Australian science in a changing world: innovation requires global engagement

Position paper

November 2011

Australian Academy of Science

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"Part of Australia continuing to succeed in the rapidly evolving world of science and technology is looking beyond our borders to work cooperatively with colleagues overseas.

Increasing our overseas linkages allows Australians to augment their knowledge and skills to help make Australia even more competitive on the world stage."

Professor Brian P Schmidt FAA
Joint winner 2011 Nobel Prize in Physics

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1 Executive Summary

Driven by science, the world in 2011 is changing fast. A decade into the 'Asian Century', Australia increasingly seeks to improve its links with its Asian neighbors, while maintaining and strengthening links with North America and Europe. Since the beginning of the 21st century, global investment on R&D has almost doubled,[1] speeding up the pace of change itself.

Australia cannot undertake science in isolation. Australian scientists are in demand worldwide, and Australia is also a key destination for scientists from other countries. If we do not compete on the world stage, we will lose scientists and ideas to other countries and forgo the opportunity to work here with the best and brightest from elsewhere and forgo the economic benefits that follow from R&D.

The global scientific landscape is rapidly developing, with the balance of power moving East and South. Australia has a closing window of opportunity to build on its high-quality research and strong links with traditional scientific powers, to connect to other established and emerging powers in Asia and elsewhere. This effort will be central to our competitiveness in the 21st century. This engagement window will not remain open for long.

As Australia enjoys the proceeds of a mining boom, our major partner economies in Asia are in the middle of a science and innovation boom. The OECD reports that China's investment in R&D alone accounted for 13% of the OECD total in 2008, up from 5% in 2001.[2] This rapid growth shows no signs of slowing, and other countries including India, South Korea, Singapore and Malaysia all show stronger R&D growth than Europe, North America and Japan. Our future engagement with these economies will require the ability to link in with their science and innovation establishments.

Other countries are responding to this change with deliberate action. The Australian Government's main program for supporting strategic international science collaboration was terminated in June, 2011. In light of these global scientific trends and the relevance of science and technology to shaping our future, reconsideration of our international engagement is urgently required. Australia has a unique opportunity, as both a Western and an Asian nation, to participate strategically in global science and innovation.

The big challenges and opportunities for Australia in the 21st century – social, economic and environmental – are global, requiring coordination and integration across scales and disciplines. Australian science and innovation can continue to play an influential role, but will increasingly need to be coordinated with and be cognisant of the efforts of others. This will require investment now by the Australian Government for the future.

The Australian Academy of Science's recommendations for Australia's future engagement in international science are set out below. A new program of $250 million over 10 years represents 0.25% of the Australian Government's total investment in science, research and innovation over the decade. This strategic investment would provide a crucial multiplier effect in terms of benefits gained through effective and ongoing access to the 97–98% of new knowledge that is produced outside Australia.

The Academy's 2010 position paper, *Internationalisation of Australian Science,* demonstrated that funding for strategic international collaboration provided a rate of return of between six and seven to one. When longer-term commercial outcomes and the attraction of international funding were taken into account, this leverage factor increased to 21. These multipliers are not, however, simple commercial functions but rather reflect financial value adding pursuant to national research priorities.

This report seeks to re-start and contribute to national debate about what Australia must do to ensure that it can maintain its links with leading international science, and continue to maximise economic and social benefits for the nation from these global networks. Delayed action now will limit our ability to make effective and efficient decisions in the future. This is the critical decade for Australia's links to the emerging world of the 21st century.

2 Summary of Recommendations

The Australian Academy of Science recommends that the Australian Government acts immediately to invest for the future in the internationalisation of science and innovation.

A new program of $250 million over 10 years should be established to complement, coordinate and optimise the government's significant existing investments in science and innovation. This would comprise the following ten actions, tailored to specific identified gaps and opportunities:

Improved competitiveness ($150 million over 10 years)

1. A program for early to mid-career researchers to establish partnerships with international leaders in their field, building the networks Australia needs for future innovation.
2. Collaborative innovation projects to deliver industry and economic benefit for Australia through research links with overseas companies and capabilities.
3. Strategic partnerships determined by existing Australian Government priorities and cooperation agreements, supplementing and aligned with existing bilateral strategic partnership funds for India and China.

Improved awareness ($50 million over 10 years)

4. An annual 'Global science and innovation watch' report to provide an evidence base to inform decisions by policy-makers and across the science sector.
5. An expanded network of Science and Innovation Counsellors and Attachés in Australian embassies in priority countries and regions around the world.
6. A prestigious new program for 'Australian Science and Innovation Special Envoys' – leading researchers and business people promoting Australian science around the world.

Improved governance ($10 million over 10 years)

7. A new national advisory board for international science collaboration, chaired by the Chief Scientist, to provide coordination and guide investment across all areas of government and the broader Australian science and innovation community.

Improved diplomacy ($40 million over 10 years)

8. Targeted programs to provide scientific support to assist Australian foreign and aid policy objectives, including capacity-building programs between Learned Academies in Asia, particularly in support of school science education in developing countries.
9. Lead the creation of a new Asia-Pacific science and innovation community.
10. Lead the creation of a Commonwealth science secretariat as an adjunct to the Commonwealth Heads of Government Meeting (CHOGM).

3 Introduction: the changing global scientific landscape

The Australian Government's 2009 innovation policy agenda *Powering Ideas: An Innovation Agenda for the 21st Century* explicitly recognises the importance of supporting both excellent Australian science and enhanced links to the rest of the world. Australia enjoys strong collaborative ties to traditional scientific powers in North America and Europe, but we must now maintain and build on these for the future. In announcing the development of a whole-of-government White Paper on *Australia in the Asian Century* in September 2011, Prime Minister Julia Gillard stated clearly that Australia must adjust its traditional thinking to deal with the "profound rebalancing" underway, to ensure that Australia "can stand strongly in our changing region".

Nothing is more important to future economic and social choice for Australia than an investment in accessing the best knowledge and applying it to realising the Asian opportunity and Australia's potential. Australia's commitment to high-quality science and research is one element of this investment for the future. An equally critical element is ongoing investment in Australia's links to the global scientific frontiers that enable the nation's researchers and innovators to contribute to, shape and access the best knowledge available around the world, and then apply it in the national interest.

This report builds on the 2010 Australian Academy of Science position paper, *Internationalisation of Australian Science*[3] that addressed the challenges arising from, and the opportunities for participating in, the continuing internationalisation of science and innovation.

Since then, the importance of international engagement in science has not diminished – in fact, its contributions to new knowledge, to our ability to understand and address major global problems, and to economic productivity and competitiveness through innovation, are more important than ever. Moreover, the internationalisation of the science and innovation system has continued, with attendant changes in the balance and patterns of activity and collaboration. The General Electric 2011 Global Innovation Barometer[4] suggests that 40% of all innovation in the next decade will be driven by collaboration across institutional and national boundaries.

