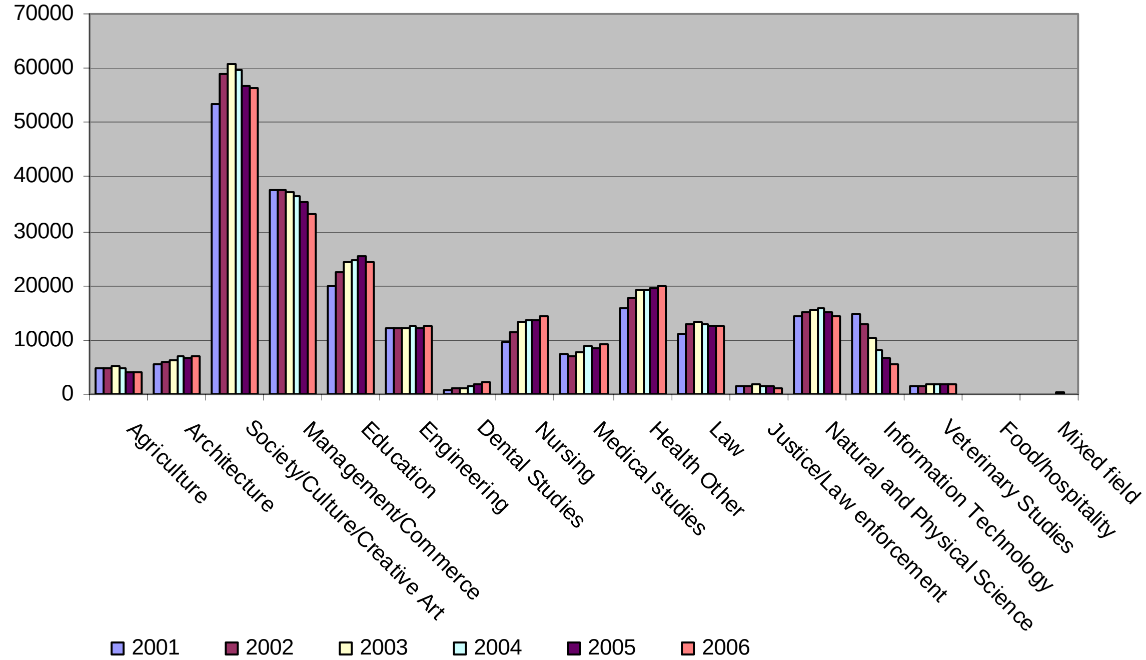
Table 6: Award course completions: all students by broad level or course for selected fields of education 2001–2004

Level of Course	Natural and Physical Sciences				Engineering and Related Technologies			
	2001	2002	2003	2004	2001	2002	2003	2004
Higher Doctorate	7	8	9	9	0	3	0	3
Doctorate by Research	1,058	1,047	1,182	1,180	421	478	531	571
Doctorate by Coursework	0	0	1	1	0	0	0	0
Master's by Research	226	206	232	198	207	188	194	223
Master's by Coursework	309	453	531	737	1,552	1,695	2,379	2,587
Postgraduate. Qual/Prelim.	7	13	6	10	8	5	9	1
Grad.(Post) Dip. - new area	142	189	189	197	106	134	196	161
Grad.(Post) Dip. - ext area	79	100	108	217	153	104	110	82
Graduate Certificate	184	223	225	270	250	241	241	284
Bachelor's Graduate Entry	17	38	31	21	3	2	2	1
Bachelor's Honours	2,390	2,431	2,413	2,369	778	727	732	917
Bachelor's Pass	9,127	9,117	9,422	10,311	6,938	6,740	7,094	7,282
Associate Degree	11	5	1	3	80	75	65	46
Advanced Diploma (AQF)	124	4	24	22	76	74	51	69
Diploma (AQF)	44	32	28	29	28	73	75	67
Other undergraduate award courses	407	104	34	105	113	297	264	456
TOTAL	14,132	13,970	14,436	15,679	10,713	10,836	11,943	12,750

Source: Higher Education Student Data Collection, DEST

As Figure 8 shows, applications for natural and physical science courses increased initially between 2001 and 2004 but have been declining for the last two years. Overall they have shown almost no net growth over the period. Applications for engineering courses increased between 2001 and 2006 by about 2.4 per cent. Most of this growth occurred in the last year. This is slightly above the average increase across all fields of education of 2.1 per cent.

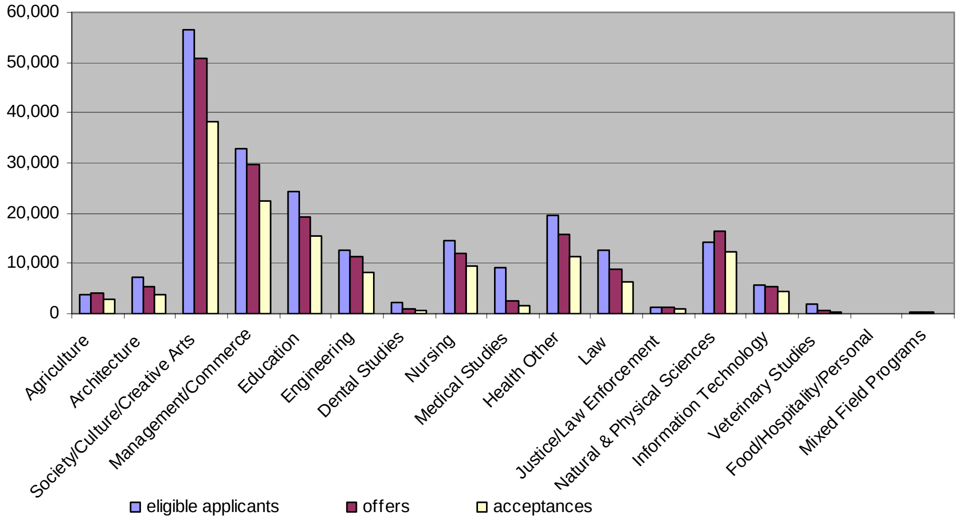
Figure 8: Eligible Applicants by Field of Education Time Series 2001–2006



Source: *Report on Applications for Undergraduate Places*, various years, AVCC

As Figure 9 shows, in 2006 there were 26,751 eligible applicants in natural and physical sciences and engineering combined which represents 12 per cent of all eligible applicants. There were 27,976 offers made to these two fields, or 15 per cent of all offers. Nearly 20,600 accepted. In engineering there were 12,478 eligible applicants, 11,438 or 92 per cent received an offer. There were 14,273 eligible applicants in natural and physical sciences and 16,538 offers (2,000 more offers than applicants).

Figure 9: Eligible applicants, offers and acceptances by field of education 2006



Source: *Report on Applications for Undergraduate Places*, 2006, AVCC

DEST maintains an overview of course provision not only through the provision of funded places, but also by requiring that institutions seek agreement on closure of specialist and nationally significant courses, including those that prepare students for entry to an occupation that is experiencing a national skill shortage.

New places are typically allocated through a competitive bidding process where providers bid for places by specifying the number of new places they would like and in what courses. This is informed by both the provider's strategic direction for course provision and levels of student demand in particular courses.

The Australian Government consults with the States and Territories in reaching decisions concerning the allocation of new higher education places to address skills shortages and workforce planning needs. Provisional agreement was reached at MCEETYA's meeting in November 2005 to institute a formal bilateral consultative mechanism on workforce planning covering areas where the State or Territory is the major employer and where there are critical skills shortages at both national and State and Territory level.

At its July 2006 meeting, the Council of Australian Governments (COAG) endorsed the need to gain a whole-of-government perspective on health workforce priorities. Governments also acknowledged that at any one time, health is likely to be one of a number of priority areas of national workforce need. It was agreed that MCEETYA would provide the forum for discussion and that outcomes from MCEETYA would inform the funding decisions made by governments, as well as the allocation of new university places. COAG determined that a clear mechanism for consultation on health workforce issues between the Australian Government and State and Territory governments be put in place in the form of a Multilateral Memorandum of Understanding (MoU). The MoU was signed at the July 2006 COAG meeting.

In the recent allocation of new medical places, the States and Territories have agreed to guarantee to provide high-quality clinical placements and intern training for Commonwealth-funded medical students. States and Territories have also agreed to continue to invest significantly in on-the-job and postgraduate training for these health professionals.

(III) DEMAND FOR VOCATIONAL TRAINING AND EDUCATION SKILLS

The vocational and technical education sector is well placed to supply human capital to industry. Currently, however, there is a serious mismatch between skill levels in the workforce and what will be required for Australia to maintain a competitive economy.

Table 7 below shows data from research undertaken by the Queensland Department of Education and Training. The table compares the qualifications profile of the working population in 2001 and predicted need for different qualification levels. It took into account current trends of high employment growth in most high-skilled occupations.

It shows that 20 percent of the working age population holds a university qualification and that 24 percent of jobs will require a university qualification. While there is some need to increase the number of people with university qualifications, the balance between the qualification level of the working age population and future job requirements is fairly close.

Table 7: Potential qualifications pathways compared with current qualifications profile of the Australian working age population

Potential qualifications pathways for jobs	**% of employment**
Jobs currently and potentially with university pathway	24.0
Jobs currently and potentially with VET pathway	62.3
Jobs not requiring tertiary qualifications	13.7
Current (2001) qualifications profile of population	**% of 15–64 population**
University qualifications	20.0
VET qualifications	29.9
No tertiary qualifications	50.1

Source: Estimated by the Qld Department of Employment and Training and Australian Bureau of Statistics Survey of Education and Work, 2004 in *Skills for Jobs Growth – A Queensland Government Research Paper,* 2005.

However the picture is quite different for vocational and technical education. Just under 30 percent of the working age population hold VTE qualifications but 63 percent of the jobs will require these qualifications.

This research is supported by recent research from the Centre for the Economics of Education and Training (CEET), which forecasts a similar increase in demand for VTE qualifications and a decrease in demand for unskilled labour. CEET also forecasts a shift in the makeup of required qualifications in the workforce (Table 8).

This forecast suggests that not only is the demand for VTE qualifications likely to increase, but that this increase will be most significant in the area of higher level qualifications. For example, by 2016 more people are expected to be employed in associate professions than trades.

The lack of vocational and technical skills within the workforce needs to be addressed before Australia is positioned to maximise the economic benefit of innovation. Addressing this skills mismatch and the skills shortages that are likely to result should therefore be a priority in the implementing of a broad-based national innovation system.

Table 8: Projected changes in the qualification profiles between 2006 and 2016 by occupation, Australia (percentage points)

Non-school qualification	Managers & Admin.	Prof.	Associate Prof.	Trades	Advanced Clerical & Service	Intermed. Clerical, Sales & Service	Intermed. Prod. & Transport	Elem. Clerical, Sales & Service	Labourers	Total
VET	9.3	-1.2	7.1	2.6	10.9	11.9	5.0	10.6	7.4	5.9
Adv Diploma	*2.8*	*-2.7*	*1.0*	*2.4*	*0.7*	*-0.1*	*2.4*	*1.3*	*0.6*	*0.6*
Diploma	*5.1*	*1.3*	*5.4*	*2.7*	*3.8*	*5.8*	*1.2*	*2.7*	*2.0*	*3.4*
Certificate IV	*-0.1*	*0.8*	*1.2*	*2.3*	*0.5*	*2.3*	*2.2*	*1.5*	*0.8*	*1.4*
Certificate III	*-1.1*	*0.2*	*3.0*	*-8.0*	*7.2*	*9.2*	*-2.6*	*6.3*	*3.4*	*1.4*
Certificate II	*3.8*	*-0.4*	*-0.3*	*0.9*	*0.5*	*-1.9*	*0.8*	*-0.1*	*1.9*	*0.2*
Certificate I	*-1.1*	*-0.2*	*-3.1*	*2.2*	*-1.9*	*-3.4*	*1.1*	*-0.9*	*-1.4*	*-1.1*
Higher Education	8.9	3.6	7.6	2.2	8.7	4.1	3.7	8.7	1.3	5.8
With quals.	18.2	2.4	14.7	4.8	19.6	16.0	8.7	19.4	8.7	11.7
Without quals.	-18.2	-2.4	-14.7	-4.8	-19.6	-16.0	-8.7	-19.4	-8.7	-11.7

Source: Estimated with consideration of predicted skills deepening by the Centre for the Economics of Education and Training (CEET), in 'The future labour market and qualifications in Australia' (forthcoming).

(IV) OUTCOMES FOR SET GRADUATES

Perceptions about career outcomes for SET graduates is one factor influencing the subject choices and career aspirations of students as well as the views of parents. An analysis of data from the Graduate Destinations Survey for 2005 shows very different outcomes for engineering and science graduates within those disciplines and in comparison to disciplines as a whole.

Table 9 shows that graduates with degrees in Engineering and Related Technologies achieved an 87.7 per cent full-time employment rate compared to 80.9 per cent for all fields of education (ranging from 83.1 per cent for Chemical Engineering to 95.4 per cent for Surveying). Similarly, median starting salaries for Engineering graduates were also well above the average of $40,000, while the starting salary for Surveying graduates was equal to the median salary for all fields of education. Mining Engineers, in particular, attracted a high starting salary of $63,000.

By contrast, graduates with degrees in the Natural and Physical Sciences achieved an average full time employment rate of 73.5 per cent (ranging from 71.3 per cent for Life Sciences graduates to 87.4 per cent for Geology graduates). Starting salaries for Science graduates are close to the median salary for all fields of education of $40,000, with Mathematics and Geology graduates receiving the highest salaries at $42,000.

Table 9: Breakdown of Science and Engineering bachelor degree graduates who are available for full-time employment; by full-time employment and median starting salaries, 2005

	In full-time employment (%)	Median starting salary ($,000)
Aeronautical Eng.	89.1	45.0
Chemical Eng.	83.1	46.7
Civil Eng.	95.7	43.0
Electrical Eng.	87.3	45.0
Electron/Computer Eng.	78.3	43.0
Mechanical Eng.	89.5	44.0
Mining Eng.	98.8	63.0
Other Eng.	86.9	44.0
Surveying	95.4	40.0
All Engineering and Related Technologies	87.7	45.0
Life Sciences	71.3	38.0
Mathematics	72.6	42.0
Chemistry	84.7	38.0
Physics	78.9	40.0
Geology	87.4	42.0
All Natural and Physical Sciences	73.5	40.0
All Fields of Education	80.9	40.0

Source: *Graduate Salaries 2005* and *Graduate Destinations 2005,* Graduate Careers Australia, Melbourne.

Table 10 shows the percentage of 2005 Engineering and Science degree graduates gaining full time employment within four months of completing their qualifications. The average employment figure for Engineering and Related Technologies graduates has been consistently higher than that for all fields of education, while the figure for the Natural and Physical Sciences has been consistently lower.

Table 10: Engineering and Science bachelor degree graduates who are available for full-time employment and in full-time employment, 2001-2005

	Engineering and Related Technologies	Natural and Physical Sciences	All Fields of Education
2001	87.3	75.5	83.0
2002	84.4	70.3	81.3
2003	85.8	68.9	80.1
2004	85.7	70.2	79.7
2005	87.7	73.5	80.9

Source: Graduate Careers Australia

Table 11 below shows the broad employment destination for the highest percentage of both Engineering and Science graduates was Industry and Commerce (54.2 per cent and 57.3 per cent respectively, compared with 35.4 per cent for all fields of education). [40] Within that field, the majority of Engineering graduates were in Manufacturing, and Business and Finance, while Business and Finance attracted the majority of Science graduates. Professional Practice was also the employment destination for a significant proportion of Engineering graduates (23.2 per cent) compared to only 4.9 per cent of Science graduates and 11.9 per cent for all fields of education. Positions in Government were also gained by 17.8 per cent of Engineering graduates and 16.3 per cent of Science graduates.

According to the 2004 report of the Graduate Destination Survey, Engineering and Surveying graduates were more likely to be employed in their broad area of training than Science graduates. Except for Aeronautical Engineers (35.5 per cent), the figures for Engineering and Surveying were quite high, ranging from 71.5 per cent to 93.0 per cent (Mining Engineers). By contrast, 35.9 per cent of Life Sciences, 38.6 per cent Mathematics, 59 per cent Chemistry and 70.2 per cent Geology graduates were employed in their broad area.

Table 11: Employment destinations for Science and Engineering bachelor degree graduates, 2005

	Engineering and Related Technologies	Natural and Physical Sciences	All Fields of Education
Government	17.8	16.3	13.0
Professional Practice	23.2	4.9	11.9
Industry/Commerce	54.2	57.3	35.4
Health	0.4	6.8	18.6
Education	1.9	9.3	16.6
Other	2.5	5.4	4.5
Total	100.0	100.0	100.0

Source: Graduate Careers Australia

While there may be little the Government can do to affect career outcomes for SET graduates, it can help students and parents make informed choices by providing accurate information about them. The research projects arising from the Skills Audit will help inform this debate.

