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Nuclear-based science benefiting all Australians

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innovationreview@innovation.gov.au

The attached submission from the Australian Nuclear Science and Technology Organisation (ANSTO) to the Review of the National Innovation System has been provided by the following:

Authors: Dr George Collins, Chief of Research and Dr Miriam Goodwin, Senior Adviser Research Management and Policy

Organisation: Australian Nuclear Science and Technology Organisation

Type of organisation: research provider and research facilities operator

Address: PMB 1, Menai NSW 2234

Email and phone contact: george.collins@ansto.gov.au, 02 9717 3288

Declaration of Interest: ANSTO is a partner in the Australian Institute for Nuclear Science and Engineering (AINSE) along with 35 Australian universities, funds joint appointments with several universities and is a member of four Cooperative Research Centres (CRCs), the Defence Materials Technology Centre (DMTC) and several Australian Research Council networks and centres; Dr Collins is president-elect of Materials Australia, a member of the Board of the Cooperative Research Centre for Biomedical Imaging Development, a director-elect of the DMTC and a director of two start-up companies; Dr Goodwin co-edits the magazine of the Australasian Research Management Society.

In this submission, ANSTO has taken up each of the questions for research institutions that were raised by the Expert Panel in its consultation forums.

We would welcome a visit to ANSTO by members of the Expert Panel and an opportunity to discuss in more detail issues raised in this submission and more generally by the Panel.

Yours faithfully,

George Collins
Chief of Research

Australian Nuclear Science and Technology Organisation submission to the Review of the National Innovation System

Introduction to ANSTO

ANSTO is Australia's national nuclear research and development (R&D) organisation and the centre of Australian nuclear expertise. It is part of the Australian Government portfolio of Innovation, Industry, Science and Research.

ANSTO is funded by the Australian Government to undertake research in the applications of nuclear science and technology and to deliver specialised advice, scientific services and products to government, universities, other research organisations, international organisations, and businesses in areas as diverse as mining and nuclear medicine. In addition, about a quarter of ANSTO's revenues are derived from contracts, sales of products and services, grants and other commercial income sources.

About one-third of ANSTO's staff are involved in research. The balance are in operations and support roles – such as reactor operations, safety, technical services, facilities management, waste management, library, government and international liaison, finance, information technology services and commercialisation – and business roles.

ANSTO's research infrastructure includes a research reactor, two accelerators and associated instruments as well as workshops and specialist laboratories. ANSTO's new research reactor, OPAL, is a world-class multi-use facility. OPAL replaces HIFAR, which has ceased operation.

ANSTO's research infrastructure is used extensively by other members of the Australian and New Zealand research communities: from universities, other science and technology organisations and industry. ANSTO also manages the Access to Major Research Facilities Program, which is funded by the Commonwealth to provide Australian researchers with access to major overseas facilities such as neutron spallation sources, physics facilities such as CERN, synchrotrons and astronomy facilities; and the Australian Synchrotron Research Project (ASRP), which has provided Australian researchers with access to three overseas synchrotrons.

From the perspective of the triple bottom line for innovation policy and programs put forward by the panel, ANSTO's role in Australia's innovation system can be described in the following way.

(i) industry innovation, and market changes to increase productivity and improve competitiveness

The facilities operated by ANSTO are used by industry to generate innovations. ANSTO staff play an active role in guiding industrial users on the best techniques, conducting experiments and assisting in analysis of results. Examples range from usage of the research reactor to conduct neutron scattering experiments, to using ANSTO's hot isostatic press – acquired for processing radioactive waste – to improve the quality of knee implants for an innovative Australian company, Advanced Surgical Design and Manufacture Limited.

ANSTO research leads to industry innovation. For example, ANSTO Minerals is a business unit that generates innovations for application in the uranium mining industry and helps the minerals processing industry to better manage naturally occurring radioactive materials (which present a problem for many mining companies).