The global scientific landscape is changing, and the pace of change is itself accelerating. Globally, the scientific centre of gravity is moving East and South. Even within regions, these changes are profound. In August 2010, China overtook Japan to become the world's second largest economy. China now produces more scientific publications than any other country except the United States. A 2011 analysis by the UK Royal Society shows that the Chinese Academy of Sciences has become "the world's most prolific publishing research organisation" as well as being the home of scientists and infrastructure of increasing quality.[5]

While the impact of the global financial crisis is yet to become clear in international research and development (R&D) statistics, experts around the world agree that the broader global shifts in science and innovation will continue. United Nations Educational, Scientific and Cultural Organization (UNESCO) data shows that, in terms of their share of total global expenditure on R&D, publications and patents (per global GDP), the Americas and Europe are declining, Africa and Oceania are flat, and Asia is rising.[6] The OECD expects global R&D to continue to grow steadily following a brief dip after the financial crisis, "driven by growth in Asia and China in particular".[7] The UNESCO report concludes that "one would expect [Asia] to become the dominant scientific continent in the coming years".

This has the potential to be of great advantage to Australia, but capturing the benefits will require urgent and sustained commitment. As the global science and innovation effort grows and moves, Australia's relative share will shrink, even if domestic investment in R&D continues to increase in absolute terms as it has over the last decade. Depending on the measure used, Australian science has in the past accounted for 2 – 3% of global totals. Because of its high quality and commitment to maintaining international links, Australia has enjoyed strong ties to the remaining 97 – 98% of new knowledge produced elsewhere. But as the global balance of scientific power shifts according to competitive forces, even our existing ties cannot be taken for granted.

Enhanced strategic ties to the knowledge produced elsewhere are essential in order to capture benefits and advantages for Australia. For example, analysis of recent Australian participation in European Union Framework Programme activities has shown that it gives Australia access to research output worth at least 30 times the costs incurred in Australia to fund such collaboration. Funding such collaboration requires commitment beyond individual researchers or research grants. Without this investment, Australia would have to invest 30 times as much domestically to be able to access the same data and findings.

Appendix 1 provides further detail on Australia's scientific performance and standing in international terms. There is clear evidence that, for its size, Australia produces high numbers of world-leading scientific publications and remains above the global average in terms of international scientific collaboration. Over the last 20 years, Australian scientists have built connections with leading research institutions in countries such as China and Singapore while retaining their crucial links with the world's best in the US, UK and elsewhere. But in the emerging global landscape, countries such as India, Indonesia, South Korea and Brazil will be important as well, as will more regional and multilateral approaches. Of equal importance will be ensuring that today's early to mid-career researchers have the same opportunities as Australia's established scientific leaders to build the necessary international partnerships in global science community competing to collaborate.

It is also clear that institutions and governments in many other nations are now taking deliberate steps to respond to the changes in the global science and innovation landscape. Appendix 2 provides examples of specific measures to boost both international engagement and national competitiveness. These programs are gathering momentum across OECD nations as well as emerging economies.

For Australia, as for other nations, this is the critical decade, where wise decisions and investments are needed for the future. US Federal Reserve Chairman Ben Bernanke, in a May 2011 speech on the role of government in supporting science and innovation, highlighted the importance of policy-makers coming to terms with the "increasing globalisation of R&D". The emerging Asian Century does not mean that Australia should cut its traditionally strong ties with Europe and North America, rather, Australia must maintain and build upon these for the 21st century.

4 Australian Government responses to global change

Powering Ideas: An Innovative Agenda for the 21st Century includes increased international collaboration as one of seven National Innovation Priorities. Overall levels of international collaboration by Australian researchers (measured by the co-publication of scientific journal articles) have risen in the last decade, but as shown in Appendix 1, this aggregates the efforts of individual scientists and masks important strategic gaps. Addressing this national priority must include enhanced strategic engagement with international science and innovation, complementary to the priority of supporting excellence in Australia.

In its 2010 report on the *Internationalisation of Australian Science*, the Academy recommended a more strategic national approach to engagement with international science. This included: whole-of-government coordination, enhanced engagement with industry, support for early-career researchers, access to key international infrastructure and global programs; and improved intelligence from a network of science counsellors at Australia's embassies overseas.

In the last two years, significant changes have occurred in the Australian Government's policy and programs that seek to support the nation's continued and effective engagement with world-leading science.

In late 2009, the government announced the expansion of the Australia-India Strategic Research Fund (AISRF), and by June 2011 had invested $65 million over five years in the AISRF, with a matching commitment from the Indian government. This is by far the largest investment by the Australian Government in such a targeted bilateral cooperation fund.

In June 2010, the House of Representatives Standing Committee on Industry, Science and Innovation released the report of its inquiry into Australia's international research collaboration. This inquiry was referred in late 2009 to the Committee by the Australian Government Minister for Innovation, Industry, Science and Research, with terms of reference that included examination of the extent of existing international research engagement, the benefits to Australia from this activity, and drivers and barriers to international collaboration at different levels.

The government's response[8] to the House of Representatives Committee review acknowledged that "improved Australian Government coordination of Australian international research activities is essential for Australia to benefit from international research and development, and to facilitate technology uptake by Australian industry". It concluded that "international science engagement is essential to maximise the economic, social and environmental impact of Australian research and to leverage Australia's investment in science and innovation".

In February 2011, the Australian Government also released the evaluation of its International Science Linkages (ISL) program, which had annual funding of approximately $10 million and, according to the evaluation report:

> *has for ten years been the Australian Government's leading mechanism for increasing Australia's participation in international research, for strengthening strategic partnerships between the Australian and overseas research communities, and for facilitating access by Australian researchers to global technology and science facilities.*[9]

The evaluation of the ISL program also pointed to the important role of government in ensuring that Australian science can "compete and collaborate on the world stage" and meet national needs

and objectives. Science collaboration with some countries and regions (China, the European Union, etc.) can only occur when formal government-to-government agreements and support are in place. The evaluation report also noted the importance of science in helping to "present a positive and contemporary image of Australia abroad". It found evidence of the complementarity of ISL with other Australian Government programs, and concluded that the ISL program should be continued, with its funding doubled to approximately $20 million per year.

In April 2011, the government announced a new three-year bilateral program for scientific cooperation with China, with targeted funding of $9 million, matched by the Chinese government.

In June 2011, the ISL program officially ended. The Academy believes renewed funding for strategic international science collaboration should be seen as a clear priority in future spending decisions.

Important recommendations from the House of Representatives Committee inquiry and ISL evaluation have not yet been addressed. And while the Australian Government has invested in strengthening research collaboration with India and China in the last two years, it maintains approximately 30 mostly unfunded bilateral government-to-government agreements for science and technology cooperation. Our global approach lacks strategic coordination and commitment, which risks alienating existing powers with which the Australian Government is actively engaged in official science cooperation dialogue (such as the US and EU) and ignores emerging and established powers elsewhere, particularly in Asia.

This lack of coordination also cuts across a number of other Australian Government portfolios, with major investments in international science collaboration now coming through aid programs and through government departments and agencies dealing with energy, health and climate change, among others. Improved coordination is necessary to ensure that the Australian Government can optimise its various investments when dealing with other governments.