Another is the mapping exercise currently being undertaken for DEST by the Business, Industry, and Higher Education Collaboration Council (BIHECC). BIHECC was set up under BAA to facilitate discussion between universities and industry across a range of issues, including science and innovation. It is currently mapping gaps in available knowledge about long term graduate destinations, and scoping future work on a long term graduate destination survey. At its next meeting BIHECC will discuss the way forward with a possible long term Graduate Destinations Survey.

BIHECC priorities for 2006–07 include:

- Developing an overview of the state of science and engineering infrastructure in universities and exploring the extent to which alternative funding structures are being used or considered by Australian universities
- Proposing ways in which business and the higher education sector can contribute to the issues identified in the SET Skills Audit.

[40] The broad category of Industry and Commerce includes: Agriculture, Forestry and Fisheries; Mining; Manufacturing; Electricity, Gas and Water; Construction; Wholesale and Retail; Transport/Storage; Communication Services; Business and Finance; Entertainment/Recreation; and Other Personal Services.

(V) ROLE OF VOCATIONAL TRAINING AND EDUCATION IN INNOVATION

The vocational training and education sector is an important source of skilled labour and industry has traditionally been an active stakeholder in this sector. The role of the sector in the diffusion of technology throughout the workforce is less well understood, and it links with the research sector are not as well developed.

The VTE sector has an important role to play in supplying sufficient numbers of appropriately skilled technicians and other associate professionals to the research sector. In 2005, the national training system had 8,831 students enrolled in courses leading to the qualifications of science or medical technical officers, and registered 1,797 completions of these courses, a slight decrease from previous years.[41] Given the expected increase in overall demand for qualifications at the associate professional level[42] demand for technicians is also likely to increase. In order for Australia to maintain a robust research sector, it is therefore of crucial importance that the VTE system is able to supply appropriately skilled technicians to meet rising demand.

The role of VTE in the early implementation of emerging technologies was acknowledged by the Australian Industry Group in *Final Report of the Emerging Technologies Taskforce*, 2005. By maintaining close ties with parts of the research sector, such as universities and cooperative research centres, training providers can not only ensure that new staff are familiar with current technologies and best-practices for their industry, they can also re-skill existing workers through short courses and workshops.

By maintaining close ties with training providers, the Viticulture CRC has been influential in improving the competitiveness of the Australian wine industry. Due to the internationally competitive nature of the wine industry, it has been estimated that wineries and growers only have two years to incorporate a new technology or practice into their business if they wish to remain ahead of the competition. Because the majority of the Australian wine industry is in small to medium sized firms (which typically have a slower uptake of new practices), the VTE sector has been of crucial importance in allowing the wine industry to maximise the economic benefit of new innovations in technology and practice. The close relationship between the Viticulture CRC and relevant training providers facilitates training of new and existing employees in current best practice as soon as its development is completed. This rapid diffusion of knowledge has been successful in maintaining Australia's competitive edge in the wine industry.

As well as assisting with the diffusion of locally produced innovation, the VTE sector is also well positioned to help industry capitalise on the latest developments in overseas research and innovation. Training providers have the ability to act as a nexus for innovative knowledge, scanning overseas markets for new procedures and technologies and then distributing them into local industry. This allows industry, particularly small to medium size enterprises, to remain internationally competitive without the need for each firm to undertake expensive international research individually.

For example, the Centre for New Manufacturing – Swinburne TAFE draws upon the latest in international developments in manufacturing to ensure that all the processes and technologies used in training are as up to date as possible. The centre has been so successful in doing this that they are frequently ahead of local industry in technological developments and industry sometimes uses the centre's facilities for product testing.

[41] National Centre for Vocational Education Research, *VET provider collections,* NCVER, Adelaide, 1996-2006.
[42] Centre for the Economics of Education and Training (CEET), 'The future labour market and qualifications in Australia' (forthcoming).

In addition to supporting high level research-based innovation, the VTE sector has a significant role to play in effecting a cultural change towards innovation within industry. As Callan[43] argues, for industry to be truly innovative, it requires a culture of innovation amongst employees at all levels. While achieving this cultural change will require contribution from many sectors, the VTE system is well placed to ensure that employees and entrepreneurs have the appropriate innovation related skills.[44]

For example, Kangan Batman TAFE in Victoria has introduced innovation training that imbues graduates with the skills and mindset necessary to operate within an innovative business environment. Particular emphasis is placed on breaking down traditional cultures of vertical leadership and lack of decision making responsibility amongst non-management employees. It is predicted that the introduction of employees trained in innovation will help to effect cultural change towards innovation in companies that employ them.[45]

In general, current policy direction in vocational and technical education is not directly targeted at science and innovation. COAG has asked the Ministerial Council for Vocational and Technical Education (MCVTE) to report by December 2006 on the next stages of training reform to ensure that the training system is able to provide the skill base for the Australian workforce into the future. Of most significance to innovative capability, the report will discuss higher level skills, cultural and workplace change and building stronger relationships between businesses and providers.

The five guiding principles for the development of the National Training System are strongly related to this, in particular the fifth principle: 'Training opportunities are expanded in areas of current and expected skills shortage, including through: improving the capacity of industry and business to determine relevant skills needs; making VTE more demand driven to ensure it is meeting the strategic needs of the Australian economy.'

The *2005–08 Commonwealth-State Agreement for Skilling Australia's Workforce* sets out the terms and conditions of the Australian Government funding appropriated under the *Skilling Australia's Workforce Act 2005* for the period 1 July 2005 to 31 December 2008.

The Agreement identifies and seeks to address several challenges that the VTE system faces in supplying human capital. Improving the system's responsiveness to rapid changes in demand for skills development and addressing skills shortages, especially in traditional trades and in emerging industries has been identified as a national priority in the current agreement. Within the agreement there are presently few provisions specifically targeted at innovation, however the agreement identifies innovation as an area for review and future development, and allows sufficient scope for policy and initiatives to be implemented at a later stage.

[43] V Callan, 'How vocational education and training providers are working innovatively with industry', *Vocational education and training and innovation: research readings*, NCVER, Adelaide, 2004, p.140.,
[44] B Bennet, D Brunker and R Hodges, 'Innovation, economic growth and vocational education and training', in *Vocational education and training and innovation,* NCVER, Adelaide, 2004, p. 68.
[45] Innovation in business – implementing new ideas to add value, Kangan Batman TAFE website, 2006, viewed 28 August 2006, <http://www.kangan.edu.au/kb2b/issue04/focus_innovation.html>.

In signing the Agreement, States and Territories also agreed to conduct a Strategic Review of Infrastructure. That review is due to report back to MCVTE in 2006. The Review is to develop recommendations on: the role of Infrastructure funding in meeting current and future training, skill and employment needs; targeting infrastructure funding to better support industry specialisation, innovation, the establishment of industry centres of excellence, the take up of ICT and value for money; and streamlining and improving administration, governance and reporting arrangements.

(VI) QUALITY OF SCIENCE TEACHING AND LEARNING IN SCHOOLS

The report *Importance of Teacher Quality as a Key Determinant of Students' Experiences and Outcomes of Schooling*[46] found that there is a direct link between students' learning outcomes and the quality of the teaching they receive. Other recent reports have also identified the quality of teaching as an important factor in science education.[47]

Programmes to improve the quality of teaching have a direct bearing on our ability to engage students in the study of science, technology and mathematics, but are also important to our ability to supply broader capabilities for an innovative society.

Another recent report, *Teaching Science in Australia*, discussed the findings of a 1999 video study of science teaching in Australia and four other countries. While generally endorsing approaches to science teaching in Australian secondary schools, the study found that the content of Australian science lessons was at a basic rather than challenging level and suggested that Australian students could be further extended in their science learning.[48]

The Boosting Innovation, Science, Technology and Mathematics Teaching (BISTMT) Programme was a response to the Review of Teaching and Teacher Education. Of the $38.8 million allocated to that programme under BAA over seven years to 2010–11, $33.7 million is being provided to schools and their partners for innovative projects through the Australian School Innovation in Science, Technology and Mathematics (ASISTM) Project. The remaining funds will go towards data collection, research and programme administration.

ASISTM aims to promote innovation and improve science, technology and mathematics teaching and learning in Australian schools. ASISTM provides funding for clusters of schools, in partnership with science organisations, tertiary education institutions, teacher professional associations, business and industry, or others to undertake innovative projects that: provide teachers and students with access to wider world expertise, activities and resources; foster better coordination of teaching and learning between primary and secondary schools; and help to connect science, technology and mathematics teaching and learning with other disciplines.

Through the engagement of teacher associates, including tertiary students, researchers and others with relevant expertise, ASISTM projects are also helping to attract greater numbers of quality students into teaching and providing positive role models for science, mathematics and technology students. ASISTM has been highly effective at linking schools with other schools and non-school partners. Nearly all of Australia's universities have become project partner organisations.

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[46] J Rowe, 'Importance of teacher quality as a key determinant of students' experiences and outcomes of schooling', background paper to keynote address presented at the ACER Research Conference, Melbourne, 19–21 October 2003.

[47] See for example, D Goodrum, *The status and quality of teaching and learning of science in Australian schools*, DETYA, Canberra, 2001; Committee for the Review of Teaching and Teacher Education, *Australia's teachers: Australia's future: advancing innovation, science, technology and mathematics,* DEST, Canberra, 2003; K Harris, *Who's Teaching Science?*: *meeting the demand for qualified science teachers in Australian secondary schools,* Centre for the Study of Higher Education, University of Melbourne, 2005; Victorian Parliament, Education and Training Committee, *Inquiry into the promotion of mathematics and science education: final report* , Victorian Government Printer, Melbourne, 2006.

[48] J Lokan, *Teaching science in Australia: results from the TIMSS 1999 video study*, Australian Council for Educational Research, Camberwell, Vic., 2006.

Over the first two funding rounds, $16.5 million has been allocated to 202 projects including over 1,250 schools and 680 non-school partner organisations. These projects are exciting and diverse and have excellent potential to realise lasting improvements in teaching and learning, and to promote exemplary practice in schools throughout Australia.

DEST supports a range of professional development activities aimed at improving the teaching and learning of science and mathematics in primary and secondary schools. Through the Australian Government Quality Teacher Programme, the Government is investing almost $300 million from 2000 to 2009 to improve the professional skills, knowledge and understanding of teachers in priority areas. The programme identifies science and mathematics as a 'targeted learning needs' priority area. In 2006, 23 professional learning activities across five States will be undertaken to support science and mathematics education.

Primary Connections is an innovative and exciting new initiative linking the teaching of science with the teaching of literacy in Australian primary schools. It provides a teacher professional learning model and curriculum resources to improve the confidence and effectiveness of primary school teachers in teaching science in their classrooms. The Government is investing a total of $4.8 million (from 2004–08) in the project, which is being led by the Australian Academy of Science.

Results from the Stage 2 trial evaluation showed real improvement in *Primary Connections* trial classrooms. A number of education authorities and many schools throughout Australia are already adopting Primary Connections.

The Australian School Science Education Framework (ASSEF) will map school science education initiatives in Australia. It will identify gaps in provision and recommend actions to address priority needs. It is due to be completed by the end of 2006, after which national endorsement is likely to be sought through the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA).

National Statements of Learning have been developed collaboratively by the Australian and State and Territory governments through MCEETYA for a number of learning areas, including science and maths, to promote national consistency and rigour. The Statements articulate the key knowledge, skills, understandings and capacities that all students should have the opportunity to learn at particular stages of their schooling (Years 3, 5, 7 and 9). They are to be implemented by all jurisdictions by no later than 2008.

A National Assessment Programme, endorsed by education ministers through MCEETYA, includes annual assessments in literacy and numeracy, an ongoing programme of national sample assessments in three priority areas, and participation in two ongoing international assessments.

The cycle of national sample assessments includes a three-yearly assessment of primary science (at Year 6). The first national sample science assessment was administered in October 2003 to over 14,000 students from 650 schools, from both the government and non-government sectors and from all States and Territories. The second assessment will be undertaken in the second half of 2006.

Following the first national Year 6 science assessment, a national standard of performance referred to as the 'proficient' standard was set. Results of the assessment show that, nationally, 58.2 per cent of students achieved or bettered the 'proficient' standard (level 3.2).

While Australia performs well overall in science literacy, this is not uniform. Several States have shown an interest in addressing science in their primary curriculum, and uptake of the Primary Connections initiative.

In the 2003 Year 6 national science assessment, Indigenous students' outcomes were significantly lower than those of non-Indigenous students.

The two international assessments which are now a regular component of assessment in Australia are the OECD Programme for International Student Assessment (PISA) and the International Association for the Evaluation of Educational Achievement Trends in International Mathematics and Science Study (TIMSS). PISA assesses a sample of 15 year olds in mathematical literacy, scientific literacy and reading literacy. TIMSS assesses Year 4 and Year 8 students in both mathematics and science.

Results indicate that Australian students compare well on measures of science knowledge and understanding. In PISA 2003, in which 41 countries participated, Australian students achieved a mean score significantly above the OECD average and were clearly outperformed by students from only three countries: Finland, Japan and Korea. In TIMSS 2002–03 Australian students achieved mean scores which were significantly above the international averages at both Year 4 and Year 8. Australia was outperformed by seven of the other 24 participating countries at Year 4 and by eight of the other 45 participating countries at Year 8.

Despite our good performance overall, there are areas for concern. In TIMSS, at the Year 4 level in mathematics, Australian students achieved only at the international average and were outperformed by students from 13 of the other 24 participating countries. In Year 4 mathematics and science and Year 8 mathematics Australian students showed no improvement in terms of mean scores between the 1994–95 and 2002–03 cycles. This compared with a number of other countries who improved both their mean scores over that period and their positions relative to Australia.

On TIMSS, a significant proportion of students are not achieving beyond the most basic proficiency levels. For example, in reading literacy, 30 per cent of Australian students failed to achieve what the OECD described as ‘one benchmark of the reading competencies required for meeting the demands of life-long learning in rapidly-changing technology-intensive societies.’

Australian students’ results overall in international assessments of science and mathematics also mask considerable unevenness in performance across different student subgroups – most notably the poorer performance of Indigenous students. Recent research by the University of New England has also identified significant disparities in results for rural and regional students.

While national benchmark testing results for Indigenous students have shown incremental improvement on previous years, there has been little significant improvement in numeracy since the first testing programme in 2000. This is particularly evident in Year 7 where there is up to a 30 percentage gap point between the proportions of Indigenous and non-Indigenous students meeting the numeracy benchmark. Only slightly more than half (52 per cent) of Indigenous students met the Year 7 numeracy benchmark in 2004.

The results from national and international assessments demonstrate quality outcomes from Australian schooling, but they also present a challenge. Bringing about uniform quality outcomes nationally in identified areas of need requires a strategic, cooperative approach.

(VII) DIVERSITY, RELEVANCE AND RESPONSIVENESS

The Government is looking at broader options for the diversification of the higher education sector. Institutions are being encouraged to play to their strengths – all universities need not be all things to all people. Universities are encouraged to seek innovative ways to restructure both their administration and their course offerings in line with their mission and build on their specialities.

A reputation for quality on a global level is an essential element of a healthy, relevant higher education system. International standing affects our ability to attract quality students, teachers and researchers. While university ranking systems should be viewed with some caution, they do provide an indication of perceptions of quality. In 2005 only one Australian university ranked in the top 20 of the *Times Higher Education Supplement* survey and only two ranked in the top 100 of the Shanghai Jiao Tong survey. This is not simply an issue for domestic supply but has profound implications for our capacity to continue to drive a strong market in educational exports. The Minister for Trade has stated that education exports for 2005–06 were $8 billion which makes education our fourth largest export.

The *Our Universities: Backing Australia's Future* (BAF) package acknowledged the lack of diversity within the Australian higher education sector. Australia needs a high quality education sector with a range of institutions servicing different communities and varied requirements. Greater diversification of the sector is required to ensure its ongoing relevance not only to domestic and international students, but to communities, industries and the broader international market for knowledge and innovation. A more diverse sector with institutions specialising in course offerings such as science and engineering could assist the effective functioning of the innovation system.

The key government policy and programme drivers of diversity in the sector are the:

- Collaboration and Structural Reform fund
- Learning and Teaching Performance fund
- Allocation of higher education places
- Capital Development Pool programme
- Workplace Productivity Programme
- Revised National Protocols for Higher Education Approval Processes.

The reforms and the measures that have followed BAF have given the higher education system the funding and flexibility it needs to become more diverse and sustainable over the long term. The Government has encouraged and facilitated diversity within and across the education sectors – access to pathways such as training and apprenticeships have been expanded, while the growth of private providers and the establishment of the first overseas university in Australia will continue to increase choice for students.