ANSTO also provides services in assessment of remaining life for the infrastructure sector, growing out of expertise it developed for its own usage. This is a pattern seen in many innovative services businesses.

Most innovations in which ANSTO is involved are incremental, although there are notable exceptions such as synroc, for the immobilisation of radioactive waste.

(ii) innovations and changes in public policies and service delivery around the production of public goods

The most significant outcomes of ANSTO's environmental research are in innovations and changes in public policy around the production of public goods in the form of a 'clean' environment and addressing climate change. Many people regard climate change as the most critical public policy issue facing the world, and ANSTO's research is particularly looking at trends in climate change in the Southern Hemisphere, which is different to the Northern Hemisphere and much less well understood. Nuclear techniques can be used to tell how old water is, and this helps local authorities and businesses to determine how much water can be taken from an aquifer without excessively depleting it. Measurement of air pollution sources and movement, using both ion beam analysis and measurement of the naturally radioactive gas, radon, have influenced policies regarding the sources of pollution.

Energy policy has come to be closely related to climate change policy. ANSTO has informed government and public debate in the last few years about nuclear energy, as part of its mandate to provide advice to government related to nuclear science and technology.

(iii) innovations and changes to address societal and environmental aspirations and challenges through the mobilisation of private and public sector capabilities around these challenges

Three examples follow from ANSTO's research:

- Nuclear techniques provide an independent input to climate change modelling, which helps reduce scepticism about climate change and therefore mobilising action. For example, research undertaken a few years ago by the former head of ANSTO's Institute for Environmental Research, based on stable isotopes of oxygen and hydrogen in water, showed how the water recycled through trees has a different 'signature' to water evaporated through rivers and lakes, which provides a way of seeing the effect of land use changes that is independent of climate change models.
- ANSTO has been working with other public sector research bodies as well as international businesses to develop new technologies that can better detect radioactive materials that a smuggler might be trying to 'mask' behind other sources of radioactivity, such as materials and foods that naturally emit radioactivity.
- By being able to show local communities the underground path of salinity, ANSTO is helping them determine what actions they want to take to solve salinity problems. ANSTO's research is only one part of the picture – communities in such situations have to deal with many aspirations, some of them conflicting.

Responses to the Panel's questions

What is the best contribution that research institutions can make to society and industry?

Research facilities

Research institutions such as ANSTO operate facilities and provide associated services that are extensively used by industry and society. Recently Australia has seen a very significant

investment in such infrastructure through establishment of OPAL and its world-class neutron scattering instrumentation, the Australian Synchrotron and the investment associated with the National Collaborative Research Infrastructure Strategy (NCRIS). Major research facilities of necessity are hosted by public sector bodies and funded, in large part if not totally, by governments. Their stewardship of such facilities is one of the most significant contributions that research institutions make within the national innovation system (NIS).

Such arrangements provide for the long-term operation and maintenance of facilities, in contrast to having facilities housed within bodies that have limited-term funding. It prevents assets being stranded or orphaned when a funding program comes to an end, as was the case in many parts of the previous Major National Research Facilities (MNRF) program.

Continued investment will be necessary to ensure Australia's research facilities remain internationally competitive but this investment should be selective and driven by careful consideration of what tools can Australia most profitably use and how many are required. In many cases the nation is best served by having only one of a particular type of research facility, or one type in any given area. This principle underpins NCRIS. There is no point in duplicating facilities that are available elsewhere, but this also requires effective and fair access arrangements that encourage a high standard of innovation.

Even for smaller technologies, locating facilities in public sector institutions reduces risk for industry and other users. They can use capabilities without their own investment, not only in equipment but more significantly in the expertise that is needed to take advantage of this equipment. This applies also to pilot and demonstration plants. ANSTO Minerals, for example, develops pilot plants for mining and minerals processing companies.