International scientific communication, exchange and collaboration are two-way processes. Even if Australian Government science and innovation policy does not prioritise strategic national action to address internationalisation, the policies of other countries clearly do.

This will affect not only the competitive ability of the Australian science sector but also the way in which Australia is perceived by the rest of the world in coming decades. In the 1950s and decades following, the Colombo Plan (initiated by a meeting of Foreign Ministers from Commonwealth nations) led to between 18,000 and 20,000 students and scholars attending Australian universities. This created an enormous and ongoing impact through alumni networks, and supported the internationalisation of Australian higher education. Many of the Plan's students returned to their own countries and eventually occupied high-level positions within science and/or government, eg. Dr. Khaw Boon Wan, Singapore's Minister for National Development, was a Colombo Plan Scholar with degrees in Engineering and Commerce from the University of Newcastle, Australia.

One of the successes of the Colombo Plan was the social and diplomatic benefit of the positive bilateral relationships subsequently built, based upon the constructive experiences and contacts these students took with them into their senior science, industry or government positions. In a rapidly changing global landscape, a similar commitment is again needed. If Australia does not exercise national strategic direction, we will necessarily be following the interests of other nations, thereby limiting the ability of Australian scientists and policy-makers to shape global research direction in line with our unique needs, perspectives and interests.

China's 1,000 talents

Originally designed to attract leading expat scientists back to China, the successful 1,000 talents scheme has now been replicated to attract overseas researchers as well. Candidates at the top of their field world-wide are granted prestigious awards which enable them to maintain overseas links while contributing to China's development. Programs such as these will attract leading young Australian researchers, but also limit the ability of Australian institutions to attract the best from elsewhere. www.guardian.co.uk/higher-education-network/2011/apr/20/chinese-universities-seeking-academics

5 Decisions and implications

A decade into the Asian Century, the Australian Government now faces a clear choice – continue to build on success in international science for the future, or step back from the leading edge.

Individual scientists will of course continue to collaborate, as they have always done. Indeed, the UK Royal Society's *Knowledge, Networks and Nations* report notes that international science has been driven for hundreds of years by the energy and passion of individuals – "the primary driver of most collaboration is scientists themselves".

The challenge for Australia is to effectively harness the energy of its researchers and align their collaboration with national interests. But with so many other countries and institutions now seeking to respond to the changing international landscape for science and innovation, this will require more strategic coordination, commitment and resourcing.

Australia and South Korea – a fork in the road

The end of the ISL program in June 2011 marked the end of 23 years of ongoing support for activity under Australia's formal government-to-government science partnership with South Korea. According to UNESCO's 2010 world science report, South Korea is "probably the world's most committed country to science, technology and innovation", with a national R&D investment target of 5% of GDP by 2012. In addition, Korea has approximately 18 dedicated science and technology diplomats and the National Research Foundation of Korea has offices in the US, Japan, China and Sweden.

The Korea Institute of Science and Technology in Europe (KIST Europe) was established in 1996 in Saarbrücken, Germany, with the support of the Korean government. Since then, it has built global networks with prominent EU research institutes and industrial companies. By the end of the next decade, the KIST Europe aims to be one of the most respected and top-quality R&D institutes recognised by the EU community.

In other areas, the Australian Government is investing in its relationship with South Korea, negotiating a bilateral Free Trade Agreement and in April 2011 announced a $10 million contribution to the Global Green Growth Institute established by the Korean government. The success of many of these actions will be underpinned by scientific breakthrough and innovation. But without coordination, these investments will fail to reap their full potential benefits, and important partners will doubt Australia's commitment to engagement. Major efforts have been undertaken in mid-2011 to keep significant international relationships on life support until a permanent solution can be found, but this is not sustainable.

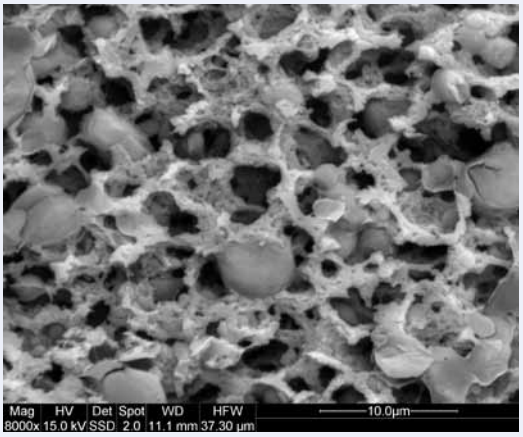
Decisions about science and innovation collaboration are being made around the world every single day. These have implications beyond science itself for a range of important national interests. What then are the consequences of a decision not to invest effort in improved coordination of Australia's international engagement in science and innovation?

5.1 Impact on competitiveness and jobs in the industries of the future

The case for the central role of science in innovation for enhanced economic competitiveness and productivity has been made frequently, including in the 2008 review of Australia's national innovation system chaired for the Government by Dr Terry Cutler. But as Australia's relative share of global R&D shrinks, strategic international collaboration targeted at national innovation priorities and needs will become more important. The Academy's 2010 report, *Internationalisation of Australian Science,* highlights the importance of being able to generate, absorb and adapt new knowledge to suit Australian conditions and maximise comparative advantage, which in turn enhances competitiveness. This requires ongoing investment in skills and high-quality research within Australia, but also in links to global leaders, wherever they may be. World-class scientific expertise and strategic international connections will also contribute to Australia's visibility and ability to attract increased foreign direct investment, an area where the nation currently rates poorly by international standards.

In the future, support for strategic international science and innovation collaboration will also be crucial for Australia to build new industries and address national needs in areas such as sustainable agriculture, water resources management and renewable energy. For example, high-speed, environmentally-friendly rail has been discussed for many years and proposed as a worthwhile addition to Australia's national infrastructure. But Australia does not have the necessary technical skills to successfully implement a national high-speed rail system. Through partnership with countries such as Japan and Korea, the required skills and knowledge could be accessed.

International science for a more competitive dairy industry



Structure of the intermediate stages during cheese making showing the protein network and individual fat globules.

In collaboration with the Australian dairy industry, researchers from The University of Melbourne have worked with partners in Ireland on innovative microscopy techniques to improve texture and to predict and control the properties of dairy products. The project aims to develop vitally important engineering methods to predict and control the functional properties of dairy ingredients and will enable Australian manufacturers to produce advanced dairy products with enhanced consistency, novel physical characteristics and new functional ingredients.

Every increase in yield of 0.5% as a result of microscopy studies could result in an additional 750 tonnes of cheese per year and an increase in annual cheese sales of$3.5 million. This will boost the international competitiveness of Australia's third largest rural industry.

As well as core research funding for this project in Australia, additional targeted funds enabled the international collaboration, thus improving both the quality and impact of the science, and the economic return to Australia.