The Government made a commitment under BAA to develop an RQF. The RQF is currently undergoing development and is designed to assess the quality and impact of research in universities and, in time, Publicly Funded Research Agencies (PFRAs). Assessment will be at a sub-institutional level, identifying and rewarding high quality and high impact research in all discipline areas and specialisations.

The Government regards the RQF as a potential tool for greater diversity in the higher education sector, focusing universities' attention on their strengths, and moving away from the 'one-size-fits-all' mould of universities. By highlighting the very best research and its broader impact, through the RQF, universities will be encouraged to take a rigorous approach to developing and implementing their own research strategies that build on their identified strengths. This process will diversify purpose and content as institutions shift their research focus to those disciplines in which they are at the forefront nationally and internationally and for which they extract significant benefit for their communities.

(VIII) SCIENCE AWARENESS

The main function of science awareness programmes is to build capacity for an innovation-based economy. They do this by engaging student interest in science from an early age, encouraging the uptake of science subjects in high school and tertiary education, and disseminating information about options for science-based careers.

In addition, a modern innovative society requires a high level of science literacy and awareness to ensure its citizens are able to recognise the value of science, accept and adapt to the changes wrought by scientific and technological change, and engage in informed and constructive debates on major science-related issues.

There is a need to facilitate continuing economic growth by ‘connecting’ the community, and parents and students in particular, to an understanding of the employment opportunities that become available to those who pursue science studies through to Year 12 and beyond.

The Science Engineering and Technology (SET) study released in January 2006 by Macquarie University[49] provides additional evidence of the need to focus on promoting science-based careers. The University’s survey of high school students found that most respondents had clear views about what is important to them with respect to career choices. In many instances these views did not match their perception of SET-based careers, although respondents had a very limited understanding of actual SET based study and career opportunities and characteristics. This was demonstrated by the fact that the top three desired job characteristics of high school students (a job that will benefit the community; a chance to interact with many different people; and a job with plenty of variety and challenges) actually matched with the top three job characteristics experienced by SET professionals. Macquarie’s study also found that ‘a large majority of SET professionals are concerned about the state of awareness and support for SET from the greater community.’

DEST is working to address these emerging issues, particularly in encouraging students to take up SET skills beyond Year 10 and in enhancing career advice provision. Within the portfolio, science awareness programmes are managed by DEST, under the Science Connection Programme and Questacon, and by CSIRO. The following is a discussion of those programmes. Further detail on these programmes is provided at Appendix 3.

Science Connections Programme

The Science Connections Programme (SCOPE) is the science awareness component of BAA. SCOPE has a budget of $25.8 million over seven years commencing in 2004–05. It continues and builds on the science awareness components of the National Innovation Awareness Strategy which concluded in 2005–06. SCOPE’s name reflects its purpose of highlighting, for young people in particular, the connection between the study of science in senior secondary school and beyond, and the career options that become available as a result. SCOPE aims to: raise community awareness of the relevance of science; celebrate and reward the efforts of our best scientists and science teachers; promote science content in news programming; promote students’ experiential contact with science and engineering; and provide extension opportunities for our most talented students.

[49] M Etheridge and M Raison, ‘Macquarie University science engineering and technology study’, Macquarie University, Sydney, January 2006.

Programme review

The predecessor to SCOPE, the National Innovation Awareness Strategy (NIAS), was reviewed in 2003. The review found that NIAS had 'effectively engaged youth, business, and the education and science communities, as well as the broader community, in a wide range of science and innovation related events, activities and programmes' and had been 'particularly successful in addressing objectives that relate to science'. It cautioned that 'despite this success, there is evidence that the connections and pathways between science, commercialisation and innovation (and their role in building a more prosperous Australia) require ongoing emphasis and promotion. It is thus worthwhile to continue to promote these connections, and the consequent positive contribution to national prosperity.' The review highlighted the leveraging effect of the NIAS programmes, particularly the ABC Science project and the National Science Week project grants, where enabling funds from the Australian Government attracted further financial support.

The University of Newcastle collects data on student enrolments in Physics, Chemistry and Mathematics at schools participating in the Science and Engineering Challenge, both before and after participation, and conducts qualitative surveys. In 2005 Year 11 students enrolled in Physics, Chemistry and Mathematics were asked whether their participation in the Challenge had influenced their decision to study these subjects. Across 59 schools, 735 students had participated in the Challenge. Of these, 196 (26.7 per cent) stated the Challenge had influenced their decision to continue in these subjects.

Limitations to wider effectiveness

There is scope to expand these programmes, for example *Science in the City* which is successful in NSW but does not have equivalents in the other States and Territories. The Science and Engineering Challenge cannot continue to expand while it is delivered only from the University of Newcastle. Support for and community participation in National Science Week in regional Australia will grow only if regional groups are funded to promote and conduct science-celebrating events.

There are some obvious successes in attracting private sector support for science awareness activities, such as: Shell's sponsorship of the Questacon Science Circus, Tenix's sponsorship of the Questacon Maths Squad, Rio Tinto/Merck Sharp and Dohme's support of the Australian Science Olympiad Programs, Network 10's partnership with CSIRO for the Totally Wild and SCOPE television programmes and the BHP Billiton Science Awards. However, private sector support is limited by a lack of immediate direct benefit to the individual organisation.

Students need greater access to information about what they could do with science skills. Surveys have indicated that products such as DVDs are, by themselves, an insufficient response to this need. The types of intervention that have the strongest and longest-lasting impacts are experiential.

In relation to the Science Connections Programme, its success is documented in accolades to good science teachers and in feedback surveys for the Challenge and 'Sleek Geek Week' (a National Science Week initiative). A Science Awareness Raising Project conducted in seven schools and their local communities across Australia in 2003 by the Australian Science Teachers Association (ASTA) also confirmed this finding.[50]

Questacon – The National Science and Technology Centre

Questacon's exhibitions and programmes are designed to engage and inspire children of all ages about science, as well as their parents, teachers and communities. In 2005–06, more than 106,000 school students from 1902 schools across all Australian States and Territories visited Questacon in Canberra through organised school visits, with more than 1.4 million people from across Australia visiting the Centre in Canberra or a Questacon programme elsewhere in Australia. Curriculum support materials, available from Questacon's website, provide resources for the school classroom and to extend learning beyond the visit. Satisfaction ratings for exhibitions and programmes exceeded 97 per cent in 2005–06.

Questacon also partners with corporations to provide outreach programmes such as the Shell Questacon Science Circus, Tenix Questacon Maths Squad and NRMA RoadZone. This corporate support enables Questacon to deliver in-school programmes to approximately 180,000 students per annum in regional areas in all States and Territories. A great deal of positive feedback is received by teachers, parents and students about the educational quality of these programmes. One of the strengths of Questacon's education programmes is that they have substantial online support materials, with curriculum links, for teachers and parents through the Questacon website (www.questacon.edu.au). The website has more than one million visitors per year.

Beyond Canberra, Questacon has a variety of outreach programmes that deliver stimulating science, maths and innovation shows using young scientists and science communicators. Questacon has a particular focus in delivering programmes to rural, regional and remote Australia including Indigenous communities.

[50] The ASTA Science Awareness Raising Project developed, trialled and evaluated a science awareness raising model that could be used by a diverse range of schools and their communities to identify, document and promote scientific literacy. The purpose of the Project was for the school to work with the community to increase the community's awareness of why science is important. The evaluation concluded the project had been differentially successful for participating groups. See http://www.dest.gov.au/sectors/school_education/publications_resources/profiles/science_awareness_raising_model_evaluation.htm

3. GLOBALLY ENGAGED SCIENCE

(I) THE CONTEXT OF GLOBAL SCIENCE ENGAGEMENT

Global challenges that require global engagement

The global community is facing global issues such as climate change, clean energy production, access to water, security and disease epidemics. No one country will be able to solve these challenges independently. Australian science and technology is making an important contribution through initiatives such as the *Asia-Pacific Partnership on Clean Development and Climate Change* and the tsunami early warning system in the Indian Ocean.

At the launch of the Asia-Pacific Partnership, hosted by the Australian Government in January 2006, Australia, the US, China, India, Japan and Korea agreed to science and technology collaboration in eight areas, including cleaner fossil fuel energy, renewable energy and coal mining.

Australia is collaborating with its regional partners to establish a tsunami monitoring and early warning system for the Indian Ocean. The Australian Bureau of Meteorology (BoM) and the US National Oceanic and Atmospheric Administration (NOAA) will share data and technology. This collaboration is occurring under the umbrella of the recently signed treaty-level *Agreement relating to Scientific and Technological Cooperation between the Government of Australia and the Government of the United States of America*.

The global context

As countries recognise the increasing contribution that science and innovation is making to the global economy, they are placing a greater emphasis on ensuring the quality of their scientific research as a means for ensuring their economies remain internationally competitive. President Bush recently announced his competitiveness initiative which provides substantial investment in scientific research and science education to encourage US innovation and strengthen the US's position as the world's economic leader. The EU, through its *Lisbon Strategy*, is aiming to transform Europe into a more knowledge-based economy in order to boost economic growth and create new jobs. It aims to achieve this through increased science and technology expenditure, setting a target of 3 per cent of GDP by 2010. The EU 7th Framework Programme will provide €54.5 billion in research funding over the period 2007–2013.

Newer players in the global economy, in particular China and India, are investing in their science and innovation systems with the aim of 'leap-frogging' their economic development. India has become one of the world leading suppliers of software and ICT and is looking to repeat this success in other areas such as biotechnology. When President Hu Jintao released China's *National Medium and Long-term science and Technology Development Plan* in January 2006, he dedicated the next 15 years to turning China into an innovation-oriented country. China's investment in R&D is growing rapidly, in real terms and as a share of GDP. China's R&D investment grew from 0.57 per cent to 1.23 per cent of GDP during the period 1996–2004 and is targeted to reach 2.5 per cent by 2020.

The Australian context

Given the increasing importance of science and innovation in the global economy, it is clear that quality of the Australian science and innovation system will have a substantial influence on Australia's capacity to compete economically. The quality of Australian science will, in turn, be dependent on the extent to which our researchers are engaged with the best researchers around the world. Although Australian research accounts for approximately 3 per cent of the world's scientific output, and thus arguably makes a contribution disproportionate to its small size, Australia must be engaged with international partners to access the other 97 per cent of science that occurs overseas.

Without access to this knowledge, Australia's capacity to produce world-class science would be seriously undermined. This dependence on international collaboration is reflected by the statistic that roughly one-third[51] of all Australian authored science and engineering publications are co-authored with at least one researcher from another country.

Australia's remoteness from other nations means that Australia needs to work harder than other nations to engage effectively with the global science community. For example, researchers in North America and Europe can often find highly skilled colleagues and equipment in the same field within two hours of air travel. In Australia, our low population density and relatively low numbers of researchers do not provide the same opportunities. For Australian researchers, the costs and time required to maintain an investment in international science are significantly greater than their European or North American counterparts. These facts are already widely recognised in the Australian science community and by those agencies that provide funds for research.

(II) BENEFITS OF INTERNATIONAL SCIENCE ENGAGEMENT

Attracting inward R&D investment

Apart from the basic necessity for international collaboration to deliver a world-class science system, the Australian science community must be globally connected so that it can take advantage of the increasing globalisation of the R&D investment made by multinationals and foreign governments. In many OECD countries, particularly those in Europe, the share of research funding from international sources can be quite high – for example, Belgium, Hungary and the Netherlands attract more than 10 per cent of their R&D funding from abroad, Greece and Iceland attract more than 15 per cent, and Austria and the UK attract 21.4 per cent and 20.2 per cent respectively.[52] By contrast, Australia's share of investment from international sources was 4.3 per cent or $523 million,[53] suggesting that there is scope to substantially increase our international support for research.

[51] According to the National Science Foundation, *Science and engineering Indicators*, in 2004 36.3 per cent of Australian science and engineering publications included contributions from at least one international collaborator.
[52] Organisation for Economic Co-operation and Development, *Main science and technology indicators, 2005/1,* OECD, Paris, 2005.
[53] Australian Bureau of Statistics, *Research and experimental development all sector summary 2002-03*, ABS, Canberra, 2004.

Nevertheless, a recent study commissioned by DEST[54] reported that Australian researchers and businesses have tapped into a wide range of different sources of international support across a number sectors and countries (with the US the largest contributor, followed by France, the UK and Japan). Drawing on the data collected by the ABS, the study found that of the total of $523 million from international sources, public sector research organisations, including universities, received about $162 million, business received $323 million and private/non-profit organisations received about $37 million.

While Australia needs to improve its ability to attract R&D investment from foreign sources, there is evidence that its world-class reputation in particular areas of research has allowed it to compete for the foreign investment in these areas. Australia, for example, does particularly well in attracting foreign support for medical and health sciences. The Allen Consulting Group estimated that in 2002–03 the medical and health science area attracted the greatest share of international support, with funding of $64.6 million for 327 projects.[54] The Allen Group also report that of the top 30 international sources support for Australian research, 12 are organisations whose primary areas of interest are medicine or pharmaceuticals.

Contributions to domestic industry

The experience of other countries is that international engagement in science and innovation has substantial 'flow-on' benefits for their domestic industries. Canada has established a space industry that in 2004 generated CAD2.4 billion, 92 per cent of which was represented as export revenue[55]. One of the key factors in developing this industry has been the close relationship between the Canadian Space Agency and foreign space agencies, especially NASA and the European Space Agency (ESA). Through international collaboration on space missions, Canada has developed knowledge, expertise and credibility that have given them the capacity to develop services and products (especially instruments carried by satellites) upon which their space industry is built. The Canadian Space Agency estimates that their annual investment CAD30 million in subscriptions to ESA is more than exceeded by the income Canadian companies receive from ESA contracts.

Sustaining Australian export industries

By sustaining and building on Australia's reputation as technologically advanced nation, it is reasonable to expect that international science collaboration has a positive impact on Australian exports, particularly important in relation to our international education market. Education exports are Australia's fourth largest export sector after coal, tourism and iron ore. The Minister for Trade announced international education exports contributed $8 billion to the Australian economy in 2005–06. International education thus contributes significantly to international competitiveness, as well as promoting the national interest. Australia's international science engagement plays a critical role in raising international awareness of the high quality of the Australian tertiary education sector and in helping to attract foreign students to Australian institutions.

[54] Allen Consulting Group, *International support for science and technology in Australia*, DEST, Canberra, 2005.
[55] State of the Canadian Space Sector, Canadian Space Agency, 2005, viewed 25 August 2006,<www.espace.gc.ca/asc/eng/industry/state.asp>.

Regional relationships

While Australia's partners in our region may not have the same standing in the international science community as some of our more distant partners, such as the US, the UK and the EU, our regional science relationships nevertheless provide substantial benefit. The Australian Centre for International Agricultural Research (ACIAR), which has a role in supporting collaborations with developing countries, recently commissioned a report on returns from bilateral R&D investments.[56] The report showed that ACIAR's investment in the Asia-Pacific provided substantial benefits, yielding benefit-cost ratios of 1.3:1 for 'substantially demonstrated' benefits, and 3.1:1 for 'potential benefits'. Although these benefits are productivity-related, the report notes that activities also provide indirect benefits such as enhanced international standing and improved international knowledge flows.

More generally, Australia's science-based interactions play an important role in promoting good relationships with its regional partners. For example, although Australia's science engagement with Indonesia is predominantly aid-based agricultural research, such activities help promote and strengthen the broader bilateral relationship and cooperation in areas such as countering terrorism, combating avian influenza and post-tsunami reconstruction in Aceh. The importance of science collaboration was recently reaffirmed when the governments of Australia and Indonesia signed a new treaty-level agreement on science and technology cooperation shortly after the 2005 Australia-Indonesia Ministerial Forum (AIMF) hosted by Australia.

(III) THE EMERGENCE OF 'BIG SCIENCE' COLLABORATIONS

In the past, the need for international science cooperation has largely been met through activities involving small groups of researchers across a diverse range of scientific disciplines. Although this form of collaboration will continue to be important, the emergence of 'big science' projects provides a new and increasingly important form of research partnership. Big science projects, such as the human genome project and the International Thermonuclear Experimental Reactor, are ambitious projects involving extensive international consortia and scientists from many disciplines, in order to answer fundamental questions. They commonly require access to, or centre on the development of expensive infrastructure that no single country can afford on its own.

Australia is a key player in international discussions towards establishing the Square Kilometre Array (SKA) radio telescope, a project aimed at transforming our knowledge of the structure and origin of the universe. With target completion in around 2020, the SKA will map the sky with a degree of sensitivity and speed around 100 times faster than is currently possible. This facility has the capacity to transform our knowledge of the overall structure of the universe. The US$1 billion cost of construction is expected to be funded by an international consortium of governments.