The return to the nation from Australia's major investments in facilities depends on the quality of research undertaken there as well as the innovative ideas that researchers have for using research facilities. These outcomes are strongly shaped by the approach taken to managing the facility. Running a user-oriented facility requires some fundamentally different approaches to running a research institute. It means a strong focus on linkages with other research providers and industrial users, particularly helping them in selecting and applying techniques. At ANSTO, the Bragg Institute regards its primary role as running a user-oriented facility – in its case, the OPAL neutron beam instruments, the Access to Major Research Facilities Program and until recently, the Australian Synchrotron Research Program. The Institute for Environmental Research operates the ANTARES and STAR accelerators, which are used by Australian researchers from a very diverse range of disciplines, and is responsible for the establishment of the National Deuteration Facility, which will assist neutron scattering users with preparation of isotopically-enhanced chemical and biological samples.

However, instrument scientists in ANSTO's facilities are expected to be active researchers in their own right as well as contributing to the research of their users. This is essential in attracting and retaining researchers for these roles, and in ensuring that they maintain a high level of knowledge of developments in relevant fields. The research that the Bragg Institute undertakes is generally to encourage new applications of neutron scattering and synchrotrons. Staff engaged in accelerator operation are especially known for their collaborations in climate change and pollution research.

A common thread through this is building awareness of the potential of particular techniques and providing access. The major other actor in this role over the last half century related to ANSTO has been the Australian Institute for Nuclear Science and Engineering. AINSE facilitates access to ANSTO's facilities by universities and other tertiary institutions and provides a focus for cooperation in the nuclear scientific and engineering fields. It also arranges for the training of scientific research workers and the award of scientific research studentships in matters associated with nuclear science and engineering, and makes students and academics aware of the potential of the technology, for example through an annual Winter School to which every member university sends a student.

Cooperative Research Centres have also helped ANSTO to reach new potential users, such as in the application of neutron and synchrotron radiation scattering to polymer science.

A research institution that is focused on users is always seeking opportunities to 'get in front of' potential users. A user who does not anticipate that nuclear science and technology can be useful will not seek out material and may well pay scant attention to material sent to them. However, face-to-face meetings, industry events and articles in trade media reach users on their own ground and offer better mechanisms for discussion. ANSTO hopes that one of the outcomes of the NIS Review will be mechanisms that bring businesses interested in innovative technologies together with facilities that could help them.

ANSTO – and similar research institutions – help to mobilise industry to adopt innovative techniques as the foundation for their own innovations. We also have been developing community of users of neutron scattering and synchrotron radiation over long periods of time. The ASRP is a strong model for user community development that could be applied in any area of innovation. It involves starting with a program to access selected international facilities, including travel and accommodation as well as practical assistance by ANSTO staff located on-site; funding fellowships to encourage postdoctoral fellows and early career researchers to develop skills; and developing a sense of community through, for example, committees to peer review applications.

Introduction of innovations

Research institutions are ideally placed to introduce innovations into Australia:

- They are constantly scanning the international environment for innovations, as this is central to undertaking research
- Their international linkages provide practical assistance
- They are not primarily driven by profit considerations
- For new technologies and techniques, they are often the home to expertise that is not to be found in the private sector.

For example, ANSTO introduced positron emission tomography for nuclear medicine into Australia when it began to produce fluorine-18 at its National Medical Cyclotron. Commercial and hospital-based operators then took it up as well and the supply network broadened.

Being lead users

In all of its research facilities, ANSTO is both a user as well as provider of a service – and is distinguished as an expert or lead user in the demands it places on the technology or the new fields in which it applies the technology. This is especially the case for OPAL, ANSTO's accelerators and some material engineering facilities, which relate to the three areas where ANSTO can best claim national and international research leadership, namely materials, the applications of nuclear techniques in the environment, and neutron scattering.