International science for a more competitive mining sector

Waste minimisation in mining

Science and engineering research at Monash University and The University of Melbourne has enabled the alumina industry worldwide to reduce the volume of waste it produces by about 50%, through recovery of valuable raw materials and elimination of the risk of storage failure. Worldwide, there are at least two major failures of old-technology storage facilities annually resulting in deaths and environmental disasters. The new technique, known as dry disposal, produces a paste for stacking and drying instead of a water-like suspension to be stored in a dam or pond. One alumina plant in Australia produces about 15,000 tonnes per year of dry waste, while a copper mine could produce as much as 250,000 tonnes per year of a similar fine particle suspension. Transition from a water-like suspension to a paste results in a non-Newtonian fluid. The research developed three simple and robust techniques for measuring the basic non-Newtonian properties required for design of a paste disposal system. The measuring techniques are now used internationally but need greater exposure in Asia, particularly in China. The dry disposal technology is also slowly being adopted by the copper, oil sands and coal industries.

Research without borders

The Ian Wark Research Institute (The Wark™), University of South Australia, and AMIRA International engaged RMDSTEM Ltd* to evaluate the AMIRA Project, P260 'Mineral Flotation', over the period 1988-2006.

The RMDSTEM Report showed the Project delivered total value of $436 million, of which 76% was associated with companies increasing recovery, 15% was associated with improving price realisation and avoiding penalties, and the remainder was associated with reducing costs and increasing throughput.

This equated to an average leveraged benefit (return on each research dollar spent) for each sponsor of over 20:1. (Further details at Appendix 3.)

5.2 Impact on science excellence

Stepping back from international collaboration would also have a negative impact on the quality of Australian science. Many studies show the positive impacts of international collaboration on quality, including increasing the relative citation impact of scientific publications. Each such collaboration reflects enhanced timely access to experience, knowledge and resources not otherwise available to a researcher restricted to their home country. The ISL evaluation report provides many examples of collaboration and co-publishing with world-leading researchers that simply would not have happened without the program. Decreasing support for international collaboration would therefore lead to a failure to fully and properly leverage the rest of the Australian Government's $9.4 billion annual investment in science, research and innovation.

5.3 Impact on educational standards

High standards in education – crucial for competitiveness in the global knowledge economy – depend on access to the best new knowledge. Engaging with the other 97 or 98% of global knowledge and education need not be about brain drain for Australia, but about brain circulation and even a brain and skills gain in strategic areas for the nation. In parallel with the increasing internationalisation of science and innovation, the international mobility of researchers – both young and more experienced – has continued to rise. Education for the science and innovation workforce of the future must include opportunities for international experience and network-building if this workforce is to be able to contribute and compete in the 21st century. Mainstream science funding, such as the programs administered by the Australian Research Council (ARC), does not adequately address these needs.

It is, therefore, important that Australia links its international research policy more to post-graduate and post-doctoral opportunities at home. Specific programs for early and mid-career researchers should include investment in not only short-term visit fellowships, like European Molecular Biology Organisation Fellowships but also more prestigious 'boomerang' fellowships along the lines of the National Health and Medical Research Council (NHMRC) CJ Martin Fellowships. These enable the researcher to spend two years working overseas and two years in Australia, allowing for a gap in between in case of an extension of the postdoc period overseas.

5.4 Impact on ability to conduct diplomacy and project a contemporary Australia to the world

In response to the changing landscape of global science and innovation, numerous other countries have strengthened the role of international science collaboration in their diplomacy, trade and aid programs. Specific "science diplomacy" programs recognise and support the contribution of science to a broad range of foreign and economic policy objectives, as well as the role of diplomacy in fostering scientific collaboration across borders. The promotion of Australia's scientific skills and engagement can also be part of a coordinated effort to present a modern, innovative nation to the rest of the world. This is an area in need of urgent attention. For example, Australia's Embassy in Jakarta is Australia's largest overseas post with well over 100 staff from various Federal Government agencies. However, not one Australian agency staff member is dedicated solely to Australian – Indonesian science and innovation. This is despite the many common issues strongly underpinned by science and technology (eg. natural hazard assessment and risk reduction, agriculture and water resources, emerging diseases (human, animal and plant), energy resource development and accessibility, and a wide variety of environmental issues).

5.5 Impact on evidence for policy-making across government

Evidence-based policy is a priority for governments around the world, including the Australian Government. Science provides important inputs to policy in addressing issues such as climate change, energy and food security and health. But with a small share of global knowledge produced here, Australia relies on strong links with international science to ensure that policy-makers have access to the best and newest information to assist in making decisions. This supports national policy-making as well as Australia's participation in international decision-making processes.

International research informs national policy, Australian law, and grows research expertise and capacity

Australian and European Union participants of the COST-DIISR cyber bullying conference, Melbourne, April 2010.

The application of new technologies continues to have a profound effect on education and schooling. The impacts can be positive, for example using a school intranet for peer-to-peer support services. On the other hand, bullying and harassment by means of new electronic technologies, primarily mobile phones and the internet ("cyberbullying") is now a serious problem.

There has been much research and action on traditional forms of bullying in schools, with some success, but researchers, pupils, parents, teachers, and governments are all only starting to grapple with the issues involved in cyberbullying.

The European Cooperation in Science and Technology (COST) organisation supports research networking and international collaboration. A global COST network with Australian participation was formed to tackle the cyberbullying problem and inform decision-makers with a scientific evidence base. The participation of the Australian researchers in this COST network was made possible through a reciprocal agreement between the Australian Academy of Science and the COST Office in Brussels.

Practical outcomes from this European/Australian collaboration that are informing Australian cyber-bullying policy and practices include:

(1) developing legal considerations and interventions for schools through the Australian Research Council Linkage grants on Cyberbullying and the Law;

(2) growing the research expertise and capacity of Early Career Researchers and PhD candidates through the second Australian Research Training School in the area of bullying prevention;

(3) developing safe and supportive, youth-led, user-driven research partnerships, through the Cooperative Research Centre for Young People, Technology and Wellbeing;

(4) developing DVD/film resources on International Research Collaborations to inform researchers & policy makers;

(5) the formation of the Australian Anti-Bullying University Research Alliance.

5.6 Reduced national security

International scientific collaboration plays an important role in Australia's defence and biosecurity. For example, the training of quarantine officials from across the Asia-Pacific region over many years in the Australian Animal Health Laboratory operated by Commonwealth Scientific and Industrial Research Organisation (CSIRO) has contributed both to national security and to Australia's standing in the region. Improved biosecurity in the surrounding Asia-Pacific provides more effective protection for Australian agriculture and biodiversity; with associated risk management benefits.

Awareness of relevant issues, problems and data, especially within our immediate region, is a key component of Australia's defence policy.[10] Broad scientific understanding and access to scientific information provides evidence, detail and advance notice of potential concerns such as food security or disease management. Improved scientific collaboration would improve Australian expertise and awareness of the natural and physical characteristics and trends. Such access would allow better forecasting (eg. food security) and inform responses to identified risks. This "preparedness" function is a valuable product of international science cooperation, providing policy-makers with current intelligence and mechanisms for modelling responses to emerging threats.