Australia is currently being considered as a possible site for the SKA. This is based on Australia's capacity to offer world-leading astronomers, provide a view of the Southern Hemisphere and ability to provide the radio quietness that will be essential to effective SKA operation. The SKA project provides an example of the benefits that can potentially flow from engaging in big science projects. If Australia is chosen as the SKA site it will have substantial benefits such as reinforcing Australia's standing as a key science nation and provide inspiration for young Australians to pursue careers in science and technology. In addition, estimated tangible economic outcomes include:

- An expected net benefit of more than $90 million from hosting and securing technology contracts (an estimated benefit to cost ratio of 1.84:1)

[56] D Raitzer and R Linder, *A review of the returns to ACIAR's bilateral R&D Investments,* Australian Centre for International Agricultural Research, Canberra, 2005.

- An injection of an estimated $74 million (in current dollar terms) into the Western Australian economy, with almost half of this generated through construction services
- In addition to the local employment opportunities during construction, approximately 200 staff will be required on an ongoing basis to run the facility
- The engineering specifications required for the SKA will drive local innovation and skill development, particularly in high-tech areas that are likely to have broader application in the telecommunications sector.

The prospect of attracting the SKA and the likely benefits has already captured the interest of local industry. An Australian SKA industry cluster has formed, currently with eleven members and with other companies expected to join, and is working to identify opportunities within the SKA project.

(IV) AUSTRALIAN INTERNATIONAL COLLABORATION

Australian science agencies, funding bodies, universities and learned academies engage in extensive international collaboration:

- DEST estimates that there are approximately 4,500 agreements in place between Australian universities and counterparts in around 100 countries – approximately 70 per cent of these agreements make provision for research collaboration
- In 2005 CSIRO reported that is was engaged in 746 activities with international partners from 85 countries. The scale of these activities ranged from multi-million dollar long-term projects to short-term technical consultancies
- The ARC has memoranda of understanding with counterparts in 11 countries and has other agreements in place for collaborative research funding with the US National Science Foundation (NSF) and the UK Economic and Social Research Council. Over half of all grantees funded in 2006 indicated they intended to collaborate with researchers in at least one other country, resulting in almost 1,800 intended collaborations. The ARC also administers the *Linkage – International* programme which provides funding for Australian researchers to participate in research projects with international partners and fellowships for international researchers to be hosted in Australian institutions or for Australian researchers to spend time overseas
- The Australian Academy of Sciences supports Australian scientists to travel overseas through its *International Scientific Collaborations Programme.* Funded by the Australian Government's *International Science Linkages (ISL) Programme*, this initiative gives Australian researchers the opportunity to collaborate with colleagues in North America, Europe and North East Asia.

DEST plays an important role in supporting and facilitating the collaborative activities of Australia's research organisations. DEST's responsibility includes management of bilateral relationships with key science partners, such as the US, the EU, China and India, to remove any government level impediments to collaboration between researchers and identify strategic opportunities. These objectives are achieved through a range of activities such as managing formal inter-governmental agreements, convening bilateral meetings to identify common science priorities and coordinating participation in major science projects.

DEST's activities are supported by a network of international counsellors and locally engaged staff around the globe. Five of these have significant science functions, namely Washington, Beijing, Brussels, Paris and Delhi. These positions play an important role in advancing Australia's priority partnerships, including facilitating dialogue with relevant science agencies, negotiating joint research initiatives and facilitating high level visits to and from those countries. The deployment of counsellor resources is reviewed periodically in response to evolving priorities for global collaboration.

A key component of DEST's support for international collaboration is the ISL Programme: a $94.8 million package funded over ten years to 2010–11 under the BAA. The ISL Programme supports access to strategically focused, leading edge international science and technology through activities such as joint research projects and organising international conferences. Unlike the research funding provided by other Australian Government funding bodies, such as the ARC, ISL funding is not restricted to university based researchers, but extends to government research agencies (AIMS, ANSTO and CSIRO) and the private sector.

The ISL programme comprises three main elements:

- *Competitive Grants* – a bottom-up process which allocates funding based on the merits of proposals received from researchers. This includes a fund open for collaboration with any country and two country-specific bilateral funds with France and China. In the case of the bilateral funds, there is negotiation with the bilateral partner to agree on high ranking projects that best meet mutual research priorities.
- *Strategic Policy* – a top-down process which allows Australia to identify and seed collaborative activity in research areas of strategic importance with countries that the Australian Government and the Australian research community see as priorities for scientific collaboration.
- *Science Academies Programme* (previously known as the International S&T Networks Programme) – which is outsourced to the learned science academies to manage and deliver activities such as researcher exchanges and fellowships, major international conferences and access to major international facilities.

In the 2005–06 financial year the ISL Programme supported 362 collaborative activities across a broad range of areas that included energy, health, medicine the environment and materials science. The majority of these collaborations occurred with China, France, Germany, the UK, the US and the EU. In 2005–06 under the Competitive Grants component, 18 activities were funded to the value of $5,244,433, as well as nine activities under the Australia-China Special Fund for S&T cooperation ($495,699) and 13 activities under the French-Australian Science and Technology Programme ($273,810). Thirty-three activities were funded under the Strategic Policy component in 2005–06 ($1,103,085); and 190 activities under the International S&T Networks Programme ($2,120,000).

Approximately 90 per cent of funded projects were assessed by external panels of experts or by members of the learned science academies. These assessments concluded that all projects were making important contributions to leading-edge science. Further information on the nature of activities supported under the ISL Programme is provided at Appendix 4.

There is substantial evidence that, while the ISL Programme is valued by the Australian science community, it is failing to meet the high demand for funding support for international collaboration. All competitive elements are heavily over-subscribed with application success rates of around 10 per cent being typical. The panels which assess proposals have commented previously that while the applications selected for funding are world-class, such low success rates mean that a significant number of similarly high quality and worthwhile proposals remain unfunded.

Recent Australian Government initiatives have sought to strengthen international collaboration. Earlier this year, the Prime Minister announced the new five-year, $20 million *Australia-India Strategic Research Fund* to support research collaboration between Australian and Indian researchers. The 2006–07 Federal Budget also quadrupled funding provided under the bilateral fund with China.

The Australia-India Strategic Research Fund (AISRF) is a component of *Australian Scholarships* announced by the Hon Julie Bishop MP and the Hon Alexander Downer MP on 26 April 2006.

The AISRF aims to facilitate and support Science and Technology research cooperation between Australia and India. The fund will assist Australian researchers to increase their participation in leading edge scientific research with Indian scientists, to raise the profile of Australian research, and to support the development of strategic alliances between Australian researchers and Indian researchers.

The AISRF provides funding support for Australian researchers to participate in strategically focused, leading edge, scientific research and technology collaborations with India; as well as providing funding for targeted allocations designed to benefit the Australian research community. Further information on the nature of activities supported under the AISRF is provided at Appendix 5.

(V) THE NEED TO STRENGTHEN AUSTRALIA'S INTERNATIONAL ENGAGEMENT

Although DEST's support of international science engagement has been well directed and achieved positive outcomes, the impact has been constrained by limited resources for establishing and supporting collaboration. The high demand for existing funding programmes and the substantial investments being made by other countries, suggest there are opportunities to increase and strengthen Australia's international science and thus increase the economic and social benefits that flow from this collaboration. To better position the Australian science community in capturing these opportunities, a number of issues have been identified:

- *Increased strategic focus* – Because of the limited resources available for supporting collaboration, Australia would benefit from being more strategic about engaging with the international science community. DEST recognises that, with the help of the Australian science community, it needs to identify priorities for international collaboration based on research strengths and the capacity to support national objectives for economic and social development.
- *Increased flexibility in meeting strategic priorities* – There is likely to be substantial benefit in more flexible arrangements for supporting international science collaboration. The size and broad focus of the ISL programme means that DEST has a restricted capacity to respond to opportunities to establish potentially valuable collaborations with emerging partners or emerging areas of interest. For example, the Australian Government had no capacity to respond to recent Singaporean interest in establishing a $5 million fund to 'ramp-up' science and technology collaboration between our countries. A number of other countries have shown interest in collaborating more extensively with Australia, including Argentina, Brazil, Mexico, Taiwan, South Africa, Korea and the EU.
- *Need for greater engagement with key partners* – DEST currently manages joint funds to support cooperative research with China, India and France. However, there are no specific measures maintain and build upon its relationships with important collaborators, such as the US, the UK and the EU. Even though the US is arguably Australia's most import collaborator, in terms of the number of Australian projects it contributes to and its world leadership in important disciplines, DEST has no specific programmes for supporting this relationship.
- *Need for greater participation in international science projects* – The Australian science community has little capacity to engage in major international science projects which have the capacity to leap-frog Australia's progress in important areas of science. Initiatives such as ITER, the SKA and the European Molecular Biology Organisation typically represent multi-national investments of the scale of billion[s] of dollars. Any significant Australian participation in these initiatives would require commitment of substantial funds that is beyond the scope of current programmes.

Some of these issues may be examined in the coming months by a working group of the Prime Minister's Science, Engineering and Innovation Council. This group has been tasked to explore Australia's global science and technology engagement and make recommendations on initiatives to benefit from future opportunities.

4. CONNECTED INDUSTRY AND COMMUNITIES

(I) KNOWLEDGE TRANSFER AND RESEARCH-INDUSTRY LINKAGES

The global move to a knowledge economy requires a focus not only on the way knowledge is produced but on the way it is used. One of the consequences of this development has been a concentration on research commercialisation. The BAA packages of 2001 and 2004 have invested around $8.3 billion over 10 years in Australia's science and innovation system. [57] Approximately one third of that expenditure is targeted at commercialisation, mostly through industry-focused programmes. Commercialisation of publicly funded research is directly or indirectly supported through arrangements within specific programmes, such as through the CRCs, the CSIRO National Flagships, and the ARC Linkage Programmes. In addition, the commercialisation of public sector research can benefit from 'demand-side' support through industry programmes, including the Pre-Seed Funds (which specifically target the early stage venture capital needs of university researchers), Commercial Ready, and COMET (Commercialising Emerging Technologies).

In 2000 the first National Survey of Research Commercialisation (NSRC) gathered data on the commercialisation of intellectual property in Australia's universities, medical research institutes and publicly funded research agencies. The original survey, commissioned by the ARC, CSIRO and the NHMRC, focused on patents, licensing and spin-out formation. The survey for 2001 and 2002, commissioned by DEST, was extended to cover CRCs. The results of the most recent survey – covering 2003 and 2004 – are due for release in late 2006.

The scope of the survey has been broadened in response to the report of the Coordinating Committee on Science and Technology's Working Group on Metrics of Commercialisation (2004), which recommended gathering data on research contracts and consultancies, as well as skills development and transfer. The Working Group also recommended a broadening of the definition of 'research commercialisation' to encompass commercial benefit in the broad sense, not merely the generation of financial returns to the research institution.

This broadening of the data captured on research commercialisation reflects a trend in the evolving policy around linkages between research and industry in Australia. There is a growing recognition that a narrow focus on IP commercialisation, while important in itself, does not reflect the breadth and diversity of relationships between publicly funded research and industry. This was reflected in a DEST-commissioned report by Howard Partners *The Emerging Business of Knowledge Transfer*, published in March 2005. This report demonstrated that there are at least four different modes by which research can be used to the benefit of the wider economy: knowledge diffusion, knowledge production, knowledge relationships and knowledge engagement.

The House of Representatives Standing Committee on Science and Innovation tabled its report on 'Pathways to Technological Innovation' on 19 June 2006. The report makes 18 recommendations aimed at promoting stronger links between research and industry. Notably, the report reflects and articulates the developing understanding of the complex, multi-faceted nature of the pathways by which research and science can be brought to market.

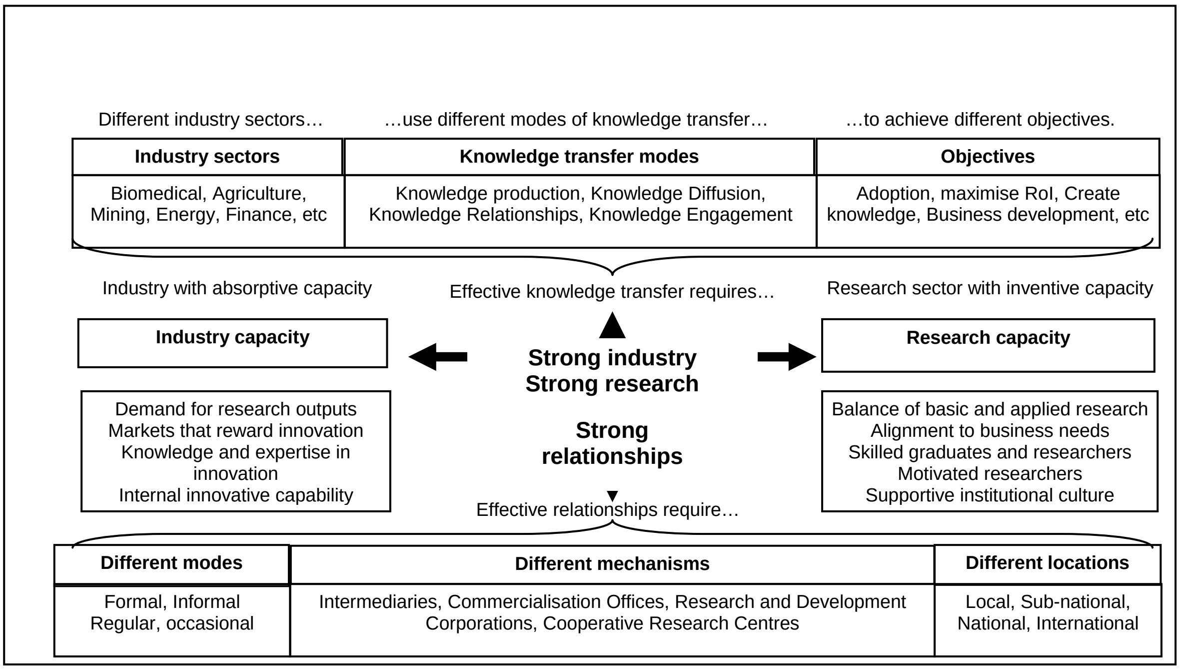
Recognising these developments in the policy debates, a policy framework has been developed to articulate the key issues and points of focus for policy development in this area (see Figure 10 below).

[57] As noted earlier, the BAA packages bring the total investment in science and innovation for the 10-year period to around $52 billion.

The main points to note from the framework are that:

- Both industry and research need to be independently strong and robust for linkages between the two to work
- There is a wide variety of industry sectors that are potentially involved, working through a variety of knowledge transfer modes
- The basis of the entire system is strong and effective relationships that involve two-way communications and interactions and use various modes and mechanisms.

Figure 10: A policy framework for industry-research linkages



Australia's future economic wellbeing will be enhanced by strong links between industry and research, and it is therefore crucial that public policy is able to properly capture the full range of industry/research relationships and assist where there is a well-supported case to do so. There are a number of areas of market failure which may warrant intervention in the broad area of research-industry linkages. These include:

- Information asymmetry between partners in knowledge transactions
- Differences in motivation and need between industry and publicly funded research
- Benefits can be considerably delayed
- Individual businesses cannot capture all the benefits of investment.

A further development in policy around this issue is the growing focus on knowledge transfer. Over the past 12 months or more, there has been a sustained public debate on the question of whether and how knowledge generated through public sector research – especially research carried out in universities – can be used to more fully benefit the Australian community, especially business and industry.

On 16 June 2006 the Hon Ms Julie Bishop MP, Minister for Education, Science and Training, delivered a speech at the Knowledge Transfer and Engagement Forum in Sydney. The Minister indicated a preference for an understanding of knowledge transfer as the process of engaging with business, government or the community to generate, acquire, apply and make accessible knowledge for quantifiable economic benefit for the community. The Minister invited the sector to provide her with a sound economic case for additional funding for knowledge transfer for economic benefit. If any case is to be made for additional funding for knowledge transfer it needs to be:

- Located somewhere midway between the extremes that have tended to emerge from the debate so far (that is, research commercialisation versus public interest community engagement)
- Aimed at economic outcomes, both directly and indirectly through, for example, support for social imperatives such as health and stronger communities that ultimately flow through to the wider economy
- Centred on the practical application of research
- Encompass both original research and the research of others that can be adapted and applied in new and productive ways
- Built on effective two-way relationships between institutions and their stakeholders.

At the forum Minister Bishop also released the report produced for DEST by PhillipsKPA on *Knowledge Transfer and Australian Universities and Publicly Funded Research Agencies.*

Linkages between public sector research and industry occur on a wide range of levels, and in many different ways. Some are more amenable to measurement and data collection than others. In particular, the standard model of commercialisation (patent-license-spin-out company) is more measurable than, say, strategic alliances. Table 12 provides comparative information on research commercialisation in universities.