In NIS literature, lead users are defined as technically sophisticated and demanding users that set the pace in an industry. Lead users may experience the same needs as most of their sector months or years later. They can provide market research input, without the constraints that most users have in conceiving novel attributes and uses for products and services. Lead users are familiar with conditions that lie in the future for most. Patterns of lead users influence the nature of NISs.[1]

ANSTO is in the position of being both a producer and a user of nuclear science and technology techniques. Its usage is advanced and provides a model for other users, and through collaborations it works alongside other users, enhancing their skills and understanding. It can thus be seen as a lead user of the technologies that it also makes available to others.

Subjective elements such as trust increase in importance when radical innovations are being introduced.[2] One of the roles of networks such as the Australian Neutron Beam Users Group and the ASRP is to foster trust among potential collaborators and between users and providers, and this is one reason why they have played such important roles in the introduction of new nuclear science and technology techniques into Australia.

Small countries face difficulties in forming relationships between producers and users because of their smaller markets,[3] but ANSTO's experience in neutron scattering and synchrotron radiation show how this can be addressed over time, with the producer itself being a user.

ANSTO is now establishing projects in fields that in Australia have not historically used neutrons as a research tool, so that as a lead user it encourages other potential users. In the area of food science, ANSTO decided three years ago to nurture the use of neutron scattering methods for problems in this area, working with CSIRO and other research organisations. We have pursued a leading role in the food science community, for example setting up a 'Protein Club' to engage industry, modelled on the carbohydrate club set up in the UK. Its first meeting attracted 23 attendees, including representatives of eight companies. A year ago, we undertook a similar approach regarding hydrogen, establishing a 'Neutrons for the Hydrogen Economy' project. In this project we are providing some coordination and leadership for the hydrogen research community to show how neutrons can be applied to a range of non-nuclear energy issues. Again, we are seeking to build relationships with other research providers.

Absorptive capacity

'Absorptive capacity' refers to the ability of organisations to learn and to use technologies developed elsewhere through a process that involves substantial investments, particularly intangible investments. 'National absorptive capacity' can be described as the institutions and actors that allow organisations in an NIS to recognise the value of external information, assimilate it and apply it commercially. 'Absorption' involves learning – and is even equated with learning. It covers not only the imitation of innovations, but also exploitation of outside knowledge such as research findings or spillovers from others, such as competitors. Building up a nation's absorptive capacity especially requires investment in scientific and technical training.[4]

Research institutions are vital in maintaining absorptive capacity in certain areas, in ANSTO's case most notably related to applications of nuclear techniques, nuclear medicine and nuclear energy. (Although Australia does not use the latter, it does have absorptive capacity for it that assists in considering its appropriateness for Australia.) A major way in which research institutions expand the nation's absorptive capacity is in their contribution to education. Although undergraduate and postgraduate education are primarily the responsibility of higher education institutions, research institutions make substantial contributions. For example, they jointly supervise students and engage in teaching through adjunct and honorary professorships and lectureships. (ANSTO staff jointly supervised 143 undergraduate or postgraduate students in 2006-07, and approximately one in seven ANSTO researchers hold an adjunct, honorary or similar role at a university.)

Research institutions are also a major training ground for researchers and higher levels of skills. Institutions recognise this explicitly in taking on postdoctoral fellows, who are expected to build their skills and undertake specific research projects over a two–three year term. ANSTO has significantly increased its employment of postdoctoral fellows in recent years, expanding Australia's skills base in the application of nuclear science and technology. The organisation has also begun a graduate program, to help address the shortage of skills in the nuclear area in Australia.

What is the distinctive role of different research institutions within the innovation system?

Role of a nuclear institution

ANSTO provides a good example of the distinctive roles of different research institutions within the innovation system. Under the ANSTO Act, the organisation's mandate explicitly relates to nuclear science and technology.