6 The role of the Australian Government

There is a clear role and responsibility for government to ensure that appropriate benefits are realised to optimise its other investments in scientific research and infrastructure; support productivity and industrial competitiveness; and enhance diplomacy, evidence-based policy-making and national security. Individual researchers, science organisations and companies cannot do all of this without government assistance.

International collaboration in science and innovation takes place across a number of different and interconnected levels, from individual researchers to collaborative teams, science institutions, national governments and global bodies. Different strategies for responding to increasing internationalisation are required at these different levels. The globalisation of science and innovation is proceeding hand-in-hand with ongoing concentration of scientific excellence, both across and within nations, with emerging hubs supported by explicit government policies. Staying up to date with this will require increased effort, above and beyond the work of individual scientists to stay on top of their fields. To make informed decisions nationally, Australia needs improved intelligence about what is happening across the rest of the world.

International Science Linkages drive the SKA

The ISL evaluation report demonstrates how scientific exchanges between Australia and the USA funded under the program contributed to the development of technologies that are now being used for the Square Kilometre Array (SKA) radio telescope. As well as facilitating the next generation of astronomical research and improving our understanding of the universe, the SKA will have spillover benefits in information and communication technologies (ICT) industry innovation, spurring the development of new wireless and sensor technologies, as well as in renewable energy technologies. In this way, strategic investments by government can align the activities of individual researchers with major national priorities that will lead to new knowledge, innovation and associated jobs. COST analysis of the broader benefits of the project concluded that "mega-science infrastructure projects such as the SKA have the potential to seed or boost technological development, enhance capabilities and efficiencies across myriad industrial and educational sectors, as well as generate economic and social benefits for society". www.cost.esf.org/download/Final%20report%20COST%20SKA

The Australian Government is already making significant investments in international science and innovation collaboration through a variety of portfolios, but this effort lacks coordination. In addition to the Department of Innovation, Industry, Science and Research (DIISR), and its agencies such as the Australian Research Council and CSIRO, international science activity occurs through:

- the aid program with substantial funding support from Australian Agency for International Development (AusAID) and the Australian Centre for International Agricultural Research (ACIAR);
- the health portfolio and the NHMRC;
- Defence and the Defence Science and Technology Organisation (DSTO);
- Austrade; and
- portfolios with responsibility for energy, agriculture, environment and climate change.

Australian scientists have a proud history of engagement with the Asia-Pacific region over many decades, funded by Australia's aid program. With increased coordination and investment for the future, this can provide a basis for 21st century engagement with countries developing strong science and innovation-driven economies.

Government can take a strategic perspective that is informed by and encourages the interests of individual research institutions and companies. This long-term view should extend into the future, identifying emerging changes in the international science and innovation system, relating these to Australia's unique capabilities and priorities, and investing accordingly. Capturing the major benefits from investments in education, research and international cooperation takes time – just as Australian science built strong links with China over decades – investments should be made now in the relationships Australia will need in 20 or 30 years.

The Australian Government's commitment to public investment in R&D is part of this long term view. A KPMG survey of econometric studies of the rate of return on publicly-funded research, prepared for Universities Australia, shows that it varies from 20 – 60% depending on the subject of the study and underlying methodology.[11] As has been presented above, strategic international collaboration can multiply this rate of return significantly.

The Australian Government's 2011 report on the national innovation system highlights the importance of international engagement to ensuring that national science and innovation policy supports the capturing of benefits for Australia. It concludes:

> *To tackle the increasing globalisation of the generation of knowledge, Australian organisations will need to strategically decide who and how to collaborate with others – domestically and globally… Specialisation is one of the strategic choices that middle size countries such as Australia are facing.*[12]

If Australia directs collaborative efforts in the areas of science where clear comparative advantage exists, then the returns to Australia will be much larger than would be achieved by allowing other countries to strategically direct efforts according to their comparative advantage.

Dyesol – innovation success story

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The creation of Dyesol started with the identification of an opportunity and a gap in Australian capabilities by the Australian Government's Energy R&D Corporation, which then in 1995 funded collaboration with researchers in Switzerland. Australian scientists developed dye solar cell technology in partnership, which led to a company now employing 50 people and working with major multi-nationals as a global leader in third generation solar technologies.

Thus, without a national priority to maintain links with the world's best knowledge, Australia's relative gains from scientific advance will be sub-optimal. In the past, Australia reaped the rewards – in agriculture, mining, and elsewhere – from the alignment of scientific and economic comparative advantage. But with the rapid changes in the global scientific landscape and economy, this needs continuing attention. This highlights the clear role for government in setting and supporting national direction.

7 Recommendations

The Australian Government's previous program for international science collaboration was devised in the 1990s and rolled out over the next decade. There is now ample evidence of the program's significance, its complementarity and its effectiveness in supporting both international collaboration by Australian scientists and the realisation of broader benefits from those links. In the Asian Century, with increased and competitive investment in global science and innovation systems, it is now time to re-think Australian Government support for international collaboration and to invest strategically for the future.

The Academy's 2010 report *Internationalisation of Australian Science* made the case for a more strategic national approach. The Academy now believes that a new government program is required to maximise Australia's opportunities in the 21st century, maintaining, strengthening and building on our strong links with leaders in North America, Europe, Asia and India. Program funding of $250 million over 10 years would equate to 0.25% of total Australian Government spending on science, research and innovation during the period but would have a significant multiplier effect.

Such a program would support Australia's access to the best new ideas, data, tools, equipment and knowledge, linking Australia to global trends, innovations, lessons and opportunities. This would support and enhance the efforts of individual researchers and institutions, delivering on national priorities and enhancing national competitive advantages.

A new program would complement but not duplicate existing activities through the full range of Australian Government support for science, research and innovation. Only a new program could provide greatly needed strategic national direction. The targeted instruments proposed below specifically address existing gaps, with one instrument for each objective, making design, implementation and evaluation clearer.

To prepare an effective innovation pipeline for the 21st Century, the Academy recommends that the overall program comprise:

Improved competitiveness ($150 million over 10 years)

1. *Specific funding to enable early and mid-career researchers to work at the leading international edge of their fields.*

   This would support early and mid-career researchers to form international networks to facilitate high quality collaboration. Current research funding avenues support established projects of high quality (including relevant international collaboration) but there is little support for early and mid-career researchers to build networks that can lead to such projects. The 2010 House of Representatives inquiry found this to be a gap that warranted particular attention.

2. *Specific funding to enable collaborative innovation projects where the delivery of benefit for Australia requires a research link with a company/capability overseas.*

   Following the Dyesol example mentioned above, this would enable R&D staff in both research institutions and innovative companies to identify a market opportunity and quickly forge the necessary links to access science skills not available domestically.

This would deliver benefits through connecting Australian researchers to leading-edge work internationally, and also through boosting the competitiveness of Australian companies, complementing other existing Australian Government programs focused on commercialisation and export promotion.