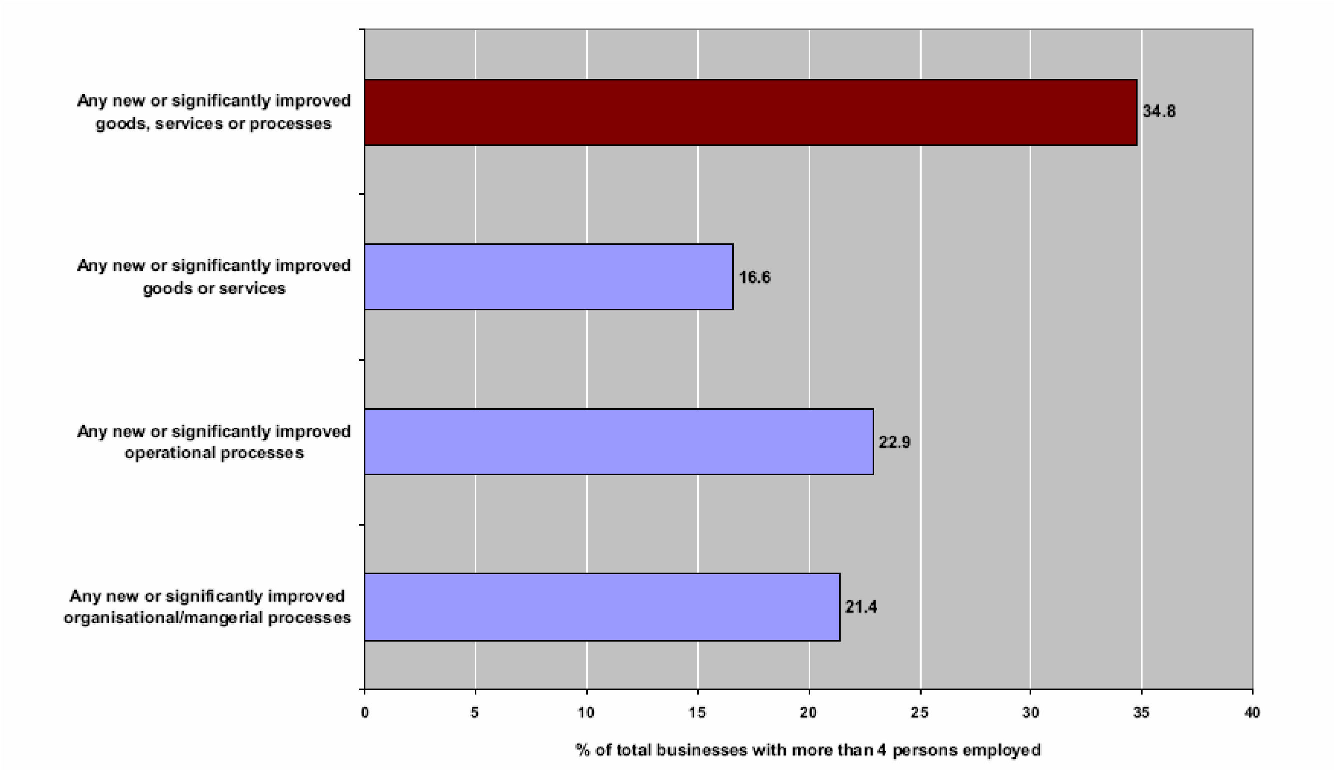
Table 12: Australia's university research commercialisation activities, in comparison with the US and Canada, 2000–2002

	Australia	United States	Canada
		Per US$ billion research expenditure	
2000			
United States patents issued	33	127	105
Licences executed	114	140	223
Adjusted gross income (US$m) from licences	31	42	17
Start-up companies formed	16	14	46
2001			
United States patents issued	10	115	93
Licences executed	85	120	188
Adjusted gross income (US$m) from licences	16	30	25
Start-up companies formed	22	15	40
2002			
United States patents issued	13	98	87
Licences executed	105	118	188
Adjusted gross income (US$m) from licences	16	30	17
Start-up companies formed	21	11	25

Source: DEST, *National survey of research commercialisation – Years 2001 and 2002.*
Note: Canadian figures include some non-university respondents in year 2000.

In industry, there are many different innovative practices, extending well beyond the standard R&D model. Figure 11 below shows the variety of ways that innovative businesses in Australia introduce new goods, services or processes. The point to be drawn from this is that Australian industry needs people, systems and structures that are highly flexible and able to deliver innovative activity across a range of areas. This places particular demands on the Australian education and training system, and on public sector research capacity, which need to be able to deliver the diversity and flexibility demanded by industry.

Figure 11: Innovation in Australian Business, 2001–03



Source: ABS, *Innovation in Australian Business*, 2003

The Business, Industry and Higher Education Collaboration Council (BIHECC) is tasked with fostering greater collaboration between Australian higher education providers, business, industry, and communities, and providing advice to the Government on a range of issues, including knowledge transfer.

In 2005 BIHECC commissioned a Howard Partners report into *Knowledge Exchange Networks in Australia's Innovation System.* The report outlines the networks and organisations that exist in Australia for the exchange and diffusion of knowledge from universities and research institutions to the wider community.

The report identifies a number of impediments at the research-business interface, including a translation gap where outcomes of research are often not instantly adoptable by industry as they may not fit high priority market opportunities and business needs. The report questions the venture capital model which focuses on immediate growth and development and notes the difficulty of raising venture capital and sustaining the investment required to bring discoveries to market. It suggests that knowledge exchange networks provide structured intermediary mechanisms to bridge these gaps, allowing users to locate, exchange and acquire knowledge in a systematic way, expediting the path from discovery to market.

The report concludes that the most effective knowledge exchange networks, in terms of the transfer of knowledge from the creators of knowledge to industry users, are those that are sponsored and supported by industry through industry associations – for example the InnovationXchange supported by the Australian Industry Group and the Department of Industry, Tourism and Resources. According to the report, there are two sectors which provide noteworthy examples of effective knowledge exchange networks between universities and research and development corporations supported by industry and government: the rural animal and plant development sector, and the mining industry.

The report also concludes that knowledge exchange networks based on the transfer of knowledge through the electronic web-based technologies have limited impact without the involvement of people and organisations performing the roles of facilitator and/or broker. The report identified the need to develop a strong skills base in industrial research management and to ensure that there are longer term career opportunities for researchers who work at the academy-industry interface.

Collaboration between industry and higher education is key to addressing Australia's skills shortages and to developing a culture of innovation, engendering a broad understanding of, and support for, the value of innovation, research and development. Continuing reform of the sector could ensure that the structures for collaboration, such as partnerships, alliances and joint ventures, are capable of delivering value for all stakeholders, and at the same time ensuring that core institutional values are preserved, forming a solid foundation for world-class education in Australian higher education institutions.

(II) COOPERATIVE RESEARCH CENTRES

The Cooperative Research Centres (CRC) Programme provides a collaborative model for undertaking high quality research focused on the needs of industry and producing outcomes which contribute to Australia's industrial, commercial and economic growth.

The CRC Programme was established in 1990 to increase collaboration between industry, publicly funded research organisations and universities. It was initially intended that a total of 50 Centres would be funded. Since 1990, 158 CRCs have been funded. In 2005–06, 72 CRCs were in existence. This will fall to 57 in 2006–07 due to CRCs winding up after seven years of funding. The numbers are expected to increase slightly in 2007–08 when the contracts for CRCs selected in the 2006 funding round are finalised.

Relative share of funds

Since the CRC Programme commenced in 1990, over $11 billion in cash and/or in-kind resources has been committed to the Programme, including for CRCs selected in the 2004 round. The source of these resources includes: more than $2.65 billion from the CRC Programme, over $2.89 billion from universities, $2.14 billion from industry, $1.26 billion from the States, $1.19 billion from CSIRO and approximately $0.5 billion from other Australian Government sources.

In the 2004 CRC funding round the Australian Government's CRC Programme provided between $20 million and $40 million over seven years to each of the 14 CRCs selected in that round. The average CRC Programme funding to each CRC was $2.45 million in 2000–01 and $2.78 million in 2004–05.

Generally, the CRCs leverage up to four times this amount in cash and/or in-kind resources from universities, industry, State governments and publicly funded research agencies such as the CSIRO. Table 13 shows that by 2004–05 the programme grant amounted to 20 per cent of total resources available to CRCs.

Table 13: Total contributions to CRCs 2000–01 and 2004–05

Total contributions to CRCs	**2000–01**		**2004–05**	
Number of CRCs	57		69	
	$'000	*%*	*$'000*	*%*
Total CRC programme funds	135,741	23.7	191,670	20.2
Total in-kind contributions (actual)	360,666	64.4	634,145	66.7
Total cash contributions to CRCs (actual)	66,943	11.9	124,362	13.1
Total contributions to CRCs	**563,350**	**100.0**	**950,177**	**100.0**

Source: CRC Aggregate Data, Financial Years, Financial Information Table 1(in-kind contribution) and Table 2 (cash contribution), unpublished and sourced from the CRC Internet System 3 Aug 06

In terms of who contributes to CRCs, Table 14 summarises contributions by participant type. Over the five years since 2000–01 the proportion of industry and university contributions have almost doubled (by 47 per cent and 50 per cent respectively). During the same period, while the amount of CRC Programme funding has increased, its proportion of the total resources has dropped by 14.8 per cent. The proportion of total Australian Government sourced funding has also reduced from around 40 per cent to just over a third.

Table 14: Total contributions to CRCs 2000–01 and 2004–05 by participant type

Total contributions to CRCs	**2000–01**		**2004–05**	
Number of CRCs	57		69	
	$'000	*%*	*$'000*	*%*
CRC Programme funds	135,741	23.7	191,670	20.2
Other Australian government	87,771	15.6	132,761	14.0
State government	65,976	11.7	116,266	12.2
Industry and Industry associations	104,387	18.5	196,589	20.7
Universities	137,483	24.4	274,799	28.9
Other (local gov't, research institute/org's, uncategorised, other)	31,992	5.7	38,092	4.0
Total contributions to CRCs	**563,350**	**100.0**	**950,177**	**100.0**

Source: CRC Aggregate Data, Financial Years, Financial Information Table 1(in-kind contribution) and Table 2 (cash contribution), unpublished and sourced from the CRC Internet System 3 Aug 06

Involvement in CRCs by industry, particularly small and medium enterprises (SMEs), is strongly encouraged and has been growing over recent selection rounds, both in terms of numbers of industry participants and the quantum of their contributions. There are now 1,177 businesses involved in CRCs compared to 988 in 2000–01. Since the programme began in 1991 industry has provided contributions (in cash and/or in-kind) of $2.1 billion. In 2004–05 industry contributions amounted to $196.6 million (see Table 15). This contribution is slightly more than the Commonwealth contributes through the CRC Programme.

Industry contribution in 1995 when the programme was in its infancy was 50 cents for every dollar invested in the CRC Programme by the Commonwealth through CRC Programme funds. By 2000 industry contributions were 78 cents for every dollar invested by the Commonwealth and by 2004–05 it had risen to almost $1.03 for every dollar invested by the Commonwealth.

Table 15: Total industry contributions to CRCs 2000–01 and 2004–05

Total Industry contributions to CRCs	**2000–01**	**2004–05**
Number of CRCs providing data to the Management Data Questionnaire	**53**	**69**
	$'000	*$'000*
Total industry cash(actual)	39,493	68,689
Total industry in-kind (actual)	64,894	127,900
Total Industry contributions to CRCs	104,387	196,589
Total resources available to CRCs	563,350	950,177
Industry contribution as % of total resources	18.53	20.69
Industry contribution as proportion of CRC Programme funds	0.77	1.03

Source: CRC Aggregate Data, Financial Years, Financial Information Table 1(in-kind contribution) and Table 2 (cash contribution), and participant counts (unpublished and sourced from the CRC Internet System 3 Aug 06)

The nature of the collaboration

The CRC Programme encourages critical mass to be brought together in research areas of national importance. The collaborative approach is designed to lead to more significant research results than individual organisations would be able to achieve, acting alone.

The structure of CRCs is a partnership model with both research institutions and businesses involved in the governance and management of the CRCs. In 2004–05 of the 69 CRCs that submitted annual reports, 53 were unincorporated joint ventures and 16 were incorporated CRCs. Since 2004 it has been a requirement of the programme that all new CRCs be set up as incorporated bodies. This business model was felt to be more in keeping with the more commercial focus of the programme, as reflected in its objective:

> *'to enhance Australia's industrial, commercial and economic growth through the development of sustained, user-driven, cooperative public-private research centres that achieve high levels of outcomes in adoption and commercialisation.'*

While there is no restriction on the field of research that may be included in a CRC, every CRC must include at least some research in the natural sciences or engineering. CRCs are supported in six broad sectors: manufacturing technology; information and communication technology; mining and energy; agriculture and rural based manufacturing; environment; and medical sciences and technology. Most CRCs have multiple research locations throughout Australia, with headquarters based in capital cities.

Table 16 provides an indication of the extent of collaboration that is involved in the CRC Programme. Indicators of collaboration include number of projects involving more than one participant, number of businesses involved in the programme and number of international alliances.

Table 16: Indicators of collaborative activity in CRCs

Research collaboration	2000–01	2004–05
No. of CRCs submitting Management Data Questionnaire data (source of this information)	***53***	***69***
No. of research locations	267	854
No. of projects carried out	1,721	2,135
Average no. of projects carried out	32.4	30.9
% of projects involving >1 participant	65%	77%
No. of contributions from State Government departments to CRCs	146	227
No. of contributions from Commonwealth Agencies to CRCs	98	123
No. of contributions from Australian universities to CRCs	225	337
Number of businesses involved		
No. of SMEs involved in the programme	464	679
No. of large businesses involved in the programme	524	498
Total no. of businesses involved in the programme	988	1,177
Total instances of business making cash of in-kind contribution to CRCs	507	605
International alliances		
No. of international commercial alliances	39	112
No. of international research education alliances	557	608

Source: CRC Information: MDQ Data Aggregated by Sector, (unpublished and sourced from the CRC Internet System 5 June 2006). Note: data from 2000–01 may have inaccuracies as it was submitted to the system unverified by the CRC

Success of CRCs in contributing to economic growth

The Allen Consulting Group report has validated the success of the CRC Programme in its study on the economic impact of the programme and has shown that for every dollar invested by the Australian Government in the CRC Programme there has been a $1.60 return on that investment.

Other measures of the success of the CRC Programme include the extent of industry involvement as evidenced by the number of companies involved and the amount of cash and non-cash contributions industry makes to the programme and the extent of the collaboration as discussed earlier.

It is also the case that in each funding round more applications are considered worthy of funding than can be funded within the limits of the CRC Programme funds. For example in the 2004 funding round 20 applications were considered highly competitive, but only 14 were funded.

Further measures of the success of the programme include income earned, commercial outcomes, education and training outcomes, and research outcomes. Achievements of this nature by CRCs in 2004–05 are summarised below drawing on data from Table 17.

- CRCs are earning income – while data is not comprehensive it appears that in 2004–05 CRCs earned approximately $67 million in income from research contracts, licences/options, sales and other agreements as well as from courses and conferences. However this figure is an underestimate as it appears to exclude income from royalties that are distributed to participants directly. Data from spin-offs is also not collected comprehensively – only data from new spin-offs in that year appears to be collected.
- CRCs are producing commercial benefit – in 2004–05, 12 spin-off companies were created, over 600 patents were maintained overseas and 22 new patents were filed overseas.

- CRCs provide education and training opportunities – over 2,000 FTE (full-time equivalent) postgraduate students were doing their studies through a CRC in 2004–05, with over 500 commencing and over 300 postgraduate students gaining employment in industry that year. There were also over 4,550 undergraduate students receiving education and training through CRCs.
- CRCs provide networking and education opportunities for end users – in 2004–05, 235 training courses were conducted and almost 800 conferences run – all aimed at end users.
- CRCs publish their research findings in a variety of ways: in 2004–05 over 3,600 publications were produced for industry including over 1,000 confidential unpublished reports, over 1,300 papers were published in refereed academic journals, 62 books were published and over 2,400 conference papers were published.