This focus enables it to liaise effectively with peers in other countries. It is common for countries to have agencies specifically for nuclear science and technology. For example, France has the Centre National de la Recherche Scientifique, which is similar in many ways to CSIRO, as well as the Commissariat à l'Energie Atomique, which is similar to ANSTO. The European Union's Framework Program parallels a nuclear specific program, EURATOM. (Similarly, marine science is also often undertaken by agencies that specialise in that area.)

Without such an organisation as ANSTO, the nation would lack these tight international linkages. These linkages are characterised by being between similar types of organisations, both in being government agencies (not university centres or the like) and in being nuclear-focused. They are vital to tapping into international innovation trends and collaborative opportunities as well as developments related to national security.

Without any nuclear science and technology capabilities at all, Australia would lack key innovation tools used by industry and public sector researchers. They would still be able to access facilities in other countries – as they do today – but at greater cost and without a high level of domestic absorptive capacity, therefore to a lesser extent and with reduced effect. As a result, Australia would effectively separate itself from developments in this technology.

It is also relevant to note that advanced domestic users are especially important when internationalisation increases.[5] When ANSTO is seen as a lead user of nuclear science and technology as well as a provider, this highlights the importance of having domestic capabilities in areas that offer unique tools.

Preparedness

Research institutions such as ANSTO play an essential role in maintaining preparedness for particular needs that the NIS might encounter in the future. This is core to the mandate of ANSTO, which focuses solely on nuclear science and technology. This was typified in the debate over the potential introduction of nuclear energy in Australia, when ANSTO was able to draw on its technical expertise, information resources and international networks to provide a broad range of information and data about emerging technologies, patterns of usage and underpinning science and technology. In recent years the expertise that ANSTO has maintained over decades related to the national security aspects of nuclear and radiation has become an important element of Australia's counter-terrorism efforts.

The importance of preparedness suggests:

- The benefits of forecasting potential future needs
- Explicit recognition that to build and maintain options for potential innovations, even those currently thought unlikely, the nation needs to maintain some core capabilities.

How might national prioritisation affect research institutions and the nature of research activity?

The second of ANSTO's Strategic Directions for 2005–10 is "Focus our Capabilities to Support Issues of National Importance". By "issues of national importance" ANSTO means subjects that government has articulated are priorities for the nation. These include the National Research Priorities (NRPs) but are much wider than them. When ANSTO's

Strategic Directions were being developed, that broader term was explicitly selected to cater for the breadth of ANSTO's functions beyond research and the range of government agencies with which it liaises. The term also encompassed the national health priorities, environmental priorities and industry Action Agendas, for example, and will, of course, include the National Innovation Priorities.

In ANSTO's experience, national prioritisation is most useful when it is targeted and based on activities that bring together the various participants in a sector (a sectoral innovation system) to identify gaps and opportunities. For example, we welcomed the establishment of the National Security Science and Technology (NSST) Branch in the Department of Prime Minister and Cabinet, due to its intention to coordinate service and research providers and users, as our efforts to increase investment in national security research were being constrained by insufficient information about end-user requirements. For similar reasons ANSTO was a founding member of the Publicly-funded Agencies Collaborative Counter-Terrorism (PACCT) program, which coordinates national counter-terrorism research and development activities. Our primary objective was to establish stronger and more effective relationships with other research and development agencies and the first responder and intelligence communities.

PACCT and the NSST have had considerably more impact than the more symbolic inclusion of Safeguarding Australia among the National Research Priorities – and ANSTO states this as one of the earliest advocates for having national security included in the NRPs.

The increasing importance in recent years of research on climate change and water is a good example of how national prioritisation affects research activity. ANSTO has been active in climate change and groundwater research for many years, as these are areas in which nuclear techniques such as analysis of isotopes can provide unique insights. The increased demand for ANSTO's capabilities has greatly increased opportunities for collaborative research and demand for knowledge and information that we can provide. Similar to the national security arena, the difference is not having climate change and water included among the formal NRPs so much as these areas becoming increasingly important in the nation, fostering stronger relations between research providers and research users.