3. *Strategic partnership funds, determined by government priorities.*

   This would be in addition to and aligned with the existing Australia-India Strategic Research Fund and Australia-China Science and Research Fund, and strengthen the Australian Government's ability to support international science and innovation collaboration as part of selected bilateral relationships.

   Where the Australian Government maintains regular bilateral science relationships and dialogue with key countries and regions (such as the European Union, United States and Japan), such funding would enable resultant, new opportunities to be supported. It would enable access to key international infrastructure similar to those accessed under the previous Access to Major Research Facilities Program (AMRFP) managed by Australian Nuclear Research and Development Organisation (ANSTO) that enabled timely use of major international research facilities not available in Australia. Where new opportunities arise for strategic government-to-government relationships that would benefit Australia – as with South Korea, Indonesia, Singapore, etc. – this funding would enable these to be realised.

Improved awareness ($50 million over 10 years)

4. *An annual "Global science and innovation watch" report for Australian policy-makers and the broader science and innovation sector.*

   This would regularly update government on developments around the world in a range of fields and sectors that have a bearing on Australia's science and innovation investment. It would feed into strategic foresighting and program design, implementation and evaluation across government, and would be a key annual output of the national advisory body proposed below.

5. *An expanded network of Science and Innovation Counsellors and Attachés in select Australian embassies around the world.*

   These staff would support Australian researchers and institutions in their international engagement efforts and gather intelligence that would inform the annual publication proposed above. They would foster government-to-government links to support international science and innovation collaboration, augmenting Australia's diplomatic capacity and ability to project a modern image of Australia to the world. A competitive network would increase the number of Counsellors from 2 to 6 and establish 5 locally engaged Science Attachés to cover regional areas:

- Counsellors
  - USA - North America (existing)
  - EU - UK (existing)
  - Japan -South Korea - Taiwan
  - China - Mongolia
  - India
  - Indonesia

- Science Attachés
    - Brazil – Chile (South America)
    - France – Switzerland – Germany – Italy – Spain – Russia
    - Sri Lanka – Pakistan – Bangladesh
    - United Arab Emirates – Saudi Arabia – Israel – Jordan (Middle East);
    - Singapore – Malaysia – Thailand – Vietnam

6. *Establish an "Australian science and innovation Special Envoys" program– leading researchers and business people who would receive support to spend time in cutting-edge laboratories, research teams and companies overseas.*

   This would be a finite part-time role, allowing the individual to contribute to the promotion of Australia's strengths around the world while also pursuing their own international collaboration and the interests of their home institution. They would be linked with government through Counsellors and Science Attachés and provide another source of intelligence, which would be captured in the annual report process. These appointments would also be prestigious and support the career advancement of individuals selected, highlighting the importance to the broader Australian community of strategic international engagement.

Improved governance ($10 million over 10 years)

7. *A national advisory board for international science and innovation, chaired by the Chief Scientist of Australia and made up of high-level members from organisations such as the ARC, NHMRC, CSIRO, DSTO, the Learned Academies, etc.*

   It would bring together representatives from the scientific community, industry and relevant government portfolios to set strategic direction and guide whole-of-government investment in international collaboration. The national advisory body would also seek input from international peers.

Improved diplomacy ($40 million over 10 years)

8. *Science diplomacy programs in support of 'innovation for development'.*

   Institutions such as the Learned Academies and government research agencies often undertake activities and perform international functions that serve the strategic international responsibilities of the Australian Government. As the role of science in "track two diplomacy" has strengthened in recent years, the importance of government coordination and support of this activity has also grown. Science institutions and leaders are able to gather information (primarily evidence and in-country perspective) and provide scientific advice to direct development according to best available scientific knowledge and Australia's national interests, including through international forums such as the United Nations and through the delivery of treaty obligations. Support would be arranged for the establishment of a Science Advisor function for the Foreign Affairs and Trade portfolio, to mirror well established arrangements in the US State Department and UK Foreign and Commonwealth Office. Specific programs would also support the scale-up of initiatives by the Academies to maintain links with peer organisations – particularly in Asia – including efforts to develop school science education programs in developing countries and to improve capacities of science Academies in developing countries.

9. *Lead the creation of an Asia-Pacific science and innovation community.*

   The Academy's 2010 report, *Internationalisation of Australian Science*, highlighted the example of the Colombo Plan and the ways in which it contributed to Australia's standing in its region. A decade into the Asian Century, the time has come for a new effort to cement Australia's place in what will become the world's leading hub of innovation. This would include coordinated effort across the various mechanisms outlined above, to demonstrate Australia's commitment to international science and to the region. Additional targeted mechanisms would include science leadership fora to bring together leading and early and mid-career researchers from Australia and across the region. Support will also be required for enhanced research into, and teaching of, Asia-Pacific languages and cultures, to equip Australians with the skills they will need to collaborate and compete in the 21st century.

10. *Lead the creation of a science secretariat as an adjunct to the Commonwealth Heads of Government Meeting (CHOGM) that would contribute to the understanding of the role of science and technology as agents of development especially for poverty reduction.*

    The secretariat would provide access to scientific knowledge for members of the Commonwealth to draw on individual and collective expertise in specific disciplines, and could propose initiatives in areas such as climate change, agriculture and food, health and energy.

8 Final Remarks

The 2010 Asialink report *Mapping our future in the Asian Century*[13] proposed that Australia commit to working towards a strong and dynamic regional research initiative:

> *It could span the whole gamut of research from medicine to life and physical sciences, engineering, social sciences and humanities... in the research area our relationship is most likely to be readily accepted, because knowledge is an internationally valued quality.*

Such a move would parallel efforts underway in other regions (Europe, Latin America, etc.) to create collaborative blocs, deliberately bolstered by government policies and funding support. This is one response to the changing global landscape for science and innovation.

As Australia strives to hold its position in global R&D over the coming years, it will be increasingly important for the nation to be able to articulate and execute a coordinated strategy for maintaining its links with leading international science, and building on these for the future. The proposals outlined in the report are designed as a template for discussion and debate about Australia interests in the Asian Century.

A successful science and innovation system – in Australia as in the rest of the world – needs diversity and dynamism rather than monolithic top-down control. But in this rapidly changing landscape individual researchers and institutions also need support and a coordinated framework within which to continue their work. This will enable Australia to harness the passion and intelligence of its scientists and innovators to address existing gaps based on our unique national priorities, interests and advantages.

Science and innovation are inherently international, and are by definition at the accelerating edge of globalisation. In the Asian Century, and with the development of the global knowledge economy, new ideas and approaches are being generated and rewarded every day.

Australia now faces a choice – take steps necessary to strategically engage with the technology driven world we can clearly see coming, or continue our present course of retreat. If we wish to build upon Australia's fruitful investment in science during the last century, and maximise our advantages in the Asian Century, Government must act on the recommendations in this report now.

9 Appendices

Appendix 1: International performance of Australian science

The Australian Government's investment in science, research and innovation institutions and programs totals approximately $9.4 billion in the 2011-12 year. Overall investment in R&D in Australia was 2.21% of GDP in 2008-09, and had grown steadily over the previous decade, driven largely by increased investment by the private sector. However this is still just below the OECD average, and well below leading nations of comparable size.