Table 17: Achievements of CRCs in 2004–05

Achievements of CRCs	**2004–05**
Commercial outcomes	
External income generated by CRCs	$67.2 m
No. of spin-offs created	12
No. of patents maintained overseas	631
No. of patents filed overseas	22
No. of patents maintained in Australia	286
No. of patents filed in Australia	68
Education outcomes	
No. of FTE post graduate students	2,045.3
No. of commencing post grad students	576
No. of students taking up employment in industry	318
No. of undergraduate students	4,550
Networking/industry professional development	
Training courses for end users	288
Conferences for end users	790
Research outcomes	
No. of publications for industry	2,479
No. of confidential/unpublished reports	1,165
No. of academic papers published	1,363
No. of books published	62
No. of conference papers published	2,427

Source: CRC Information: MDQ Data Aggregated by Sector, (unpublished and sourced from CRC Internet System 5 June 2006).

Life beyond the CRC

The CRC Programme provides funding for up to seven years. A number of CRCs are successful in successive funding rounds and have been funded for two or three rounds. Of the 72 CRCs in existence in 2005–06, 32 were first round CRCs in their first year of funding, 26 were second round CRCs and therefore in their eighth to fourteenth year of funding and 14 CRCs were third round CRCs and in their fifteenth year of funding.

Of those CRCs that wind up, the legacy can include:

- Spin-offs and commercialisation companies which has have been set up by the CRCs continuing in operation.
- Informal research collaborations continuing
- In terms of education if a CRC developed a new course or training programme, this will continue and be administered by a university partner or licensed to others
- IP being transferred to research institutes set up by the industry (for example, wine and water).

One example of a successful spin out that has lived on is provided by Dr Leanna Read, CEO and Managing Director of TGR Biosciences Pty Ltd, who stated recently at an industry seminar that:

- The CRC Programme had generated a major cultural change in bringing research and industry together
- TGR Biosciences (TGR-B) was spun-out from the former CRC for Tissue Growth and Repair in 2001 with equity funding of over $4 million over four years from four of the participants in the CRC (though not all the CRC participants). TGR-B has since raised $3.0 million from venture capitalists and is generating revenue of around $2.1 million a year. The company is planning to raise further equity in 2007 with the intention of listing on the Australian Stock Exchange in 2008.

With the revised focus of the CRC Programme the commercial and economic outcomes which can be attributed to the Programme should remain high. Nevertheless some concerns have been raised that with the refocusing of the Programme long term strategic collaborative proposals that will not generate economic growth are unable to attract funding. While these proposals may be in the national interest, such as reducing health-care costs leading to more healthy Australians, reducing loss through the mitigation of risks or result in a healthier environment, they are unlikely to be competitive.

It has also been argued that the CRC Programme does not adequately recognise the contribution that can be made from collaborations with the creative industries. The Prime Minister's Science, Engineering and Innovation Council report on *The Role of Creativity in the Innovation Economy* suggested that the role of the creative industries and their contributions to the economic growth of Australia be more formally recognised.

5. WORLD-CLASS INFRASTRUCTURE

(I) NATIONAL COLLABORATIVE RESEARCH INFRASTRUCTURE STRATEGY (NCRIS)

The National Research Infrastructure Taskforce (NRIT), which ran from July 2003 to March 2004, identified the need for ongoing investment to ensure access to the level of infrastructure needed to maintain the competitiveness of Australia's science and innovation sectors. It also recommended changes to funding and coordination arrangements to maximise the return from the investment in research infrastructure.

In the 2004 Budget the Government responded to NRIT by announcing the $542 million NCRIS initiative as part of the *Backing Australia's Ability: Building Our Future through Science and Innovation* package.

NCRIS is a significant reform of the Government's arrangements for planning and funding major research infrastructure. A key indicator that infrastructure is 'national' and 'collaborative' in this context is whether it services, and is accessible to, the research community broadly.

The focus of the Strategy is the NCRIS Roadmap; a high-level plan for directing infrastructure funding so as to maximise the quality and impact of Australia's research and innovation system. The Roadmap was developed by the NCRIS Committee[58] during 2005 through expert advice and consultations with the research community, research agencies (including government agencies with research oriented functions), research users and other jurisdictions. The Roadmap identifies 16 priority capabilities that are required to underpin Australian research and innovation over the next decade.

An important feature of NCRIS is that it is not a competitive grants programme. Rather than seeking proposals, the NCRIS Committee has commissioned the development of a coordinated investment plan for each of the priority capabilities. These are being developed by independent expert facilitators under the oversight of the Committee and will form the basis for advising the Government on specific funding allocations later in 2006.

Reform drivers include the increasing cost and complexity of scientific equipment which tends to put leading edge facilities and instruments beyond the financial scope of single institutions (or even countries) and the increasing tendency for leading edge research to be multi-disciplinary, networked and collaborative and the need to provide the appropriate infrastructure to facilitate such activity.

Under NCRIS, leading-edge national research facilities in high priority areas will be built and operated jointly by universities, Publicly Funded Research Agencies, State and Territory governments and the private sector as appropriate, and made accessible to quality researchers wherever they may be based. The priority areas have been identified through an extensive process involving consultation with stakeholders and expert advice.

In most cases the national facilities are to be built up from past investments that will be strategically enhanced in terms of scientific capability and placed in a national framework that enables greater collaboration and access. The NCRIS Committee is expected to provide advice to the Government by the end of 2006 on specific investment proposals in nine priority areas (with several others to follow in 2007).

[58] The NCRIS Committee is an expert standing committee comprised of senior government and external science and innovation policy advisers, including the Chief Scientist, the CEOs of the ARC and NHMRC and the chief scientists of DSTO and Geoscience Australia. Members have been appointed for an initial term of two years (from August 2005 to August 2007).

The NCRIS model is having a significant impact by facilitating greater collaboration and coordination across sectors. However, it does not cover areas of need outside the identified priority areas. Furthermore, it will not address the establishment of landmark infrastructures, which continue to be considered by the Government on a case-by-case basis.

NRIT's findings are consistent with *Mapping Australian Science and Innovation* which found that 'Australia's research infrastructure is under pressure in terms of investment and maintenance and in leveraging access to international research infrastructure in an environment of increasing scale, cost and technical complexity.'

At this early stage in the implementation of NCRIS, no specific outputs data is available. However, there is anecdotal evidence that the implementation phase is having behavioural impacts in the sector in relation to facilitating and encouraging greater collaboration and coordination.

Various output measures are being developed as part of an evaluation strategy for NCRIS, as follows:

Possible output data measure	**Programme objective**
Utilisation of NCRIS funded infrastructure.	Meeting priority research needs; and developing infrastructure that is accessible for meritorious research.
Quality and impact measures for research conducted within NCRIS funded infrastructure.	Producing world-class infrastructure that enables world-class research.
The financial viability of NCRIS funded infrastructure.	Creating sustainable infrastructure through high quality governance and management regimes.
The development of collaborative networks of researchers who use NCRIS funded infrastructure.	Behavioural change in research communities towards more collaborative approaches to: • developing proposals for research infrastructure funding; and • research activity.

There is potential to internationally benchmark NCRIS, or elements of it, against a number of national and transnational programmes with comparable aims in the EU, the UK and North America.

(II) E-RESEARCH

Research is increasingly characterised by national and international collaboration within and across disciplines. There is a growing requirement by researchers to access and share large and diverse data holdings, high speed networks, distributed and high performance computing facilities and remote instruments. Most OECD countries and APEC members are investing heavily in enabling ICT capabilities and in coordination mechanisms. While the benefits of such investments are apparent, progress in many areas does not lend itself to measurement by traditional metrics.

The term 'e-Research' encapsulates research activities that use a spectrum of advanced ICT capabilities and embraces entirely new research methodologies that emerge from increasing access by researchers to ICT infrastructure and services, including those supported through Systemic Infrastructure Initiative and NCRIS investments. Improved access to information and to each other will enable researchers to function more creatively, efficiently and collaboratively across long distances, and disseminate their research outcomes with greater impact. Using e-Research, researchers can work seamlessly from desk-to-desk within and between organisations.

The increasingly intensive use of information and knowledge is driving value creation, productivity, and economic growth more generally throughout the economy. There is a strong symbiotic relationship between e-Research and e-transformation in other sectors, including the delivery of government services, health services, finance and security.

Consequently, there are strong reasons to ensure that Australia participates effectively in e-Research. This will require not only the provision of the necessary physical infrastructure but equally importantly, the necessary coordinating and governance mechanisms, and human capital skills base among researchers and the ICT professionals who collaborate with and support them.

In accordance with its 2004 election promise to implement a coordinated structure for e-Research, the Government established the e-Research Coordinating Committee to provide expert advice about developing Australia's e-Research capacity. The Committee has engaged the interest, knowledge and enthusiasm of stakeholder groups in developing an e-Research policy and implementation agenda which will inform investments in infrastructure, human capital and support services for e-Research.

The e-Research strategic framework will in turn assist Australia to gain maximum return on key Government infrastructure investments made under the BAA initiative.

Within BAA, the $542 million investment in research infrastructure under NCRIS will result in distributed infrastructure capable of supporting significant interactivity by the highly distributed Australian research community. Strategic investments of $246 million under the SII, particularly in relation to the Australian Research and Education Network (AREN), Australian Partnership for Advanced Computing (APAC) and Australian Research Information Infrastructure Committee (ARIIC) projects, are providing the foundations to build Australia's e-Research capability.

(III) INFRASTRUCTURE IN THE HIGHER EDUCATION SECTOR

A challenge for the higher education sector is an ageing infrastructure. Higher education expanded rapidly in the 1970s and 1980s and many universities are now facing rising costs of maintaining ageing infrastructure that should be replaced or redeveloped. Twelve institutions are now substantially above the acceptable threshold of deferred maintenance backlog, some of them far above.

Universities' estimates total $1.2 billion in deferred maintenance, or an average of 5 per cent for all institutions. Deferred maintenance of institutions above the acceptable threshold ranges from a low of $14.3 million (or 4.4 per cent) to a high of $330 million (or 22.2 per cent).

The Australian Government provides capital funding for universities through the Capital Development Pool (CDP) programme. In its current form, the programme primarily supports teaching and learning across all eligible categories including ICT infrastructure and 'bricks and mortar' capital projects.

A number of projects to assist universities in delivering science education and training have been funded through the CDP programme. For example, Edith Cowan University received $8.4 million over 2001-2004 for its Science and Health Building and James Cook University received $9.3 million over 2002–04 for its Health Sciences and Science precinct. In the 2005 CDP application process, a number of science-related projects were allocated CDP funding for 2008:

- The relocation of Curtin University's Department of Applied Chemistry to the Minerals and Chemistry Research and Education Precinct ($5 million)
- Veterinary Science facilities at Charles Sturt University ($2.4 million)
- The Science Building at the University of the Sunshine Coast ($2.0 million)

- The Science and Innovation Learning Centre at Flinders University ($2.1 million, in addition to $1 million allocated for 2007).

Demand for CDP funding far outweighs the funding available. For example, in the 2005 application round the Department received 60 applications for funding totalling $194 million, but only $44.9 million was available for funding.

In response to this, the Government announced in the 2006–07 Budget that additional CDP funding of $95.5 million will be provided over four years to support higher education providers in developing up-to-date infrastructure for teaching and learning in areas that have high infrastructure needs, such as science and engineering. This additional funding will also ensure that the higher education sector's continued ability to produce quality graduates with the skills the economy needs to be internationally competitive.

The Government has also recognised the need for additional capital through specific Budget measures for particular capital projects. Those that will support higher education providers in delivering science education, training and research include:

- A one-off capital grant of $125 million to the Australian National University in 2005–06 for a programme of capital renewal, including the John Curtin School of Medical Research
- $12 million from 2004 to 2006 for veterinary and agricultural science facilities at James Cook University
- $25 million over 2005–2008 for a range of infrastructure projects at the University of Western Sydney, including $2 million to upgrade teaching and research facilities and a Confocal Multiphoton Fluorescence Microscope System.

Continuing reform of the sector could assist to attract students to science courses at all levels and provide the facilities to ensure that they receive a world-class education in Australian higher education institutions.

(IV)MAJOR NATIONAL RESEARCH FACILITIES (MNRF) PROGRAMME

The current MNRF Programme was launched in 2001 as part of the BAA initiative, with over $150 million in funding allocated to 15 facilities over the 5 years from 2001–02 to 2005–06. A previous MNRF Programme operated from 1996 to 2001.

The MNRF Programme aims to provide better access for Australian researchers to world-class specialised research facilities which would not otherwise be available, to increase opportunities for excellence in scientific research and development, and to attract overseas researchers and companies to Australia as well as retain local expertise and talent.

MNRFs are expensive, large equipment items or highly specialised laboratories that are vital for conducting leading-edge research in science, engineering and technology. In some cases, the MNRF grant provides access to overseas equipment (for example, synchrotrons and the Gemini telescope). MNRFs generally involve a consortium approach with contributions from participating organisations in the public and private sectors.

Funding provided under the MNRF Programme was required to be matched by cash and/or in-kind resources from participants in the facility. Programme funding is able to be used to cover some operating costs as well as the cost of the infrastructure itself.

All funds under the Programme were allocated through a one-off competitive process in 2001. The Programme will be superseded by the National Collaborative Research Infrastructure Strategy (NCRIS).

Outcomes from the MNRF Programme include:

- The International Livestock Resources and Information Centre (ILRIC) reported a number of commercialisation activities related to individual software products developed for primary producers such as ILR2, HerdMASTER, MISDI and LabMagic products. ILRIC reported that industry uptake of these products both domestically and internationally has been significant and are well established with users such as breeders, small and large producers, and industry consultants. For example, BREEDPLAN is currently utilised by 45 per cent of the UK market and HerdMASTER is now used in eight countries
- Provisor Pty Ltd developed a strong industry user base for its wine research related services including vineyard variability assessment, small-scale winemaking, fermentation trials and sensory assessment. Provisor has provided services or undertaken research for a range of companies, including small scale wine making services, and is currently undertaking sensory trials and product testing for Zork, a start-up company funded by venture capital to develop a cork alternative
- The Bandwidth Foundry collaborated with Heidelberg Instruments in the development of a new lithographic system for writing submicron-scale patterns. Heidelberg Instruments is a leading global manufacturer of laser photomask systems, as used in the production of photonics components for the telecommunications and consumer electronics industries
- The Australian Phenomics Facility (APF) discovered a new gene that contributes to autoimmune diseases such as type 1 diabetes and lupus. Researchers found that a mutation in the novel gene, which they have named Roquin, causes the body's infection fighters, or T-cells, to attack their own tissue; the realisation opening the way to explore new treatments for people at risk of developing type 1 diabetes.

(V) SYSTEMIC INFRASTRUCTURE INITIATIVE

The Systemic Infrastructure Initiative (SII) was announced by the Government in January 2001 as part of BAA. Over $246 million is being provided over 2002–06 for systemic research infrastructure to support world-class research and research training at Australian universities. Five key areas of need have been identified which will build the enabling infrastructure to support the research effort in Australia:

- A robust communications network
- Distributed high performance computing
- Accessible data and information repositories
- Accessible research facilities and instruments
- Middleware and common technical standards

Two expert committees have been set up to consult with stakeholders and to provide advice on broadband and information infrastructure needs of the higher education sector.

The Australian Research and Education Network Advisory Committee (ARENAC) was established to oversee the development of the Australian Research and Education Network (AREN) as the next generation communications network for universities and the wider research community. Operating as AARNet3 and connecting more than one million end users over 30,000 kms of fibre, AREN is one of the largest, most advanced optic fibre research and education networks in the world. Nationally (illustrated in Figure 12), it connects research and teaching institutions and users from Cairns to Perth and from Darwin to Hobart, including isolated facilities such as radio telescopes. Internationally (illustrated in Figure 13), it connects the east coast of Australia to multiple points of presence on the west coast of the US and the west coast of Australia to Singapore, Frankfurt and on to Europe.

The Australian Research Information Infrastructure Committee (ARIIC) is providing advice on the research information infrastructure needs of the research community, involving the effective management of research information, middleware issues, including storage, access and authentication issues, and common technical standards.

Introducing common legal and technical methods of storing research outputs such as data-sets or papers will enable a greater portion of research to be discovered, accessed and shared. As a result, these methods will enhance the ability of researchers to collaborate across traditional time, geographic and disciplinary borders. Successful work has also been completed to link existing disparate data sets in the health sciences, enabling researchers to examine a large variety of patient symptoms for relationships between risk-factors. The projects have been critical in providing the middleware tools needed to maximise Australia's contribution to global research.

The SII also provides funding for the Australian Partnership for Advanced Computing (APAC) and a range of initiatives to further the development of common approaches to the development of IT systems and software.

Over $236 million has been spent to date on major research infrastructure projects including:

- $55.2 million to support 22 projects for enabling infrastructure around key instruments/ facilities
- $55 million involving 16 Information infrastructure projects
- $84 million involving 18 projects for the AREN
- $29 million for APAC
- $13.2 million on supporting projects, including for common technical standards.