Having said that, until the last year, ANSTO struggled over several years to build the collaborations it was seeking in its water research project. We actively approach departments and agencies to build awareness, as we regularly encounter departmental and agency staff who are not aware of the role that nuclear techniques can play. One hindrance is the high level of turnover in relevant positions in public sector agencies: so much depends on individual staff-members' awareness, yet staff often change positions. This indicates the need within government as much as within the private sector for easy access to information on the contribution that research institutions can play in specific sectors – that is, a user-focused guide.

Funds invested in research prioritisation as typified by PACCT and NSST are spent on the research itself. In contrast, the NRPs have come to involve significant reporting costs that take funds away from research itself and which do not increase dissemination or accountability. From ANSTO's perspective, the NRPs *per se* have not had a notable effect.

What is the true cost of funding research?

In discussing the true cost of funding research, ANSTO would like to shift the emphasis somewhat to the true cost of extracting *value* from research.

Many organisations cannot sustain research over the long-term and then see the outcome through commercialisation (broadly defined). In many institutions, organisational and funding structures work against sustained effort unless specific programs are put in place. Moreover, there is a cultural challenge in that researchers are often keen to move onto new projects, so it takes extra effort to keep them seeing innovations through the commercialisation pipeline.

Many are reluctant also as the reward system in which they have worked encourages publication, not commercialisation. ANSTO's approach has been to establish an internal Innovation Forum, which identifies and nurtures new ideas and inventions discovered by ANSTO staff. It comprises experienced ANSTO staff (and, where appropriate, external business people and scientists) who work with inventors to ensure that the ideas and inventions are robust and are developed in a way which is relevant to ANSTO's research projects and external industry. Where new ideas or inventions fall outside ANSTO's normal research projects, the Innovation Forum can nurture and fund these opportunities and identify potential industry partners that might be interested in utilising the idea or invention once proof-of-concept has been demonstrated. The Innovation Forum also helps ensure staff are aware of commercialisation issues and expectations.

The Innovation Forum bridges the gap from project phase to commercialisation and ANSTO believes that it offers a model that could be applied elsewhere in the NIS.

It depends in part on ANSTO being funded at the organisation level, in contrast to university researchers who depend in large part on funding of individuals for specific, fixed term projects.

ANSTO would also like to reinforce its concerns about the cost of reporting on research that does not encourage its dissemination and provides a lesser level of accountability than that provided in the organisation's annual report. Reporting systems that minimise administrative costs and maximise opportunities for dissemination should be a feature of all new innovation programs.

Have we got the capital structures of institutions right?

A critical point in this regard is that ANSTO is mandated under its Act to operate facilities on behalf of the nation. This raises capital structures to a greater prominence than is the case for institutions with mandates that concentrate on matters that primarily involve operational expenditures, such as conducting research.

OPAL was constructed with dedicated funding approved at Cabinet level (being Outcome 1 for ANSTO in the Portfolio Budget Statement [PBS]). ANSTO regards this as the appropriate funding mechanism for a substantial investment for the nation such as OPAL (described as "landmark facilities" in NCRIS). However, the ongoing operation of OPAL is under a different part of the PBS, which increases the ability of the organisation to meet unanticipated costs by diverting funds from other parts of the organisation's budget, such as we have experienced in recent months when OPAL was not operating. This suggests that enabling hosting institutions to manage funds themselves maximises accountability and flexibility. It is unfortunate, however, that the research activities of the organisation have most borne the brunt of the savings needed to cover the costs of the unplanned OPAL shutdown.

The management of facilities on behalf of the nation (output 3.1 for ANSTO in the PBS) accounts for approximately half of ANSTO's expenditure (excluding Outcomes 1 and 2, the latter being for shipping spent fuel from our previous reactor, HIFAR). A significant proportion of funding for facilities management has been anticipated costs of depreciation. Having such costs in a fund under ANSTO's control ensures that replacement of elements of these facilities is properly taken into account, and that major capital expenditure today does not become threatened in the future if components cannot be replaced due to lack of funding from an external source. There are instances – not involving ANSTO – of this risk in the previous MNRF program.