Australian science is respected around the world and competes well by any number of existing measures – for example, with only 0.3% of world population, the Australian Government's own 2011 annual report on the national innovation system notes that Australia produced over 3% of total world scientific publications in 2008, with an even higher share (4%) of the world's highly cited (top 1%) publications.

The government's annual report describes Australia's research and skills base as "moderate to good compared with other OECD nations". It goes on to note that Australia "has a relatively low rate of international collaboration on R&D and innovation" compared with other nations. However, this analysis is based on measures of international collaboration by innovating businesses and R&D activity financed from abroad.

In terms of scientific research, Australia performs above the global average for international collaboration, with rates having risen between 1990 and 2005 in parallel with global trends. This increase has also been largely responsible for the overall rate of growth in Australia's scientific publications over this period. An analysis of total Australian publications for 2010 (using Web of Science/Thomson Reuters data) suggests that approximately 40% were co-authored with international collaborators. The UK Royal Society puts the global average of internationally co-authored scientific publications at approximately 35% in 2008. However, given Australia's relative share of global science and distance from major partners, it could be argued that our rates of international collaboration should be much higher than average.

Analysis by Thomson Reuters in March 2010 demonstrated that, at the institutional level, the Chinese Academy of Sciences was now the single most frequent partner institution for Australian collaboration as measured by publication data between 2004 and 2008.[14] In the same period, six of the 10 most frequent collaborating institutions for Australian scientists were from the Asia-Pacific region, with three of the remaining four institutions being Harvard, Cambridge and Oxford universities. This clearly demonstrates both the attractiveness of Australian scientists as partners for leading international collaboration, and Australia's growing engagement with its region while maintaining traditional ties with leading US and European centres.

Improved analysis is required across these different levels, to inform wise decision-making. While the overall picture may look healthy, the detail is more revealing. Comparative analysis by the US National Science Board in 2010 shows that Australia actually collaborates more than could be expected with countries such as China, the UK, Singapore and South Africa, but less than could be expected with leading nations such as the United States, Japan, South Korea, India, Germany and France.[15]

Appendix 2: Recent developments in other countries

The Academy of Science's report, *Internationalisation of Australian Science*, clearly highlighted the ways in which other countries were responding to the changing global scientific landscape, and the need for proactive engagement. That report provided an overview of relevant policy and initiatives in leading countries such as the USA, UK and Denmark, as well as touching on developments in Japan and China.

These countries employ a mix of policies and mechanisms, including direct funding for international collaboration and mobility, intelligence-gathering and representational staff posted around the world, science diplomacy activities and support for innovative companies operating in global markets. Both bilateral and multilateral mechanisms are used, as well as inward and outward communication, depending on the desired outcome.

The OECD's 2010 *Science, Technology and Industry Outlook*[16] includes a focus on the importance and impacts of increasing internationalisation, which it says requires improved coordination at the regional, national and international levels. The OECD notes that nations are responding to this imperative in a number of ways.

Firstly, many countries have set ambitious investment targets to boost core spending on R&D – in its survey of 29 leading countries and regions, over half have set targets for R&D spending of 3% of GDP or higher.

Secondly, in addition to increasing general investment levels, many nations have overhauled their policies and programs designed to specifically improve international collaboration. The OECD asked 24 governments to rate the importance of addressing internationalisation, on a scale of 1-8. Well over half provided a rating of six or higher. Australia is yet to respond.

The OECD report singles out Germany and the Nordic countries as having developed the strongest and most coherent internationalisation strategies as part of their overall science and innovation policies. In Germany for example, as part of a broader national plan, research institutions are provided additional government support for their own international strategies. German government support is also available for strengthening institutional links with leading international clusters, for example the establishment of the Max Planck biosciences institute in the United States. In its innovation programs for small to medium-sized businesses (SMEs), the German government provides 20% additional funding to projects with international partners. A range of other measures assist individual researchers.

In Finland, the national funding agency for technology and innovation Tekes has included conditions of international collaboration in almost all of its programs. The Finnish government also supports national innovation centres in a range of countries including China, Japan, Russia and the United States. An example of increasing regional cooperation in international engagement is the way in which the Nordic countries are also now working together to support opportunities for leading US graduate research fellows to spend time in their research institutions.

Appendix 3: Research without borders in mining

The Wark™ adds $436 million value to the Minerals Industry.

University of South Australia

If you want to maximise your returns from Australia's mining boom, consider asking The Wark™ some big questions.

For more than a decade the Ian Wark Research Institute (The Wark™) at the University of South Australia (UniSA) has been a part of finding business solutions for mining leaders such as Rio Tinto and BHP Billiton, and major corporates including Dow and Unilever.

The Wark has been dubbed an *'Australian national treasure',*[1] and Dr Megan Clark from BHP Billiton[2] says it is *'one of only three institutes in the world we are working with that is positioned for breakthroughs in science relevant to several industries.'*

The Wark has state-of-the-art facilities currently worth in excess of $30 million and attracts a strong flow of external funding and repeat business. Its researchers are internationally published and its graduates are forging highly successful careers around the world.

One institute, many roles.

The Wark has had a groundbreaking role in becoming the lead partner for the Australian Mineral Science Research Institute (AMSRI), an institute supported by the largest single research grant ever awarded by the Australian Research Council. AMSRI is backed by $26 million from industry, State and Federal governments and four participating universities. AMSRI also has 24 international collaborating partners.

The Wark has also been the Australian government-sponsored ARC Special Research Centre for Particle and Material Interfaces since 2000. Its impact in forging valuable international research relationships has been described as *'exceptional'* and the filing of six patents since the inception of the facility has *'demonstrated the excellence and commercial impact of research undertaken by the Centre'*[3].

Research without borders.

The Wark's operating revenue has more than doubled since its foundation in 1994 and it has established formal links with more than 19 institutions on five continents. This includes world leaders such as the Max Planck Institute for Metals in Germany.

Founding Director and South Australia's first Scientist of the Year[4], Laureate Professor John Ralston believes the strength of The Wark's achievements and these global networks foster genuine, international collaboration.

The Wark is distinctive in its creative and flexible approach to research and development, where a mixture of fundamental and applied research is conducted across a wide range of project areas. Its unique structure combines academic rigour and inquiry with an appreciation of industry imperatives.

'It's the ability to explore new realms to create knowledge and then turn those ideas into effective industrial outcomes that is our distinguishing feature.'

Laureate Professor John Ralston, Director, The Wark™

Independent report reveals $436 million value added to the Minerals Industry.

Since 1988, the AMIRA International project P260 has been conducted with the aim to improve flotation of minerals in the minerals processing industry. The project also has applications across other industry sectors.

To evaluate the benefits from this project since its inception up until 2006, AMIRA International and The Wark commissioned RMDStern Limited[5], an independent organisation with an extensive track record and proven experience, to conduct the study.