SII will cease at the end of 2006. Several projects being developed build on previous information infrastructure initiatives and provide the underpinning infrastructure for the technical requirements of the implementation of the Research Quality and Accessibility Frameworks.

In addition, further proposals are being considered to enhance aspects of the AREN fibre optic infrastructure, including lighting the second fibre between Adelaide and Perth to support high performance computing and radio astronomy in Western Australia and addressing a small number of gaps in the network in regional areas of Western Victoria, Queensland and Western Australia.

Figure 12: National capacity of AREN

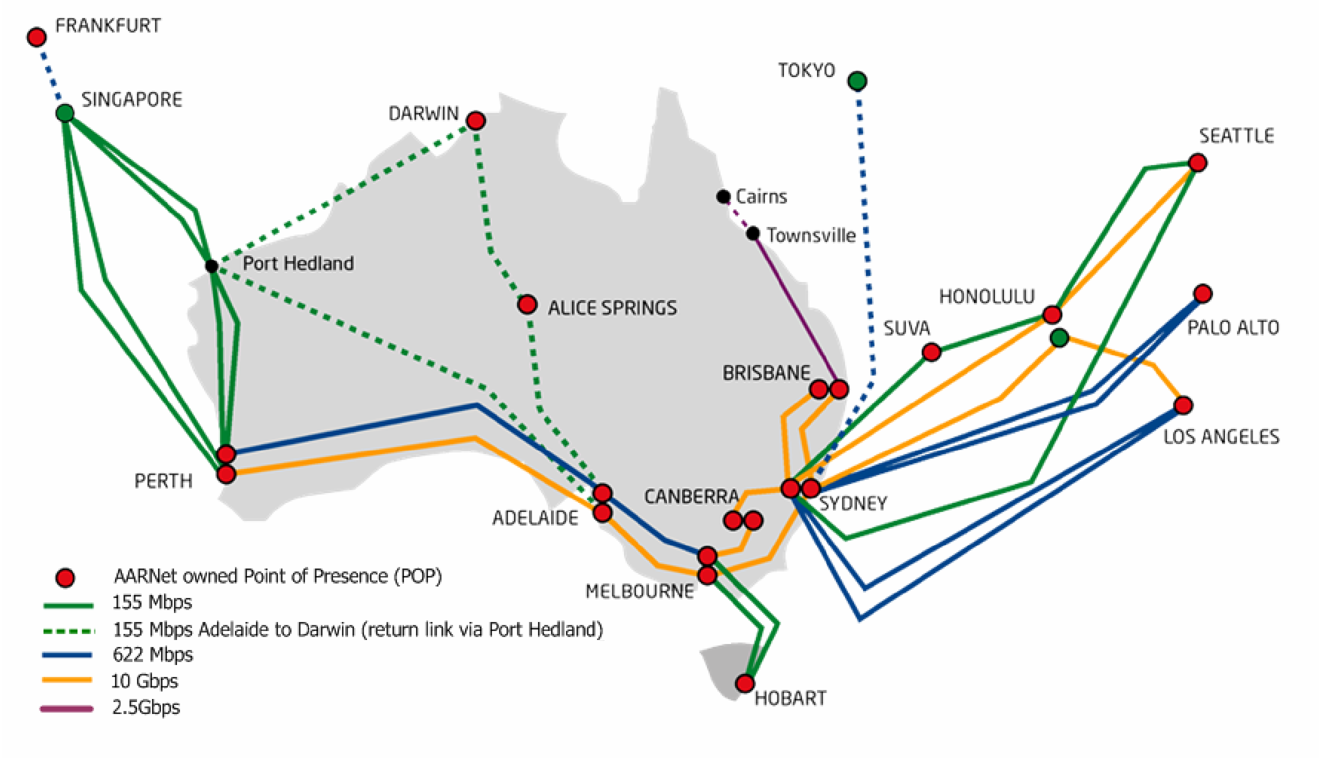
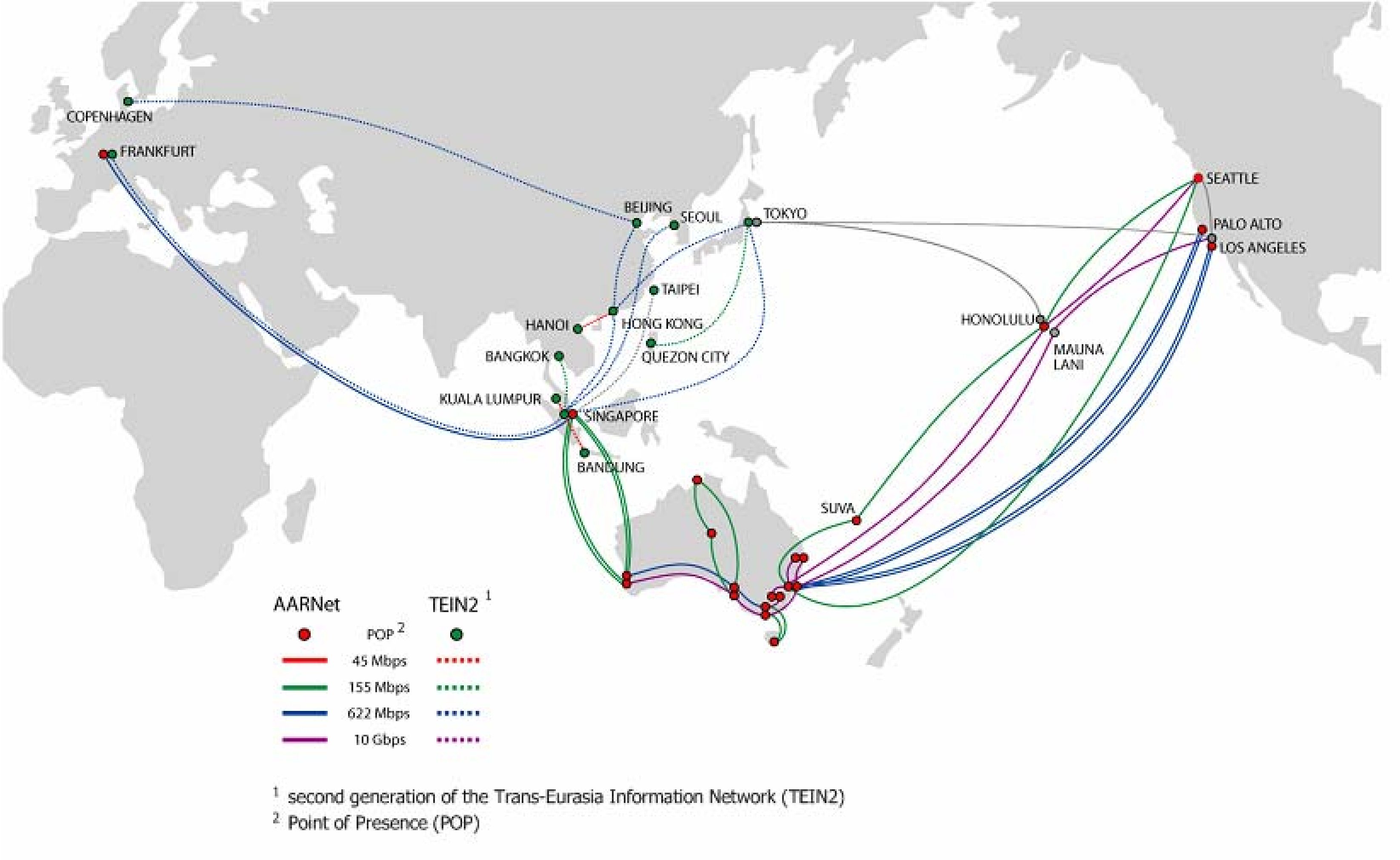


Figure 13: High capacity internationally for AREN on the AARNet3 Network



APPENDIX 1: LEVEL AND NATURE OF GOVERNMENT SUPPORT

There are three interconnected ways in which the Australian Government supports science and innovation. The first is through a variety of foundation policy settings in areas such as economic management, taxation, social policy, and security. These are aimed at creating a conducive environment for investment in and the conduct of research, innovation and commercialisation. The second is through policies and programmes aimed at promoting the skills, knowledge and human capital base in Australia, running from early childhood through to higher education, postgraduate research and lifelong learning. The third is through direct support for the conduct of science and innovation in the public and private sectors. The following is focused on this last element, but the critical links to the other two need to be borne in mind.

In the 2006–07 Budget, Australian Government support for science and innovation, through the budget and special appropriations, total $5.97 billion.[59] This includes an estimated $967.8 million from the Government's $8.3 billion 10-year BAA initiatives, announced in the 2001–02 and 2004–05 Budgets.

Over the past decade, Australian government support for science and innovation achieved an average annual real growth rate of 1.9 per cent. A greater proportion of Australian Government spending has been allocated to supporting science and innovation programmes over the decade, increasing from 2.55 per cent in 1996–97 to 2.72 per cent in 2006–07. However, government spending on science and innovation, relative to GDP, has declined to 0.59 per cent in 2006–07, from 0.68 per cent in 1996–97.

Analysis of the OECD data on government budget appropriations or outlays for R&D (GBAORD) indicates that Australia's government spending on R&D has grown at a moderate rate compared to other OECD countries over the past decade. Its growth rate is faster than the UK, Italy, France, Germany, Netherlands, New Zealand and Switzerland, but lower than others including Japan, the US, Canada, Korea, Finland and Denmark.

Government support for science and innovation comprises four main components: support for major government research agencies, support for R&D and innovation in the business sector, support for research and research training in the higher education sector, and support for science and technology programmes that straddle more than one sector (multi-sector). Each of these components represents a group of government programmes which address the key challenges facing science and innovation in Australia.

Support for major government research agencies

In 2006–07, Australian government support for major government research agencies is expected to be $1,351.7 million. Among the 11 government research agencies receiving the funding, CSIRO continues to have the single largest amount ($607.2 million), followed by Defence Science and Technology Organisation ($340.7 million), Australian Nuclear Science and Technology Organisation ($129.7 million), Geoscience Australia ($113.0 million) and Antarctic Division ($99.7 million). Other smaller agencies will receive a combined total of approximately $61.4 million.

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[59] This figure refers to the total Australian government spending on science and innovation through the Budget and special appropriations, including Australian government spending on its research agencies and the other programmes that have as their immediate and direct objective the enhancement of Australia's science and innovation performance and capability. More detail is available in the Australian Government's 2006–07 Science and Innovation Budget Tables, on which this funding analysis is based.

These research agencies will receive funds in addition to those appropriated directly in the Budget that are not included in the amounts referred to above. Such external funding has increased significantly in recent years. For example, CSIRO receives business funding, funds from earned revenue (from licensing fees, disposal of assets etc.) and additional Australian Government support won competitively via the special purpose grant schemes. In 2006–07, direct appropriations to CSIRO are expected to amount to $607.2 million, but the total income of the organisation is expected to be approximately $970 million.

Partly owing to such a level of funding of the major government research organisations by the Australian government, Australia has now established and sustained a government research sector that is relatively large by international standards. In 2002, Commonwealth and State government research agencies undertook research and development worth 0.33 per cent of GDP, ranking eighth out of the OECD countries, and well above the 0.25 per cent for both the OECD and EU-15 averages. The research and development performed in the Australian Government research agencies concentrate on several key areas of national interest such as defence, the environment, health, economic development and agriculture.

Support for research and research training

Direct Australian Government support for research and research training in the higher education sector is estimated to be $2,234.3 million in 2006–07. Over the past decade, government support for university research and research training has increased by 4 per cent in real terms.

In 2006–07, the largest programmes providing funds for research in the higher education sector will be the National Competitive Grants Programme administered by the Australian Research Council ($570.3 million), and the performance-based block grants administered by the Department of Education, Science and Training ($1,214.3 million). The latter includes the Institutional Grants Scheme ($302 million), Research Training Scheme ($573.9 million), Australian Postgraduate Awards ($95.3 million), International Postgraduate Research Scholarships ($18.8 million), Research Infrastructure Block Grants ($203.9 million), and Systemic Infrastructure Initiative ($17.1 million).

An additional estimated $447.7 million in 2006–07 will support higher education research and research training (which will include funding for the ANU’s Institute of Advanced Studies).

Support for science and technology programmes

The Australian government also provides support for science and technology programmes, comprising a number of research grant schemes and programmes which are directed to specific areas of interest – health and medical research (NHMRC), rural research, energy R&D, and some smaller programmes. The CRCs, established for the purpose of promoting linkages, are also included in this category.

In 2006–07, a total of $1,135.5 million will be provided to science and technology programmes or the so-called special purpose research grant schemes and programmes. The amount includes $437.6 million for NHMRC Research Grants, $189.4 million for Cooperate Research Centres Grants, $221.4 million for Rural Research, $140.6 million for energy and environment R&D, and the remainder for other smaller science and technology programmes.

Total government support for science and technology programmes experienced a slight drop in 2006–07 from the peak of $1,265.0 million in 2005–06 following several years of rapid increases. Over the last decade, Government support for science and technology programmes experienced the highest growth rate among the key components of the Australian Government support for science and innovation. Consequently, its share of the total Government support has risen from 12.7 per cent in 1996–97 to 19.0 per cent in 2006–07. The BAA initiatives have been particularly instrumental in that growth.

Support for business R&D and innovation

Australian Government support for industrial R&D and innovation in the business sector, including both direct support through appropriations and the estimated effects of tax revenue forgone, is expected to be $1,252.5 million in 2006–07. This is a real increase of 9.3 per cent from 2005–06, resulting from an estimated real increase of 2.6 per cent through the industrial R&D tax concession, together with a real increase of 17.8 per cent in direct support for innovation through the Commercial Ready Programme and smaller support measures.

In the 2006–07 Budget, industry R&D Tax Concession is expected to reach $657.0 million, which accounts for just over half of the total support for business R&D and innovation. Given that almost 80 per cent of total support for business R&D and innovation was allocated to the industry R&D Tax Concession in 1996–97, a significant shift is noticeable in the government support for business R&D and innovation toward direct support over the past decade.

Direct support to business R&D and innovation will rise to $595.5 million in 2006–07, an increase of $104.8 million over 2005–06. Among the largest programmes are the Automotive Competitiveness and Investment Scheme ($238.0 million), Commercial Ready Programme ($199.0 million), Pharmaceutical Partnerships Programme ($31.6 million) and ICT Centre of Excellence ($24.0 million). Over the past decade, direct support for business R&D and innovation increased by 17.8 per cent in real terms.

APPENDIX 2: ESTIMATES OF THE RATE OF RETURN TO PUBLIC R&D

Author (s)	Subject	Methodology/ Framework [a,b,c,d]	Annual rate of return[e]
Z Griliches 'Research Costs and Social Returns: Hybrid Corn and Related Innovations', *Journal of Political Economy*, vol. 66, no. 5, 1958, pp. 227–43.	Hybrid corn	Economic surplus approach	21–40%
W Peterson ' Returns to poultry research in the United States' PhD dissertation, University of Chicago, June 1966.	Poultry	Production function approach	21–25%
RE Evenson, 'The contribution of agricultural research and extension to agricultural production', PhD dissertation, University of Chicago.	Aggregate agricultural research	Production function approach	28–47%
A Schmitz and D Seckler, 'Mechanized agriculture and social welfare: The case of the tomato harvester' *American Journal of Agricultural Economics*, vol. 52, 1970, pp. 569–77.	Tomato harvester	Economic surplus approach	16–46%
PL Cline, 'Sources of Productivity Change in United States Agriculture' PhD dissertation, Oklahoma State University, 1975.	Aggregate agricultural research	Production function approach	41–50%
M Knutson and LG Tweeten 'Toward an optimal rate of growth in agricultural production research and extension' *American Journal of Agricultural Economics* vol. 61,1979, pp. 70–76.	Aggregate agricultural research	Production function approach	28–47%
JS Davis 'Stability of the research production coefficient for US agriculture', PhD dissertation, University of Minnesota 1979.	Aggregate agricultural research	Production function approach	37%
E Mansfield, 'Basic research and productivity increase in manufacturing' *American Economic Review*, vol. 70, no. 5 (December), 1980, pp. 863–73.	Industrial R&D	Total factor productivity approach	12%
JS Davis and W Peterson 'The Declining Productivity of Agricultural Research' in *Evaluation of Agricultural Research* GW Norton, WL Fishel, AA Paulsen and WB Sundquist, eds Miscellaneous Publication 8 Minnesota agricultural Experiment Station, University of Minnesota, 1981.	Aggregate agricultural research	Production function approach	37%
GM Scobie and WM Eveleens 'Agricultural Research: What's it Worth?', *Proceedings of the 38th Ruakura Farmers' Conference, Hamilton*, Ministry of Agriculture and Fisheries, 1986, pp. 87–92.	Aggregate agricultural research (New Zealand)	Total factor productivity approach	30%
E Mansfield, 'Academic research and industrial innovation' *Research Policy* 20 1991, 1–12.	All academic science research	Return on investment approach	28%
WE Huffman and RE Evenson, *Science for Agriculture: A Longterm Perspective*, Iowa State University Press, Ames 1993.	Aggregate agricultural research	Production function approach	43–67%
J Mullen and T Cox, 'The returns from research in Australian broadacre agriculture', *Australian Journal of Agricultural Economics*, vol. 39, no 2, 1995, pp 105–28.	Agricultural research: broadacre (Australia)	Total factor productivity approach	50–328% [f]
I Cockburn and R Henderson, *Public-Private Interaction and the Productivity of Pharmaceutical Research*, NBER Working Papers 6018, National Bureau of Economic Research Inc., 1999.	Pharmaceuticals	N/A – study presents a literature review	30%+

Source: Adapted from as yet unpublished work by Econtech.