The ASRP shows how assets can evolve over time, which also raises some issues for capital structures. An instrument installed by the ASRP at the National Synchrotron Radiation Research Center in Taiwan has been returned to Australia and installed on the Australian Synchrotron in Melbourne. This has been taken into account in ASRP funding, elements of which are segueing into the Australian Synchrotron by way of NCRIS, but the example

shows one of the challenges for Australia in management of facilities over time, during which ownership can change.

What are the benefits of and limits to collaborative activity?

Collaboration is intrinsic to the way in which ANSTO operates. It brings:

- Researchers into direct engagement with industry and communities seeking solutions (for example, ANSTO Minerals' activities, ANSTO's work with the Australian Pipeline Industry Association over many years and groundwater research)
- Different expertise together, e.g. coupling ANSTO's expertise in nuclear techniques with others' expertise in specific fields (for example, as in the Food Science project discussed above)
- Fresh insights from people with different experiences in a field or a problem
- New outlets for research dissemination and communication, such as the ability to reach new markets or to contribute to global projects (such as ANSTO's atmospheric research feeding into the World Meteorological Organisation Global Atmospheric Watch Program)
- Connections that are valuable for other, nationally strategic reasons (such as the role that ANSTO plays in Cooperative Research Projects of the International Atomic Energy Agency, which increases Australian knowledge of nuclear developments in our region and spreads a culture of safeguards and safety, in which Australia is an international leader)
- Access to facilities or sites (such as ANSTO climate change researchers working in Tibet in collaboration with the Chinese Academy of Sciences)
- Efficient and effective access to contracts and customers (for example, a contract recently obtained by ANSTO Inc. in the US from Battelle Energy Alliance, which operates the Idaho National Laboratory).

There has been a tendency to treat collaborations as if they are an outcome and an indicator of actual performance. However, this is misleading. They are an *input* to research, which should be seen as a way of increasing productivity by obtaining more from research effort. Due to the nature of some funding programs, sometimes researchers approach institutions like ANSTO to gain access to grants rather than for the broader benefits of collaboration. Collaboration *can* encourage dissemination, but only when consciously done.

This is typical of the problem that arises when the adage "what can't be measured, can't be managed" is turned on its head so that the *measurable* has become the *managed*. It is easier to record and count inputs than outcomes, and so the number of collaborations is reported, not the benefits obtained.

ANSTO suggests that the NIS Review Expert Panel should take this problem with reporting on collaborations into account in designing any new or modified programs and indicators.

In addition, there is a form of 'passive collaboration' that should also be considered in describing the national innovation system in the global context. It is the diaspora from institutions –the network of researchers who have worked together and relationships built up when working in facilities in other countries. Research institutions are yet to foster 'alumni' networks the way that professional services firms do and there is real potential for Australia to take a more systematic approach to this. The development of a strategy in 2005-06 to increase Australian involvement in fusion energy science and engineering provides an example. The strategy consultation process engaged many Australian researchers and researchers who have undergone part of their education in Australia but who are now living

in other countries, as they are keen to see Australia play a role in the next phase of international fusion research.

How do different funding models affect institutional performance and capability?

On the discussion of capital structures, ANSTO highlighted one way in which it benefits from institutional-level funding, in its ability to manage innovations through the pipeline after the initial research project has been completed.

A different aspect of institution-level funding is the ability to determine research plans on the basis of capabilities, risks and opportunities. Nonetheless, community attitudes and government policy both induce innovation and can block – often appropriately – the development of certain innovations. ANSTO has experienced this in recent years as attitudes to nuclear energy have evolved. Under the last two years of the previous government, ANSTO began working on materials research, especially towards participation in global programs, and launched a program to increase the nation's skills base in nuclear S&T. Since the change in government, ANSTO has readjusted its materials research plans.