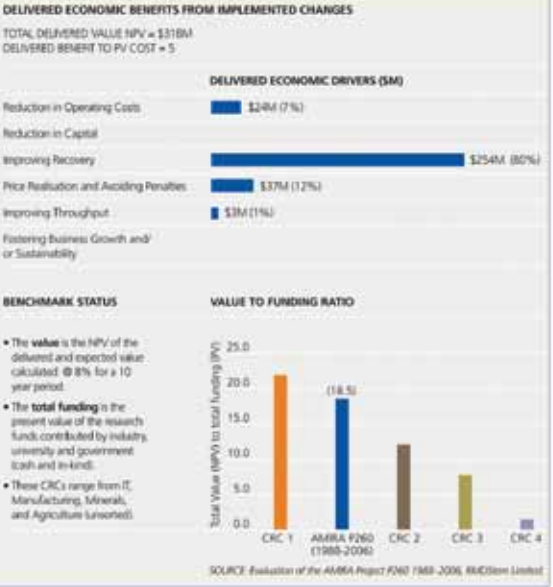
Study outcomes reveal results for industry.

The study showed industry end-users were very effective in transferring the AMIRA P260 Project research outputs into useful outcomes. The financial value derived by end-users:

- Delivered Net Present Value (NPV) $318M – primarily through improved recovery, price realisation (by improving grade and quality of concentrates), and reduced operating costs.
- Expected NPV $118M – primarily improving recovery, price realisation, reduction in operating costs and improving throughput.
- Total value $436M.

The benefits NPV to cost ratio is (21.5 to 1) for industry.
The benefits to cost ratio for The Wark is (18.5 to 1).

Full details can be obtained by contacting The Wark (www.unisa.edu.au/iwri) or AMIRA International (www.amira.com.au)



1 Australian Academy of Science citation, May 2005
2 Dr Megan Clark, Vice President Technology, BHP Billiton Limited
3 2005 Review Panel, ARC Special Research Centre six-year review
4 2007 South Australian Science Excellence Awards
5 RMDStern Limited is a resource management and consulting group specialising in providing consulting and contracting services to the mining and mineral processing industries.

Make the decision today to incorporate The Wark™ into your business strategy.

Experience. The Difference.

www.unisa.edu.au/iwri

Appendix 4: List of Acronyms

AISRF	Australia-India Strategic Research Fund
AMRFP	Access to Major Research Facilities Program
ANSTO	Australian Nuclear Science and Technology Organisation
ARC	Australian Research Council
AusAID	Australian Agency for International Development
CHOGM	Commonwealth Heads of Government Meeting
COST	European Cooperation in Science and Technology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DIISR	Department of Innovation, Industry, Science and Research
DSTO	Defence and the Defence Science and Technology Organisation
EU	European Union
GDP	Gross Domestic Product
ISL program	International Science Linkages program
ICT	Information and Communication Technologies
KIST Europe	Korea Institute of Science and Technology in Europe
NHMRC	National Health and Medical Research Council
OECD	Organisation for Economic Co-operation and Development
R&D	Research & Development
The Academy	Australian Academy of Science
UNESCO	United Nations Educational, Scientific and Cultural Organization
SKA	Square Kilometre Array
UK	United Kingdom
US	United States

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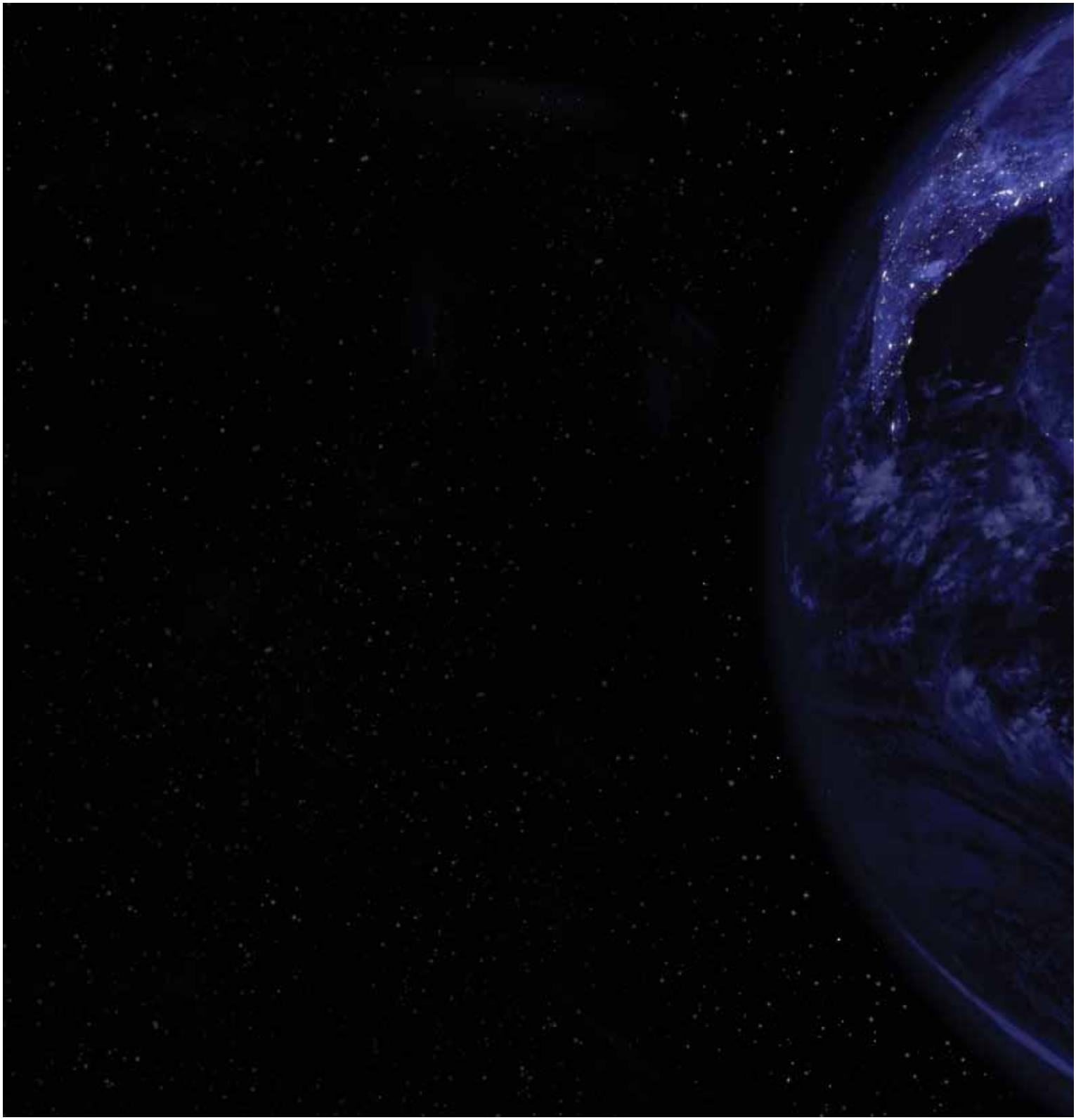

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