Notes:

a) The economic surplus approach evaluates yield of productivity changes that can be attributed to research. Productivity changes are interpreted as shifts in the supply function.

b) The production function approach relies on the estimation of production functions that contain R&D expenditures as an explanatory variable.

c) The total factor productivity approach is a variant of the production function approach where instead of relating R&D to output, R&D is related to the growth in total factor productivity (TFP).

d) The return on investment approach estimates the rate or return that makes the discounted flow of costs and social benefits of R&D add up to zero.

e) Figures in this table are average values.

f) Evaluated at 1998 values.

APPENDIX 3: SCIENCE AWARENESS PROGRAMMES

Science Connections Programme

National Science Week: The nation's major celebration of science, engineering and innovation involving community-based projects and activities by science centres, universities, science personalities, professional organisations and schools.

The Prime Minister's Prizes for Science: These five prizes recognise and publicly celebrate the achievements of Australia's best and most promising scientists and science teachers.

Eureka Prizes for science communication: In partnership with the Australian Museum, the administrator of the Eureka Prizes, the Australian Government sponsors three annual Eureka Prizes for science communication, the Prizes for Science Journalism, for Promoting Understanding of Science and for Environmental Journalism.

The ABC Science Project: Through its flagship website 'The Lab' the ABC delivers high quality on-line material – programmes, news features and teaching resources on science, technology and innovation. Major DEST-funded elements include 'The ExperiMentals', a series of science shows that model science-based careers ('Why is it So?', Ace Day Jobs and Catapult), and science outreach activity such as Café Scientific.

The Science and Engineering Challenge: This interschool competition designed and implemented by the University of Newcastle is rapidly growing into one of Australia's most significant measures in generating student interest in applied science, through participation in hands-on activities including the building of siege catapults, balsa bridges and flying dirigibles. In 2005 over 300 schools and 10,000 Year 9–10 students participated in the Science and Engineering Challenge.

EngQuest: This hands-on set of activities is designed by Engineers Australia for distribution to primary schools nationally. An important outcome is the engagement of members of Engineers Australia with primary schools. Combined with comprehensive resources and teacher support, EngQuest is designed for primary school teachers across Australia to use in conjunction with the curriculum or as a stand-alone activity.

The Australian Science and Mathematics Olympiads: The Science and Mathematics Olympiads are national high-quality examination and extension programmes for gifted high school students who wish to participate as members of Australian teams in International Olympiads in Physics, Chemistry, Biology, Mathematics and Informatics. Each year, the Olympiads programme selects up to 30 students for participation in Olympiad teams.

Questacon

Shell Questacon Science Circus: The Shell Questacon Science Circus is staffed by scholars from the Australian National University completing a Diploma in Scientific Communication. Specialised training allows staff to present exciting science shows in schools and deliver professional development workshops for teachers. The local community also benefits from a Science Circus visit, when the team sets up a portable science centre complete with interactive science exhibits, performances and science shop.

Questacon Smart Moves: Questacon Smart Moves travels to regional secondary schools throughout Australia presenting multi-media presentations of cutting-edge science, technology and business. Smart Moves presenters give students an interactive, humorous and high energy look at Australian innovation and the science and technology career opportunities of the future. The shows are fast paced and carefully designed to capture the imagination of teenagers. The programme's website allows students and teachers to become involved in programmes, competitions and events and to explore a number of science and innovation-related careers.

Smart Moves began in July 2001 with funding of $3.7 million. In 2004, a further $11.4 million was allocated to Smart Moves over seven years under BAA. Smart Moves is unique in its content and distribution and has been seen by nearly 300,000 secondary students throughout rural and regional Australia since its inception in 2002.

Questacon Smart Moves Invention Convention: The Questacon Smart Moves Invention Convention promotes inventiveness in young people. Each year 30 young people, ranging from 14 to 18 years of age, from rural and regional Australia, come to Canberra for a week of business mentoring and networking. Participants hear from guest lecturers from both science and business and learn about money management, marketing and intellectual property. Mentors and online resources are available to delegates to provide support and networks beyond the Convention.

Questacon ScienceLines: Since 1988 Questacon has delivered presentations and workshops to remote Indigenous communities through Outreach programmes. It includes Questacon ScienceLines, and Together Online, which allows three Indigenous communities to share Indigenous knowledge and culture via the internet. The programme also participates in Croc Festivals, specialised programmes for remote and isolated Indigenous communities, as well as the *Burra Gathering – Sharing Indigenous Knowledge* online experience.

Tenix Questacon Maths Squad: The Tenix Questacon Maths Squad presents mathematics as a way of thinking, rather than just numbers. Two presenters visit schools all over Australia, delivering interactive presentations and workshops to students and teachers. Students learn to devise solutions to a range of problems through stimulating puzzles and engaging stories and to recognise that maths plays an important role in everyday life. The programme is suitable for students in Kindergarten through to Year 12. The Tenix Questacon Maths Squad also offers professional development sessions for teachers of all grades.

Questacon Science Squad: The Questacon Science Squad operates in Sydney and is staffed by professional science communicators. Using lively presentations and demonstrations, each show aims to inspire students and to encourage a positive interest in science. Shows are available from kindergarten level through to secondary school levels. Visits are supported by online educational material that relates to the NSW Board of Studies' Science Syllabus. The Science Squad also presents at public exhibitions, demonstrating and providing workshops to the general public.

Mini-Q (Years 0 to 6): Mini-Q is an accessible community-wide resource that supports learning and development of younger children, introducing them to a stimulating and tactile environment while teaching them coordination and confidence in relaxed and safe surroundings. Mini-Q's environment for babies, toddlers, pre-schoolers and school-aged children was designed with advice from early childhood educators. Mini-Q features seven spaces featuring different sets of activities designed for both individual and team play.

CSIRO outreach and education

SCOPE/Totally Wild: SCOPE, a joint initiative between CSIRO and Network Ten, was launched in September 2005 and is a fast-moving, half-hour science television programme for students aged 10–15 years. It screens at 4.00pm each Monday and has a viewing audience of over 400,000. CSIRO has had a close relationship with Network Ten extending over 12 years. This partnership has previously created entertaining and informative science on television for young people through the popular Totally Wild programme.

CSIRO Discovery: CSIRO Discovery opened to the public in August 2000 and offers an interactive journey through CSIRO and Australian science history. It is one of the national capital's major attractions. During 2005, 18,502 school students visited CSIRO Discovery and participated in a school programme and 1,708 teachers and family members accompanied these students.

CSIRO Science Education Centres (CSIROSECS): The CSIROSECS provide interactive, curriculum-linked science education programmes to schools throughout their region. Nine CSIROSECs operate around Australia, in each capital city plus Townsville. Over 330,000 students, teachers and other visitors come to CSIROSECs, or are visited at schools by CSIROSEC staff each year through an extensive travelling programme. This ‘Lab on Legs’ uses 25 vehicles to travel across the length and breadth of Australia.

CREST: CREativity in Science and Technology (CREST) students undertake real-life open-ended science and technology research projects. CSIRO’s CREST Awards programme is open to all primary and secondary students, covers both science and technology areas of the curriculum, is non-competitive and allows students to pursue a topic of interest to them. More than 6,000 Australian students achieve CSIRO CREST Awards each year.

Student Research Scheme and Teacher Research Scheme: The Student Research Scheme and Teacher Research Scheme provide opportunities for senior secondary science students and science teachers to undertake a research project with a scientist. Each year, the Scheme involves 400 students working with scientists from over 150 research institutions. Evaluations indicate that most participants are influenced towards science careers and/or the institution where they will study.

Double Helix Science Club: Since 1986 CSIRO’s Double Helix Science Club has provided young Australians with an effective mechanism to have fun while learning about science. The Club currently has over 17,000 members and is open to anyone of any age, anywhere in the world. Club members receive a science magazine every two months (either Scientriffic or The Helix), invitations to member events, the Science by Email newsletter, and various discounts and special offers. Research indicates that 80 per cent of members had a higher regard for the value of scientific research as a result of belonging to the Club.

The Helix and Scientriffic magazines: *The Helix*, written to appeal to ages 10 and up, is one of the magazines of CSIRO's Double Helix Science Club. Established in 1999, *Scientriffic* magazine for ages 7+ contains science news, feature stories, hands-on experiments, competitions and brain-bending puzzles every two months.

Science by Email: Science by Email is a free email newsletter that has proven to be extremely popular with members of CSIRO's Double Helix Science Club, teachers and anyone with an interest in science. 19,000 subscribers receive this email weekly. It is produced by CSIRO in partnership with 'mecu' credit union and the Australian Greenhouse Office. Surveys of readers have indicated extremely strong support, particularly amongst teachers, who make up approximately one third of the subscribers and advise that they use it regularly in the classroom.

APPENDIX 4: INTERNATIONAL SCIENCE LINKAGES PROGRAMME

International Science Linkages – inputs

ISL COMPONENT	OBJECTIVES	INPUTS	ACTIVITIES SUPPORTED
1. COMPETITIVE FUNDING Support is provided on a competitive basis for strategically focused, researcher-initiated, international and bilateral science and technology collaborations. Applications are assessed and merit ranked against specific assessment criteria by an independent Assessment Panel appointed by the Minister responsible for science.			
1 (a) Competitive Grants	Provides support for Australian researchers to participate in leading edge, international scientific research and technology collaborations.	Funding for Competitive Grants is made on a competitive basis against specific criteria. Applications are assessed by an independent assessment panel. The Minister responsible for science decides on the successful applications. There are currently two application rounds held each financial year with funding of approximately $3 million per round.	– Participation in collaborative scientific research projects (including collaboration on European Union Framework Programme projects); – major international conferences held in Australia; – showcasing; and – strategic planning activities.
1 (b) Australia-China Special Fund for S&T Cooperation (Australia-China Fund)	Supports Australian participation in bilateral collaborative scientific and technological research projects which draw on the complementary strengths of researchers from Australia and China.	The Australia-China Fund is administered jointly with the government of China. Applications are assessed on a competitive basis against specific criteria by an independent assessment panel The Australia-China Joint Science and Technology Commission Working Group decides on the successful applications. Funding of $250,000 per financial year was provided 2001–02 and 2002–03; $500,000 per financial year 2004–05 and 2005–06; and $2 million per financial year will be provided from 2006–07 to 2009–10. Generally, one round is held each financial year.	– Projects that build productive alliances, enhance opportunities for Australian and Chinese products and expertise, and create opportunities for researchers in both countries; – International networking activities; and – showcasing Australia's science and technology capabilities.
1 (c) French-Australian Science and Technology Programme (FAST)	Supports Australian participation in bilateral collaborative scientific and technological research projects which draw on the complementary strengths of researchers from Australia and France.	FAST is administered jointly with the government of France. Australia and France jointly call for applications and select projects for funding. Australian applications are assessed on a competitive basis against specific criteria by an independent assessment panel. The Australia-France Joint Steering Committee selects projects to be funded based on a merit ranking. One round is held each financial year with funding provided of $250,000 per round.	– Joint collaborative research projects; and – small strategically focused workshops.

2. STRATEGIC POLICY	Promotes effective research collaboration by providing a vehicle for the Australian Government to establish, reinforce and leverage strategic links and relationships with overseas counterparts. Strategic Policy enables the Australian Government to support international scientific cooperation in priority areas of science with key countries.	Funding of $1.13 million per financial year.	– Bilateral activities with priority countries; – Australian participation in key multilateral international activities, such as under the auspices of the Organisation for Economic Co-operation and Development (OECD) and Asia-Pacific Economic Cooperation (APEC); – Other strategic activities that meet the objectives of the ISL programme.
3. INTERNATIONAL SCIENCE AND TECHNOLOGY NETWORKS	Provides targeted support for specific activities using the networks and expertise of the Australian Academy of Science (AAS), the Australian Academy of Technological Sciences and Engineering (AATSE), the Australian Nuclear Science and Technology Organisation (ANSTO) and the University of Sydney, representing the Australian Institute of High Energy Physics (AUSHEP).	Funding of $8.362 million allocated over four years to 2005–06.	Exchanges and fellowships, missions and workshops, access to major research facilities, access to high energy research facilities and international conferences.
3 (a) International exchanges and fellowships		Delivered by the Australian Academy of Science. Funding of $3.26 million over four years to 2005–06.	Fellowships and exchanges with Europe, North America and North East Asia.
3 (b) Frontiers of S&T missions and workshops		Delivered by the Australian Academy of Technological Sciences and Engineering. Funding of $1.742 million over four years to 2005–06.	Targeted scientific and technological missions and workshops with key economies to promote S&T collaboration.
3 (c) Access to major research facilities		Delivered by Australian Nuclear Science and Technology Organisation. Funding of $2.56 million over four years to 2005–06	Australian scientists' visits to world leading facilities not available in Australia.
3 (d) Access to high energy research facilities		Delivered by the University of Sydney (representing The Australian Institute for High Energy Physics). Administered ISL support of $800,000 over four years to 2005–06.	Involvement of Australian high energy physicists in a number of international collaborative experiments.
The Sir Mark Oliphant International Frontiers of S&T Conferences		Has provided financial support of up to $100,000 per conference. Normally two conferences are supported each financial year.	Strategically significant international conferences in Australia on high priority, cutting edge, multi-disciplinary themes.

APPENDIX 5: AUSTRALIA-INDIA STRATEGIC RESEARCH FUND (AISRF)

AISRF – inputs

AISRF COMPONENT	OBJECTIVES	INPUTS	ACTIVITIES SUPPORTED
1. COMPETITIVE FUNDING Support is provided on a competitive basis for strategically focused, researcher-initiated, bilateral science and technology research activities and workshops. Applications are assessed against specific assessment criteria through a peer review process overseen by an independent Advisory Panel appointed by the Minister responsible for science.			
1 (a) Indo-Australian S&T Fund	Provides support on a competitive basis for collaborative research activities in all fields of science and technology (other than biotechnology) through projects that build productive alliances, enhance opportunities for Australian and Indian expertise, and create opportunities for researchers in both countries. Funding for collaborative biotechnology projects is available through the *Indo-Australian Biotechnology Fund.*	Administered jointly with the Indian Department of Science and Technology. Funding decisions for Indo-Australia S&T Fund projects are made on a competitive basis. Applications are assessed against specific assessment criteria through a peer review process overseen by an independent Advisory Panel. Successful projects are bilaterally decided at annual Australia-India Joint Science and Technology Committee meetings. The inaugural application round will be open for a two-month period from 25 September 2006. $6 million is available over a five-year period.	– The Indo-Australian S&T Fund provides funding support for collaborative research activities and workshops.
1 (b) Indo-Australian Biotechnology Fund	Provides support, on a competitive basis, for collaborative activities in fields of biotechnology through projects that build productive alliances, enhance opportunities for Australian and Indian expertise, and create opportunities for researchers in both countries.	Administered jointly with the Indian Department of Biotechnology. Funding decisions for Indo-Australia Biotechnology Fund projects are made on a competitive basis. Applications are assessed against specific assessment criteria through a peer review process overseen by an independent Advisory Panel. Successful projects are bilaterally decided at annual Australia-India Joint Biotechnology Committee meetings. The inaugural application round will be open for a two-month period from 25 September 2006. $6 million is available over a five-year period.	– The Indo-Australian Biotechnology Fund provides funding support for collaborative research activities and workshops.

2. TARGETED ALLOCATIONS	The Targeted Allocations component of the AISRF promotes effective research collaboration by providing a vehicle for the Australian Government to establish, reinforce and leverage strategic links and relationships with Indian counterparts. The Department may consult with the Australian research community, industry and government to identify activities that will be likely to best meet the objectives of the AISRF. Targeted Allocations are not open to application and there is no formal call for proposals.	$8 million is available over a five-year period. The Minister responsible for science will decide on the successful activities.	– Targeted Allocations enables the Australian Government to support scientific cooperation with India in strategic activities that meet the objectives of the AISRF.