Conclusion

Research institutions have a distinct role to play in the NIS. Because of their specialist mandates, they bring unique capabilities and sets of linkages.

Their significant contributions include:

- Operating facilities used by themselves and other actors in the NIS
- Adding to the body of knowledge through their research
- Building skills, and thus absorptive capacity, through education and training
- Maintaining national preparedness in their particular area of expertise.

Appendix: CRCs

ANSTO is a member of four Cooperative Research Centres:

1. Polymers
2. Biomedical Imaging Development
3. Integrated Engineering Asset Management
4. Sustainable Resource Processing.

ANSTO also has supporting participation in CAST (particularly using neutron tools in understanding light alloy performance).

CRCs provide the ideal mechanism for exploiting ANSTO's capabilities in 'spin out areas' and linking with other research providers and end-users. As a result of its participation in CRCs, ANSTO has built new communities and advocates for use of neutron scattering. These are the dominant source of industrial users, notably in polymers and engineering applications.

CRCs also provide a channel for taking ANSTO intellectual property to market. This has been particularly valuable for otherwise unexploited radiopharmaceutical ligands, as well as for ceramic materials with applications in photoelectric applications.

Among the ANSTO contributions to new technologies now available in the market resulting from its work with CRCs are:

- Hardwear Pty Ltd using laser cladding for turbine blade refurbishment
- ANSTO expertise in new tools for infrastructure management, developed through AusIndustry and industry associations

References

[1] Gregersen, "The Public Sector as a Pacer in National Systems of Innovation", in Lundvall B-Å (ed), National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London, Pinter, 1992, p143; Von Hippel E, The Sources of Innovation, New York, Oxford University Press, 1988, p7; Fagerberg J, "The Home Market Hypothesis Reexamined: The Impact of Domestic User–Producer Interaction on Export Specialisation, in Lundvall (ed) 1992, p237; Lundvall B-Å, "Introduction" in Lundvall (ed) 1992, p13; Andersen ES, "Approaching National Systems of Innovation from the Production and Linkage Structure, in Lundvall (ed) 1992, p85; Andersen ES and Lundvall B-Å, "Small National Systems of Innovation Facing Technological Revolutions: An Analytic Framework", in Freeman C and Lundvall B-Å (eds), Small Countries Facing the Technological Revolution, London, Pinter, 1998, p33; Goodwin MW, Technology Absorptive Characteristics of a National Innovation System, PhD thesis, University of Sydney,1997, p43

[2] Lundvall B-Å, "User–Producer Relationships, National Systems of Innovation and Internationalisation" in Lundvall (ed) 1992, pp57–59

[3] McFetridge DG, "The Canadian System of Industrial Innovation", in Nelson RR (ed), National Innovation Systems: A Comparative Analysis, New York, Oxford University Press, 1993, p302

[4] Organisation for Economic Co-operation and Development, Technology and the Economy: The Key Relationships, Paris, OECD 1992, p17; Cohen and Levinthal, "Innovation and Learning: The Two Faces of R&D", The Economic Journal, 99, September 1989, pp569–596; Wegloop P, "Linking Firm Strategy and Government Action: Towards a Resource-Based Perspective on Innovation and Technology Policy", Technology in Society, 17, 4, 1995, p419; Mowery DC and Oxley JE, "Inward Technology Transfer and Competitiveness: The Role of National Innovation Systems", Cambridge Journal Economics, 19, 1, 1995, pp67–93

[5] Fagerberg, "User-Producer Interaction, Learning and Comparative Advantage", Cambridge Journal of Economics, 19, 1, 1995, pp 243–256; Porter M, The Competitive Advantage of Nations, Free Press, New York, 1990, p89; Fagerberg, "The Home Market Hypothesis Reexamined", p228